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Agricultural Policies and Perceptions to Climate Change:Insights from Western Himalayas, India

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"Dharma exists for the welfare of all beings. Hence, that by which the welfare of all living beings is sustained, that for sure is dharma."

------- ***Mahabharta (Shanti Parva 109.10)***

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Abstract

This dissertation explores the intersection of agricultural policy, community perception, and climate change adaptation in the Western Himalayas, India—an ecologically fragile yet critically important agrarian region. As climate change continues to pose severe threats to food security and rural livelihoods, especially in mountain systems, understanding the effectiveness of existing policy frameworks and their reception among local farming communities becomes essential. The research adopts a mixed-method, tripartite design rooted in the production of system, target, and transformative knowledge. Through qualitative content analysis of 31 national agricultural policy documents, focus group discussions conducted across three altitudinal zones of Himachal Pradesh, and a global systematic review of 121 peer-reviewed articles, the study investigates: (1) how agricultural policies address climate change and sustainability; (2) how farming communities perceive, experience, and respond to these policies; and (3) what behavioural, institutional, and governance factors influence the adoption of sustainable agricultural practices.

Findings reveal a dominant emphasis on productivity and economic outcomes in most policy documents, with limited integration of climate change adaptation or sustainability principles—particularly in terms of social equity and ecological resilience. Smallholder and marginalized farmers, despite being highly vulnerable to climate impacts, are often inadequately represented or supported in policy narratives. Field data highlight a widespread gap between policy formulation and ground realities, with farmers experiencing challenges in accessing information, financial services, and institutional support. Perceptions of policy effectiveness vary, shaped by contextual factors such as altitude, farm size, education, and livelihood diversification.

The study argues for a shift towards participatory, context-sensitive, and inclusive policy frameworks that recognize the agency of local communities and the complexities of mountain agriculture. It recommends regionally tailored adaptation strategies that integrate traditional ecological knowledge with scientific innovation, improved extension services, and stronger cross-sectoral governance. By synthesizing insights across multiple knowledge domains, the dissertation contributes to the discourse on sustainable transitions in agriculture and offers practical pathways for enhancing resilience and food security in the Himalayan region and similar vulnerable agro-ecological zones globally.

Zussamnenfassung

Diese Dissertation untersucht die Schnittstelle zwischen Agrarpolitik, Wahrnehmung der Bevölkerung und Anpassung an den Klimawandel im westlichen Himalaya in Indien – einer ökologisch fragilen, aber ökologisch wichtigen Agrarregion. Da der Klimawandel weiterhin eine ernsthafte Bedrohung für die Ernährungssicherheit und die Lebensgrundlagen der ländlichen Bevölkerung darstellt, insbesondere in Bergregionen, ist es unerlässlich, die Wirksamkeit bestehender politischer Rahmenbedingungen und deren Akzeptanz in den lokalen Bauerngemeinschaften zu verstehen. Die Forschung basiert auf einem dreiteiligen Mixed-Method-Ansatz, der auf der Erzeugung von System-, Ziel- und transformativem Wissen basiert. Anhand einer qualitativen Inhaltsanalyse von 31 nationalen agrarpolitischen Dokumenten, Fokusgruppendiskussionen in drei Höhenzonen von Himachal Pradesh und einer globalen systematischen Überprüfung von 121 begutachteten Artikeln untersucht die Studie: (1) wie die Agrarpolitik mit dem Klimawandel und der Nachhaltigkeit umgeht; (2) wie die Bauerngemeinschaften diese Politik wahrnehmen, erleben und darauf reagieren; und (3) welche Verhaltens-, institutionellen und governancebezogenen Faktoren die Einführung nachhaltiger landwirtschaftlicher Praktiken beeinflussen.

Die Ergebnisse zeigen, dass in den meisten Politikdokumenten der Schwerpunkt auf Produktivität und wirtschaftlichen Ergebnissen liegt, während die Integration von Prinzipien der Anpassung an den Klimawandel oder der Nachhaltigkeit – insbesondere in Bezug auf soziale Gerechtigkeit und ökologische Resilienz – nur begrenzt erfolgt. Kleinbauern und marginalisierte Landwirte sind zwar besonders anfällig für die Auswirkungen des Klimawandels, werden jedoch in politischen Narrativen oft nur unzureichend vertreten oder unterstützt. Felddaten zeigen eine weit verbreitete Kluft zwischen der Politikgestaltung und den Realitäten vor Ort, wobei Landwirte Schwierigkeiten beim Zugang zu Informationen, Finanzdienstleistungen und institutioneller Unterstützung haben. Die Wahrnehmung der Wirksamkeit der Politik variiert und wird durch kontextuelle Faktoren wie Höhenlage, Betriebsgröße, Bildung und Diversifizierung der Lebensgrundlagen beeinflusst.

Die Studie plädiert für einen Wandel hin zu partizipativen, kontextsensitiven und inklusiven politischen Rahmenbedingungen, die die Handlungsfähigkeit der lokalen Gemeinschaften und die Komplexität der Berglandwirtschaft anerkennen. Sie empfiehlt regional zugeschnittene Anpassungsstrategien, die traditionelles ökologisches Wissen mit wissenschaftlicher Innovation, verbesserten Beratungsdiensten und einer stärkeren sektorübergreifenden Governance verbinden. Durch die Synthese von Erkenntnissen aus verschiedenen Wissensbereichen leistet die Dissertation einen Beitrag zur Diskussion über nachhaltige Übergänge in der Landwirtschaft und bietet

praktische Wege zur Verbesserung der Resilienz und Ernährungssicherheit in der Himalaya-Region und ähnlichen gefährdeten agroökologischen Zonen weltweit.

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1. Introduction

Climate change poses complex economic, social, and political challenges globally, with its impacts on agriculture and food security being particularly severe in developing countries (IPCC, 2007, 2014; Pandey et al., 2017; Ojo & Baiyegunhi, 2019; Omerkhil et al., 2020). Among these, India is one of the most vulnerable due to its dependence on climate-sensitive agriculture (IPCC, 2014; Guntukula, 2020; Praveen & Sharma, 2019). Supporting two-thirds of the workforce, contributing 17% to GDP, and ensuring food and livelihood security, agriculture has proven to be the backbone of India (Venkateswarlu et al., 2011). Intensifying climate changes also pose significant challenges to the livelihood of India's smallholder farmers, who are highly vulnerable and yet contribute minimally to global emissions (Singh et al., 2020). Without counteractive measures, the intensity of climate change impacts will continue to escalate, necessitating adaptation as a vital strategy (Huang & Sim, 2021; Dorward et al., 2020).

Agricultural adaptation involves modifying agronomic practices to mitigate climate risks and foster resilience (Paudel et al., 2014; Jha et al., 2017). Research shows that region-specific adaptation can significantly enhance productivity despite adverse climatic conditions (Bradshaw et al., 2004; Di Falco et al., 2011). Developing countries face additional barriers, including socio-economic, geographical, and climatic constraints, making adaptation challenging (IPCC, 2014; Patnaik & Das, 2017; Khan et al., 2020; Omerkhil et al., 2020). The need for adaptive strategies is urgent, yet the success of these strategies hinges on the role of supportive policies and the perceptions of farming communities towards them (Bryan et al., 2013; Deressa et al., 2009).

Farmers and associated communities play a central role in adaptation as decision-makers operating within socio-economic, cultural, and ecological contexts (Crane et al., 2010; Bryan et al., 2013). Their perception of climate change, shaped by past experiences and local climatic events, influences their willingness to adopt adaptive strategies and benefit from the associated policies (Jodha et al., 2012; Ayanlade et al., 2017). However, such decisions are complex, requiring awareness of policies being implemented, motivation to act, and farm dynamics (Bryan et al., 2009; Celio et al., 2014). Effective policy implementation also requires timely action, yet farmers often face delays in acquiring and processing necessary information (de Jalón et al., 2018). Given the numerous hurdles, conflicts and expectations from farming communities towards agricultural policies, it becomes imperative to bring reform, not only in terms of policies but also agricultural practices (Creemers et al., 2019; Annika et al., 2024). Bringing in sustainable food systems in terms of agricultural reform is the most obvious and

justifiable pathway (Passel, 2013). Transforming agricultural systems to a genuinely sustainable system requires social and political commitment to guarantee acceptability (Røpke, 2009; FAO, 2014). This entails bringing perception of farming communities on the current state of governance and other barriers such as resource acquisition, attaining information, and external uncertainties (Gbetibouo, 2009; Bryan et al., 2009; Jha and Gupta, 2021).

1.1. Research Gaps

This PhD therefore investigates the case of Himalayan agriculture communities to better understand the climatic challenges these communities are facing, and the role policies play. This thesis addresses several critical gaps in the existing literature on Himalayan agriculture, climate adaptation, and policy evaluation. While there is a substantial body of work on agricultural challenges in the region (Rasul et al., 2021; Sharma et al., 2019), few studies systematically examine how contemporary policies incorporate—or fail to incorporate—climate change adaptation. Moreover, policy analyses rarely consider the three core dimensions of sustainability—economic, environmental, and social—leaving the convergence or divergence of policy priorities underexplored. Existing evaluations often focus narrowly on policy outputs, such as subsidies or schemes, without attending to broader issues of policy framing, strategic intent, or climate resilience. There is also a notable lack of empirical research exploring farmers lived experiences with agricultural policies in the Himalayas (Tiwari et al., 2008; Gentle & Maraseni, 2012). Most studies portray farmers as passive recipients of policy rather than as active agents with diverse perceptions and decision-making strategies. Furthermore, current evaluation approaches tend to rely on quantitative metrics (e.g., adoption rates, income changes), overlooking more nuanced, perception-based assessments that capture issues of legitimacy, trust, and local relevance. Finally, there is limited synthesis of how human-dependent factors—such as behavior, institutional dynamics, and governance structures—interact to shape sustainable agriculture adoption in fragile ecosystems. A transdisciplinary and integrative review of these dimensions is lacking, particularly one that offers actionable insights for designing policies and programs that support transformative change at the community level.

1.2. Aims and Research Questions

Understanding the current state of climate change policies and the perception of the agricultural community regarding these policies is imperative in influencing farmers' decisions and for designing effective interventions to support sustainable farming practices in the face of climate change. With this backdrop, this dissertation aims **to identify the role played by policies and perception of policies for adaptation to climate change and sustainable agricultural practices**, by addressing the gaps found in current research being done in the Himalayas.

Thus, the study will be built upon the following ***research questions***:

RQ1: What are the focus points of agricultural policies currently being implemented in the western Indian Himalayas? Is climate change a major concern of these policies?

RQ2: How does the agricultural community benefit from the policies? How does the community perceive the current policies?

RQ3: What is the major role of behavioural, institutional, and governance factors in determining adoption of sustainable agriculture practices?

1.3. Thesis Structure

This thesis adopts a publication-based format, consisting of a series of journal articles (1 peer-reviewed and published, 1 under review, 1 under internal review) that collectively address the central research questions. The structure is designed to integrate these publications within a cohesive academic narrative. In the next chapter, I will therefore describe the background of this research needed to understand the current scenario of agriculture and related policies in India. It also provides a brief background of the potential solution to increasing burden of food security. Chapter 3 describes the research design, built up using 'integrated approach'. The core of the thesis comprises Chapter 4, containing the standalone publications. Following the publications, a synthesis chapter integrates the main findings, drawing cross-cutting insights, highlighting the collective contribution to the field, and critically reflecting on theoretical and practical implications. The final chapter concludes the thesis by summarizing the overall contributions, addressing limitations, and offering directions for future research. References and appendices are provided to include supplementary material, such as extended data, methodological details, or co-authorship declarations where required.

2. Background

2.1. Policies and agriculture: Indian scenario

Climate projections for India suggest increased temperature extremes, more erratic rainfall patterns, prolonged droughts, and higher incidence of floods—factors that directly influence crop productivity, soil health, and water availability (INCCA, 2010; Roxy et al., 2017). The impacts are particularly severe in the Indian Himalayan Region (IHR), where fragile ecosystems, altitude-dependent agriculture, and limited infrastructure pose unique challenges for resilience-building (Pandey et al., 2021). In response, India launched the National Action Plan on Climate Change (NAPCC) in 2008, which identifies eight core missions including the National Mission for Sustainable Agriculture (NMSA). The NMSA promotes climate-resilient farming through interventions in soil management, water conservation, agroforestry, and risk mitigation strategies (GoI, 2010). However, the program's uniform design has been criticized for inadequate regional customization. Mountain-specific constraints such as short growing seasons, steep terrain, and limited irrigation infrastructure are not sufficiently addressed (Sharma & Bhadwal, 2019). The Himalayan context also requires greater integration of hydrological and cryospheric data into agricultural planning, given the region's dependence on glacier-fed irrigation systems.

With retreating glaciers and disrupted snowmelt patterns, downstream water availability is projected to decline, thereby threatening agricultural viability in both hills and plains (Immerzeel et al., 2013). Unfortunately, most existing agricultural policies do not factor in these complex mountain hydrology dynamics. Recent studies underscore the regionally differentiated impacts of climate change on agriculture in India (Hazrana & Birthal, 2023; Pattanayak et. al., 2021). Assessments by the Indian Council of Agricultural Research (ICAR) suggest that climate change may reduce wheat yields by 6–23% by 2050 in northern India, including parts of the Himalayan foothills (ICAR-NICRA, 2020). Similarly, rice cultivation in rainfed areas of eastern India is expected to become increasingly vulnerable to variable monsoons (Rao et al., 2019). The vulnerability is compounded by low adaptive capacity among smallholders, who often lack access to credit, insurance, market information, and extension services (Sharma et al., 2019; Rasul et al., 2021).

To address these challenges, ICAR's National Innovations on Climate Resilient Agriculture (NICRA) program was launched in 2011. NICRA supports the development and dissemination of climate-resilient crop varieties, integrated farming systems, and early warning systems across multiple agro-climatic zones (ICAR-NICRA, 2020). It also pilots Climate-Smart Villages

(CSVs), which combine technological innovation with institutional strengthening and farmer participation. Yet, scalability remains a constraint due to resource intensity and variability in institutional performance across states (Aggarwal et al., 2018). Further decentralization through State Action Plans on Climate Change (SAPCCs) has enabled some degree of localization. States like Himachal Pradesh, Uttarakhand, and Sikkim have developed adaptation frameworks targeting climate-resilient agriculture. However, evaluations reveal that these plans often remain aspirational due to lack of funding, weak interdepartmental coordination, and limited engagement with local farming communities (Dubash et al., 2018; CEEW, 2020). Moreover, the inclusion of hill-specific indigenous farming practices remains minimal, despite their demonstrated ecological resilience and sustainability (Tripathi & Singh, 2020).

In conclusion, while India's climate change policies reflect a growing recognition of agricultural vulnerabilities, significant gaps persist in regional tailoring, institutional coordination, and community participation. For the Himalayan region particularly, there is a pressing need for agroecological adaptation strategies that integrate scientific innovation with traditional ecological knowledge, along with targeted investments in infrastructure, research, and capacity-building (Gentle & Maraseni, 2012; Rasul, 2014).

2.2. Community Perception: Why?

In the Himalayan region, agricultural adaptation to climate change has become increasingly critical, as shifting weather patterns, glacial melt, and altered precipitation cycles directly impact crop viability and food security. Communities have responded by modifying traditional cropping patterns, adopting climate-resilient varieties, and altering planting schedules. These adaptive practices are deeply informed by local perceptions of environmental change, which are shaped by lived experiences and intergenerational knowledge. Community perception plays a pivotal role in the formulation and implementation of agricultural policies, influencing both the design of interventions and their ultimate effectiveness. Community perception, thus not only reflects the immediate realities of climate-induced transformations but also guides grassroots-level innovations, making it a vital input for policy frameworks aimed at fostering resilience in mountain agro-ecosystems. The socio-cultural and experiential knowledge of local communities forms an essential layer of context-specific understanding that complements top-down approaches to policymaking (Pretty, 2003). Farmers and rural stakeholders often possess nuanced insights into ecological cycles, land management practices, and socio-economic constraints that are not always evident in formal data or technocratic planning models (Chambers, 1994). Consequently, integrating community perceptions can enhance the relevance, acceptability, and sustainability of agricultural policies.

A significant body of research highlights the disconnect that frequently exists between policy intent and on-ground realities when local perceptions are overlooked (Meinzen-Dick et al., 2018). For example, policies promoting the adoption of improved seed varieties or conservation practices often fail due to lack of alignment with farmers' values, perceived risks, or historical experiences with similar programs (Feder, Just, & Zilberman, 1985). Community perception serves as a proxy for assessing the local legitimacy of interventions, making it a valuable indicator in the early stages of policy design. Community perception is closely linked to behavioural responses and policy compliance. Studies in behavioural economics suggest that farmers are more likely to adopt new agricultural practices or technologies if they perceive them as beneficial, fair, and coherent with their traditional knowledge systems (Duflo, Kremer, & Robinson, 2011). In this regard, perception shapes not only attitudes but also the social acceptability of innovations. Participatory approaches, such as farmer field schools and village-level consultations, have proven effective in eliciting perceptions and translating them into actionable policy feedback (Van den Ban & Hawkins, 1996).

In climate-resilient agriculture, perception becomes even more critical, as adaptive strategies must be locally grounded to be effective. According to Bryan et al. (2009), farmers' perceptions of climate variability significantly influence their adoption of adaptation strategies, such as altering planting dates or diversifying crops. If policy measures ignore these subjective yet experiential insights, they risk being deemed irrelevant or impractical. Integrating community perception fosters inclusivity and equity in policy making. Marginalized groups—such as smallholders, women, and indigenous populations—often have distinct perspectives shaped by differential access to resources and decision-making power (Agarwal, 2001). Policies that actively seek to incorporate diverse perceptions are more likely to address systemic inequalities and promote social cohesion within agricultural systems.

Taken together, community perception acts as a critical input for designing context-sensitive, behaviourally realistic, and socially just agricultural policies. Policymakers who engage with local perceptions not only increase the likelihood of successful implementation but also contribute to the co-production of knowledge that bridges scientific and local expertise (Cash et al., 2003). Therefore, participatory and perception-sensitive frameworks should be foundational in contemporary agricultural policy formulation.

2.3. Sustainable agriculture practices: Solution to increasing the burden of food security

Food insecurity is a mounting global concern exacerbated by climate change, resource depletion, and socio-economic inequalities. As the global population is projected to surpass 9.7

billion by 2050, current agricultural practices, heavily reliant on synthetic inputs and monocultures, are increasingly viewed as unsustainable (FAO, 2021). Sustainable agriculture, characterized by environmentally sound, economically viable, and socially responsible farming practices, has emerged as a viable strategy to enhance food security by ensuring long-term productivity, resilience, and ecological balance (Velten et al., 2015; Pretty et al., 2018). It integrates practices such as crop diversification, agroecology, organic farming, and conservation agriculture. These systems are designed to enhance soil health, reduce dependency on chemical inputs, and improve biodiversity (Reganold & Wachter, 2016; Khan et al., 2021). For instance, agroecological approaches that mimic natural ecosystems have shown substantial yield improvements in low-input systems, especially in sub-Saharan Africa and Latin America (Altieri et al., 2015). Moreover, studies reveal that sustainable agriculture enhances resilience against climate extremes through improved water management and soil organic carbon sequestration, thus contributing to long-term food stability (Tittonell, 2014). Additionally, environmental degradation due to the Green Revolution — such as groundwater depletion, loss of biodiversity, and declining soil fertility — further exacerbates agricultural vulnerability (Pingali, 2012). In this context, sustainable agriculture has gained policy relevance. Initiatives like Zero Budget Natural Farming (ZBNF) in Andhra Pradesh exemplify low-cost, ecological alternatives that aim to reduce farmers' input costs while improving yields and ecosystem health (Khadse et al., 2018).

Empirical studies in Indian agro-ecologies have demonstrated that sustainable practices such as organic farming, System of Rice Intensification (SRI), and integrated pest management (IPM) can achieve comparable or even higher yields than conventional methods, particularly over the long term (Badgley et al., 2007; Parameswaran et al., 2021). Additionally, sustainable agriculture in India has shown potential to empower smallholders, especially women, by reducing financial risks and fostering knowledge-intensive practices (Nelson et al., 2020). However, the transition to sustainable agriculture is impeded by institutional and governance barriers, lack of market access for eco-labeled products, and limited extension services (Andersson & Feder, 2004; Morrison-Saunders & Retief, 2012). Policy frameworks must therefore align subsidies, credit systems, and research agendas toward promoting diversified, sustainable production systems that are inclusive of marginalized communities (Pretty et al., 2018). Globally and in India, sustainable agriculture is not merely an environmental imperative but a strategic response to ensure equitable and resilient food systems in the face of increasing food insecurity.

3. Research Approach & Methods

This research is designed to explore the interaction between agricultural policy frameworks, community responses, and the systemic factors influencing sustainable agriculture in the Himalayan region. By aligning the three central research questions with a layered integration of system analysis, community feedback, and strategic transition planning, the study employs an ***integrated approach*** to diagnose the current situation, define desirable change, and propose actionable strategies for sustainable transitions. Traditional siloed approaches are insufficient to address the multifaceted challenges of environmental degradation, agricultural instability, and socio-economic marginalization that characterize the Himalayan agricultural landscape. An integrated approach allows for the synthesis of insights from multiple academic disciplines—such as environmental policy, rural sociology, agricultural economics, and governance studies—into a coherent framework that connects system-level drivers, community-level perceptions, and transformative strategies. This research avoids disciplinary isolation by constructing bridges between theoretical frameworks and empirical findings from different domains, producing a more holistic understanding of sustainable agriculture in mountainous regions.

Each research question in this study represents a distinct yet interlinked analytical layer. The first explores how current policies are structured and to what extent they integrate sustainability principles. The second investigates how these policies are perceived and experienced by farming communities, revealing gaps between policy formulation and on-ground realities. The third synthesizes evidence on the factors that facilitate or hinder the adoption of sustainable practices, offering strategic directions for policy design. Together, these components produce a unified knowledge base that informs both scholarly inquiry and practical interventions in sustainable agriculture.

Table 1: Overview of the Publications included in the dissertation.

	PAPER 1	**PAPER 2**	**PAPER 3**
WORKING TITLE	A critical analysis of the policy potential for sustainable agriculture in India	Unraveling climate change policy potential in Himalayan agricultural scenario: Determining the	Meta-Analysis of the major determinants of sustainable agriculture practices

		barriers perceived by communities	adoption: A global Systematic Review
RESEARCH GAPS	Limited examination of climate change mainstreaming; Lack of comparative policy studies; Focus on outputs over framing	Lack of perception-based studies; Farmers seen as passive recipients; Overemphasis on top-down approach	Fragmented understanding of adoption barriers; Lack of interdisciplinary synthesis; Under exploration of mountain contexts
AUTHORS	N. Chauhan, H. von Wehrden	N. Chauhan, M. Jain, D. Mattias, H. von Wehrden	N. Chauhan, M. F. Krestchmer, J. G. Rodriguez-Aboytes, H. von Wehrden
STATUS	Published in Discover Sustainability	Internal Review	Under Review in Land Use Policy
METHODOLOGY	Content Analysis	Semi structured Focus Group Interviews	Systematic literature review
DATA ACQUISITION & SOURCES	Policy documents freely available on various GoI website	9 FGDs in three altitudinal zones in western Himalayas	121 English-peer reviewed articles from WoS & Scopus
DATA ANALYSIS	Text mining, policy analysis using MAXQDA	Gioia Method, quantitative content analysis	Quantitative word analysis, qualitative content analysis
KNOWLEDGE TYPE	The theory- System Knowledge	The practice- Target Knowledge	Way forward- Transformative Knowledge
FOCUS AREA	Policy analysis; Climate change integration into	Community experiences; Policy legitimacy; Perceptions	Adoption drivers; human-influenced

	agriculture policy frameworks	of	effectiveness and fairness	factors; Leverage points for change

3.1. RQ1. Policymakers and Climate Change: The Theory (System Knowledge)

System knowledge refers to understanding the structures, processes, and dynamics that characterize the current state of a system. In our study, system knowledge involves analyzing the policy landscape that shapes agricultural development and building climate resilience in the Himalayan region. This section of our study investigates the **focus areas of agricultural policies** and critically assesses the extent to which **climate change concerns** have been mainstreamed. The aim is to map the major focus points of agricultural policies currently being implemented in the Himalayas and identify the potential of said policies in enhancing agricultural sustainability. By generating 'system knowledge', this research lays the groundwork for understanding both the opportunities and limitations inherent in current policy making approaches.

3.2. RQ2. Communities and Policies: The Practice (Target Knowledge)

Target knowledge moves beyond diagnosing what *is* to envision and what *ought* to be. It focuses on defining objectives for sustainable transformation based on an understanding of community needs, values, and capacities. This section investigates **how communities experience and perceive agricultural policies**. It explores the degree to which policies meet local expectations, address contextual realities, and are seen as legitimate and beneficial. By generating target knowledge, this research identifies the mismatches between policy intentions and community experiences, helping to define what kind of policy interventions are seen as desirable and necessary by the agricultural communities.

3.3. RQ3. Adoption determinants of sustainable agriculture practices: The Way Forward (Transformative Knowledge)

Transformative knowledge focuses on understanding how change can be catalysed. It encompasses the identification of pathways, interventions, and systemic leverage points to foster sustainable transitions. This part of our study, which systematically reviews **how various factors such as behavioural, institutional, and governance, shape the adoption of sustainable practices in agriculture**. This provides insight into the mechanisms through which sustainable practices are either facilitated or constrained. By generating transformative knowledge, this research identifies leverage points for intervention, offering practical

recommendations for policymakers, development practitioners, and local institutions aiming to foster sustainable agricultural transitions in the Himalayas.

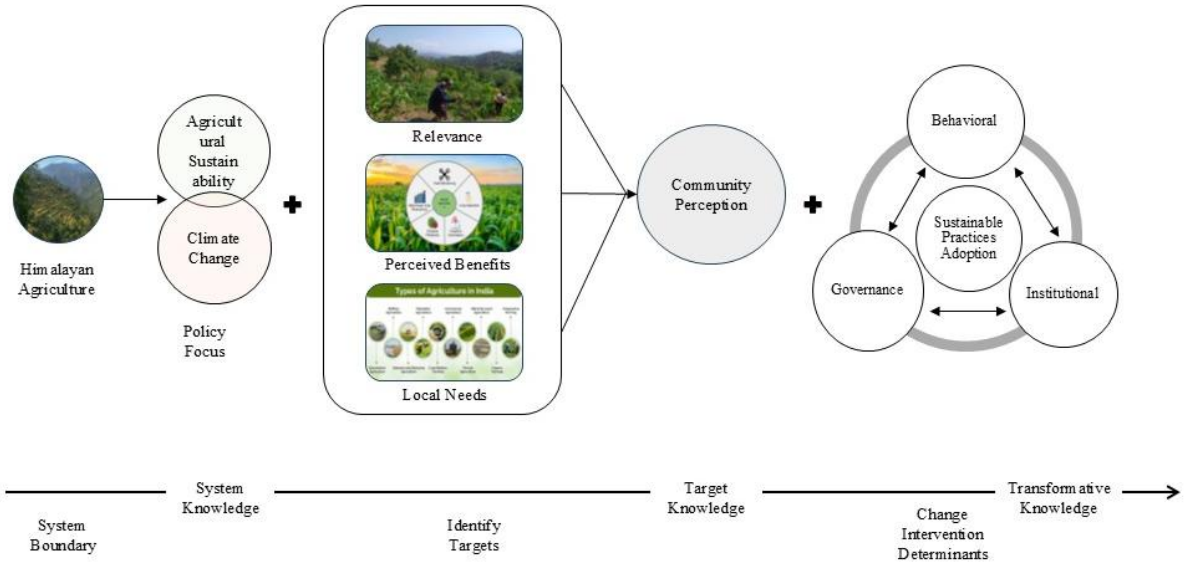

Figure 1: Integrated research design framework. The tripartite design ensures that the research maps the current system, diagnoses the gaps between intention and reality, and identifies pathways for transformation.

The holistic integration of these three layers is crucial. Without understanding the system (RQ1), one risks proposing policy formulations that are disconnected from reality. Without appreciating community perceptions (RQ2), one risks designing interventions that are rejected or misused by communities concerned/targeted by policies. Without identifying transformation pathways (RQ3), one risks being directionless.

Thus, this research not only advances academic understanding but also offers *practically grounded, context-sensitive, and strategically targeted recommendations* for fostering climate-resilient, sustainable agriculture and handling increasing food insecurity, in one of the world's most vulnerable yet vital reg

3.4. Study Area:

3.4.1.1. Western Himalaya: An Overview

Geographic Features:

The stretch of these mountains extends over 3500 kms, spreading from Afghanistan in the west to Myanmar in the east- The Hindu Kush Himalayas- are unarguably the youngest mountain range (Karan, 1987; Alfthan et al., 2018;). The rugged range is occasionally broken by broad valleys, such as Kathmandu, Paro, and Srinagar. Within this broader range, lies the mountain range expanding in the north of India - Indian Himalayan Range (IHR). The Indian Himalayan Range consists of 12 Indian states and lies between 21°57′-37°5′ N latitude and 72°40′- 97°23′ E longitude. It comprises 16% of the total Geographical region of India. About 51 million people inhabit the IHR, most practicing hill agriculture. Western Himalaya is a longitudinal subsection of this wider and greater mountain range (Figure 1).

Based on population features, regional characteristics and vegetations dynamics, western Himalaya encompasses three physiographic provinces, Jammu and Kashmir, Himachal Pradesh and Uttarakhand, out of which Himachal Pradesh and Uttarakhand are largely agricultural states of the western Himalaya and have approximately 75% of population dependent solely on farming as their livelihood. For Jammu and Kashmir, only 9% of the population is main cultivars, whereas both for the Himachal Pradesh (30%) and the Uttarakhand (15 %) it is higher (GoI, 2018). Based on the high percentage of total cultivars in Himachal, the state was considered for the present study.

The geologically newer western Himalayas (Study area) have three altitudinal divisions: 1. The Greater Himalayas or Trans Himalayas and Tibetan Plateau 2. Middle or Lesser Himalayas, and 3. The Lower Himalayas or the Sivalik Range. The fauna and flora distribution are altered and affected by the influence of altitudinal changes and climatic conditions. High species richness, including various endemic species, the western Himalayan ecosystem is both diverse and fragile (Tewari et al., 2017; Thakur, 1992). The extensive network of rivers, streams, canals and other water bodies, makes them a potential and sizable source of hydropower. Western Himalayan glaciers also feed numerous perennial rivers located downhill (Schild, 2008; GoI, 2010; DST, 2012). Holding high significance globally in terms of biodiversity, species richness, indigenous wealth, and socio-cultural diversity, the region has been identified as one of the biological ‘hotspots’ (CI, 2011; Gautam et al., 2013). The fragility of the landscape, physiography of the mountain system, makes it highly susceptible to external hazards and enhances the predisposed vulnerability (Shukla et. al., 2018; Pandey et al.,). There is ongoing concern about the constantly changing climate and its impacts, such as untimely and erratic

precipitation, increased drought frequency, flash floods and cloudburst, landslides, and threatened food security (Barnett et al. 2005; Cruz et al. 2007; Xu et al. 2009).

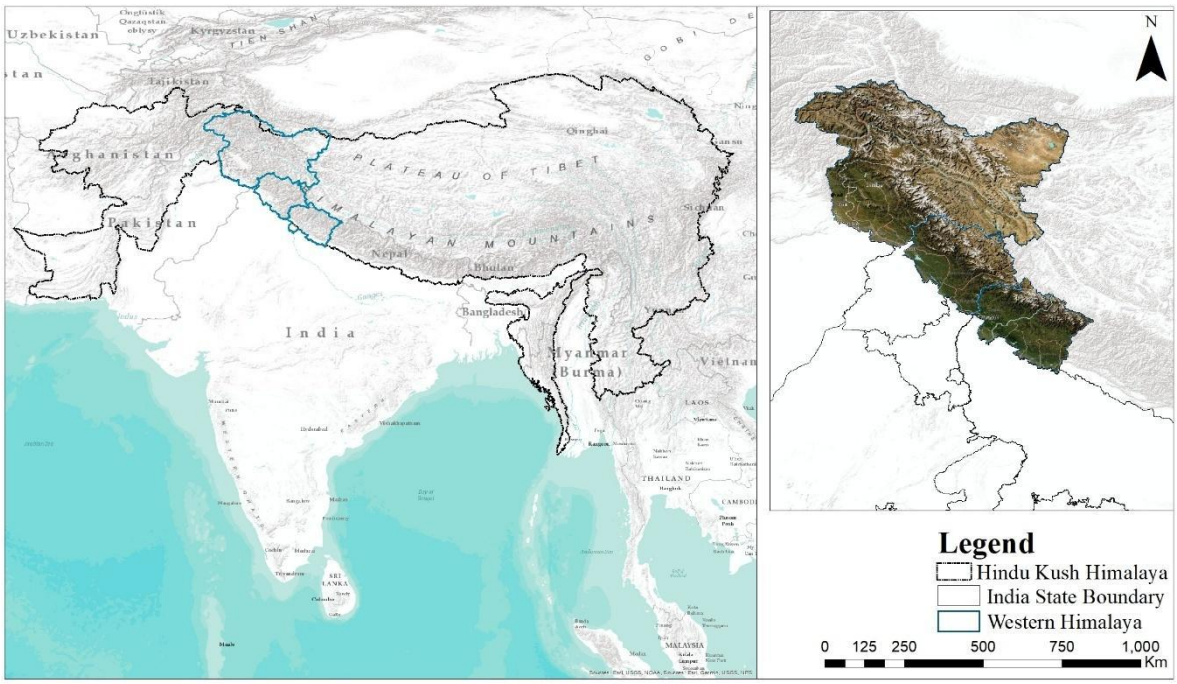

Figure 2: Map showing Western Himalaya's location within Hindu Kush Himalaya.

Demographic Features:

The Himalayas are the most densely populated mountain ranges around the globe and are consistently having a positive population growth rate. Although, drastically increasing demographics is becoming a global phenomenon, the population growth in Himalayas is dependent on numerous factors such as economic, biophysical, and political, leading to extreme variation in population distribution. Together, the population density for Himachal Pradesh is 123 per km2. The region consists predominantly of rural population, with 89.97% population presiding in rural areas. Agriculture forms the primary source of livelihood for the rural population. Agriculture is carried out amid the complex multidimensional setup, guided by a set of social and cultural norms. The major socio-economic and biophysical characters are mentioned in Table 2.

Himachal Pradesh has a diverse religious and cultural profile. The inhabitants consider the Himalayas to be sacred and adore them. In essence, the Himalayas represent the region's pride and necessity. Hierarchy among the communities can be still seen, motivated by the traditional caste system. The region has seen an increase in the overall literacy, with literacy rate being above the national average. The average literacy rate for the region is 81.25%. The growing uncertainty in the agriculture sector, restricted livelihood opportunities, constricted institutional

and infrastructural amenities, has led to out-migration of the male members of the households. Over the years, the region has faced the vicissitudes of population outflow, but, the traditions, culture, indigenous knowledge has managed to survive (Apollo, 2017; GoU, 2014; Nandy et al., 2000).

Table 2: Socio-economic and biophysical characters

Category	**Details**
Total Area	55,673 sq. km
Topography	Mountainous (Lower, Middle and Trans Himalayas)
Climate	Subtropical to alpine; highly variable by altitude
Soil Types	Mountain soils, alluvial soils, forest soils
Forest Cover	66
Main Crops	Wheat, maize, barley, rice, pulses, potato
Major Horticulture Crops	Apple, pear, peach, cherry, plum, apricot
Area under Cultivation	13.4
Irrigated Area	19
Population Dependent on Agriculture	75
Labour Force in Agriculture	55 (men: 60, women: 50)
Average Landholding Size	1.1 hectares
Livestock	Cattle, sheep, goats, yaks
Population	7.4 million (3.76 mil- Men; 3.64 mil- Women)
Population Density	123 persons/sq. km
Sex Ratio (females/1000 males)	974
Literacy Rate	81.25 (Men- 89, Women- 77)

Rural Population	89.97
Other Main Industries	Hydropower (major hydroelectric producer, 27 of India's total potential), tourism, horticulture, pharmaceuticals

*All the numbers are in percentage, except for sex ratio & otherwise mentioned.

Agriculture Systems

More than 75% of the population depends on agriculture and allied sectors such as horticulture, silviculture, pisciculture for their major source of livelihood (REF). Though, only a small section of total geographical area i.e., 13.4 % is suitable for cultivation (Census of India, 2011). The agriculture intensity of both the states is 167% implying that the land is cultivated more than once annually. The major cereal crops grown in the region are wheat, maize, barley, and rice. The region has undergone considerable divergence in the agricultural practices, inclining more towards high earning crops such as fruits, vegetables and other cash crops. Like the other mountain systems, agriculture in the region is a complex system comprising various social and environmental factors. Combined, these factors formulate the coupled intricate system of agriculture, with human and ecological systems consistently interacting with each other. Both, human and ecological systems, are heavily dependent on each other. Agriculture in the region represents an entangled combination of human and natural resources. The farmers extract huge quantities of resources from the natural capital such as forests, waterbodies, and livestock. This high dependency on natural resources makes it imperative that for every hectare of cultured land, there must be 10-15 hectares of forest land (Kuniyal, 2003).

The average landholding size is less than 1 hectare in the region, leading to smallholder farmers practicing subsistence agriculture (Negi and Makhuri, 2013). The already small land holdings are continuously decreasing, raising livelihood concerns in the region (Kumar, 2011). Furthermore, most of the land is rainfed, due to shortage of proper irrigation facilities. And not to forget about the consistent challenge of complex and marginalized topography, posing obstacles in access to resources (Sati, 2012, Shukla et al., 2018). All the above conditions make it difficult to find ways to enhance agricultural development and productivity. As a result, the region's limited cultivable land, combined with poor irrigation and infrastructural facilities, has led to declining productivity and failed agriculture in context of food security and livelihood demands. Aside from the inherent topography-related issues, current climatic stressors have further destabilized agriculture systems, resulting in the impoverishment of dependent farmers.

3.4.1.2. Climate Change and Impacts:

The region under study has a variety of climatic conditions due to its diverse landscape. The high altitudinal zones are cold, and snow covered and thus can be considered alpine zone. The middle Himalayan zone is moderate with temperate conditions, whereas the lower zone is hot, and humid with tropical conditions. The temperature ranges from 18°C and 36°C (lowest and highest mean), in the low altitude areas, whereas in the high-altitude areas, the temperature lies between 14°C and 22°C. The trans-Himalayan Tibetan plateau faces a harsh winter, with sub-zero temperatures and extreme snow. The mean annual rainfall spans from 1200 to 1500 mm (Krishnan et al., 2019). Winter precipitation in the region consists of 40-45% of total annual precipitation and is important for snow cover in glaciers and rabi crops. The snow cover further acts as the water source for summers.

Erratic weather behaviour such as increased fog incidences, enhanced occurrence of hailstorm, increase in drought conditions are also being observed in the region. All this can be attributed to significant change in the temperature and rainfall pattern in recent times (Madhura et al., 2015; Dimri et. al., 2015). Substantial increase in the rates of mean temperature, as high as 0.104°C per decade has been noticed recently (Ren et. al., 2017) over last century. The condition is anticipated to deteriorate soon, posing a serious threat to Himalayan agriculture, farmers' livelihood, food security, and welfare (Macchi et al. 2014). Agriculture being a highly climate sensitive livelihood option, communities dependent on agriculture face a direct threat from climate change and under direct exposure to associated risks (Barnes et al. 2013; Niles and Mueller 2016).

Regardless of the uncertainty in the climate sensitive sector of agriculture due to changing climate profile, a detailed and inclusive vulnerability assessment of the community is deficient. There is little awareness about the role played by various social and environmental factors in the vulnerability of the agriculture communities. The region's diversified, rural, marginalized, and agrarian profile grabs attention and makes it a unique study site for climate change studies, with special focus on agriculture communities.

4. Results:

4.1. A critical analysis of the policy potential for sustainable agriculture in India

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Discover Sustainability

Review

A critical analysis of the policy potential for sustainable agriculture in India

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Abstract
Aligning the progress in terms of policy formulation in India with the changing climate is imperative for the evolution of agriculture towards a more sustainable and environment friendly sector, especially for an agro-dependent country like India with 17.6% contribution in GDP. As per last census conducted (in 2011), 54.6% of India's total population depends on agriculture as their primary livelihood. In this context, the current study emphases on ascertaining the major themes of the current policies being implemented in agriculture in India, while evaluating the potential of these policies in restructuring the agriculture into a more sustainable sector. The paper explores the different themes of the policies and the extent to which climate change and adaptation to climate change is discussed in the policies. The methodology includes a qualitative content analysis of the National level policies by using MAXQDA as the analysis tool. Policies largely focuses on increasing the cost-effectiveness and productivity of the agriculture and wants to increase the profitability from the economic sector with limited attention to farmer diversity and nuances of the socio-economic disparity. Tackling the disconnect between the policies and the nuances of the climate change reality of agriculture in India is imperative for comprehensive adaptation solutions and enhancing the sustainability of agriculture while addressing the increasing food security issues.

Clinical trial registration Not applicable.

Keywords Policy · Climate change adaptation · Sustainability · Content analysis

Introduction

Climate change represents one of humanity's most serious challenges in the twenty-first century. Changing climates particularly affect agriculture due to its direct dependence on climatic conditions. These changes can lead to reduced crop yields, altered growing seasons, and increased pressure from pests and diseases. Exacerbations in climate change disproportionately affects the agricultural productivity

through erratic weather patterns, soil degradation, and water scarcity [18, 38]. The Intergovernmental Panel on Climate Change (IPCC) reports that for every degree Celsius increase in global temperatures, yields of staple crops like wheat, rice, and maize could decline by 6%, 3.2%, and 7.4%, respectively [28]. These reductions in crop productivity pose severe risks to food security, particularly in regions already suffering

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from food shortages [3]. The intertwined nature of agriculture and climate change necessitates comprehensive strategies that balance productivity with ecological stewardship. Sustainable agriculture has emerged as the solution in the global discourse in response to climate change and food security. As the world grapples with the dual challenges of environmental degradation and the need to ensure food for a growing population, agricultural systems are under increasing pressure to transition toward sustainability.

Sustainability in agriculture involves the adoption of practices that meet current food needs without compromising the ability of future generations to meet their own needs. The importance of sustainability in agriculture is underscored by the global commitment to the United Nations Sustainable Development Goals (SDGs), particularly Goal 2: Zero Hunger, which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. This goal emphasizes responsible agricultural production and consumption to ensure that the nutritional needs of the estimated 9.6 billion population (by 2050) are met [57]. Achieving these targets requires a comprehensive understanding of how climate change affects agriculture and the development of strategies to mitigate and adapt to these impacts.

India, home to over 1.4 billion people and one of the world's most agrarian economies, provides a unique lens through which to explore the intersection of sustainable agriculture and climate adaptation. Despite its critical role in global food supply chains, India's agricultural sector is characterized by significant structural and policy challenges, including resource overexploitation, inequitable land distribution, and high levels of vulnerability to climate risks [43]. These issues underscore the urgency of re-evaluating and reforming agricultural policies to foster resilience and sustainability.

India's agricultural policies have evolved significantly since independence, primarily focusing on achieving food security and self-sufficiency. The Green Revolution of the 1960s and 1970s, marked by the introduction of high-yielding varieties (HYVs) of seeds,

extensive use of chemical fertilizers and pesticides, and expansion of irrigation infrastructure, led to a dramatic increase in food grain production [59, 70]. However, these policies also contributed to environmental degradation, including soil health deterioration, groundwater depletion, and increased greenhouse gas emissions, and created economic dependencies on fertilizer, seed material and land ownership, to name some of the examples of the effects of globalisation.

But, recently, policy efforts have shifted towards addressing the environmental impacts of intensive agriculture while continuing to support productivity and income growth for farmers. The Indian government has recognized the need to integrate climate resilience into agricultural policies. The National Action Plan on Climate Change (NAPCC), launched in 2008, outlines India's strategy to address climate change through eight national missions [41]. Programs such as the National Food Security Mission (NFSM) and the Rashtriya Krishi Vikas Yojana (RKVY) (launched in 2016) have aimed to promote balanced fertilizer use, efficient water management, and integrated pest management practices [21].

However, a critical gap exists in understanding how India's agricultural policies align with its climate commitments and broader sustainability goals. While the importance of sustainable agricultural practices has been widely recognized, the focus has often been on macro-level analyses or isolated case studies. Recent literature, such as the works of [17, 79] has highlighted the need for region-specific evaluations that integrate socio-economic and environmental dimensions. Existing research has either been limited in scope or has failed to account for the dynamic interplay of institutional frameworks, economic incentives, and local realities. Key components include the development of climate-resilient crop varieties, soil health management, efficient water use, and the promotion of agroforestry and organic farming. Despite these initiatives, the existing policy framework often falls short of addressing the complex and multifaceted challenges posed by climate change.

The themes of agricultural policies shape how food is produced, how resources can be managed to the best, better livelihood provisions for rural economies, and ensure sustainable development of the agriculture sector [20]. Analyzing themes in agricultural policies is essential for understanding their effectiveness in addressing complex, interconnected challenges such as food security, climate change, and rural poverty. Policy analysis allows for the identification of strengths, gaps, and unintended consequences, helping to improve policy design and implementation [64]. By examining themes like sustainability and economic resilience, analysts can assess how well policies align with ecological principles and market demands, supporting more adaptive and long-term solutions [5–7, 55]. Additionally, analyzing these themes aids in the evaluation of social equity impacts, particularly for smallholder farmers and vulnerable populations who may be disproportionately affected by policy shifts [71].

Given the current scenario, climate change and its adaptation become an imperative aspect to be focussed in policies. It is suggested that the policies should focus on rainwater harvesting and the development of robust water storage infrastructure to mitigate the impacts of monsoon variability and seasonal droughts to ensure a reliable water supply for irrigation, thus preparing farmers for better adaptation [49, 63]. Developing and disseminating crop varieties that can withstand heat, drought, and flooding, encouraging crop diversification and integrated farming systems can reduce the risk associated with climate variability and improve their adaptability [76, 78]. Policies focused on strengthening extension services to disseminate knowledge about climate-smart agricultural practices can empower farmers to adapt to climate change effectively [1].

This precarious situation demands a comprehensive review and revision of existing agricultural policies to ensure they are robust enough to address emerging climate-related challenges and promote sustainable agricultural practices. In countries like India, where agriculture is a crucial component of the economy and the primary source of livelihood for a large segment of the population, the impacts of climate change are particularly profound [22]. The interplay between climate change and agricultural policies is therefore critical in shaping the future of India's agricultural sector. Current policies must be aligned with the goals of enhancing climate change adaptation and sustainability to protect the livelihoods of millions of farmers and ensure long-term food security. By integrating climate adaptation and sustainability into the policy framework, India can better equip its agricultural sector to cope with the adverse effects of climate change. This approach will not only safeguard food security and farmer livelihoods but also contribute to the broader goals of environmental sustainability and economic stability [6].

Therefore, the present study is intended to assess the current state of policy affairs in Indian agriculture, their role in making agriculture more climate-adaptable, enhancing its sustainability, and eliminating concerns hindering the growth of agriculture in India. Building on seminal contributions in ecological economics and sustainable policy frameworks [25, 68, 79] and recent advancements in understanding the socio-economic impacts of climate-adaptive strategies, this paper seeks to provide a holistic perspective. This study contributes to the evolving literature on sustainable agricultural transformations in the Global South.

Methodology

Our analysis of national-level policies was aimed at coding and analysing the policy documents that focus on agriculture policies on a national level and are compiled in English by performing a 'qualitative content analysis' [39](Table 1). The analysis focussed on Indian agricultural policies on climate change and sustainability in agriculture. The analysis was used to identify specific parts of the policy texts that

discuss agriculture and shape the practices being implemented in agriculture. The framework used in the study addresses the determinants of transformation towards sustainable agriculture. All factors creating an impact on farmers such as financial support, educational support, assets and endowments, and production-oriented support were analysed. The policies were coded based on predefined categories such as climate change, relationships with other policies, the definition of farmers, monitoring of policies, and bodies governing the implementation of policies, in addition to the topics mentioned in the initial framework.

Policy search and collection

For the past few years, transformation in agriculture has been widely discussed in various capacities in India, with a dedicated focus on climate change and its adaptation. Various policies have incorporated climate change mitigation, and its impacts (NMSA; NBM, PMFBY). All the policies aiming at the improvement of agriculture, whether be it by reforming market availability or reducing production risk, or increasing yield, were compiled, and considered for this analysis (see online appendix). All documents not available in English language or electronic form were excluded (Fig. 1). Hence a total of 49 policy documents and mission guidelines were downloaded for content analysis at the national level. Out of these policies, after first screening 31 significant policies were selected for the final analysis (see Supplementary data). All the policies were available on open-source website maintained by the Government of India (https://a gricoopgov.o r g).

Qualitative content analysis (QCA)

Qualitative content analysis aims to determine the presence of certain phrases, concepts, or themes in a text, allowing the researcher to evaluate the information contained in a policy document by rendering the language used by policymakers [10, 24, 39]. QCA of policy documents was conducted using a deductive as well as inductive approach to structure the content. Based on aspects stemming from the literature, a category system to code the material was developed (Table 1). We used MAXQDA (version 22) to conduct the content analysis, focussing on examining the incidence and treatment of current issues faced by agricultural communities in India (Fig. 2). The coded text was read and interpreted manually after obtaining the word frequencies from the text search.

Table 1 Followingframeworkwasusedtocodethepolicies

Level	Category	Diversitydimension	Codingscheme(textsearchquery)
Individual	Financial	Loans	Varioustypesofloans,mentionofloan,increaseordecreaseinloanamount,changesindocumentsrequiredfor loan,considerscroplossbynaturaldisasters
		Credit	Moneyprovidedoncredit,considerscroplossbynaturaldisasters,creditvalueincreasedordecreasedover time,creditvaluevariesfromclimatesensitivezonestoleastimpactedzones
		Banks/banking	Considerscroplossorlandqualityimpactedbynaturaldisasters,monetaryassistance,interestrates
	Educational	Scholarships/Vocationaltraining	Agriculturaltraining,coursesaboutadvancedtechniques,teachingadaptationmethods
		Agencies/educationalcenters	SuchasvariousNGOs,governmentalorganizations
Community	Assetsandendowments	Landowned	Subsidyinlandprices,ownershipbenefits,qualityofsoil
		Irrigation	Changeinrules/regulationsregardingirrigationfacilities,helpprovidedforirrigationpurposes,and,establish - ingandmaintainingirrigationsources
		Livestockholding	Anysupportforlivestockrearingandbearing
		Livelihooddiversification	Diversifyingincomesources,helpinhandloomormini-industriessetup
		Marketoriented	Accessibilitytomarket,maximumsellingpriceregulation
	Productionorientation	Subsistence	Typesoffoodcrops,supportfortraditionalmethodsorconventionalmethods
		Seeds	Subsidyontheseedprices,seedbanks,helpforseedconservation
		Fertilizers	Subsidyonfertilizers,changesinfertilizersqualityorquantity,organicfarming

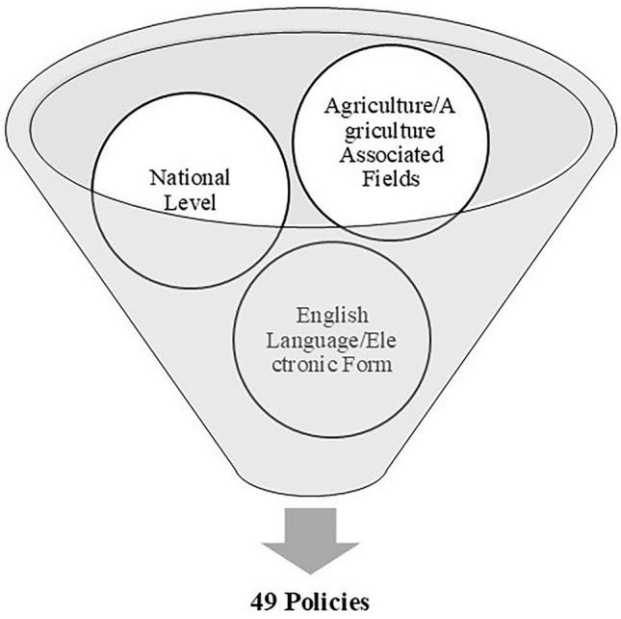

Fig. 1 Diagram showing the policy selection criteria for our current study

We analysed the texts and passages that included the terms related to 'climate change', 'sustainability in agriculture', and 'climate adaptation' within the documents. We sought to examine how government policies evolve through the lens of a climate change-related policy paradigm, focusing on policy problems, objectives, and tools [4, 77]. By analysing the textual corpus as a product of expansive policymaking practices [26], we aim to interpret the findings within a broader sustainability context, exploring the climate understanding and knowledge frameworks that inform the creation of these policies.

Results

Key themes of the policies

The policies hardly define the small and marginal farmers as families those owning cultivable land up to 2 ha. Land endowment is only discussed in 2 of the total 41 policies, defined in none. Defining helps in specific targeting of these families highlighting the focus on supporting the most vulnerable agricultural stakeholders. Despite huge 'feminization of agriculture' (defined by Pattnaik and Lahiri-Dutt [51] as women's increased responsibilities in agriculture) in India, only 13 documents out of the total 31 documents talk about gender-based differences among farmers. Even then, most often the discussion is combined with the caste or culture of the community. Another major theme was 'dissemination

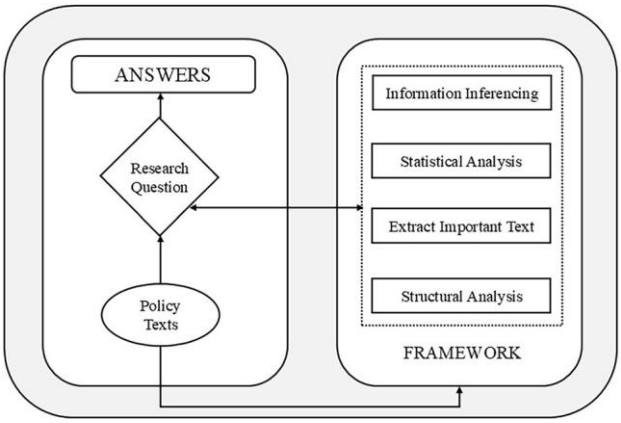

Fig. 2 Diagrammatic representation of steps involved in content analysis

of information' or 'educational/vocational training'. Opening centres providing information and knowledge to farmers regarding seed quality, better mechanization and irrigation technologies, seemed few of the priority agendas in these policies.

The main target of most policies is to improve farm productivity, enhance agricultural research, and support the most vulnerable agricultural stakeholders. This is achieved by having policies which focus to improve soil health to increase yield production (discussed in 25% of policies), fertilizer subsidy or support (discussed in 20% of policies), as well as improving infrastructure and seed quality. The policies (29%) discuss integrated approach towards agricultural development to ensure a comprehensive approach to agricultural productivity. Almost 87% of the policies focus on enhancing productivity of the agricultural yield, highlighting the 'production oriented' attitude of Indian policy makers.

Many policies discuss providing financial and technical assistance to the farmers as their key theme. Almost 24% of the policies talk about providing financial assistance in the form of loans or direct credit. The policies also talk about machinery banks which supports farmers in buying agricultural related machinery. Policies such as AMI, ATMA, NFSM have a detailed funding mechanisms and the provision of technical training for extension officers and scientists. They also have required vocational training programs for farmers, thus underlining the commitment to capacity building and resource allocation. More than half (58%) of the policies have infrastructure development as their key theme. Initiatives like the development of high yield seed quality, rural haats*, Mandi's (local sellers' markets), and micro-irrigation systems aim to build robust agricultural infrastructure at the grassroots level.

A data-driven approach was also noticed in policy making. Agricultural census data was collected and utilized in better formulation and evaluation of the implemented policies. The analysed documents also outline extensive collaboration between national, state, and local bodies, as well as international organizations, indicating a multi-level governance model. Regular monitoring by agencies like NABARD and state-level committees ensures accountability and effectiveness in the implementation of various schemes.

Attitude towards climate change and adaptation provisions

The content analysis showed a rather sad attitude towards discussing climate change and associated adaptation provisions. Total of 8 policies fall under the umbrella of

climate change, but no one defines climate change. The policies do discuss the adaptation and mitigation measures in the text. From the other agricultural policies at national level, climate change and related concerns are absent. Only one policy, NMSA discusses the importance of implementing sustainable agricultural practices as an important step in adapting towards changing climate. Table 2 gives the list of policies and their adaptation initiatives.

The table shows a clear picture of most policy initiatives aiming at reducing the production risk due to erratic rainfall or decrease in arable area. A great emphasis is laid on managing irrigation sources or providing financial aid to farmers suffering loss during harvest. The technical solutions for risk management such as better variety of seeds, heat tolerant varieties, micro-irrigation systems, crop insurance etc. are also mentioned and often seem to be the primary response of the policies. Considering the need to mitigate social risks, short-term interventions such as livelihood diversification, sustainable tourism are also mentioned, but not to great extent. Despite technical risk management approaches being successful, their uptake depends largely on the socio-economic status of the farmers, making them non-equitable resolutions for all farmers [14, 42, 52]. Therefore, viewing them as "one-size fits all" would be a mistake on the part of the policy formulators.

Table 2 Adaptation provisions mentioned in the policies

Adaptation provisions in policies	Policy	Discuss subsistence farming	Anyone/ no mention
Improved crop seed variety/livestock and fish cultures	NMSA, RKVY, ATMA, NDPRA, SAARK	+	+++
Better technology, mechanization, infrastructure	RKVY, ATMA, NAP, NMAET, SMSP	+++	++
Soil quality improvement and nutrient management	RPS, NABARD,	+	+++
Water use efficiency	NMSA, RKVY	+++	+
Research and education, skill development	SMSP, SAME	++	+++
Increasing forest cover	RPS, agroforestry (RKVY)	–	+++

Table 3 Codes distribution (deductive) into three dimensions of sustainability

Environmental	Economic	Social
CC	Banks	Awareness
Fertilizer	Credit	Website
Livelihood	Infrastructure	Agencies
Livestock	Insurance	Subsistence
Irrigation	Land owned	
Soil quality	Loans	
	Market	
	Scholarship	
	Seeds	
	Technology	
	Subsidy	
	Yield	

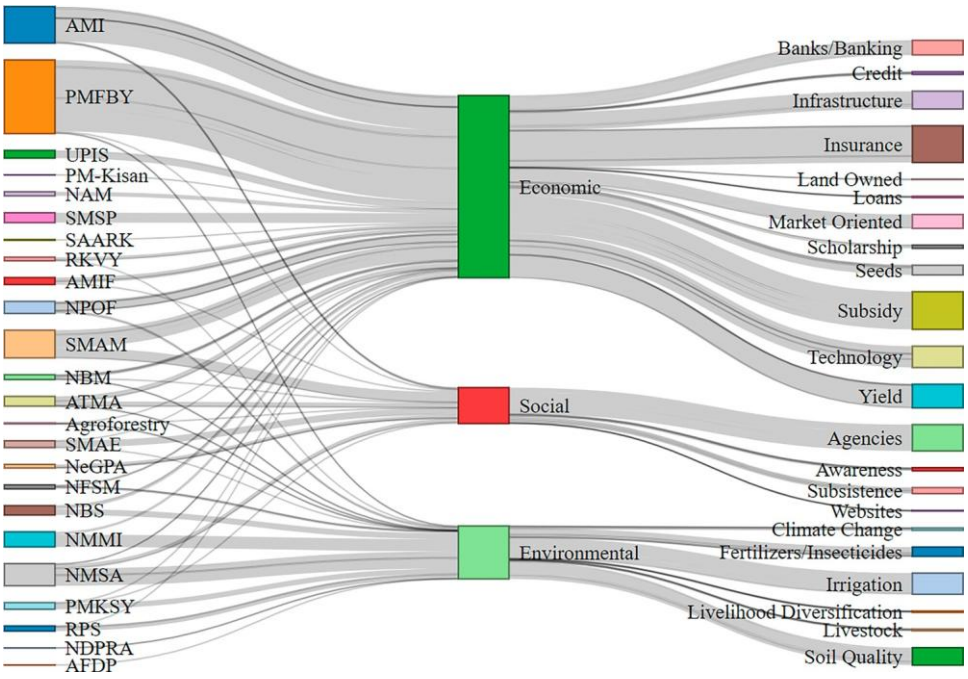

Fig. 3 A sankey plot showing the flow and strength of connections from policies (right hand side) to codes (left hand side) through the three sustainability dimensions

(center)

Furthermore, technical resolutions contribute to the current dominance of 'lab to land' nature of adaptation provisions, which fail to factor in the specific needs and individual veracities of farmers [12]. Although, NMSA document does acknowledge the importance of an holistic approach and the role of "Involving knowledge institutions and professionals in developing climate change adaptation and mitigation strategies for specific agro-climatic situations and promoting them through appropriate farming systems" and lays priority on understanding micro-climate for better strategy development, but there seems to be lack of provisions bridging the gap between imminent climate threats and future impacts of the same.

Policies and sustainability elements

The agricultural ministry of India has realized this necessity which can be seen in the recently formulated policies with emphasis on enhancing sustainability of agriculture. To further understand the contribution of each policy into sustainability, we tried to break (deductively) the codes into dimensions of sustainability. This will help us in identifying the sustainability dimension lacking behind. We divided the codes into Environmental, Economic and Social dimensions of sustainability (Table 3). Then we tried to plot the movement of relations among the policies, codes and dimensions (Fig. 3).

Economic dimension contributes the most (almost 53% by frequency of codes discussing sustainability), followed by environmental (29%) and social (only 18%). A huge amount of attention is given to providing communities with subsides and insurance, this highlights the poor economic state of Indian farmers. Technology adoption is another tool mentioned in policies alongside yield. Significance of farming technological innovations in making agriculture more sustainable has been considered

a huge contributor but its adoption is often dependent upon the wealth farmers' family hold [45, 50]. The policy analysis provides no evidence that the above has been considered during policy formulation. But one can say that considering technology as a solution, is a big step by Indian policy makers.

Discussion

In recent years, policy analysis has taken an argumentative turn, most of which use a heuristic approach, encouraging the critique of policies and thus, pave the road towards improving them [75]. Such type of policy analysis has proved themselves useful in development of a just and sustainable world, consistently providing vital insights into the issues and problems between the policy formulation and implementation [16, 19, 36]. Our study suggests changes or reforms to established policies for enhancing agricultural productivity, food security and diversify livelihood while simultaneously make it more sustainable.

Regardless of the efforts made by the authorities, there still seems to be missing pieces crucial for adaptation of agriculture and associated communities to climate change. One such piece is farm and family size. None of the policies discuss these within the text. Especially in the India, average farm size positively co-related with income levels [58]. During the last few decades, the share of farm size has decreased from >5 to <1 ha, which shows an increase in smallholder farmers. The fragmented nature of landholdings, with a significant proportion of farmers operating small and marginal farms [44, 66] leads to a lack of resources and access to technology. Farm size determines the agricultural outlook of farmers and enables better adaptation towards climatic stressors [3, 9, 31]. The family size has been a well-established factor in helping farmers cope with the changing climate and its stressors [8, 74]. The above-mentioned discoveries reveal that limited attention is given to individual farm household needs within policy domain. There seems to be a lack of significance given to understanding diversity among the farming community which are identified to be critical for Indian farmers. These farmers often lack the resources.

One reason of the low abundance of climate change within policy documents can be rooted to huge disparity in socio-economic status of agricultural communities in India. Socio-economic disparity has been a continuous challenge in India and thus created an almost singular focus for policymakers [56]. The fact that increasing climate change contributes to enhancing these disparities by making the communities differentially vulnerable is often overshadowed and underrepresented in the policies [65, 72]. This aligns with the results of our analysis where most of the policies are focussed on providing financial support to farmers, and on setting up social service agencies (Fig. 1). Subsidy, insurance, irrigation, infrastructure are some of the major concerns tackled in our current policies, which gives us a picture of the existing socio-economic state of agricultural community.

Even the codes representing the environmental dimension of sustainability aligns with the idea of overall development by improving economic state (enhanced productivity, increased livelihood, better yield and infrastructure etc.) of agriculture and associated communities. This also proves that there is a growing consensus among the key stakeholders of Indian agriculture, along with the government, policy makers and industry, of utilising a diverse range of fertilizers (chemical, organic, bio-fertilizers) for heightening the agricultural productivity. However, numerous studies have suggested that excessive fertilizer use has led to a decrease in soil quality (and in turn longevity of farmland), increased release of ammonia into atmosphere etc. [13, 32, 46].

Our analysis also points out that awareness is among the least discussed despite numerous studies proving that access to education can prepare agricultural communities with knowledge and information about modern farming approaches, mechanization, enhanced adaptation capabilities, and thus in turn better equipped towards climate change. Education also makes the communities aware about the sustainable methods of farming, e.g., organic farming, environmentally friendly pest control, soil testing etc. and increases the chances of their adoption [48, 67]. The current global environmental situation, and it's impacts on Indian sub-continent, has put agriculture in India at a critical crossroad, demanding tactical planning to transform the agriculture while concurrently upholding the required food security and ensuring sustainability for the future [11, 30, 53, 76].

Unlike earlier studies, which often focused on isolated factors like financial access or agricultural yield, [35, 61] this analysis adopts a holistic approach, integrating diverse domains such as climate change, financial structures, educational efforts, and production orientation [7]. The present study expands its scope to include technological adoptions, infrastructure improvements, and capacity-building initiatives. The current study highlights a more nuanced understanding of adaptation provisions, tailored to specific farming contexts, such as subsistence farming versus market-oriented approaches. This differentiation marks a departure from earlier studies that typically applied one-size-fits-all strategies. The findings underscore the significance of diversified livelihood strategies, infrastructure advancements, and educational outreach, which were often underrepresented in prior analyses [47, 57]. Notably, the comparative analysis of policy effectiveness, ranging from soil quality management to skill development programs, aligns with emerging research advocating for multifaceted and adaptive policy frameworks. Such an inclusive and detailed approach offers a more actionable roadmap for policymakers, ensuring that interventions cater to varied agricultural and socio-economic contexts.

T he role of farmers in sustainable agriculture

In the past years, administrative interventions for agriculture have strengthened, and can be further improved. One of the most effective ways to make Indian agriculture more sustainable is by promoting sustainable farming practices. Farmers are at the

forefront of sustainable agriculture as they are the primary managers and decision makers with regards to agricultural lands and resources. Their actions and decisions significantly influence the sustainability of agricultural systems, making their role critical in achieving the goals of sustainable agriculture [73]. Farmers can have a huge contribution to sustainable agriculture by adopting various practices that reduce environmental impacts and enhance the resilience of agricultural systems [55]. One example is implementing crop rotation and diversification which helps in maintaining soil fertility, reducing pest pressures, and increases biodiversity on farms [37]. Another example is, conservation tillage practices, which includes minimal soil disturbance, maintaining soil cover, reduces soil erosion, and conserve water, and enhance soil organic matter, contributing to better soil health and carbon sequestration [29, 34].

Farmers are also responsible for making decisions regarding resource managements in fields, such as water distribution, fertilizers use, and mechanization. Making farmers more aware and trained in better techniques, such as drip irrigation, organic farming, rainwater harvesting, efficient machinery use, reducing waste can prove to be a vital component of sustainable agriculture. These practices are essential in many parts of India where water scarcity is a significant concern, fertilizer use is being exploited, and old-school tools are still being used [23, 40]. With increasing concerns about habitat and biodiversity loss, and a huge land being used in agriculture, we can enhance bon-farm biodiversity by maintaining natural habitats, such as riparian buffers and hedgerows and support ecosystem services alongside getting the added benefits of integrated pest management [33].

The above section shows that how most of the decisions and possible changes in agriculture to make it more sustainable rely on farmers and their families. Despite their critical role, farmers face several challenges in implementing sustainable practices. Economic constraints, lack of access to knowledge and resources, and market barriers can hinder the adoption of sustainable farming methods [54]. To overcome these challenges, there is a need for supportive policies, financial incentives, and education programs that promote sustainable practices. Engaging farmers in participatory research and extension services can also empower them to innovate and adapt sustainable practices to their local conditions, thereby enhancing the sustainability of agricultural systems globally [2, 15]. Effective and updated framing and implementation of policies is a major component for constructing the way and determining indisputable progress within the agriculture domain and in making it sustainable [57].

Conclusion

In an agrarian country like India, where farmers are the main end-decisions makers, making agriculture sustainable at a national level, during the entire process of crop production, from farm to feed, is a difficult task. Yet we want to highlight this step as crucial in current times where the vulnerability of farming communities is increasing

with changing climate. The present analysis tried to understand which changes into the policies will make the transition smooth and fast, as well as align the interests of farmers. The results indicated that 'social factors' should be more included within policy initiatives, as social factors have the capacities to tackle the vast diversity present in Indian agrarian scene [62, 69]. Our study also indicated that farmers should have 'access to' food grains, rather than focusing the target on 'production of' food grains. Heterogenity among the farming community is often overlooked which hinders the smooth implementation of current policies. This makes one to question the inclusivity of the existing precatory measures being applied while consider equal distribution of resources via subsidy policies [60].

Finally, our policy content analysis also determines that the existing policy framework needs an immediate change for timely success of sustainable agriculture. Agriculture and Farmers Welfare (A&FW) is India's ministry which is dedicated to the cause of agriculture and is responsible for formulation of numerous missions and policies. This decisively indicates that agriculture is a key concern for Indian Government. But out policy analysis notices a lack of concern and growth towards sustainability of agriculture. Missions focussing on some of the concerns regarding providing farmers with the autonomy and authority to make agriculture sustainable have been drafted in recent years (SMAM in 2014–15, NMSA in 2014, RKVY-AGRICOOP, 2014 etc.). A detailed list of policies and their roles can be found in supplementary datasheet. We need to implement 'Integrated Farming System' and formulate policies that consider these.

The following points should be considered by policy makers while trying to incorporate sustainability and climate change in current policies:

1. Strengthen multi-stakeholder collaboration for financial inclusion and technological dissemination.
2. Expand educational outreach and vocational training tailored to climate-resilient agriculture and the needs of local communities.
3. Enhance the monitoring and evaluation frameworks for policy implementation effectiveness.
4. Increasing the integration of digital tools like websites/applications to improve access to policy benefits and resources is required.

However, the effectiveness of these interventions hinges on addressing the implementation challenges and exploring the role of finances in supporting sustainable agriculture and providing educational measures. Future strategies must incorporate digital tools, such as climate-resilient technologies to enhance farmers' adaptation capacities and resilience [27].

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References

1. Agarwal B, Agrawal A. Do farmers really like farming? Indian farmers in transition. Oxf Dev Stud. 2017;45(4):460–78. https:// doi. org/ 10. 1080/ 13600 818. 2017. 12830 10.
2. Altieri MA. Linking ecologists and traditional farmers in the search for sustainable agriculture. Front Ecol Environ. 2004;2(1):35–42.
3. Arshad M, Kächele H, Krupnik TJ, Amjath-Babu TS, Aravindakshan S, Abbas A, et al. Climate variability, farmland value, and farmers' perceptions of climate change: implications for adaptation in rural Pakistan. Int J Sust Dev World. 2017;24(6):532–44.
4. Baniya B, Aryal PP. Can the framing of climate mitigation actions into government policies lead to delivering them?—Insights from Nepal's experience. Environ Manage. 2022;70(2):179–200.
5. Barra C, Falcone PM. Environmental performance of countries. Examining the effect of diverse institutional factors in a metafrontier approach. Socioecon Plann Sci. 2024;95: 101972. https:// doi. org/ 10. 1016/j. seps. 2024. 101972.
6. Barra C, Falcone PM. Institutional quality and bioeconomy performance in European countries: unveiling the evidence. Ecol Econ. 2024;220: 108188. https:// doi. org/ 10. 1016/j. ecole con. 2024.1 08188.
7. Barra C, Falcone PM. Unraveling the impact of economic policy uncertainty on environmental efficiency: how do institutional quality and political orientation matter? Econ Politics. 2024;36(3):1450–90. https:// doi. org/ 10. 1111/ ecpo. 12297.
8. Billah MM, Sarker MA, Miah MAM, Kabir KH. Adaptation of farming practices by the smallholder farmers in response to climate change. J Agric Ext Rural Dev. 2015;7(2):33–40.
9. Birthal PS, Hazrana J. Crop diversification and resilience of agriculture to climatic shocks: evidence from India. Agric Syst. 2019;173:345–54. https:// doi. org/ 10. 1016/j. agsy. 2019. 03. 005.
10 . Bryman A, Bell E. Business research methods. Oxford: Oxford University Press; 2015.
11. Caulier-Grice J, Davies A, Patrick R, Norman W. Defining social innovation. A deliverable of the project: "the theoretical, empirical and policy foundations for building social innovation in Europe" (TEPSIE), European Commission—7th Framework Programme. Brussels: European Commission, DG Research; 2012. 22 pp.
12 . Chaudhari R, Patel DD, Khadayata KG. Constraints faced by the farmers about use of smartphone applications in agriculture. Guj J Ext Edu. 2020;31(2):68–70.
13. Davydov R, Sokolov M, Hogland W, Glinushkin A, Markaryan A. The application of pesticides and mineral fertilizers in agriculture. In: MATEC web of conferences, vol. 245. Les Ulis: EDP Sciences; 2018. p. 11003.
14. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Chang. 2009;19(2):248–55. https:// doi. org/ 10. 1016/j. gloen vcha. 2009. 01. 002.
15. Dogliotti S, García MC, Peluffo S, Dieste JP, Pedemonte AJ, Bacigalupe GF, et al. Co-innovation of family farm systems: a systems approach to sustainable agriculture. Agric Syst. 2014;126:76–86.
16. Durose C, Lowndes V. Gendering discretion: why street-level bureaucracy needs a gendered lens. Political Studies. 2024;72(3):1026–49.
17. Erb K-H, Matej S, Haberl H, Gingrich S. Sustainable land systems in the Anthropocene: Navigating the global land squeeze. One Earth. 2024;7(7):1170–86.
18. Ersado DL, Awoke AG. A multi-criteria decision analysis approach for ranking the performance of CMIP6 models in reproducing precipitation patterns over Abaya-Chamo sub-basin, Ethiopia. Heliyon. 2024;10(12).
19. Fischer F. In pursuit of usable knowledge: critical policy analysis and the argumentative turn. In: Handbook of critical policy studies. Cheltenham: Edward Elgar; 2015. p. 47–66.

20. Godfrey SS, Ramsay GC, Behrendt K, Wynn PC, Nordblom TL, Aslam N. Analysis of agribusiness value chains servicing small-holder dairy farming communities in Punjab, Pakistan: three case studies. Int Food Agribus Manag Rev. 2019;22(1):119–36.
21. GOI. Report on policies and action plan for a secure and sustainable agriculture, submitted to principal scientific advisor. 2019. Available at Government of India. https:// psa. gov. in/ repor ts.
22. Guntukula R. Assessing the impact of climate change on Indian agriculture: evidence from major crop yields. J Public Aff. 2020;20(1): e2040.
23. Hanumappa HG, Rajasekhar D. Use and abuse of chemical fertilizers in a resource-scarce economy: Karnataka province, India. In: The economics of agro-chemicals. London: Routledge; 2018. p. 127–36.
24. Hecker S, Wicke N, Haklay M, Bonn A. How does policy conceptualise citizen science? A qualitative content analysis of international policy documents. Citiz Sci Theory Pr. 2019;4(1):32.
25. Huber R, Kreft C, Späti K, Finger R. Quantifying the importance of farmers' behavioral factors in exante assessments of policies supporting sustainable farming practices. Ecol Econ. 2024;224.
26. Huckin TN. Critical discourse analysis. Functional approaches to written text: Classroom applications. 1997;78–92.
27. Idroes GM, Rahman H, Uddin I, Hardi I, Falcone PM. Towards sustainable environment in North African countries: the role of military expenditure, renewable energy, tourism, manufacture, and globalization on environmental degradation. J Environ Manage. 2024;368: 122077. https:// doi. org/ 10. 1016/j. jenvm an. 2024. 122077.
28. IPCC. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. 2014.
29. Jat HS, Datta A, Sharma PC, Kumar V, Yadav AK, Choudhary M, et al. Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India. Arch Agron Soil Sci. 2018;64(4):531–45.
30. Jha GK, Velayudhan PK, Bhatia A, Laishram C, Kumar D, Begho T, Eory V. Transitioning towards sustainable agriculture: analysing the factors and impact of adopting multiple sustainable inputs by paddy farmers in India. Front Sustain Food Syst. 2024;8:1447936. https://d oi. org/ 10. 3389/ fsufs. 2024. 14479 36.
31. Koirala P, Kotani K, Managi S. How do farm size and perceptions matter for farmers' adaptation responses to climate change in a developing country? Evidence from Nepal. Economic Analysis and Policy. 2022;74:188–204.
32. Krasilnikov P, Taboada MA, Amanullah. Fertilizer use, soil health and agricultural sustainability. Agriculture. 2022;12:462.https:// doi. org/ 10. 3390/ agric ultur e1204 0462
33. Kremen C, Miles A. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and tradeoffs. Ecol Soc. 2012;17(4):40.
34. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004;304(5677):1623–7.
35. Landes M. Indian agriculture and policy in transition. In: Food for policy-reforming agriculture. Cambridge: Cambridge University; 2008.
36. Li Y, Wagenaar H. Revisiting deliberative policy analysis. Policy Studies. 2019;40(5):427–36.
37. Liebman M, Dyck E. Crop rotation and intercropping strategies for weed management. Ecol Appl. 1993;3(1):92–122.
38. Lobell DB, Schlenker W, Costa-Roberts J. Climate trends and global crop production since 1980. Science. 2012;333(6042):616–20.
39. Mayring P. Qualitative content analysis: Theoretical background and procedures. Approaches to qualitative research in mathematics education: Examples of methodology and methods. 2015;365–80.
40. Mishra V, Thirumalai K, Jain S, Aadhar S. Unprecedented drought in South India and recent water scarcity. Environ Res Lett. 2021;16(5): 054007.
41. MOEFCC: GOI. Annual report, 2008–2009. 2008. Available at Ministry of Environment Forests and Climate Change, Government of India. https:// moef. gov. in/ uploa ds/ 2018/ 04/ Annual_ Report_ ENG_ 0809. pdf.
42. Mohammed K, Batung E, Saaka SA, Kansanga MM, Luginaah I. Determinants of mechanized technology adoption in smallholder agriculture: implications for agricultural policy. Land Use Policy. 2023;129: 106666.
43. Nandi S, Reddy MJ. Investigating the projected changes in water balance components under climate change considering the effect of storage structures. J Water Clim Chang. 2024;15(5):1981–2000.
44 . Niroula GS, Thapa GB. Impacts and causes of land fragmentation, and lessons learned from land consolidation in South Asia. Land Use Policy. 2005;22(4):358–72.
45. Onumah JA, Osei RD, Martey E, Asante FA. Welfare dynamics of innovations among agricultural households in Ghana: implication for poverty reduction. Heliyon. 2023;9: e18066. https:// doi. org/ 10. 1016/j. heliy on. 2023. e18066.
46. Pahalvi HN, Rafiya L, Rashid S, Nisar B, Kamili AN. Chemical fertilizers and their impact on soil health. Microbiota and biofertilizers, vol 2: ecofriendly tools for reclamation of degraded soil environs. Cham: Springer; 2021. p. 1–20.
47. Pande R. Can mandated political representation increase policy influence for disadvantaged minorities? Theory and evidence from India. American economic review. 2003;93(4):1132–51.
48. Pandey SC, Modi P, Pereira V, Fosso Wamba S. Empowering small farmers for sustainable agriculture: a human resource approach to SDGdriven training and innovation. Int J Manpow. 2024.
49. Parween F, Kumari P, Singh A. Irrigation water pricing policies and water resources management. Water Policy. 2021;23(1):130–41.
50. Passarelli M, Bongiorno G, Cucino V, Cariola A. Adopting new technologies during the crisis: an empirical analysis of agricultural sector. Technol Forecast Soc Change. 2023;186: 122106. https:// doi. org/ 10. 1016/j. techf ore. 2022. 122106.
51. Pattnaik I, Lahiri-Dutt K. Do women like to farm? Evidence of growing burdens of farming on women in rural India. J Peasant Stud. 2022;49(3):629–51.
52. Piya L, Lall K. Determinants of adaptation practices to climate change by Chepang households in the rural Mid-Hills of Nepal. Reg Environ Change. 2013;13:437–47. https:// doi. org/ 10. 1007/ s10113- 012- 0359-5.
53. Praveen KV, Aditya KS. Fertilizer consumption in wheat production systems: trends and policies. In: New horizons in wheat and barley research: crop protection and resource management. Singapore: Springer; 2022. p. 453–73.

54. Pretty J. Interdisciplinary progress in approaches to address social-ecological and ecocultural systems. Environ Conserv. 2011;38(2):127–39.
55. Pretty J, Benton TG, Bharucha ZP, Dicks LV, Flora CB, Godfray HCJ, et al. Global assessment of agricultural system redesign for sustainable intensification. Nat Sustain. 2018;1(8):441–6.
56. Priyadarshini A, Tiwari BK, Rajauria G. Sustainable food production systems: the potential of pulses. In: Pulse Foods. Elsevier. 2021;487–506.
57 . Priyadarshini P, Abhilash PC. Policy recommendations for enabling transition towards sustainable agriculture in India. Land Use Policy. 2020;96: 104718.
58. Priyadarshini P, Abhilash PC. An empirical analysis of resource efficiency and circularity within the agri-food sector of India. J Clean Prod. 2023;385:135660.
59. Ramaswami B, Pray CE. India: confronting the challenge—the potential of genetically modified crops for the poor. In: The gene revolution. London: Routledge; 2012. p. 156–74.
60. Rao PP, Lagesh M, Deb UK, Jagadeesh E. Typology of agriculture for india for technology targeting and development planning. 2019.
61. Rao CH, Gulati A. Indian agriculture: emerging perspectives and policy issues. Econ Pol Wkly. 1994;29(53):A158–69.
62. Ravera F, Martín-López B, Pascual U, Drucker A. The diversity of gendered adaptation strategies to climate change of Indian farmers: a feminist intersectional approach. Ambio. 2016;45:335–51.
63 . Rodell M. Application of satellite gravimetry for water resource vulnerability assessment (no. GSFC. BOOK. 6126.2012). 2012.
64. Ruttan VW. Productivity growth in world agriculture: sources and constraints. Journal of Economic Perspectives. 2002;16(4):161–84.
65. Shonkoff SB, Morello-Frosch R, Pastor M, Sadd J. The climate gap: environmental health and equity implications of climate change and mitigation policies in California—a review of the literature. Clim Change. 2011;109:485–503.
66. Siddik MA, Rahman A. Causes and impacts of rural land fragmentation in the coastal belt of Bangladesh. Indones J Geogr. 2022;54(2):206–12.
67. Siebrecht N. Sustainable agriculture and its implementation gap—overcoming obstacles to implementation. Sustainability. 2020;12(9):3853.
68 . Smith EK, Kolcava D, Bernauer T. Stringent sustainability regulations for global supply chains are supported across middle-income democracies. Nat Commun. 2024;15(1):1049.
69. Sugden F, Maskey N, Clement F, Ramesh V, Philip A, Rai A. Agrarian stress and climate change in the Eastern Gangetic Plains: gendered vulnerability in a stratified social formation. Glob Environ Chang. 2014;29:258–69. https:// doi. org/ 10. 1016/j. gloen vcha. 2014. 10. 008.
70. Swaminathan MS. An evergreen revolution. Crop Sci. 2006;46(5):2293–303.
71. Swinnen J, Kuijpers R. Inclusive value chains to accelerate poverty reduction in Africa. Dev Policy Rev. 2020;38(6):749–68.
72. Thomas K, Hardy RD, Lazrus H, Mendez M, Orlove B, Rivera-Collazo I, et al. Explaining differential vulnerability to climate change: a social science review. Wiley Interdiscip Rev Clim Change. 2019;10(2): e565.
73. Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature. 2002;418:671–7.
74. Uddin MN, Bokelmann W, Entsminger JS. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: a farm level study in Bangladesh. Climate. 2014;2(4):223–41.
75 . Van Hulst M, Durose C, Agger A. How local practices of sociopolitical innovation develop: and why this matters for urban transformations. Int J Urban Reg Res. 2024;48(4):585–602.
76. Vermeulen SJ, Aggarwal PK, Ainslie A, Angelone C, Campbell BM, Challinor AJ, et al. Options for support to agriculture and food security under climate change. Environ Sci Policy. 2012;15(1):136–44.
77. Vij S, Biesbroek R, Groot A, Termeer K. Changing climate policy paradigms in Bangladesh and Nepal. Environ Sci Policy. 2018;81:77–85.
78. Whitbread AM, Dhulipala RK, Nedumaran S, Padhee A, Padmaja R, Rao K, et al. Designing climate resilient agricultural systems with some examples from India. In: 5th International agronomy congress, 23–27 November 2021, Hyderabad, India. 2021.
79. Zhang J, Drury M. Sustainable agriculture in the EU and China: A comparative critical policy analysis approach. Environ Sci Policy. 2024;157:103789.

4.2. Unravelling climate change policy potential in Himalayan agricultural scenario: Determining barriers perceived by communities

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Abstract

The Western Himalayas are undergoing pronounced climatic variability, including rising temperatures, erratic rainfall, reduced snowfall, and an increased frequency of extreme weather events such as hailstorms, flash floods, and landslides. These changes have severely impacted agriculture, the primary livelihood for many in the region, leading to disrupted sowing schedules, water scarcity, crop failures, and shifts to less water-intensive but economically inferior crops. Farmers report significant challenges in maintaining productivity and nutritional security, while the region's rich biodiversity faces threats from habitat loss and ecological imbalances. Multiple government policies and state-level initiatives aim to address the challenges through climate-resilient farming practices, subsidies, and infrastructure development. However, the study reveals widespread skepticism among agricultural communities regarding the effectiveness of these policies. Farmers perceive them as disconnected from local realities, hindered by bureaucratic inefficiencies, inadequate resource allocation, and limited outreach.

Using focus group discussions (FGDs) conducted across nine villages in Himachal Pradesh, the study explores farmers' perceptions of climate change and government policies. Participants demonstrated a nuanced understanding of climate change impacts, citing rising temperatures, erratic rainfall, and reduced snowfall as key indicators. While some farmers acknowledged the presence of policies, they expressed frustration over systemic barriers such as complex procedures, lack of awareness, and limited access to subsidies. Women and marginalized groups faced additional challenges due to socio-economic disparities and exclusion from decision-making processes. Findings highlight a generational divide in climate change perceptions, with younger individuals expressing greater concern compared to older residents. Farmers also reported mistrust in government initiatives, citing performative actions, favoritism, and inadequate follow-through as major obstacles to policy effectiveness.

The study concludes that addressing these challenges requires participatory policymaking, improved resource distribution, and consistent monitoring to enhance policy implementation and rebuild trust. It emphasizes the need for localized interventions tailored to the unique agro-ecological conditions of the Himalayas, alongside capacity-building efforts to empower communities. While providing valuable insights into community perceptions, the study underscores the importance of collaborative efforts among stakeholders to strengthen climate change policies and ensure their accessibility and effectiveness in mitigating the impacts of climate change in the Western Himalayas.

Introduction

The Western Himalayas are witnessing pronounced climatic variability that directly impacts agricultural productivity and resilience. Meteorological records and empirical studies underscore the region's warming trend, with average temperatures increasing by 1.5°C over the last century and a significant reduction in precipitation during critical growing seasons (Bhutiyani et al., 2007; Negi et al., 2022). These changes translate into reduced crop yields, altered growing seasons, and increased vulnerability to pests and diseases, significantly straining the region's agrarian economy. The repercussions of climate change in the Western Himalayas are multifaceted, affecting both natural ecosystems and human societies. Agriculture, the primary livelihood for many, faces challenges due to unpredictable weather patterns, leading to crop failures and food insecurity. Holding high significance globally, in terms of biodiversity, species richness, indigenous wealth, and socio-cultural diversity, the region has been identified as a biological 'hotspot' (CI, 2011; Gautam et al., 2013). The fragility of the landscape and the mountain system's physiography make it highly susceptible to external hazards and enhance the predisposed vulnerability (Shukla et. al., 2018; Pandey et al., 2012). There is ongoing concern about the increased frequency of erratic weather behaviour such as increased fog incidences, the enhanced occurrence of hailstorms, untimely and unreliable precipitation, increased drought frequency, flash floods, and cloudburst, landslides, and threatened food security (Barnett et al. 2005; Cruz et al. 2007; Xu et al. 2009).

All this can be attributed to recent changes in the temperature and rainfall pattern (Madhura et al., 2015; Dimri et al., 2015). A substantial increase in the rates of mean temperature, as high as 0.104°C per decade has been noticed recently (Ren et. al., 2017) over last century. The condition is anticipated to deteriorate further soon, posing a serious threat to western Himalayan agriculture, farmers' livelihood, food security, and welfare (Macchi et al. 2014). Agriculture being a highly climate-sensitive livelihood option, communities dependent on agriculture face a direct threat from climate change and under direct exposure to associated risks (Barnes et al. 2013; Niles and Mueller 2016). Farmers in the region have reported erratic rainfall patterns that disrupt sowing schedules and lead to water scarcity during critical agricultural periods (Sharma et al., 2020). Additionally, reduced snowfall has adversely affected the recharge of natural springs and rivers, key water sources for irrigation (Bhatta et al., 2015). Traditional crops such as wheat, barley, and millets, once resilient to the region's cold climate, are now facing productivity challenges, compelling farmers to shift to less water-intensive but economically inferior crops (Negi et al., 2022). A study in the Western Himalayan Region highlighted that

climate change has forced communities to alter their traditional food choices, impacting nutritional security (Das & Mishra, 2023).

Beyond agriculture, the region's rich biodiversity is at risk. Alterations in temperature and precipitation patterns threaten endemic species and disrupt ecological balances. For example, the retreat of glaciers and changes in snow cover have been linked to habitat loss for species adapted to cold environments. Additionally, the increased frequency of natural disasters, such as landslides and floods, poses direct threats to human settlements and infrastructure.

India’s policy response to climate change in the Himalayas is rooted in frameworks such as the NAPCC, launched in 2008. Of the NAPCC's eight national missions, the National Mission for Sustainable Agriculture (NMSA) and the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) are directly relevant to the Western Himalayas. These missions emphasize climate-resilient farming practices, promotion of organic agriculture, soil health management, and conservation of the Himalayan ecosystem (Ministry of Environment, Forest and Climate Change, 2022). At the state level, programs such as the Himachal Pradesh Integrated Watershed Development Project and the Uttarakhand Climate Action Plan aim to reduce climate risks by improving water management, introducing drought-resistant crop varieties, and enhancing rural livelihoods (Negi et al., 2022). Additionally, financial instruments like crop insurance schemes and subsidies for drip irrigation systems seek to mitigate the economic risks faced by farmers. While these policies are ambitious in their scope, their effectiveness relies heavily on active community participation and perception. Studies suggest that the degree to which communities perceive these policies as relevant, accessible, and beneficial significantly influences their willingness to adopt the proposed measures (Sharma et al., 2020).

Local agricultural communities often have pronounced recognitions of climate change, offering valuable insights into its on-ground manifestations. Studies conducted in regions like Kullu and Pithoragarh have demonstrated that farmers possess a nuanced understanding of climatic changes and their impacts on agriculture (Sharma et al., 2020). Farmers frequently identify reduced snowfall, irregular monsoon rains, and rising temperatures as the primary indicators of climate change. Their responses include adaptive practices such as changing crop varieties, adopting soil conservation techniques, and diversifying income sources through animal husbandry or seasonal migration (Bhatta et al., 2015). While Himalayan farmers feel the impact of climate change and have initiated various adaptation strategies, the effectiveness of these measures is often constrained by technological, financial, and policy-related challenges.

Limited access to resources, fragmented landholdings, and inadequate infrastructure further exacerbate their vulnerability. Addressing these issues through comprehensive capacity building, financial support, and integrated policy development is essential for enhancing the resilience of Indian agriculture to climate change. This context makes government interventions critical in providing the technical, financial, and institutional support needed to enhance community resilience (Sharma et al., 2020).

Understanding community perceptions of government policies is pivotal for assessing their effectiveness and identifying gaps in implementation. Recent studies in the Western Himalayas reveal a mixed response to policy interventions. On one hand, many farmers recognize the importance of government programs in introducing climate-resilient practices and providing financial support. On the other hand, challenges such as bureaucratic inefficiencies, lack of awareness, and limited outreach undermine policy effectiveness (Negi et al., 2022).

One of the most frequently cited issues is the lack of localized solutions tailored to the unique agro-ecological conditions of the Himalayas. Farmers often perceive government initiatives as top-down approaches that fail to incorporate traditional knowledge and community-specific needs (Bhatta et al., 2015). For example, while the promotion of cash crops like apples and horticultural crops has been successful in certain areas, it has also led to overexploitation of water resources, exacerbating existing vulnerabilities (Sharma et al., 2020). Moreover, accessibility remains a significant barrier, particularly for marginalized communities. Smallholder farmers and those in remote areas often lack the resources or knowledge required to avail themselves of government subsidies and programs. This disparity underscores the need for greater emphasis on capacity building, participatory planning, and decentralized implementation (Negi et al., 2022).

Although existing literature provides valuable insights into climate change impacts and policy responses in the Western Himalayas, several gaps remain. Most studies focus on either climatic trends or policy analysis, with limited attention to the interplay between community perceptions and policy outcomes. Researchers often overlook the socio-cultural dimensions of perception, such as the influence of education, gender, and caste on community attitudes toward government interventions.

Keeping the points in mind, this study aims to bridge these gaps by exploring the following questions:

1. How do agricultural communities in the Western Himalayas perceive climate change and government policies aimed at mitigating climate change impacts?

2. What factors shape these perceptions, and how do they vary across the three biogeographic zones of the Himalayas?

3. To what extent do these perceptions influence adoption of climate-resilient practices?

Study Site:

Our study site

Himachal Pradesh, nested in the northwestern part of India, characterized by its diverse geographical features, topography, rich cultural heritage and socio-economic dynamics, is primarily an agrarian state (Singh & Kumar, 2014). Covering an area of approximately 55,673 square kilometers, it is bordered by Jammu and Kashmir to the north, Punjab to the west, Haryana to the southwest, Uttarakhand to the southeast, and the Tibet Autonomous Region to the east. The state's name, derived from Sanskrit, translates to "in the lap of the Himalayas," reflecting its predominantly mountainous terrain. Elevations in Himachal Pradesh range from about 350 meters to over 6,000 meters above sea level, encompassing a variety of climates from subtropical in the lower regions to alpine and glacial in the higher altitudes. This topographical diversity contributes to a rich array of flora and fauna, with forests covering approximately 27.73% of the state's area, featuring deodar, oak, and pine (Kumar & Gupta, 2023).

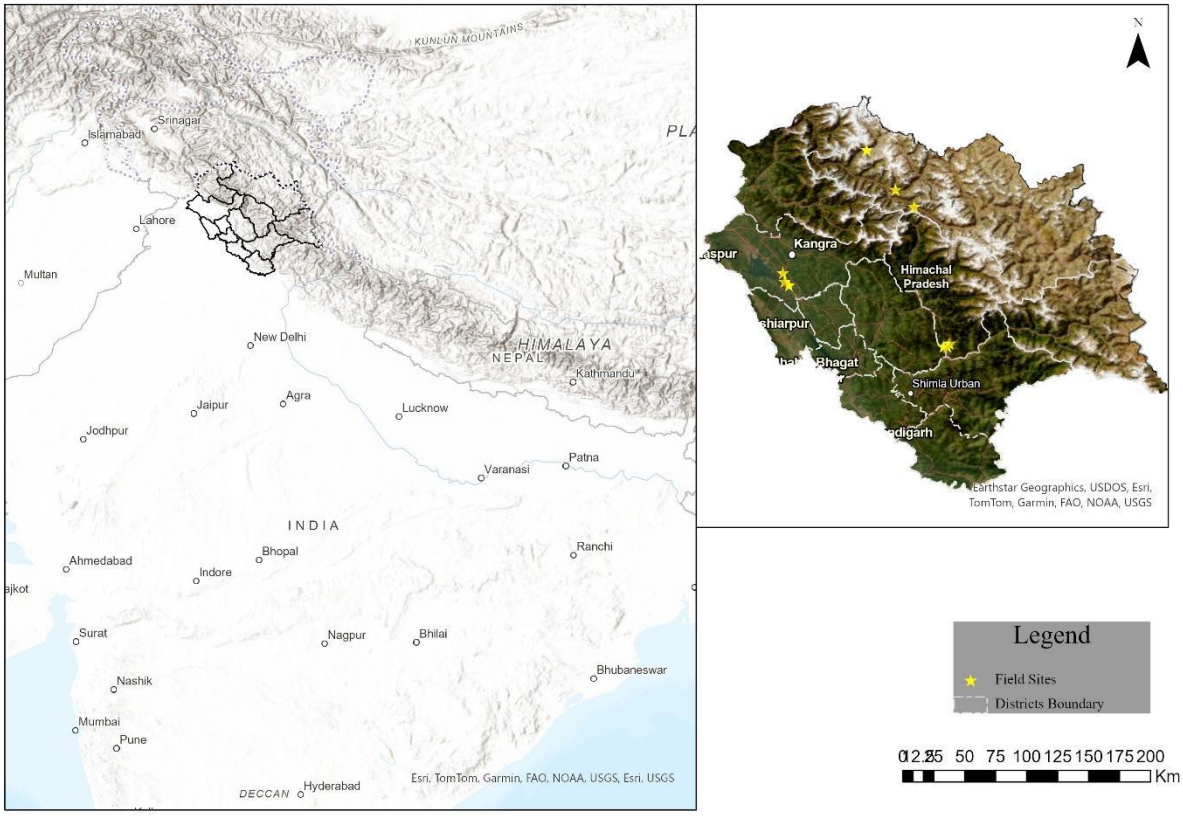
Demographic and Agricultural Profile:

As per the 2011 Census, Himachal Pradesh had a population of 6,864,602, comprising 3,481,873 males and 3,382,729 females, resulting in a sex ratio of 972 females per 1,000 males. The decadal growth rate from 2001 to 2011 was 12.94%, a decline from the previous decade's 17.53%. The population density stood at 123 individuals per square kilometre. A significant majority, approximately 89.97%, resided in rural areas, underscoring the state's rural character. Scheduled Castes and Scheduled Tribes constituted 25.19% and 5.71% of the population, respectively. The literacy rate was commendable at 83.78%, with male literacy at 90.83% and female literacy at 76.60%.

Agriculture plays a pivotal role in Himachal Pradesh's economy, with about 70% of the main workers engaged in agricultural pursuits. The sector contributes approximately 13.62% to the state's Gross State Domestic Product (GSDP). However, only 13.4% of the total area is cultivable, primarily due to the challenging hilly terrain, which limits extensive farming

activities. The state has witnessed a shift from traditional agriculture to horticulture over the past few decades. The area under fruit cultivation expanded from 792 hectares in 1950-51 to a substantial figure in recent years, with fruit production reaching 1,027,000 tonnes. Apple cultivation dominates, especially in districts like Shimla, Kullu, and Kinnaur, contributing significantly to the state's horticultural output. In terms of food grain production, the state achieved 1.528 million metric tonnes, while vegetable production was higher at 1.867 million metric tonnes. The primary foods include wheat, maize, rice, and barley. The state's diverse agro-climatic conditions allow for the cultivation of both temperate and sub-tropical crops, enabling a variety of agricultural produce.

The average size of land holdings in Himachal Pradesh is relatively small, averaging around 1.0 hectares as of 2015-16. This fragmentation poses challenges for large-scale farming but has encouraged the adoption of intensive farming practices and diversification into high-value crops like fruits and vegetables. The state has also focused on developing infrastructure to support agriculture, including establishing cold storage facilities and improved transportation networks to facilitate market access for perishable goods. Agriculture remains the backbone of the state's economy, with a significant shift towards horticulture in recent decades. Despite challenges such as limited cultivable land and small land holdings, the state's diverse climatic conditions and focused infrastructural developments have enabled it to become a significant contributor to India's agricultural production.



Methodology:

Research Strategy:

To answer the above-mentioned questions, the researchers implemented an abductive approach and developed a theory using a case study (Panico et al., 2024) coupled with a data structure using the Gioia Methodology (Gioia, 2012). This strategy has led the researchers to successfully understand farmers' perception of current agricultural policies and the hurdles they face while benefiting from policies and the suggestions to better them. The major steps included in our strategy are as follows:

Collecting data:

ocus group discussions (FGDs) were used to gather qualitative data on farmers' understanding of climate change and their perceptions of climate change policies. This data was collected in August-September 2023. This method allows researchers flexibility to explore hidden information by engaging in in-depth discussions without limitations (Dhanya & Ramchandaran, 2015; IFPRI 2014; Nambi & Bahinipati 2013; USAID, 2010). The FGDs included a semi-structured questionnaire with open-ended questions about climate change and associated

policies, and other support from the government, and encouraged comprehensive discussion. (Table: Semi-structured questionnaire).

Focus Point	**Purpose: To Generate Info On**
Understanding of Climate Change and it's impacts	Communities understand climate change, how much they know about the changes occurring and the factors responsible for them. What are the perceived impacts of climate change on the community? What is the perceived scale of these changes?
Access to information about climate change	What kind of information on weather and climate variability and associated issues is being used by farmers in your region? What is the mode of information?
Understanding of the policies and their structure	Whether the communities know about the policies being implemented to support the community during these times of changing climate
Perception about the implementation and usability of these policies	Are these policies bringing any change in the community? Is there any positive impact of these policies? Do the communities benefit from the policies?
Support received by the community	What support or subsidies does the community receive from the government? What barriers do they have to face in receiving these benefits?
Financial Support from the government	Have you availed any credit/ loan in recent years for agricultural purposes? Which are the main sources of credit? Have you opted for crop insurance? If yes, why?
Other support from the government	Are you aware of the various policies/organizations by the Government to help you adapt better to changing climate? Is any member of your household part of any of such organizations?

Focus Point	Purpose: To Generate Info On
	What does the government provide subsidy on? Are you able to avail benefits from these subsidies?
Solution seeking	Who do they talk to and complain to?
Most common adaptation strategies used	What are the coping mechanisms in case of current adverse situations? To what extent are adaptive measures needed to manage climate change-related agriculture impacts?

The focus group discussions (FGDs) were conducted in collaboration with the local communities from the three altitudinal zones and panchayat officials. The FGDs involved participants who practice agriculture as their primary source of livelihood (Table- showing field site information). The FGDs were conducted in Hindi with a mixture of local dialects from field sites which varies drastically. The data from the FGDs was then manually transcribed, translated into English, and compiled for further analysis using MAXQDA software. A total of 167 pages of transcriptions were generated.

Field Site table

Sites	Binan	Kungash	Karana	Dhuala	Khabli	Bankhandi	Chhaling	Teling	Keylong
Range	Middle Himalayas	Middle Himalayas	Middle Himalayas	Lower Himalayas	Lower Himalayas	Lower Himalayas	THTP	THTP	THTP
Population	373	2743	1047	765	217	458	141	184	1127
Altitude	1475.72 meter	1475.1 m	1468.2 m	520.59 m	521.5 m	535 m	3338.7 m	1189 m	3181.8 m

Number of Groups	1	1	1	1	2	1	1	1	2
Size/Range of Groups	10-12	7-9	9-11	12-15	7 & 12	15	6	4	8 & 6
Stratification Criteria	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)	Primary Livelihood (Farming)
Natural Stratification (If any)	Mostly Men (1 woman)	Shifted to apple farming 5-6 years ago	Secondary livelihood – selling milk	Secondary Livelihood – Run shops. Mostly men	Secondary Livelihood – Run shops.	Secondary Livelihood—Mostly Women	All Women	Old People	One member of family is employed in Govt sector
Primary findings	All these villages fall in drought prone zone and thus rely heavily on irrigation support provided by the government. People have already started to look at alternative livelihood sources as agriculture is failing.			The villagers feel that government has a high bias towards the farmers residing in middle and Trans Himalayas, because as per their perception most of the policies suit better for the high mountainous farming communities.			The increasing temperature has converted the cold desert into a farmable landscape now. This has led to people getting more benefit from farming and being more interested in it.		

Data cleaning and analysis

A qualitative content analysis approach was employed using MAXQDA software to explore and interpret the data. The analysis followed a coding process that included inductive, open, and axial coding. Initially, inductive coding allowed themes to emerge naturally from the data without the constraints of a predetermined framework (Rizzo et al., 2024). This approach ensured that the analysis was grounded in the data itself. Open coding was then conducted to break down the data into discrete segments and assign descriptive labels to each segment, allowing for the identification of key concepts. After finishing open coding, the codes were reviewed to find connections or relationships between the codes. We grouped similar concepts and identified relationships that formed overarching categories and themes, a.k.a axial coding. MAXQDA facilitated the systematic application and refinement of codes, enabling the development of a clear thematic structure. Throughout the analysis, memos and reflective notes were recorded to document insights and enhance analytical rigor. The process was iterative, with constant comparison used to refine codes and ensure saturation. MAXQDA's visualization features, such as code matrices and mind maps, were employed to aid in identifying patterns and relationships across the data. This multi-step coding process ensured a comprehensive and transparent analysis, providing rich and meaningful insights.

Findings & Discussion:

Climate Change Understanding

Analysing the transcriptions indicates that the communities have a clear understanding of changing climate, and it's impacts. The participants have been practicing farming as their primary livelihood and have been facing the impacts erratic rainfall or temperature change have on the crops. There is a consensus among the participants that the weather is changing, with some experiencing more erratic weather patterns like hotter summers, colder winters, and heavy, less frequent rain (Table X shows some excerpts from the transcription supporting the major concerns of communities in terms of changing climate).

Major concerns	Excerpts from the transcript in support
Temperature	*"To deal with the rising temperature, some people are taking some measures at home on their own, some prevention means some treatment is being done on their own... Planting trees and all."*

	"The temperature in Ani (a tehsil in middle Himalayas) it has reached so high now a days, it was much cooler earlier. During summer it sometimes reaches like 35 degrees Celsius. Whereas earlier it was like 20-25 max, never went beyond that."
Erratic Rainfall	*"Yea, he is right. The problem with rainfall is, either is does not rain at all. Or it just pours down so much that the ground cracks. Last year was so bad."*
	"The continuous rain for like a week or 10 days, it ruins the flowering of apple trees. Scattered rainfall here and there, does not impact the crop that much,,, but this year it was continuous."
Snowfall	*"Isn't it so? Earlier it used to snow a lot but now the amount of snow has reduced. What should I say? Earlier there were no peas, potatoes etc., We could not grow them because it was too cold. Now, you can grow anything which grows in warmer regions."*
	"The snow started in March end, in begining of April, that was a mixture of winter and rain then. Not good"
Extreme Weather Events	*"I mean, I am 95 years old, and in a period of 50 years, last 50 years, till date I have never seen anything like this. ……. This year, thousands of houses were destroyed, and if there was anything left, then it was also not in good condition. So, its impact on agriculture is also as such."*
	"Hailstorm completely destroyed our apples, they are becoming so frequent now. We are facing so much loss, can't state"

Most participants mentioned the negative impacts these changes or variabilities are having on their crops, and do not deny it. A farmer situated in the THTP, when discussing climate change, mentioned how these changes sometimes leave them with failed crops.

"*The crops are not ready on time to be harvested. There is no water available to irrigate them. If they are not given water on time, then everything dries up.*" hence there are severe impacts of these changes have on their livelihood. The participants also mentioned that these changes

are not recent and sudden. They have been noticing these changes for years now, some report the changes dating back many decades:

"*I think the effect, these changes has happened gradually, in my opinion far more in last 15-20 years. It was happening before as well, 25 years ago at that time too, but not like this."*

Participants also blamed governments' excessive felling of trees, unplanned construction, and excavation of mountains for increasing the localized changes and impacting the local environment adversely. "*Less trees, less plants. They are cutting down trees and everything. Due to this, the temperature is increasing. There is no other major reason, except that we are changing our surroundings too much."* Said a participant from the lower Himalayas.

Although, there is a split in how the changes are conceptualized. Some use the term “climate change,” while others prefer “weather variability” or “environmental damage” to describe natural fluctuations in weather patterns and think that ‘nature is a consistently changing entity’. Those who use "climate change" see it as a serious issue, often linked to global factors, while those who use "weather variability" view it as part of a historical pattern and are sceptical of the climate change narrative.

Participants who are concerned about climate change tend to focus on environmental and financial impacts. The former group expresses worry about long-term environmental harm, while the latter is more concerned about how climate change could affect their livelihoods, especially in farming and other weather-dependent sectors. In contrast, those less concerned about climate change emphasize rural resilience and scepticism, seeing it as a myth or something that communities can adapt to. They often compare it to past challenges and feel the current debate is clouded by misinformation. The study also shows that people, although not informed about the global climate scenario, understand that changes taking place in one country or region impact others and vice versa. There's also a generational divide: younger people tend to be more concerned, while older residents, especially farmers, often downplay the issue based on historical experiences. Despite these divisions, there is a common concern about the potential financial impact of climate policies, particularly the failing of the crops, degrading farmland quality and sudden disastrous events, which harm rural communities economically.

Policy Understanding

‘Climate change policy’ perception

The findings of this study highlight the complex relationship between the Himalayan agricultural community and India's climate change policies. The perceptions of farmers in the

region reflect a mix of awareness, skepticism, and adaptation challenges influenced by geographical, socio-economic, and policy-related factors. While scientific studies have documented significant environmental responses to climate and human impact, it is equally crucial to examine people's perception of climate and the environment to understand how human societies will respond to ongoing climate changes. Policy perception in these communities is marked by skepticism and a growing sense of futility. While people understand the presence of policies meant to address their issues, they often see these policies as disconnected from on-the-ground realities. One participant expressed this disconnection, saying, *"For the last three years, this crop is getting ruined, but no one comes to check."* The perception is that policies remain on paper, with little tangible impact. This also encourages the sentiment that policies are performative rather than impactful. Another common theme noticed among people was the feeling of government announcements being mere empty promises, as highlighted by someone stating, *"They come, take photos, make promises, and then nothing happens."* The lack of follow-through amplifies distrust, making communities less likely to participate in government initiatives or voice concerns through formal channels.

We also found that community members feel excluded from the policy creation process itself. *"They never ask us what we need,"* said one individual, reflecting a broader pattern where policies are designed without meaningful consultation with the affected populations. This top-down approach fuels alienation and perpetuates the cycle of policy failure. The communities also discussed about their perceived understanding of reasons behind the policies being ineffective. The causality of policy failure appears multifaceted and deeply rooted in systemic inefficiencies. A primary factor is the difficulty in reaching government actors who can enact change (see Table). Across different locations, communities consistently voice frustration with systemic inaction tied to bureaucratic inefficiency. People repeatedly report issues while lodging complaints and seeking governmental support. Despite successful repetition of complaints, they often cycle through complex bureaucratic loops without resolution. Resource shortfalls further exacerbate this inaction. Even when officials are willing to help, a lack of funds, personnel, or infrastructure often stalls progress. The combination of limited resources and sluggish administrative processes fosters a sense of helplessness, as people watch their problems persist despite engaging with the system.

The layers of administrative red tape act as barriers to swift policy responses. Community members recounted instances where they were redirected across multiple departments, with no clear accountability. *"We are sent from one office to another like a ball,"* said one frustrated resident, capturing the endless circulation of grievances through an unresponsive system. The

participants perceive that process of accessing governmental support is fraught with systemic challenges, and over time, this has bred reluctance among community to seek assistance. Mistrust in the system amplifies this reluctance. The perception that complaints are futile — captured in statements like *"Areyyy, we complain about every little thing, but nothing changes"* — discourages people from engaging with government services. The repeated experience of being ignored or bounced between departments erodes faith in the very institutions meant to offer relief. Even basic support mechanisms feel out of reach, with people describing complex procedures and an overwhelming lack of guidance.

The participants believe that another significant contributor to policy failure is the lack of local capacity-building. Many people expressed a lack of awareness about their rights or the procedural mechanisms to escalate issues. This lack of knowledge disempowers citizens, leaving them dependent on intermediaries who may exploit their vulnerability or misrepresent their concerns. The absence of monitoring and evaluation mechanisms exacerbates the situation. Policies are often launched with fanfare, but their long-term impact is rarely assessed. As one participant pointed out, *"They inaugurated the new water system with cameras and speeches, but the pipes broke within a month, and no one came back to fix it."* This lack of sustained oversight means that policies frequently collapse after initial implementation, further deepening public disillusionment. Additionally, the incompetence of the employees, fuel lack of transparency and trust of the community in the government. Some people believe that policies are intentionally designed to be disproportionate, serving as conduits for favoritism. This echos a widespread belief that policy inefficacy is not accidental but deliberate.

This disconnect between policymakers and affected populations, compounded by poor accountability structures, perpetuates policy inefficacy. The problem is poignantly summed up in the statement, "The whole system is a problem, as I told you before." Such expressions underscore the urgent need for systemic reform and more responsive governance due to a lack of trust in the overall system. Policymaking needs to transition from a distant, bureaucratic exercise to a collaborative, community-driven process where the people most affected are not just passive recipients but active participants in shaping solutions.

The communities also perceive that the policies are formulated with inherent bias towards the upper or old Himachal, which comprise largely of high mountainous regions. The participants of the lower Himalayan region felt that most policies benefit the old Himachal agricultural community as they are formulated keeping in mind the needs of apple orchards and horticulture. This feeling of neglect is compounded by a lack of visibility of government officials at the

grassroots level in these locations. Such statements demonstrate how community members perceive policies as tools which are highly beneficial for some, not for all, rather than sustained developmental change. The participants, especially women, bear a disproportionate burden of labor while facing systemic inequalities that limit their access to resources, decision-making, and policy support. Despite being the backbone of subsistence farming, women's contributions are often undervalued, and their specific needs overlooked in policy implementation. The participants do not seem to perceive it as a big issue but rather seem to have accepted it as the societal structure. The interviewed participants mentioned the exclusion of formal dialogues and knowledge. This deprives women from direct access to information, subsidies, and training opportunities that could enhance their productivity and resilience.

Perception Theory

Scientific data on human well-being in the Himalayan region remains limited, but climate change has affected livelihoods, health, and natural resource availability (Sharma et al. 2009). Many local farmers recognize changes in temperature, erratic rainfall, and an increase in extreme weather events. These observations align with scientific indicators of climate change, such as longer and more frequent droughts, rising temperatures, decreasing snowfall, and unpredictable rainfall patterns (Below et al. 2010). However, awareness of government climate policies remains insufficient. Farmers report a lack of access to policy information, subsidies, and technical support, which prevents them from fully benefiting from climate adaptation initiatives. Based on our findings, three major dimensions requires immediate attention to make the climate change policies more effective and accessible:

Excerpts from Transcript	Location	Second order themes	Aggregate Dimensions
1. 'because they don't know how to make proper zonation based on requirements from people'	Binan	Inefficient and insufficient resource allocation	Bureaucracy: Inaction and Resource Shortfalls
2. 'Everything is supplied in lesser quality, not enough for people...'	Dhuala		
1. Our panchayat officers are also unaware most of the time.. Ha ha	Bankhandi	Lack of awareness and information	

2. Until the time people do not become aware of these policies, how will they know what is happening	Garh		
1. We can't even get benefits. People with money gets all the benefits. For us, it's hard to get any subsidies, and we are ones who need it.	Kungash	Incompetence and favoritism among officials	
2. It's a political tug of war. Everybody wants to benefit their 'own people	Binan		
1. "I just don't feel like doing it yet." this argument does not work.	Teling	User don’t want to put effort	Accessing Support: Systemic Challenges and User Reluctance
2. There are other issues as well. People do not come to the meetings, neither do the agriculture people.	Krana		
1. Been living here for so long, never have anyone come here to ask for our problems and give support or information.	Dhuala	Poor Monitoring System	
2. For like 8-10 years in between, no one recieved anything, people stopped paying premiums.	Kungash		
1. The problem is the whole thing, as I told you earlier, there is no one to go to. Either the offices are far away, or are lacking employees.	Bankhandi	Lack of critical infrastructure	
2. But, no special team from the center or any state has not visited our Panchayat till now.... we are left to struggle for ourselves.	Krana		

1. Villages are also deep in rural areas. So, they don't even go. Don't even try to organize camps.	Dhuala	Topographical & Cultural Barriers	Inherent Barriers to Policy Benefits
2. Also, we have such diverse culture, language, it's hard to bring people together and ask them to work for something.	Chhaling		
1. See, the upper regions of Himachal (old Himachal), Karsog Mandi, if there is a disaster, your house is demolished..in such a case of disaster you get ₹1,00,000, we get only get 10 thousand rs from Govt as support, here in Kangra.	Dhuala	New and Old Himachal	
2. By the way Panchayat.... also, the one in upper side works much better. Cause they care. All the work goes into apples, pomegranate, nothing is for us. People who grow vegetables, are not in the priority list.	Bankhandi		
1. We don't know much. We are women, you know. Most are illetrate.	Chhaling	Gender Disproportionate	
2. Men would know about this matter better than us. They are the ones making such decisions.	Bankhandi		

Bureaucracy – Inaction and Resource Shortfalls: Perceptions of bureaucratic inefficiencies often stem from suboptimal resource allocation and administrative inertia. Empirical studies indicate that inadequate distribution of governmental resources contributes to systemic inefficiencies, with deficiencies in financial and human capital exacerbating institutional

bottlenecks (Smith et al., 2020). Furthermore, a lack of public awareness regarding available services and entitlements creates an information asymmetry that hampers effective policy implementation (Jones & Taylor, 2018). Additionally, administrative incompetence and favoritism have been documented as factors that erode public trust, leading to widespread reluctance in engaging with governmental mechanisms (Kumar, 2021).

Moreover, poor employee quality and favoritism exacerbate inefficiencies by misallocating resources and favoring specific groups over broader public interest (Gupta & Singh, 2022). Rigid hierarchical structures within governance institutions also act as barriers to adaptive policymaking, limiting the system's ability to respond to evolving socio-economic challenges (Mehta, 2023). These structural impediments reinforce the perception that bureaucratic institutions are ineffective, ultimately fostering disengagement among citizens.

Accessing Support – Systemic Challenges and User Reluctance:

Even when institutional support mechanisms exist, multiple barriers prevent effective utilization. Studies suggest that the perceived complexity of accessing governmental support contributes to significant user reluctance (Fernandez & Lee, 2020). A primary factor is the general lack of awareness regarding eligibility criteria and procedural requirements, leading to underutilization of available services (Patel et al., 2021). Infrastructure deficits, including inadequate road networks and limited digital access, further constrain citizens' ability to engage with governmental institutions (Hoffman & Patel, 2019).

Moreover, the bureaucratic application process itself has been identified as a significant deterrent. Research indicates that extensive documentation requirements, coupled with lengthy verification protocols, discourage individuals from seeking support (Chakrabarti & Bose, 2022). Digital literacy also plays a crucial role in accessibility, as marginalized populations often struggle with navigating online portals and digital applications (D'Souza, 2021). Language barriers further compound the issue, as governmental communication often lacks localization efforts, excluding non-dominant linguistic communities from participation (Rahman et al., 2023). Social stigma associated with reliance on government aid has also been reported as a factor deterring eligible beneficiaries from availing themselves of policy benefits (Anderson & Gupta, 2020). These systemic challenges collectively contribute to the perception that, despite the existence of policies, access remains highly restrictive.

Inherent barriers to policy benefit: Geospatial and socio-economic constraints significantly influence public perception regarding the accessibility and efficacy of policy benefits. Rural

and geographically isolated populations face unique challenges due to the physical inaccessibility of government offices and service centers (Singh & Sharma, 2021). Additionally, adverse topographical conditions, including mountainous terrains and inadequate transportation infrastructure, further hinder participation in policy frameworks (Mitra, 2022). The divide between "New" and "Old" Himachal exemplifies regional disparities in administrative outreach, where resource allocation remains unevenly distributed (Verma et al., 2020).

Economic and social stratifications further affect access to policy benefits. Studies indicate that lower-income demographics experience disproportionate obstacles, such as financial constraints that limit their ability to travel to government offices or procure necessary documentation (Das & Bhatia, 2021). Gender-based disparities in policy access have also been documented, with restrictive mobility norms and socio-cultural expectations limiting women's engagement with bureaucratic processes (Nair & Banerjee, 2022). Institutional biases, both implicit and explicit, contribute to further marginalization of certain social groups, thereby exacerbating inequities in policy implementation (Mukherjee, 2023).

Additionally, climate-related variables impose additional constraints on policy accessibility. Empirical evidence suggests that extreme weather events such as landslides and heavy snowfall periodically disrupt essential services, delaying access to benefits (Roy et al., 2022). Agricultural communities, in particular, face vulnerabilities due to seasonal fluctuations that impact their ability to meet bureaucratic deadlines and fulfill eligibility criteria for subsidies and aid (Sarkar, 2021). These factors collectively contribute to a perception of governmental inefficiency and deepen public skepticism regarding the equitable distribution of policy benefits.

Conclusion:

Perceptions of governance inefficacy are shaped by a confluence of bureaucratic inefficiencies, structural accessibility barriers, and socio-economic disparities. Addressing these concerns necessitates an evidence-based approach that integrates improved resource allocation, transparency mechanisms, and targeted outreach initiatives. Policy reforms must prioritize simplifying application procedures, enhance digital and linguistic inclusivity, and fostering equitable infrastructural development (Williams & Chen, 2023). Without such interventions, public trust in governance frameworks will likely continue to erode, reinforcing disengagement and systemic skepticism.

The study's findings, which show deep mistrust in governmental policies and their implementation, have important implications for further development of climate change policies. This highlights the need for promoting local participation, particularly among small and marginal landholders who are most vulnerable to climate change. To ensure proper implementation of the policies, it is essential for various stakeholders, including local communities, governments, and organizations, to collaborate and strengthen the lost user belief. One strength of the study is its detailed micro-level analysis of how farmers perceive climate change and the associated policies in nine villages. This research integrates a broad range of socioeconomic data, offering valuable insights into the perceived causes of policy failure in the area. The study provides a deeper understanding of how local communities are responding to governmental support, especially among Himalayan agricultural communities.

However, the study also has some limitations. A major constraint is its focus solely on Himalayan community, which means the findings may not apply to other agricultural communities. This limits the broader understanding of the policies, given that it’s imperative for a country like India, where most policies are centralized, as it does not capture the full spectrum of policy perception across different regions. Another limitation is the unilaterality of the participants. The research design could have been improved by incorporating FGDs from the stakeholders and government employees, who are responsible for implementation of the policies. Including other approaches, alongside FGDs, could also have provided further insights into regional differences in policy perception. Although the study highlights the need of local intervention for successful climate policies, it also emphasizes the need of consistent monitoring and feedback from the communities regarding the policies. Institutional backing, improved access to support, bureaucratic reform are key to strengthening implemented climate policies.

References:

Agarwal, A., Perrin, N., Chhatre, A., Benson, C. S., & Kononen, M. (2012). Climate policy processes, local institutions, and adaptation actions: Mechanisms of translation and influence. *WIREs Climate Change*, *3*(6), 565–579. https://doi.org/10.1002/wcc.193

Amaru, S., & Chhetri, N. B. (2013). Climate adaptation: Institutional response to environmental constraints, and the need for increased flexibility, participation, and integration of approaches. *Applied Geography*, *39*, 128–139. https://doi.org/10.1016/j.apgeog.2012.12.006

Bahinipati, C. S. (2012). Adaptation to Climate Change and Livelihoods: An Integrated Case Study to Assess the Vulnerability and Adaptation Options of the Fishing and Farming Communities of Selected East Coast Stretch of Tamil Nadu, India. *Asian Journal of Environment and Disaster Management*, *4*, 297–322. https://doi.org/10.3850/S1793924012001691

Bailey, J. (2008). First steps in qualitative data analysis: Transcribing. *Family Practice*, *25*(2), 127–131. https://doi.org/10.1093/fampra/cmn003

Baker, S. E., & Edwards, R. (2012). How many qualitative interviews is enough?

Banerjee, R. R. (2015). Farmers' perception of climate change, impact and adaptation strategies: A case study of four villages in the semi-arid regions of India. *Natural Hazards*, *75*(3), 2829–2845. https://doi.org/10.1007/s11069-014-1466-z

Barrett, K., & Bosak, K. (2018). The Role of Place in Adapting to Climate Change: A Case Study from Ladakh, Western Himalayas. *Sustainability*, *10*(4), 898. https://doi.org/10.3390/su10040898

Barua, A., Katyaini, S., Mili, B., & Gooch, P. (2014). Climate change and poverty: Building resilience of rural mountain communities in South Sikkim, Eastern Himalaya, India. *Regional Environmental Change*, *14*(1), 267–280. https://doi.org/10.1007/s10113-013-0471-1

Beg, S. (2019). Favoritism and flooding: Political alignment and allocation of irrigation water. *World Development*, *114*, 175–195. https://doi.org/10.1016/j.worlddev.2018.09.030

Below, T. B., Schmid, J. C., & Sieber, S. (2015). Farmers' knowledge and perception of climatic risks and options for climate change adaptation: A case study from two Tanzanian villages. *Regional Environmental Change*, *15*(7), 1169–1180. https://doi.org/10.1007/s10113-014-0620-1

Bhagat, R., Walia, S. S., Sharma, K., Singh, R., Singh, G., & Hossain, A. (2024). The integrated farming system is an environmentally friendly and cost-effective approach to the sustainability of agri-food systems in the modern era of the changing climate: A comprehensive review. Food and Energy Security, 13(1), e534.

Bullock, H. L., Lavis, J. N., Wilson, M. G., Mulvale, G., & Miatello, A. (2021). Understanding the implementation of evidence-informed policies and practices from a policy perspective: A critical interpretive synthesis. *Implementation Science : IS*, *16*, 18. https://doi.org/10.1186/s13012-021-01082-7

Butler, J. R. A., Suadnya, W., Puspadi, K., Sutaryono, Y., Wise, R. M., Skewes, T. D., Kirono, D., Bohensky, E. L., Handayani, T., Habibi, P., Kisman, M., Suharto, I., Hanartani, Supartarningsih, S., Ripaldi, A., Fachry, A., Yanuartati, Y., Abbas, G., Duggan, K., & Ash, A. (2014). Framing the application of adaptation pathways for rural livelihoods and global change in eastern Indonesian islands. *Global Environmental Change*, *28*, 368–382. https://doi.org/10.1016/j.gloenvcha.2013.12.004

Buys, L., Miller, E., & van Megen, K. (2012). Conceptualising climate change in rural Australia: Community perceptions, attitudes and (in)actions. *Regional Environmental Change*, *12*(1), 237–248. https://doi.org/10.1007/s10113-011-0253-6

Chapter 1—Bio-physical and socio-economic set up in the Indian Upper Himalayas. (n.d.). Retrieved 25 January 2025, from https://www.fao.org/4/x5672e/x5672e02.htm

Dahal, K. R., Dahal, P., Adhikari, R. K., Naukkarinen, V., Panday, D., Bista, N., Helenius, J., & Marambe, B. (2023). Climate Change Impacts and Adaptation in a Hill Farming System of the Himalayan Region: Climatic Trends, Farmers' Perceptions and Practices. *Climate*, *11*(1), Article 1. https://doi.org/10.3390/cli11010011

Dalgic, E., & Long, N. V. (2006). Corrupt local governments as resource farmers: The helping hand and the grabbing hand. *European Journal of Political Economy*, *22*(1), 115–138. https://doi.org/10.1016/j.ejpoleco.2005.07.001

Das, S., & Mishra, A. J. (2022). Traditional communities and dietary habits: Understanding the dynamics of food and climate change in the western Himalayan region. *British Food Journal*, *125*(4), 1335–1354. https://doi.org/10.1108/BFJ-12-2021-1270

Datta, P., Behera, B., & Rahut, D. B. (2022). Climate change and Indian agriculture: A systematic review of farmers' perception, adaptation, and transformation. *Environmental Challenges*, *8*, 100543. https://doi.org/10.1016/j.envc.2022.100543

Dhungana, N., Silwal, N., Upadhaya, S., Khadka, C., Regmi, S. K., Joshi, D., & Adhikari, S. (2020). Rural coping and adaptation strategies for climate change by Himalayan communities in Nepal. *Journal of Mountain Science*, *17*(6), 1462–1474. https://doi.org/10.1007/s11629-019-5616-3

García De Jalón, S., Silvestri, S., Granados, A., & Iglesias, A. (2015). Behavioural barriers in response to climate change in agricultural communities: An example from Kenya. *Regional Environmental Change*, *15*(5), 851–865. https://doi.org/10.1007/s10113-014-0676-y

Gehman, J., Glaser, V. L., Eisenhardt, K. M., Gioia, D., Langley, A., & Corley, K. G. (2018a). Finding Theory–Method Fit: A Comparison of Three Qualitative Approaches to Theory Building. *Journal of Management Inquiry*, *27*(3), 284–300. https://doi.org/10.1177/1056492617706029

Gehman, J., Glaser, V. L., Eisenhardt, K. M., Gioia, D., Langley, A., & Corley, K. G. (2018b). Finding Theory–Method Fit: A Comparison of Three Qualitative Approaches to Theory Building. *Journal of Management Inquiry*, *27*(3), 284–300. https://doi.org/10.1177/1056492617706029

Gioia, D. (2021). A Systematic Methodology for Doing Qualitative Research. *The Journal of Applied Behavioral Science*, *57*(1), 20–29. https://doi.org/10.1177/0021886320982715

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Gioia, D., Corley, K., Eisenhardt, K., Feldman, M., Langley, A., Lê, J., Golden-Biddle, K., Locke, K., Mees-Buss, J., Piekkari, R., Ravasi, D., Rerup, C., Schmid, T., Silverman, D., & Welch, C. (2022). A Curated Debate: On Using "Templates" in Qualitative Research. *Journal of Management Inquiry*, *31*(3), 231–252. https://doi.org/10.1177/10564926221098955

Glaser, B. G., & Strauss, A. L. (2017). *The discovery of grounded theory: Strategies for qualitative research*. Routledge.

Hassan, M. (2024, March 26). Grounded Theory—Methods, Examples and Guide. *Research Method*. https://researchmethod.net/grounded-theory/

Hecker, S., Wicke, N., Haklay, M., & Bonn, A. (2019). How Does Policy Conceptualise Citizen Science? A Qualitative Content Analysis of International Policy Documents. *Citizen Science: Theory and Practice*, *4*(1), 32. https://doi.org/10.5334/cstp.230

Hussain, A., Rasul, G., Mahapatra, B., & Tuladhar, S. (2016). Household food security in the face of climate change in the Hindu-Kush Himalayan region. Food Security, 8, 921-937.

Huq, N., Hugé, J., Boon, E., & Gain, A. (2015). Climate Change Impacts in Agricultural Communities in Rural Areas of Coastal Bangladesh: A Tale of Many Stories. *Sustainability*, *7*(7), 8437–8460. https://doi.org/10.3390/su7078437

Jha, C. K., & Gupta, V. (2021). Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India. *Environmental and Sustainability Indicators*, *10*, 100112. https://doi.org/10.1016/j.indic.2021.100112

Kanon, M. (2024). The networked bureaucracy: Reinventing formalization in the context of collaborative governance. *Public Management Review*, *26*(10), 2921–2942. https://doi.org/10.1080/14719037.2023.2298230

Kleinheksel, A. J., Rockich-Winston, N., Tawfik, H., & Wyatt, T. R. (2020). Demystifying Content Analysis. *American Journal of Pharmaceutical Education*, *84*(1), 7113. https://doi.org/10.5688/ajpe7113

Kumar, J., Choudhary, A. K., Gupta, D. S., & Kumar, S. (2019). Towards Exploitation of Adaptive Traits for Climate-Resilient Smart Pulses. *International Journal of Molecular Sciences*, *20*(12), 2971. https://doi.org/10.3390/ijms20122971

Kumar, S., & Gupta, D. (2023). *Article no.IJPSS.104842 Review Article Kumar and Gupta*. *35*, 888–907.

Macchi, M., Gurung, A. M., & Hoermann, B. (2015). Community perceptions and responses to climate variability and change in the Himalayas. *Climate and Development*, *7*(5), 414–425. https://doi.org/10.1080/17565529.2014.966046

Magnani, G., & Gioia, D. (2023). Using the Gioia Methodology in international business and entrepreneurship research. *International Business Review*, *32*(2), 102097. https://doi.org/10.1016/j.ibusrev.2022.102097

Mahl, D., Guenther, L., Schäfer, M. S., Meyer, C., & Siegen, D. (2020). "We are a Bit Blind About it": A Qualitative Analysis of Climate Change-Related Perceptions and Communication Across South African Communities. *Environmental Communication*, *14*(6), 802–815. https://doi.org/10.1080/17524032.2020.1736116

Malik, I. H., & Ford, J. D. (2025). Monitoring climate change vulnerability in the Himalayas. *Ambio*, *54*(1), 1–19. https://doi.org/10.1007/s13280-024-02066-9

Mayring, P. (n.d.). *Qualitative Content Analysis*.

McMullin, C. (2023). Transcription and Qualitative Methods: Implications for Third Sector Research. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations*, *34*(1), 140–153. https://doi.org/10.1007/s11266-021-00400-3

Mukherjee, A., Rakshit, S., Nag, A., Ray, M., Kharbikar, H., Shubha, K., Sarkar, S., Paul, S., Roy, S., Maity, A., Meena, V., Roy Burman, R., & Mukherjee, A. (2016). *Climate Change Risk Perception, Adaptation and Mitigation Strategy: An Extension Outlook in Mountain Himalaya 10*.

Mukherji, A., Molden, D., Nepal, S., Rasul, G., & Wagnon, P. (2015). Himalayan waters at the crossroads: Issues and challenges. *International Journal of Water Resources Development*, *31*(2), 151–160. https://doi.org/10.1080/07900627.2015.1040871

P, D., & A, R. (2016). Farmers' perceptions of climate change and the proposed agriculture adaptation strategies in a semi arid region of south India. *Journal of Integrative Environmental Sciences*, *13*(1), 1–18. https://doi.org/10.1080/1943815X.2015.1062031

Pandeya, S., Gajurel, A., Mishra, B. P., Devkota, K., Gyawali, B. R., & Upadhaya, S. (2024). Determinants of Climate-Smart Agriculture Adoption Among Rice Farmers: Enhancing Sustainability. *Sustainability*, *16*(23), Article 23. https://doi.org/10.3390/su162310247

Panico, T., Pascucci, S., Cicia, G., & Del Giudice, T. (2024). Farming in the shadow of violent organizations: Understanding farmers' relational place-making in socio-ecological crises. *Sustainability Science*, *19*(3), 1003–1020. https://doi.org/10.1007/s11625-024-01499-1

Pattanayak, A., Kavi Kumar, K. S., & Anneboina, L. R. (2021). Full article: Distributional impacts of climate change on agricultural total factor productivity in India. *Journal of the Asia Pacific Economy*, *26, 2021*(2), 381–401. https://doi.org/10.1080/13547860.2021.1917094

Ram, A., Tiwari, D. A. K., & Sharma, K. C. (2021). *Socio-Economic Development in Himachal Pradesh: A Disaggregated Study*. *9*(12).

Rasul, G., Saboor, A., Tiwari, P. C., Hussain, A., Ghosh, N., & Chettri, G. B. (2019). Food and Nutrition Security in the Hindu Kush Himalaya: Unique Challenges and Niche Opportunities. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People* (pp. 301–338). Springer International Publishing. https://doi.org/10.1007/978-3-319-92288-1_9

Roy, K. C., & Tisdell, C. A. (1998). Good governance in sustainable development: The impact of institutions. *International Journal of Social Economics*, *25*(6/7/8), 1310–1325. https://doi.org/10.1108/03068299810212775

Shukla, R., Agarwal, A., Gornott, C., Sachdeva, K., & Joshi, P. K. (2019). Farmer typology to understand differentiated climate change adaptation in Himalaya. *Scientific Reports*, *9*(1), 20375. https://doi.org/10.1038/s41598-019-56931-9

Shukla, R., Agarwal, A., Sachdeva, K., Kurths, J., & Joshi, P. K. (2019). Climate change perception: An analysis of climate change and risk perceptions among farmer types of Indian Western Himalayas. *Climatic Change*, *152*(1), 103–119. https://doi.org/10.1007/s10584-018-2314-z

Singh, R. B., & Hietala, R. (Eds.). (2014a). *Livelihood Security in Northwestern Himalaya: Case Studies from Changing Socio-economic Environments in Himachal Pradesh, India*. Springer Japan. https://doi.org/10.1007/978-4-431-54868-3

Singh, R. B., & Hietala, R. (Eds.). (2014b). *Livelihood Security in Northwestern Himalaya: Case Studies from Changing Socio-economic Environments in Himachal Pradesh, India*. Springer Japan. https://doi.org/10.1007/978-4-431-54868-3

Singh, R. B., & Kumar, P. (2014). Geographic and Socio-Economic Realities of Himachal Pradesh, Northwestern Himalaya. In R. B. Singh & R. Hietala (Eds.), *Livelihood Security in Northwestern Himalaya: Case Studies from Changing Socio-economic Environments in Himachal Pradesh, India* (pp. 11–26). Springer Japan. https://doi.org/10.1007/978-4-431-54868-3_2

Stemler, S. E. (2015). Content Analysis. In R. A. Scott & S. M. Kosslyn (Eds.), *Emerging Trends in the Social and Behavioral Sciences* (1st ed., pp. 1–14). Wiley. https://doi.org/10.1002/9781118900772.etrds0053

Soussi, A., Zero, E., Sacile, R., Trinchero, D., & Fossa, M. (2024). Smart sensors and smart data for precision agriculture: a review. Sensors, 24(8), 2647.

Suleiman, N., & Othman, Z. B. (2021). Forensic Accounting Investigation of Public Sector Corruption in Nigeria: The Gioia Methodology. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2021.3907

Sultan, H., Zhan, J., Rashid, W., Chu, X., & Bohnett, E. (2022). Systematic Review of Multi-Dimensional Vulnerabilities in the Himalayas. *International Journal of Environmental Research and Public Health*, *19*(19), 12177. https://doi.org/10.3390/ijerph191912177

Timilsina, R. R., Joshi, H. P., & Rahut, D. B. (2025). Enhancing food and nutrition security in Himalayan foothills with neglected and underutilized millets. *Scientific Reports*, *15*(1), 3182. https://doi.org/10.1038/s41598-024-85090-9

Uddin, M., & Anjuman, N. (2014). Participatory rural appraisal approaches: An overview and an exemplary application of focus group discussion in climate change adaptation and mitigation strategies. *International Journal of Agricultural Research, Innovation and Technology*, *3*(2), 72–78. https://doi.org/10.3329/ijarit.v3i2.17848

Ullah, A., Arshad, M., Kächele, H., Khan, A., Mahmood, N., & Müller, K. (2020). Information asymmetry, input markets, adoption of innovations and agricultural land use in Khyber Pakhtunkhwa, Pakistan. *Land Use Policy*, *90*, 104261. https://doi.org/10.1016/j.landusepol.2019.104261

Zimmermann, S., Dermody, B. J., Theunissen, B., Wassen, M. J., Divine, L. M., Padula, V. M., Von Wehrden, H., & Dorresteijn, I. (2023). A leverage points perspective on Arctic Indigenous food systems research: A systematic review. *Sustainability Science*, *18*(3), 1481–1500. https://doi.org/10.1007/s11625-022-01280-2

4.3 Major determinants of sustainable agriculture practies adoption: A systematic review

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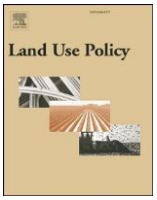

Major determinants of sustainable agriculture practices adoption: A systematic review

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ABSTRACT

Despite growing innovations and work in the field of sustainable agriculture practices, the adoption of such practices remains low. The increasing global population demands the agricultural systems to produce more food, enough to feed almost 10 billion mouths by 2050. However, despite their recognized benefits, SAP adoption remains limited due to various socio-economic, institutional, and governance-related barriers. This makes it imperative that we understand the determinants of low adoption rate of sustainable agricultural practices and perform necessary changes in current adoption approaches based on the desired requirements. This study conducts a global systematic review to identify the key determinants influencing SAP adoption. A total of 121 studies published between 2000 and 2024, focusing on one of the three determinants: Behavioural, Governance & Institutional, were identified, investigated and reviewed. Using hierarchical cluster analysis and word co- abundance techniques, we categorize these determinants into five clusters: governance support and incentives, household-level demographics, institutional incentivization, farmer perceptions and behaviour, and technological advancements. These clusters help us tackle the determinants in depth by performing a full-text analysis to understand the above-mentioned determinants and identify effective policy and adoption strategies. The findings highlight that financial constraints, lack of institutional support, and limited farmer awareness hinder widespread adoption, while education, market access, and policy interventions serve as enablers. We propose targeted policy recommendations, including financial incentives, farmer education programs, and infrastructure improvements, to promote SAP adoption. This study contributes to a deeper understanding of the multi-faceted drivers and barriers to sustainable agriculture, offering insights for policymakers and stakeholders aiming to enhance global agricultural sustainability.

Introduction

With the global population expected to reach approximately 9.8 billion by 2050, there is an increasing demand on agricultural systems to produce more food while relying on fewer natural resources, thereby safeguarding ecosystems and promoting socio-economic resilience (FAO, 2017). Currently, the global agricultural systems face unprecedented challenges due to increasing demands for food, climate change, environmental degradation, and the depletion of natural resources. Agriculture is thus both a driver as well as severely affected by these changes, leading to soil erosion, deforestation, increase in carbon footprint, and biodiversity loss (Maeda et al., 2021; Peplau et al., 2023). Many countries that primarily rely on agriculture as income sources create land deterioration and desertification due to chemical fertilizers use and poor irrigation practices (Olanipekun et al., 2019; Qadeer et al., 2024).

Global climate changes leads to rising temperatures, altered precipitation patterns, and extreme weather events—such as droughts, floods, and heatwaves—that diminish agricultural productivity,. The Intergovernmental Panel on Climate Change (IPCC) predicts global crop yields could decline by up to 30 % by 2050, with tropical and subtropical regions facing the greatest losses (Legg, 2021). Key crops like rice, maize, and wheat are particularly susceptible to temperature increases, which shortens the growing seasons negatively impacting the crop yields (Siebert et al., 2014; Agnolucci et al., 2020). Additionally, water scarcity, exacerbated by both droughts and competing demands, further threatens food production (Young et al., 2021). Another major climate-related risk to agriculture is the decreased suitability of land for different crops, affecting the microbial population and their enzymatic activities (Malhi et al., 2021). Understanding the determinants that influence the adoption of sustainable agricultural practices is therefore essential, and a systematic review provides the methodological rigor needed to synthesize the diverse evidence required to address this global challenge.

Sustainable agriculture- way out

Sustainable agriculture changes agricultural policy and practice to meet the growing need to address the dual challenges of ensuring global food security while simultaneously reducing agriculture's negative environmental impact (FAO, 2020). As a result, there has been a growing emphasis on the adoption of sustainable agricultural practices (SAPs) such as agroecology, drought-resistant crops, and improved water management, that can help reconcile food production with environmental preservation and social welfare (Giller et al., 2015; Pretty, 2023). Moreover, these practices tend to be more economically sustainable in the long run for smallholder farmers, who are vulnerable to food insecurity, by reducing dependency on expensive synthetic inputs and improving long-term profitability (Mugula et al., 2023). Sustainable agriculture's central goal is to enhance agricultural resilience in the face of climate change.

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Despite literature extensively highlighting the advantages of SAPs (Tey et al., 2014; Coulibaly et al., 2021; Muhie, 2022) its adoption is still low, especially in developing countries. Their widespread adoption still needs to be improved by identifying the underlying determinants acting as barriers or enablers to their adoption, which vary across regions, farming systems, and socio-economic contexts (Ansari and Tabassum, 2018). Numerous studies investigate the determinants that impact the adoption of sustainable agriculture, including financial constraints, lack of access to knowledge, and insufficient government support. Transitioning to sustainable practices often requires upfront investment in education, technology, and infrastructure, which many small-scale farmers, particularly in developing countries, cannot afford (Diop et al., 2022; Reij and Winterbottom, 2015). Additionally, government policies often favour conventional farming systems, which hinder the adoption of sustainable alternatives (FAO, 2020). Despite these barriers, numerous case studies, such as the System of Rice Intensification (SRI) in Asia and agroforestry practices in Sub-Saharan Africa, demonstrate the potential for sustainable agriculture to both enhance food security and mitigate environmental degradation (Uphoff, 2007; Nair, 2014). Addressing these challenges through targeted policy interventions, financial incentives, and education programs can unlock the full potential of sustainable agriculture as a key strategy for combating food insecurity worldwide.

Studying the role of determinants in the adoption of sustainable agriculture is critical in the context of addressing global challenges such as climate change, food security, and environmental degradation (Saltiel, 2010; Zeweld et al., 2017; Foguesatto et al., 2020). Understanding the determinants that influence farmers' decisions to adopt SAPs can aid policymakers and allow for the development of more effective strategies to promote sustainability across agricultural sectors. Incentives for farmers can help to adopt these practices and improve their long-term productivity in shifting climate patterns. Knowledge about socio-economic determinants such as income and access to credit can lead to tailored financial support programs, ensuring that farmers have the resources needed to transition to sustainable practices. Lastly, studying the determinants also provides valuable insights into how technology, innovation, and knowledge transfer can facilitate the adoption of SAPs. With advances in agricultural technologies and practices, farmers may face challenges in accessing and utilizing new tools. Understanding the existing technological and informational barriers can help to make information on dissemination and technology transfer accessible, enabling farmers to adopt more efficient, sustainable methods.

By making a systematic review of the existing literature we synthesize evidence on the types of sustainable agricultural practices and the key determinants that either promote or hinder their uptake. We built on existing reviews that investigated aspects of what we focus on here. Pineiro (2020) scoped the role of incentives in the adoption of various ˜ environmentally friendly practices. Begho (2022) focuses on the factors determining the adoption of sustainable agriculture but with a special focus on South Asian countries to provide an evidence based repository which tackles the relationshios between drivers and barriers of successful

adoption of SAPs. Rosario (2020) conducts a systematic review with a special focus on sustainable innovation adoption. Most studies only tackle one specific type of sustainable practice or one type of determinant of adoption. So far, none of the studies integrate a focus on the determinants that can be manipulated or regulated by humans - Behavioural, Institutional, and Governance.

Theoretical background

The available literature to date explores institutional, governance, and behavioural determinants, while emphasizing the complexity of agricultural systems and the importance of an integrated view. Governance determinants examine how a governing body polices itself, focusing on internal controls and practices to maintain compliance with regulations, implement best practices, and amend policies (Chibanda et al., 2009). The institutional determinants focus on policies, practices, or characteristics of the institutions that structure the society and human interaction (Kelly 1999; Kherallah and Kirsten, 2002), the behavioural determinants are attributed to the cultural values of a community and their attitudes towards the concerning issues, in this case, environmental issues; yet the collection of behaviours is specific to the population in consideration (Burton, 2004)

The above-mentioned determinants also address issues such as information asymmetries, opportunism, and conflicts of interest, but existing research often isolates these elements. There is a need to examine the extent of the interrelations of these determinants. Despite the growing interest in understanding adoption of SAPs, research synthesizing global evidence on this issue remains limited.

Existing studies tend to have primarily treated institutional, and governance as interlinked but separated from behavioural, with institutional and governance focusing on policy implementation and formulation while providing external support and behavioural addressing farmers attitude and perception (Clement, 2010; Feola and Binder, 2010; Bachev, 2010). To date, only a small number of reviews have attempted to examine the topic at a global scale, and those that exist often lack comprehensive coverage or consistent analytical frameworks. This gap highlights the need for a systematic, globally oriented review that consolidates available evidence and provides clearer insights into cross-regional similarities, differences, and emergent themes.

However, a gap remains in understanding the interdependencies between these determinants. Much of the existing literature also links SAPs to financial performance, such as share yield, productivity or profitability (Pretty, 2007). While valuable, this connection is often simplistic, and there is a lack of research on how the determinants mediate the relationship between SAP adoption and farmers. Considering these broader impacts and the trade-offs involved in adoption decisions, a more comprehensive understanding of determinants is required. By addressing this gap, our study offers a more holistic understanding of the global landscape and contributes essential context for researchers, practitioners, and policymakers working in this domain.

Methodology

To identify the most effective policy and other strategies to overcome barriers that hamper sustainable agriculture adoption and promote the scalability of sustainable practices in diverse agricultural systems, we conducted a systematic review of the above-mentioned determinants using a mixed methods design (Gough, 2015). A systematic review is a structured, transparent, and replicable method for synthesizing existing evidence to answer a clearly defined research question. This approach is especially appropriate when the literature on a topic is broad, multidisciplinary, and potentially inconsistent—as is the case with determinants of sustainable agriculture practice adoption. By enabling comprehensive identification, appraisal, and integration of findings across diverse studies, a systematic review reduces bias and uncovers overarching patterns that may not be evident in individual analyses (Hanley and Cutts, 2013). Guided by predefined inclusion criteria, systematic search strategies, critical quality assessment, and thematic or comparative synthesis, it ensures that the resulting conclusions are both rigorous and analytically grounded (Pollock and Berge, 2018). When applied to key determinants such as behavioral, institutional, and governance factors, this method facilitates a nuanced understanding of how farmer perceptions, organizational support structures, and broader policy environments interact to shape adoption outcomes.

The review utilizes multivariate statistics full-text articles combined with a full quantitaive analysis to explore and synthesize the academic literature, which helps us comprehend the heterogeneity within and among the articles, and nurture information among different clusters. Thereby, we try to reinforce the importance of 'holistic approach' in removing adoption obstacles and crafting customized policies resonating with realities of farmers. The bibliographic data were collected from two comprehensive scientific databases, Scopus and Web of Science (WoS) Core Collection, which are widely recognized for their extensive coverage and suitability for bibliometric research (Mongeon & Paul-Hus, 2016), on 12th March 2024 using the following search string:

[(TITLE-ABS-KEY ("sustainable agricult*") AND ("adopt*") AND ("factors") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT- TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "English AND PUBYEAR > 2000 AND PUBYEAR < 2024")) AND (LIMIT-TO (LANGUAGE, "English"))]

Only peer-reviewed journal articles written in English and published between 2000 and 2024 were included. Conference papers, book chapters, reviews, and grey literature were excluded to maintain the consistency and quality of the dataset. All retrieved records were exported from the databases in both BibTeX and CSV formats and were subsequently cleaned and standardized (Donthu et al., 2021). Duplicates and incomplete records were removed during this process. The final dataset represented a curated collection of publications forming the basis of both bibliometric and qualitative analyses. We obtained a raw sample of 2867 articles to which we applied to following inclusion criteria by screening only the articles' titles and abstracts:

1. The article is a peer-reviewed publication.
2. The article discusses SAP, specifically their adoption.

As a result, the sample was narrowed down to 659 articles. We then proceeded with a title and

abstract screening of the sample and applied the following inclusion criteria:

1. The article discusses the behavioural, institutional and governance factors responsible for their adoption.
2. The article considers communities and their role in SAP adoption.

The sample was then reduced to 121 articles. Fig. 2 shows the geographical, temporal and categorical distribution of articles

Tables 1–3.

For the analysis of the final sample (n = 121), we first conducted a textual abundance analysis, in which words were treated analogously as species and the respective articles as sites. The purpose of this analysis is to examine the relationship between research communities and the gradients between them based on the vocabulary composition they share (Abson et al., 2014; Rathgens et al., 2020; Engler et al., 2024). Conceptual vocabulary was extracted from the pdfs and stored into respective text files using pdf mining techniques and natural language processing filters in Python. The conceptual vocabulary was reduced to

Table 1
Description of main steps involved in paper selection.

Steps	Approach	Criteria	Outcome (n ¼)
Step 1	‚Search Query' with keywords in scopus & web of science	[(TITLE-ABS-KEY ("sustainable agricult*") AND ("adopt*") AND ("factors") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT- TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "English AND PUBYEAR > 2000 AND PUBYEAR < 2024")) AND (LIMIT-TO (LANGUAGE, "English"))]	2867
Step 2	Title Screening	Peer-reviewed publications, Sustainable Agriculture practices, adoption, factors of adoption	659
Step 3	Abstract Screening	At least one of the three determinants: Behavioural, Institutional, Governance; Study focuses involves communities	130
Step 4	PDFs Found	PDFs available on various sources as open access	121

Table 2
The major variables categorized.

Category	Representative Variables
Farm/Land Characteristics	Farm size, fertility, plot size, plot quality, farm ownership, irrigation, farm management, weed control, tillage, land tenure, land titling, desertification, slope, following, land degradation, erosion,
Household Characteristics	Family size, age, gender, livestock, education, finances, household head
Organizational Characteristics	Market access, cooperatives, social networks, social capital, credit availability,
Crop Characters & Yield	Productivity, cover crops, intercropping, crop health, crop type, seed quality, crop rotation,
Climatic Characteristics	Drought, flooding, slope, temperature, rainfall

nouns as they carry more conceptual meaning, denoting entities, objects and categories (Gentner, 1982).

The text files were imported in R to build an abundance table (conceptual vocabulary as rows and articles as columns, and frequencies in the cells) to continue with the textual abundance analysis:

1. Using the abundance table as the input, a detrended correspondence analysis (DCA) (Hill and Gouch, 1980) was used to generate coordinates for each noun and axes that serve as gradients explaining the nouns composition across articles, with the first axis the one with more explanatory power. Words close together appear in similar articles while words more far apart appear in different ones. The DCA plot generated has only two axes for readability reasons.
2. An agglomerative hierarchical clustering (using Ward's method) was applied to the abundance table to group all those articles with similar word composition. The number of clusters were decided based on the distribution of the number of articles in each cluster.
3. Once the gradients and groups were done, an indicator species analysis (Dufrˆene & Legendre 1997) was carried out to find the words that are more characteristic in each cluster of articles, that is, the words that occur

mainly in each cluster and the words that appears in most of the articles from each cluster.

Finally, a word cloud was produced to visualize how the words appear grouped in the ordination space. The clusters of articles were utilized as the entry point to explore and analyse qualitatively the full- text of the sample. For each of the cluster, articles were coded inductively and then analysed for common themes regarding aspects of sustainability agricultural practices.

We finally explored the clusters using a qualitative full-text analysis of the respective articles to identify the clusters´common denominator. A qualitative content review of the included articles was conducted using MAXQDA (Version 24.7.0). Each article was reviewed in full to identify key themes, theoretical perspectives, methodologies, and findings relevant to the research focus. Coding was performed inductively to allow themes to emerge from the data, and the coding scheme was refined iteratively to ensure consistency and depth of interpretation. This qualitative synthesis complemented the bibliometric findings by providing contextual and interpretive insights into how the field has developed conceptually over time.

Data integrity and reliability were ensured through repeated validation steps. All analyses were conducted independently by two authors, and coding discrepancies in MAXQDA were discussed until consensus was achieved. Cross-validation between textual abundance analysis and qualitative themes enhanced the robustness of the overall interpretation.

Results/findings

Since the 1987 Brundtland report (Keeble, 1988) research on sustainable agriculture and the practices being associated with sustainable agriculture has gradually increased. The millennium Declaration report (2000) marks an explicit focus on sustainable development and the necessity to increase food security, thereby the literature increased with most articles published in 2021 & 2023 (36 %). The articles discuss a variety of sustainable agricultural practices being practiced (Fig. 1 and 2. Conservation agriculture is the most widely talked about and discussed (12 %), followed by organic farming and a mixture of climate-smart agriculture and integrated pest management. 32 % of the studies focus on several practices, ranging from sustainable land management, and precision agriculture to green control technology. However, only 4 articles talk about sustainable agricultural practices explicitly.

Based on the literature, we identified 117 different variables considered in the studies included in the review (See Supplementary). We

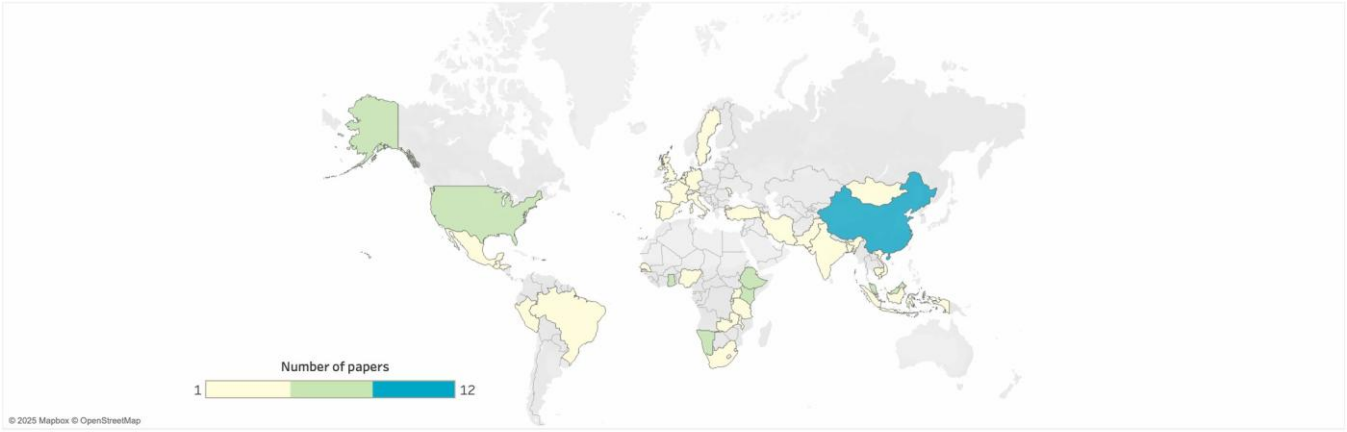
Table 3
The five clusters of determinants of sustainable agriculture practices, with number of contributions, few examples and ten most significant conceptual words.

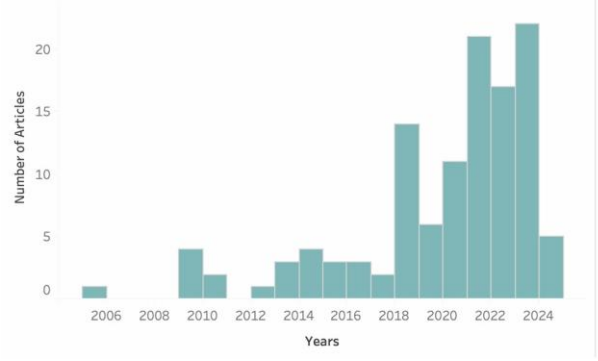
Cluster	Words	Number of articles	Examples
Governance Support	smallholder, head, maize, household, probability, poverty, rainfall, manure, fertility, access	38	Mazhar et al., 2021; Rodriguez et al., 2009
Household heads	agriculture, education, information, level, use, management, university, interest, production, sample	24	Kudama et al., 2021; Abera et al., 2020
Institutional Incentives	construct, intention, alpha, belief, modeling, reliability, theory, innovation, path, phenomenon	20	Marques et al., 2015; Boz, 1018
Farmers Behaviour	implementation, lack, forestry, system, society, agriculture, barrier, management, movement, cycle	30	Bottazzi et al., 2023; Coulibaly et al., (2021); Foguesatto & Machado, 2021
Technological Advancements	cognition, dummy, village, treatment, robustness, county, estimation, acquisition, roster, column	7	Zhao et al., (2022);

identified the most frequently discussed variables in the papers to

Sustainable Agriculture Practice	Determinant		
	Behavioural	Institutional	Governance
Climate Smart Agriculure		3	
Conservation Agriculture	5	5	4
Good Agricultural Practices		2	
Green Fertilizers Technique	2		
Integrated Pest Management		1	1
Multiple	7	10	19
Natural Resource Management			2
Not Applicable			2
Organic Farming	1	4	5
Other	1	6	9
Smart Farming	2	2	1
Sustainable Agriculture Intensification	3	3	
Sustainable Land Management		2	2
Technology Adoption	1	1	4
Total	22	39	49

Fig. 1. Distribution of the articles discussing various SAPs across type of determinants. 9 papers discussed multiple determinants in their study. 1- Behavioural Determinants, 2-Institutional Determinant, 3-Governance Determinant 102 studies are empirical and investigated various aspects of farming communities in terms of practicing SAPs. 46 % of the studies are conducted at a regional scale, followed by local (32 %). A mere 4 studies were conducted at an international or multinational level. 73 % have smallholder and subsistence farming communities as their main concern, whereas only 5 % are interested in large-scale commercial farmers. Maize is the most investigated crop (17 %), among other cereals (rice, wheat, rye & barley). Fruits are another commodity discussed concerning crops being grown by farming communities using SAPs. Natural components of the agriculture (soil, water, trees, etc.) (35 %) is the most investigated component of agriculture, followed by human/social (29 %) and then artificial (14 %) (such as machinery, technology, etc). Many papers also focussed on multiple components.





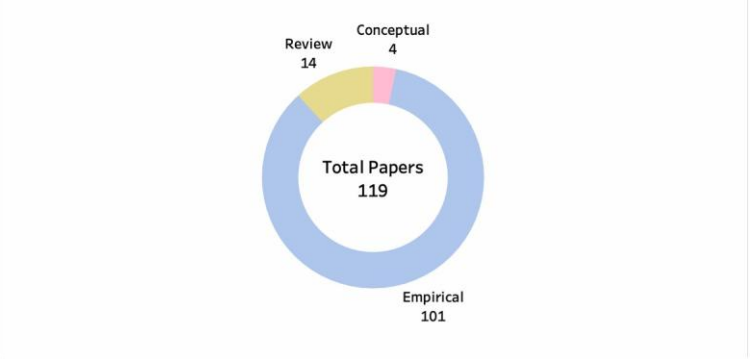


Fig. 2. Distribution of all 121 publications globally a) article share per country b) number of articles published over the years c). article distribution as empirical, conceptual and review.Out of 102 empirical studies, 26 papers performed descriptive analysis, and the rest implemented regression models with multivariate probit regression being the lion's share. The conceptual papers all comprise 'framework papers' proposing the various policy and institutional reforms in making SAP adoption widespread. The reviews either were scoping reviews or systematic reviews. The systematic reviews conducted the review using the PRISMA framework.

analyse the factors impacting SAP adoption (as shown in the table below) and categorized them following Knowler and Bradshaw (2007). It is evident that 'farmland characteristics' are the most commonly and widely used variables, followed by 'household characteristics'. Many studies also considered the organizations and their role as an important variable while studying adoption of SAP. Multiple studies mention land tenure or land ownership, market access, knowledge and information, labour access as some of the major barriers when considering SAP adoption among farmers. Whereas, income, education, experience, farm size, government support, and soil quality, are some of the facilitators in SAP adoption.

Bibliometric full text analysis

The focus of this study is to analyse the major determinants functioning either as a barrier or as enablers of SAPs adoption. While screening, articles comprising at least one of the three determinants: Behavioural, Institutional & Governance were considered. The clusters through co-abundancy were built. Fig. 3 shows the distribution of underlying determinants across clusters, highlighting the determinant overlap among studies. The top 10 most abundant words in each cluster are shown below.

Full-text analysis: types of clusters

Cluster 1: governance support (n = 33/121)
This cluster focusses predominantly on the support the government can and should provide to improve the adoption of SAPs, along with recommending policy reforms. The studies in this cluster focus on various governmental or institutional incentives while trying to grasp the impacts of various projects/schemes/policies on farmers' adoption behaviours. Existing incentive mechanisms primarily emphasize marketing enhancement, policy and informational outreach, and the provision of advisory services (Mazhar et al., 2021; Feliciano D, 2022; Ferreira et al., 2020), with fewer initiatives explicitly targeting governance-related dimensions critical to the widespread adoption of sustainable agricultural practices (Pineiro et al., 2020; Coulibaly et al., 2021; Priya & Singh, 2024).This cluster differs from the third cluster in that it approaches SAPs by trying to help or motivate farmers to adopt such practices, thus making this cluster essentially about 'implementation' while documenting the barriers.

Most studies (19) review 'agroforestry' or 'reforestation' or 'tree planting' as the potential form of a sustainable solution to increasing pest growth, land degradation, or erosion. The studies also identify awareness and information dissemination as the limiting factor in the adoption of SAPs by the farmers. The studies also highlight the lack of attention given to certain socio-economic factors of the targeted regions while formulating policies. Many studies (Tiraieyari et al., 2014; Adjei et al., 2017; Akenroye et al., 2021) find that lack of information dissemination (on the government's part), high application cost, and poor technical know-how of farmers are the major reasons holding back the adoption of SAPs. Ndah (2018) conducted a study trying to understand the reasons behind the success of conservation

agriculture (CA) in Zambia. The study finds that the systematic promotion of CA by the government, along with providing ample knowledge and support led to the success of CA.

This cluster does engage with practices, but the government policies or role in enhancing the sustainability of agriculture by promoting such practices. Multiple studies conclude that 'numerous barriers form a self- reinforcing system in which farmers perceive to have little leeway to implement sustainable practices'.

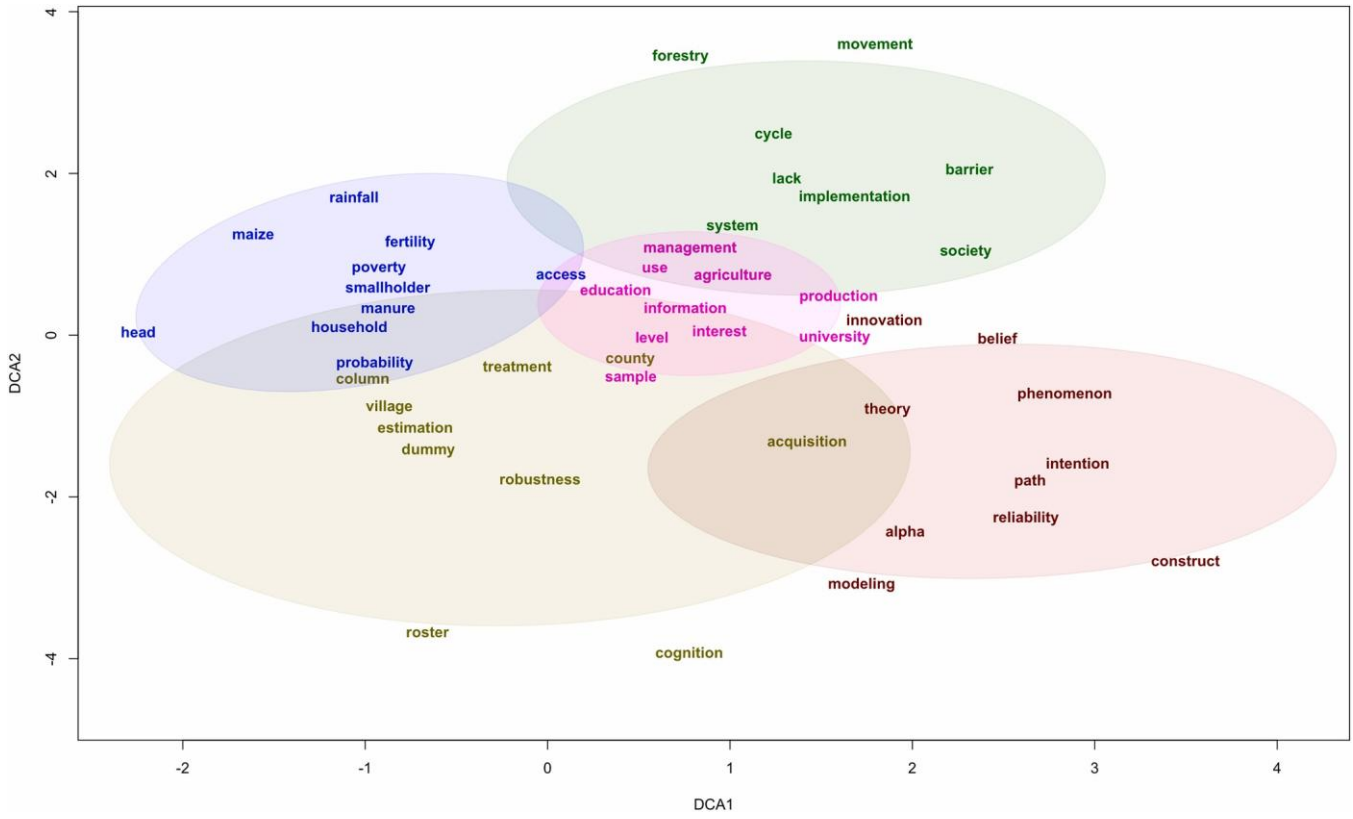


Fig. 3. Figure showing the overlap of clusters and the word cloud showing gradient between 'social and natural context' and 'individual behaviour', in the first axis (DCA 1) while the second axis (DCA2) is about 'implementation of SAP' & their 'modelling'.

Cluster 2: demography & households (n = 38/121)

This cluster was deductively formed after we realized that many papers focus on demographic determinants of SAP adoption. The papers also focus on other determinants, namely institutional and governance, but their main investigative points are households and their demographic qualities and how that plays a role in households' decisions regarding any SAP, consequently leading to the separation of this cluster.

This cluster aims at household income, livelihood options, remittances, and any other form of secondary income and tries to underline the role played by individual finances in SAP adoption decisions. Questionnaire surveys were conducted with household (HH) heads (22) as respondents, as HH heads are considered the decision-making authority in study areas, responsible for resource distribution and other decisions. A substantial proportion of studies investigated how variations in plot or farm size and the biophysical condition of the land affect household heads' decision-making processes concerning the adoption of sustainable agricultural practices (Kassie et al., 2009; Pilarvo et al., 2018; Morgan et al., 2019; Pham et al., 2021) Gender, education, knowledge, and training of the household head and other

members are determined to be some of the major influential factors (Myeni et al.,2019; Marfo et al., 2021; Onoja, 2023; Mdoda et al., 2023). Financial, natural, and manual resource use and distribution are also considered and explored as major driving factors while adopting certain practices (Zondo and Baiyegunhi, 2021; Aguilar et al., 2024). Fertilizer management and distribution is the most widely discussed factor, followed by labour, and farm training and experience. Many studies also tried to quantify the yield differences, soil quality, and impact of seed quality by analysing plots.

Many studies concluded that households with lower access to diversified income, financial support, and training were less likely to adopt sustainable agriculture practices. Khataza (2018) stresses that farmers who have survived drastic events adversely impacting the crops are more likely to take chances with 'risky' practices. Innovative solutions, land monitoring and management, and land tenure alongside economic mechanisms proved to be beneficial in boosting SAP adoption. Kudama (2021) mentions the role of literacy and organizational support, as they help farmers become aware of the innumerable available sources.

Cluster 3: Institutional Incentivisation (n = 23/121)

This cluster is the first and only cluster among all others that has active discourse surrounding 'sustainability' in the studies (Savari et al., 2013; Aydogdu et al., 2020; Bourne et al., 2021;Topp et al., 2023). The studies talk about 'alternative farming systems and methods' that can ensure farmers' profitability and tackle the decreasing global food security. This cluster predominantly talks about bringing institutional- level changes to make the adoption of SAPs successful at a wider level. Boz (2018) mentions the importance of environmental programs and the role of financial security in establishing a wider network of SAP adoptions. This cluster also recognizes the significance of maintaining soil quality to continuously produce quality produce without much environmental exploitation.

Policy formulation and amendments are a major theme in this cluster. The farmers were surveyed about their awareness regarding incentivization to tackle the degradation of various environmental components, owed to agricultural malpractices, especially soil and land degradation (15 out of 23 studies). Most studies examined how capacity- building initiatives, economic incentives, social capital, education levels, and policy support collectively shape farmers' decisions to adopt sustainable agricultural practices (Jussaume and Glenna, 2009; Boz, 2018; Sheng et al., 2018; Caffaro and Cavallo, 2019). Consequently, many studies focus on considering the role of 'chemical fertilizers', and 'erosion' in degrading land and soil quality. Marques (2015) is analyzing what measures do the vine growers in Central Spain take and how their awareness of governmental initiatives regarding the excessive erosion problem shapes their adoption rate of sustainable land management. The studies in this cluster investigate the contribution of local actors and their interaction with institutional actors in decision-making leading to SAP adoption. The studies also explore alternative agrifood developmental practices with farmers' involvement. The idea is to have a revised vision of modernity that has equity and sustainability at its core.

Cluster 4: farmers' behaviour and perception (n = 20/121)

This cluster deals prominently with the farmers' behavior and their perception of different SAPs

being implemented. The studies in this cluster (13) work on at least one of the following theories: Theory of Planned Behaviour, Social Attribution Theory, and Norm Activation Theory. Farmers' attitudes, perceptions, perceived usefulness, and ease of use are the major factors studied (Rosario et al., 2022; Bottazzi et al., 2023; Bhujel and Joshi, 2023; Kirungi et al., 2023). Coulibaly and others (2021) proposed a framework to fill 'the intention behaviour gap' in SAP research. The framework is based on the 'Theory of planned behaviour' and 'Norm Activation Theory'. The key objective of this cluster is to understand multiple behavioural factors determining the adoption of SAP.

This cluster focuses on how intent and interaction with farmers implementing certain practices influence farmers' decision-making process. Mutyasira et al., 2018 tries to understand farmers conservation behaviours by studying how personal norms link to SAP adoption. Their findings highlight a positive relationship between the two. This highlights how social norms and networks can be used to motivate farmers to adopt newer sustainable practices. The cluster concludes that adoption models based entirely on economics fail to capture the deeper complexity of farmers' decision-making and behaviour. Bottazzi and others (2023) emphasize the drawbacks of viewing farmers as 'rational agents whose main objective is to improve yields and profits'. They called this approach 'reductive' as it limits the scope of understanding the influence of cultural and social barriers in decision-making.

Cluster 5: technological advancements (n = 7/121)
This cluster largely focuses on agriculture's impact on environmental pollution and the possible cure for the same. Another common theme running through the cluster is the role of land tenure or land consolidation in the adoption of SAPs. Some authors are also trying to understand the role of digital finance in helping farmers obtain credit support and 'alleviate their credit constraints' (Zhao et al., 2022). The studies consider SAPs which are rather technical. All the studies were conducted in China, except for one which was conducted in Vietnam.

Another aspect within this cluster is that it focuses (6) on the importance of social credit/capital and subsidy/financial credit in enhancing farmer's green technologies adoption. Empirical evidence across studies indicates that digital financial services, land endowment structures, and targeted subsidy schemes constitute key institutional and economic drivers influencing the adoption of sustainable agricultural practices. The impacts are often enhanced if the land is tenured in farmers' names for a longer period or if they own it. A few authors also try to quantify the impact of subsidy support on adoption rates experimentally (Thu et al., 2020; Zhang and Fu, 2022).

Discussion

The results of this review highlight the increasing scholarly attention toward sustainable agriculture practices (SAPs) over the past two decades, with a significant surge in 2021 and 2023 (Fig. 2). This growing research interest aligns with the global policy shift following the Millennium Declaration (2000), which emphasized sustainable development and food security. The observed focus on conservation agriculture, organic farming, and climate-smart agriculture (Fig. 1) reinforces the notion that the academic discourse has matured from

conceptual debates on sustainability toward empirically grounded examinations of practical interventions. The distribution of studies across determinants and scales (Figs. 2–4) underscores that SAP adoption remains a multifaceted process shaped by interactions among behavioural, institutional, and governance factors. The predominance of smallholder- and subsistence-based studies (73 %) suggests a strong geographical and socio-economic concentration, with limited research on commercial or large-scale farming systems. This imbalance may limit the generalizability of the findings to global agricultural systems, despite the increasing number of multinational studies.

The negative impacts of conventional, input-intensive farming practices on the environment and human health have increased globally with the increasing demand for food supply (Hazel & Wood, 2008; Gomiero et al., 2011). The emphasis on natural components (soil, water, trees) over artificial or technological inputs (machinery, irrigation systems) further demonstrates that sustainability is still primarily framed through an ecological rather than a techno-economic perspective (35 % studies focused on natural component as compared to 14 % on machinery or technology in agriculture). These growing concerns have enhanced the interest of researchers worldwide in sustainable agriculture and associated practices. Such practices are vital for preserving the environment by minimizing less efficient agricultural practices and resource wastage. These practices also enhance soil, water, and air quality and support food security by improving the nutritional value of produce (Njeru, 2016). They reduce cultivation costs, boost farmer incomes, and contribute to rural development through diversified farming methods like crop rotation and intercropping, which create employment opportunities.

Despite government efforts worldwide to promote SAPs, adoption rates remain limited. Experiences from countries like the USA, Belgium, Thailand, Nepal, and China highlight several factors influencing SAP adoption, including socio-economic, biophysical, institutional, financial, technical, and psychological considerations (Barnes et al., 2019). Farmers' decisions to adopt sustainable agricultural practices in response to these efforts are complex and multifaceted (Adhikari et al., 2017, Foguesatto et al., 2020). Rather than being a binary choice, adoption occurs along a continuum influenced by numerous factors. These include the government's efforts' design, stakeholders' responsibilities, the type and level of incentives provided, and individual attributes such as environmental preferences, personal perspectives, education, and farming experience (Mdoda et al., 2023; Setiawan et al., 2024).

Farmers' choices are deeply rooted in personal views—such as their attitudes toward conservation, perceptions of program benefits, and risk tolerance. Economic circumstances, including income levels, asset ownership, age, and access to alternative livelihoods, also play a key role in determining their capacity to engage with such initiatives (Bhujel and Joshi, 2023). Adjei (2016) argues that the adoption of innovative agricultural practices is rooted in their awareness of the cost-benefits and ease of adoption of such practices. Educational levels play a significant role in sustainable agriculture practices adoption, with educated farmers more likely to adopt sustainable methods (Mogaka et al., 2022). This trend is more evident in developing countries like Nigeria and Thailand,

and to some extent in India, and China where educated farmers are more environmentally conscious (Lee, 2005; Akinyi et al., 2022). Governments should focus on grassroots educational campaigns to increase awareness.

Beyond individual and economic factors, the decision-making process is further impacted by the physical features of the land, ownership of the land, the regulatory and institutional environment, and even shifts in agricultural market dynamics (Emerton and Snyder, 2018; Singh et al., 2016). The distribution of determinants across all clusters also supports the argument that determinants are composed of multiple factors and cannot be treated as a 'case isolate' (Munguia et al., 2020). These interconnected variables underscore the need for context-specific policies and diverse, adaptable strategies to encourage the adoption of sustainable practices effectively. The determinants can be considered as the guiding focus, but evidence shows that several other factors are impacting their adoption (Anibaldi et al., 2021; Baumgart-Getz et al., 2012; Knowler and Bradshaw, 2007; Pannell et al., 2006). Henceforth, targeting one determinant often is not enough to tackle the underlying problem of low adoption of SAPs.

The clustering analysis also provides deeper insights into how these determinants interact to shape SAP adoption. The *Governance Support* cluster (Fig. 4 and 5demonstrates that policy interventions and institutional incentives can substantially improve adoption rates when coupled with knowledge dissemination and capacity-building mechanisms (e.g., Ndah, 2018). In contrast, the *Demography & Household* cluster (Fig. 4) emphasizes the socio-economic heterogeneity among farmers—education, gender, household income, and resource access are key enabling or constraining variables, confirming earlier findings by Knowler and Bradshaw (2007) that adoption decisions are rarely homogeneous within farming communities. Similarly, the *Institutional Incentivisation* cluster (Fig. 4 and 5) reveals that well-designed environmental and financial programs are instrumental in mainstreaming SAPs, especially when institutional and local actors collaborate to align sustainability goals with farmers' economic interests.

Behavioural determinants (Fig. 4) add further complexity by showing that adoption is not solely a rational economic choice but also a socially and psychologically mediated process. The application of behavioural theories—such as the Theory of Planned Behaviour and Norm Activation Theory—highlights that farmers' perceptions, attitudes, and social networks significantly influence their willingness to adopt sustainable practices (Coulibaly et al., 2021; Bottazzi et al., 2023). Finally, the *Technological Advancement* cluster (Fig. 3 and 4) suggests that digital finance, credit access, and land tenure security are emerging as pivotal enablers of SAP adoption, especially in rapidly developing agricultural economies such as China and Vietnam. Together, these findings underscore that promoting SAPs requires a multidimensional approach—one that simultaneously strengthens institutional structures, addresses socio-economic inequalities, and leverages behavioural and technological innovations to achieve broad-based agricultural sustainability.

Sustainable agriculture implementation frameworks should employ an integrated approach that addresses immediate priorities, such as growing food

insecurity, degrading natural resources, poor soil quality, and economic profitability, while concurrently working toward long- term environmental objectives (Clune, 2021; Alaoui et al., 2022; Wieliczko & Florianczyk, 2021). Formulating such policies often necessitates navigating trade-offs among long-term outcomes, diverse environmental goals, and equity and efficiency considerations. In the context of sustainable agriculture, policymakers often must balance between the negative and positive outcomes of SAPs being implemented (Kanter et al., 2018). For instance, productivity-based SAPs often compete with SAPs focusing on soil quality, and there is an obvious productivity trade-off with the first few years of organic farming. These outcome measures also need to account for trade-offs among various types of incentives and explore how SAP choices might complement the farmers' household conditions to achieve desired objectives.

Focusing on wealthier landowners often results in greater environmental benefits (Adolph et al., 2021). These farmers typically face lower opportunity costs for adopting sustainable practices compared to poorer farmers, whose primary focus may be subsistence production. In such cases, achieving environmental goals may exacerbate socioeconomic disparities. SAPs targeting wealthier regions with significant environmental degradation may yield higher environmental returns but risk excluding poorer farmers. Additionally, this may further increase the income gap, intensify inequality and decrease the chances of SAP adoption (Makate et al., 2017). Therefore, reconciling environmental objectives with equity and development goals often requires differentiated policy tools. However, the alignment of equity and efficiency is typically heightened for policies directed toward SAP adoption among impoverished farming communities (Sunny et al., 2022). Multiple studies advocate for a systems-based approach in evaluating trade-offs and synergies across scales (Bernues et al., 2011; Rosa-Schleich et al., 2019; Allouche, 2024). They recommend promoting self-sufficient, low-input systems with more focus on informed decision-making and practices suited to local conditions. This methodology enables the design of adaptive strategies tailored to specific contexts, ultimately fostering sustainable agricultural development.

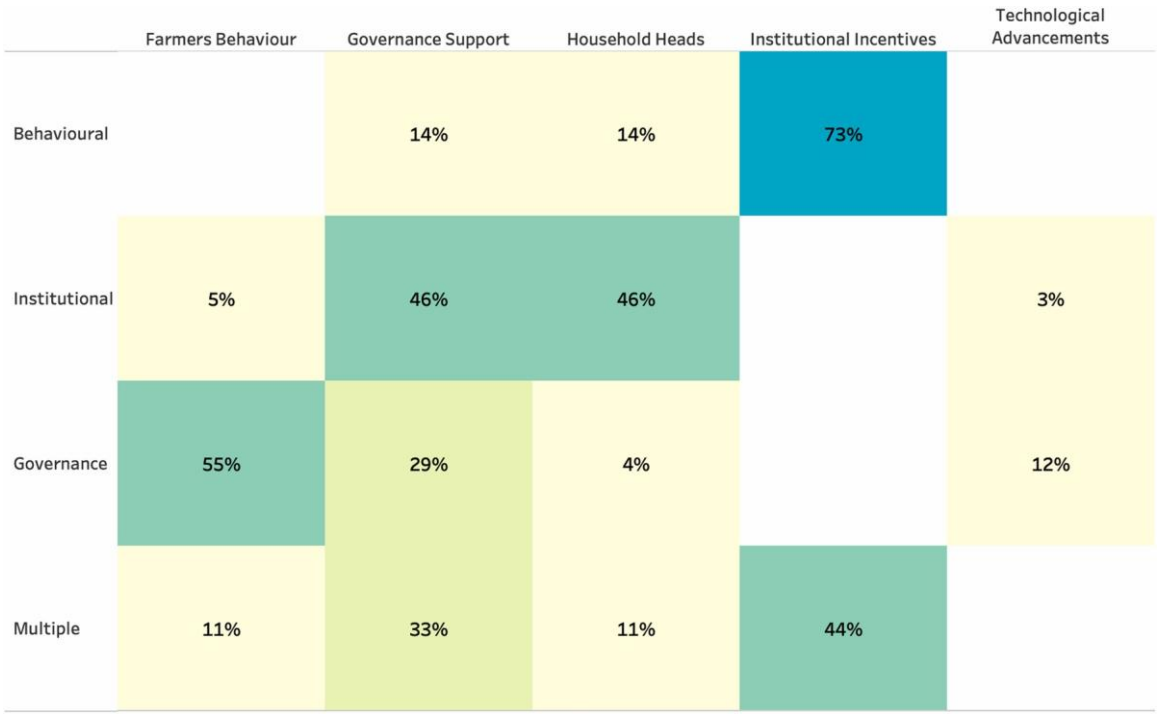


Fig. 4. Chart shows the distribution of papers with different determinants across the five clusters. 1- Behavioural Determinants, 2-Institutional Determinant, 3-Governance Determinant and, 4- Multiple Determinants.

	Cluster				
Sustainable Agriculture Practice	Farmers Behaviour	Governance Support	Household Heads	Institutional Incentives	Technological Advancements
Climate Smart Agriculure	1	2			
Conservation Agriculture	2	3	6	2	1
Good Agricultural Practices			2		
Green Fertilizers Technique				2	
Integrated Pest Management	1	1			
Multiple	7	21	5	7	2
Natural Resource Management	2				
Not Applicable	2				
Organic Farming	4	2	2	1	1
Other	7	2	3	1	3
Smart Farming	1		2	2	
Sustainable Agriculture Intensification		3	1	3	
Sustainable Land Management		3	2		
Technology Adoption	3	1	1	2	
Total	30	38	24	20	7

Fig. 5. Distribution of percentage of articles discussing various SAPs across five clusters.

An alternative strategy is to direct efforts in SAP adoption towards areas most vulnerable to changing climate or farmers with the least resources and accessibility (Weltin & Zasada, 2018). Thus, bundled or multipronged practices that integrate social, economic, and productivity components are particularly effective in developing countries. This raises the critical question of when and where extra efforts are necessary to stimulate adoption. Farmers likely to adopt sustainable practices often reside in regions with lower deforestation risks, prefer conservation initiatives, face lower opportunity costs, or perceive high net benefits from adopting sustainable methods (Zabala et al., 2015; Rahman et al., 2017). These benefits are enhanced together with economic incentives. Thus, incentivization can be regarded as a secondary driver of sustainable practice adoption, and considered while formulating a trade-off (Wunder et al., 2008; Bremer et al., 2014). Targeting incentive programs toward regions or populations where adoption is less probable ensures higher adoption and enhances environmental efficiency.

Policy recommendations

There is a diverse range of determinants at play in the adoption of SAPs. Some of these determinants are directly linked to governmental policies, while others are related to individual-level choices made by farmers, with the potential to be influenced by policies. Consequently, the way policymakers respond to the underlying variables of these determinants has a significant impact on the adoption of SAPs (Peshin et al., 2019; Tey et al., 2012). It is imperative to identify the variables that require higher priority to address and formulate policies accordingly. Economic challenges, such as high upfront costs, can be mitigated by providing subsidies, low-interest loans, and facilitating farmer participation in carbon markets (Wreford, 2017). Policies must also invest in farmer education through extension services, technical training, and farmer field schools to improve knowledge about sustainable practices (Coulibaly et al., 2021). Additionally, infrastructure enhancements like efficient irrigation systems and digital platforms can support farmers in adopting eco-friendly techniques (World Bank, 2020). To stabilize markets, governments should offer premium pricing for sustainably grown produce, guaranteed procurement, and cooperative marketing opportunities, ensuring fair value for farmers' efforts (Bland et al., 2023). These measures, combined with regulations promoting reduced chemical use and soil conservation, align agricultural practices with the Sustainable Development Goals, especially No Poverty (SDG1), ZERO Hunger (SDG2), and Climate Action (SDG 13)

Moreover, addressing climate change through incentives for agroforestry, disaster insurance schemes, and the promotion of climate- resilient crops is vital for sustainable farming's long-term viability (IPCC, 2022). Engaging communities through participatory policy development and awareness campaigns can overcome social and cultural resistance, while inclusive policies ensure gender equity in farming (Laborde Debucquet et al., 2024). Investments in research and development (R&D) can deliver

localized solutions for soil fertility, water conservation, and pest management (FAO, 2021). International collaboration on knowledge-sharing and sustainable trade agreements can further accelerate adoption, especially in developing nations (World Economic Forum, 2023). Investing in research to develop region-specific sustainable practices that consider local environmental conditions and crop varieties, while tailoring solutions to the specific needs of farmers is more likely to be effective and adopted (Barbosa Junior et al., 2022). By consolidating these strategies, governments can address barriers holistically, fostering a global transition toward sustainable agriculture.

Conclusion

The adoption of sustainable agricultural practices is essential for addressing the growing challenges of food security, climate change, and environmental degradation. Despite their numerous benefits, sustainable agriculture practices adoption remains limited due to a complex interplay of behavioural, institutional, governance, and demographic factors. The review achieved two main objectives: highlighting and identifying key determinants influencing farmers' adoption of sustainable agriculture practices and policy strategies for their enhanced adoption and emphasizing methodological gaps in existing studies to guide future research. It confirmed that sustainable agriculture adoption is driven by multiple interconnected factors rather than isolated influences.

From a policy perspective, several actions can be taken to promote sustainable agricultural practices. Policymakers must adopt a multi- faceted approach to overcoming these barriers, integrating financial support, education, infrastructure development, and regulatory frameworks to encourage sustainable farming. International collaboration, market-based incentives, and localized research tailored to specific agricultural systems can further accelerate sustainable agriculture practices adoption. Governance and institutional support play a crucial role in facilitating adoption through targeted policies, incentives, and awareness campaigns. Investments in education and training can improve farmers' skills and awareness, while technical support from consultants and industry experts can facilitate adoption.

Financial incentives such as grants, and tax benefits can lower costs and barriers. Encouraging knowledge sharing among farmers and implementing awareness campaigns can further drive adoption. Additionally, household characteristics, particularly income, education, and access to resources, significantly impact farmers' willingness to adopt sustainable practices. Behavioural factors, including perceptions of risk, social norms, and cultural values, further shape adoption decisions, underscoring the need for context-specific strategies. Technological advancements, financial accessibility, and land tenure security are also instrumental in scaling up sustainable agriculture practices implementation. By addressing these determinants holistically, governments and stakeholders can drive a global transition toward resilient,

sustainable, and climate-smart agricultural systems, ensuring long-term food security and environmental conservation.

These insights contribute to policy discussions on promoting sustainable agriculture innovations, especially in parts demanding it most. Understanding farmers' needs and local requirements more thoroughly can lead to more effective policies, avoiding unrealistic assumptions in policy design. For instance, the European Common Agricultural Policy (CAP) has had mixed success due to its reliance on traditional policy tools without fully accounting for farmers' motivations. The study's findings could help policymakers tailor interventions to farmers' specific needs, ultimately supporting the achievement of the United Nations Sustainable Development Goals (SDGs) by 2030.

However, the review has certain limitations. First, its systematic approach still involves subjective decisions, meaning different researchers might emphasize different aspects. Second, it exclusively analyzed scientific articles, excluding books, newspaper articles, commentaries and other gray literature, and only considered studies indexed in Scopus and Web of Science, potentially overlooking relevant research. Third, the review focused solely on three determinants, namely Behavioural, Institutional, and Governance missing insights from articles focusing on other factors. The studies reviewed did not allow for a deep examination of how other factors interact with the considered determinants. Despite these limitations, the study has theoretical, methodological and practical implications. Theoretically, it aims to fill gaps in the fragmented literature, especially regarding the three determinants which fall under human control, directly or indirectly. It also supports the idea that socio-demographic, behavioural, and governance factors consistently interact and should be considered together. Methodologically, it provides guidance for conducting systematic reviews with stronger validity and more rigour. This leaves future research with a lot of possibilities to explore within agricultural sector.

CRediT authorship contribution statement

Jorge Gustavo Rodriguez Aboytes: Writing – review & editing, Visualization, Methodology, Formal analysis. **Henrik von Wehrden:** Writing – review & editing, Supervision, Resources, Conceptualization. **Neha Chauhan:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kretschmer Max**

Friedemann: Writing – review & editing, Writing – original draft, Methodology, Formal analysis.

Ethics statement and informed consent

Not Applicable

Author contributions

Neha Chauhan conceptualized and designed the study. Material preparation, data collection and analysis were performed by Neha Chauhan, Max Kretschmer and Jorge Gustavo Rodriguez Aboytes. The first draft of the manuscript was written by Neha Chauhan, except for methods section which was written by Max Kretschmer and Jorge Gustavo Rodriguez Aboytes. The manuscript was revised/reviewed by Max Kretschmer, Jorge Gustavo Rodriguez Aboytes and Henrik von Wehrden. The study was supervised by Henrik von Wehrden. The final manuscript was read and approved by all the authors.

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Declaration of Competing Interest

The authors declare that

- the work described has not been published previously in any form.
- the article is not under consideration for publication elsewhere.
- all authors approve the article's publication.
- if accepted, the article will not be published elsewhere in the same form, in English, or any other language, including electronically, without the copyright holder's written consent.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2026.107941.

Data availability

The data (research articles) are available on open source government websites.

References

Adhikari, R.K., Kindu, M., Pokharel, R., Castro, L.M., Knoke, T., 2017. Financial compensation for biodiversity conservation in Ba Be National Park of Northern Vietnam. J. Nat. Conserv. 35, 92–100. https://doi.org/10.1016/j.jnc.2016.12.003.

Adolph, B., Allen, M., Beyuo, E., Banuoku, D., Barrett, S., Bourgou, T., Bwanausi, N., Dakyaga, F., Derbile, E.K., Gubbels, P., Hi´e, B., Kachamba, C., Naazie, G.K., Niber, E. B., Nyirengo, I., Tampulu, S.F., Zongo, A.-F., 2021. Supporting smallholders' decision making: managing trade-offs and synergies for sustainable agricultural intensification. Int. J. Agric. Sustain. 19 (5–6), 456–473. https://doi.org/10.1080/ 14735903.2020.1786947.

Agnolucci, P., Rapti, C., Alexander, P., De Lipsis, V., Holland, R.A., Eigenbrod, F., Ekins, P., 2020. Impacts of rising temperatures and farm management practices on global yields of 18 crops. Nat. Food 1 (9), 562–571. https://doi.org/10.1038/ s43016-020-00148-x.
Akinyi, D.P., Karanja Ng'ang'a, S., Ngigi, M., Mathenge, M., Girvetz, E., 2022. Cost- benefit analysis of prioritized climate-smart agricultural practices among smallholder farmers: evidence from selected value chains across sub-Saharan Africa. Heliyon 8, 4.
Alaoui, A., Barao, L., Ferreira, C.S., Hessel, R., 2022. An overview of sustainability˜ assessment frameworks in agriculture. Land 11 (4), 537.
Allouche, J., 2024. Nexus framing of sustainability issues: feasibility, synergies, and trade-offs in terms of water-energy-food. Annu. Rev. Environ. Resour. 49 (49, 2024), 501–518. https://doi.org/10.1146/annurev-environ-112321-112445.
Anibaldi, R., Rundle-Thiele, S., David, P., Roemer, C., 2021. Theoretical underpinnings in research investigating barriers for implementing environmentally sustainable farming practices: insights from a systematic literature review. Land 10 (4), 386.

Ansari, S.A., Tabassum, S., 2018. A new perspective on the adoption of sustainable agricultural practices: a review. Curr. Agric. Res. J. 6 (2), 157–165. https://doi.org/ 10.12944/CARJ.6.2.04.
Bachev, H. (2010). Governance of agrarian sustainability. 〈https://mpra.ub.uni-muen chen.de/99867/〉 .
Barbosa Junior, M., Pinheiro, E., Sokulski, C.C., Ramos Huarachi, D.A., de Francisco, A. C., 2022. How to identify barriers to the adoption of sustainable agriculture? a study based on a multi-criteria model. Sustainability 14 (20). https://doi.org/10.3390/ su142013277.
Barnes, A.P., Soto, I., Eory, V., Beck, B., Balafoutis, A.T., Sanchez, B., Vangeyte, J., Fountas, S., Van Der Wal, T., Gomez-Barbero, M., 2019. Influencing incentives for´ precision agricultural technologies within European arable farming systems. Environ. Sci. Policy 93, 66–74. https://doi.org/10.1016/j.envsci.2018.12.014.
Baumgart-Getz, A., Prokopy, L.S., Floress, K., 2012. Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. J. Environ. Manag. 96 (1), 17–25.
Bhujel, R.R., Joshi, H.G., 2023. Understanding farmers' intention to adopt sustainable agriculture in Sikkim: the role of environmental consciousness and attitude. Cogent Food Agric. 9 (1), 2261212.
Bland, R., Ganesan, V., Hong, E., & Kalanik, J. (2023). Trends driving automation on the farm.
Bremer, L.L., Farley, K.A., Lopez-Carr, D., 2014. What factors influence participation in payment for ecosystem services programs? An evaluation of Ecuador's SocioParamo´ program. Land Use Policy 36, 122–133. https://doi.org/10.1016/j. landusepol.2013.08.002.
Burton, R.J.F., 2004. Reconceptualising the 'behavioural approach' in agricultural studies: a socio-psychological perspective. J. Rural Stud. 20 (3), 359–371. https:// doi.org/10.1016/j.jrurstud.2003.12.001.
Chibanda, M., Ortmann, G.F., Lyne, M.C., 2009. Institutional and governance factors influencing the performance of selected smallholder agricultural cooperatives in KwaZulu-Natal. Agrekon 48 (3), 293–315. https://doi.org/10.1080/ 03031853.2009.9523828.
Clement, F., 2010. Analysing decentralised natural resource governance: Proposition for a "politicised" institutional analysis and development framework. Policy Sci. 43 (2), 129–156. https://doi.org/10.1007/s11077-009-9100-8.
Clune, T., 2021. Conceptualising policy for sustainable agriculture development. Aust. J. Public Adm. 80 (3), 493–509.
Coulibaly, T.P., Du, J., Diakit´e, D., 2021. Sustainable agricultural practices adoption. Agric. 67 (4), 166–176. https://doi.org/10.2478/agri-2021-0015.
Diop, M., Chirinda, N., Beniaich, A., El Gharous, M., El Mejahed, K., 2022. Soil and water conservation in Africa: state of play and potential role in tackling soil degradation and building soil health in agricultural lands. Sustainability 14 (20), 13425. https:// doi.org/10.3390/su142013425.
Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., Lim, W.M., 2021. How to conduct a bibliometric analysis: an overview and guidelines. J. Bus. Res. 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.07.
Emerton, L., Snyder, K.A., 2018. Rethinking sustainable land management planning: understanding the social and economic drivers of farmer decision-making in Africa. Land Use Policy 79, 684–694.
FAO (Ed.). (2017). Leveraging food systems for inclusive rural transformation. Food and Agriculture Organization of the United Nations.
,FAO: Global Forest Resources Assessment 2020: Main Report, FAO, Rome, http://www. fao.org/documents/card/en/c/ca9825en (last access: 10 July 2022), 2020.
Feola, G., Binder, C.R., 2010. Towards an improved understanding of farmers' behaviour: the integrative agent-centred (IAC) framework. Ecol. Econ. 69 (12), 2323–2333. https://doi.org/10.1016/j.ecolecon.2010.07.023.
Foguesatto, C.R., Borges, J.A.R., Machado, J.A.D., 2020. A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. Sci. Total Environ. 729, 138831. https://doi.org/10.1016/j.scitotenv.2020.138831.
Gentner, D., 1982. Why nouns are learned before verbs: linguistic relativity versus natural partitioning. BBN Rep. *4854* (no).
Giller, K.E., Andersson, J.A., Corbeels, M., Kirkegaard, J., Mortensen, D., Erenstein, O., Vanlauwe, B., 2015. Beyond conservation agriculture. Front. Plant Sci. 6, 870.
Gomiero, T., Pimentel, D., Paoletti, M.G., 2011. Is there a need for a more sustainable agriculture? Crit. Rev. Plant Sci. 30 (1–2), 6–23. https://doi.org/10.1080/ 07352689.2011.553515.
Gough, D., 2015. Qualitative and mixed methods in systematic reviews. Syst. Rev. 4 (1), 181. https://doi.org/10.1186/s13643-015-0151-y.
Hanley, T., Cutts, L., 2013. What is a systematic review? Couns. Psychol. Rev. 28 (4), 3–6.
Hill, M.O., Gauch Jr, H.G., 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio 42 (1), 47–58. https://doi.org/10.1007/ BF00048870.
Kanter, D.R., Musumba, M., Wood, S.L.R., Palm, C., Antle, J., Balvanera, P., Dale, V.H., Havlik, P., Kline, K.L., Scholes, R.J., Thornton, P., Tittonell, P., Andelman, S., 2018. Evaluating agricultural trade-offs in the age of sustainable development. Agric. Syst. 163, 73–88. https://doi.org/10.1016/j.agsy.2016.09.010.
Keeble, B.R., 1988. The brundtland report: our common future. Med. War. 4 (1), 17–25.
Kherallah, M., Kirsten, J.F., 2002. The New Institutional Economics: applications for agricultural policy research in developing countries. N. Inst. Econ. are blueCollar guys a Heart appetite Real. " Oliver Williamson 2000a. Agrekon 41 (2), 110–133. https://doi.org/10.1080/03031853.2002.9523589.
Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. Food Policy 32 (1), 25–48. https://doi.org/ 10.1016/j.foodpol.2006.01.003.
Laborde Debucquet, D., Olivetti, E.B., & Pineiro, V. (2024). Transforming agricultural ˜ support for a sustainable future: A Latin America and Caribbean view. 〈 https://hdl. handle.net/10568/151915〉 .
Lee, D.R., 2005. Agricultural sustainability and technology adoption: Issues and policies for developing countries. Am. J. Agric. Econ. 87 (5), 1325–1334.
Legg, S., 2021. IPCC, 2021: climate change 2021 - the physical science basis. Interaction 49 (4), 44–45. https://doi.org/10.3316/informit.315096509383738.
Maeda, E.E., Abera, T.A., Siljander, M., Aragao, L.E., Moura, Y.M.D., Heiskanen, J., 2021.˜ Large-scale commodity agriculture exacerbates the climatic impacts of Amazonian deforestation. In: Proceedings of the National Academy of Sciences, 118.
Makate, C., Makate, M., Mango, N., 2017. Sustainable agriculture practices and livelihoods in pro-poor smallholder farming systems in southern Africa. Afr. J. Sci. Technol. Innov. Dev. 9 (3), 269–279.
Malhi, G.S., Kaur, M., Kaushik, P., 2021. Impact of climate change on agriculture and its mitigation strategies: a review. Sustainability 13 (3). https://doi.org/10.3390/ su13031318.
Mdoda, L., Christian, M., Gidi, L., 2023. Determinants of adoption of multiple sustainable agricultural practices (SAPS) by smallholder farmers in the Eastern Cape Province in South Africa. Afr. J. Food Agric. Nutr. Dev. 23 (4). Article 4.
Mogaka, B.O., Karanja Ng'ang'a, S., Bett, H.K., 2022. Comparative profitability and relative risk of adopting climate-smart soil practices among farmers. A cost-benefit analysis of six agricultural practices. Clim. Serv. 26, 100287.

Mugula, J., Ahmad, A.K., Msinde, J., Kadigi, M., 2023. Economic impact of adopting bundled SAPs on crop yields and household incomes among smallholder maize farmers in Morogoro region, Tanzania. Int. J. Res. Bus. Soc. Sci. 12 (8), 2147–4478. https://doi.org/10.20525/ijrbs.v12i8.2977.
Muhie, S.H., 2022. Novel approaches and practices to sustainable agriculture. J. Agric.

Food Res. 10, 100446. https://doi.org/10.1016/j.jafr.2022.100446.
Nair, P.R., 2014. Grand challenges in agroecology and land use systems. Front. Environ. Sci. 2, 1.
Njeru, M.K., 2016. Factors influencing adoption of organic farming among farmers in nembure division. Embu Cty. Kenya 6 (4).
Olanipekun, I.O., Olasehinde-Williams, G.O., Alao, R.O., 2019. Agriculture and environmental degradation in Africa: the role of income. Sci. Total Environ. 692, 60–67. https://doi.org/10.1016/j.scitotenv.2019.07.129.
Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R., 2006. Understanding and promoting adoption of conservation practices by rural landholders. Aust. J. Exp. Agric. 46 (11), 1407–1424.

Peplau, T., Poeplau, C., Gregorich, E., Schroeder, J., 2023. Deforestation for agriculture leads to soil warming and enhanced litter decomposition in subarctic soils. Biogeosciences 20 (5), 1063–1074.
Peshin, R., Bano, F., Kumar, R., 2019. Diffusion and adoption: factors impacting adoption of sustainable agricultural practices. Nat. Resour. Manag. Ecol. Perspect. 235–253.
Pollock, A., Berge, E., 2018. How to do a systematic review. Int. J. Stroke 13 (2), 138–156.
Pretty, J., 2007. Agricultural sustainability: concepts, principles and evidence. Philos. Trans. R. Soc. B Biol. Sci. 363 (1491), 447–465. https://doi.org/10.1098/rstb.2007.2163.
Pretty, J., 2023. Regenerative Agriculture and Redesign for Sustainability. Proceeding of Biological Approaches to Regenerative Soil Systems, Second ed.). CRC Press.
Qadeer, A., Wakeel, A., Cheema, S.A., Shahzad, T., Sanaullah, M., 2024. Integrated impacts of soil salinity and drought stresses on the decomposition of plant residues. Sustainability 16 (13), 5368.
Rahman, S.A., Jacobsen, J.B., Healey, J.R., Roshetko, J.M., Sunderland, T., 2017. Finding alternatives to swidden agriculture: does agroforestry improve livelihood options and reduce pressure on existing forest? Agrofor. Syst. 91, 185–199.
Rathgens, J., Groschner, S., von Wehrden, H., 2020. Going beyond certificates: a ¨ systematic review of alternative trade arrangements in the global food sector. J. Clean. Prod. 276, 123208. https://doi.org/10.1016/j.jclepro.2020.123208.
Reij, C., & Winterbottom, R. (2015). Scaling up Regreening: Six Steps to Success. 〈https://www.wri.org/research/scaling-regreening-six-steps-success〉 .
Rosa-Schleich, J., Loos, J., Mußhoff, O., Tscharntke, T., 2019. Ecological-economic trade- offs of diversified farming systems – a review. Ecol. Econ. 160, 251–263. https://doi. org/10.1016/j.ecolecon.2019.03.002.
Setiawan, R.B., 2024. Challenges, opportunities, and strategies of pentahelix stakeholders in realizing sustainable supply chains in indonesia. Enrich. J. Multi. Res. Devel. 2 (7).

Siebert, S., Ewert, F., Rezaei, E.E., Kage, H., Graß, R., 2014. Impact of heat stress on crop yield—on the importance of considering canopy temperature. Environ. Res. Lett. 9 (4), 044012. https://doi.org/10.1088/1748-9326/9/4/044012.
Singh, C., Dorward, P., Osbahr, H., 2016. Developing a holistic approach to the analysis of farmer decision-making: implications for adaptation policy and practice in developing countries. Land Use Policy 59, 329–343.
Sunny, F.A., Karimanzira, T.T.P., Peng, W., Rahman, M.S., Zuhui, H., 2022. Understanding the determinants and impact of the adoption of technologies for sustainable farming systems in water-scarce areas of Bangladesh. Front. Sustain. Food Syst. 6, 961034.

Tey, Y.S., Li, E., Bruwer, J., Abdullah, A.M., Brindal, M., Radam, A., Ismail, M.M., Darham, S., 2014. The relative importance of factors influencing the adoption of sustainable agricultural practices: a factor approach for Malaysian vegetable farmers. Sustain. Sci. 9 (1), 17–29. https://doi.org/10.1007/s11625-013-0219-3.
Uphoff, N., 2007. System of Rice Intensification (SRI) to enhance both food and water security. Food and Water Security. CRC Press, pp. 145–158.
Wieliczko, B., Florianczyk, Z., 2021. Priorities for research on sustainable agriculture: the´ case of Poland. Energies 15 (1), 257.
Wunder, S., Engel, S., Pagiola, S., 2008. Taking stock: a comparative analysis of payments for environmental services programs in developed and developing countries. Ecol. Econ. 65 (4), 834–852. https://doi.org/10.1016/j. ecolecon.2008.03.010.
Young, S.L., Frongillo, E.A., Jamaluddine, Z., Melgar-Quinonez, H., P˜ erez-Escamilla, R., ´ Ringler, C., Rosinger, A.Y., 2021. Perspective: the importance of water security for ensuring food security, good nutrition, and well-being. Adv. Nutr. 12 (4), 1058–1073. https://doi.org/10.1093/advances/nmab003.
Zeweld, W., Van Huylenbroeck, G., Tesfay, G., Speelman, S., 2017. Smallholder farmers' behavioural intentions towards sustainable agricultural practices. J. Environ. Manag. 187, 71–81. https://doi.org/10.1016/j.jenvman.2016.11.014.
Zhao, P., Zhang, W., Cai, W., Liu, T., 2022. The impact of digital finance use on sustainable agricultural practices adoption among smallholder farmers: an evidence from rural China. Environ. Sci. Pollut. Res. 29 (26), 39281–39294. https://doi.org/ 10.1007/s11356-022-18939-z.

5. Synthesis: The Importance of an Integrated Approach

The intersection of agricultural policy, community perception, and the behavioural, institutional, and governance factors influencing sustainable agriculture adoption is not merely coincidental—it is fundamentally causal and cyclical. The challenges faced by the Himalayan agricultural sector cannot be adequately understood, let alone addressed, through fragmented analysis. Rather, they demand a holistic and systemic approach that sees policies, perceptions, and adoption drivers as parts of an interconnected whole. Fragmented or siloed analyses fail to capture the complex interdependencies influencing agricultural sustainability in the Himalayan context.

An integrated analytical framework reveals critical insights pertinent to the contemporary scientific discourse on climate-resilient agriculture in mountainous regions. Our findings are consistent with emerging literature emphasizing that agricultural policy, community engagement, and enabling governance environments are co-determinants in the sustainable transformation of agri-food systems in ecologically sensitive zones like the Himalayas. This integrated perspective reveals several critical insights that are essential for understanding the dynamics of agricultural sustainability in the Himalayas.

5.1. Evolving Policy Landscapes in Response to Climate Change

Agricultural policy within the Indian western Himalayas is undergoing a paradigmatic transition, increasingly acknowledging climate change adaptation, livelihood resilience, and ecosystem sustainability. However, the extent and specificity of this integration are uneven across states and policy regimes. While food security, poverty reduction, and productivity enhancement remain foundational policy goals, there is a discernible policy shift towards organic agriculture, agroecology, watershed management, and diversified livelihoods—aligning with global climate-resilient development frameworks (e.g., IPCC AR6, UNFCCC adaptation agendas). The disproportionate focus of the policies undermines the integration of socially embedded sustainability dimensions, including demographic transitions, intergenerational equity, gender dynamics, and indigenous agroecological knowledge systems—factors that are well-established in the literature as critical to sustainable agriculture in mountainous and indigenous regions

While some farmers appreciate the attention to sustainability and diversification, many express skepticism regarding policy effectiveness, citing implementation gaps, lack of local contextualization, and insufficient participation in decision-making processes. As our study suggests, policies designed without meaningful community engagement often fail to resonate

with the local realities, leading to superficial compliance or outright rejection. In the Himalayas, where socio-economic, cultural, and ecological contexts are highly localized and diverse, the mismatch between centrally crafted policies and ground-level needs is particularly pronounced. Especially, smaller and marginalized groups — such as women, indigenous peoples, and landless farmers — often perceive these policies as top-down measures that fail to adequately address their localized needs and experiential knowledge.

5.2. Perception as a Mediator of Policy Efficacy

Agricultural policies act as the structural backbone of rural agricultural systems, defining the incentives, resources, and constraints within which farmers make decisions. Agricultural policies, however, do not function in isolation but are mediated through the interpretive frameworks of farming communities. The effectiveness of policy is not a linear function of design quality or scientific validity but is critically mediated by how rural actors perceive, interpret, and act upon these interventions. In the Himalayan region, these perceptions are shaped by a confluence of historical experiences with state interventions, local epistemologies, and cultural norms surrounding land, food, and environment.

Empirical evidence demonstrates that farmers' perceptions of policy relevance, credibility, and alignment with local agro-ecological and cultural contexts critically shape adoption behaviors. Communities often express skepticism due to implementation gaps, limited participatory engagement in policy formulation, and inadequate localization of interventions. Moreover, policy discontinuity—frequently a result of donor-driven agendas or political transitions—erodes institutional trust and impairs long-term behavioral change. The temporality of interventions, when misaligned with long-standing farming traditions and livelihood strategies, diminishes farmers' risk tolerance and receptivity to change, consistent with behavioural economics literature on policy perception and loss aversion. There is a growing demand for broader research underscoring the importance of participatory and co-designed approaches in agricultural innovation systems, especially in heterogeneous, culturally diverse landscapes like the Himalayas.

Farmers' perceptions are shaped not only by the material benefits or costs associated with a given policy but also by longevity of the programs. The short-term nature of many programs, driven by donor priorities or political cycles, undermines trust in institutions and continuity, thus impacting cultural values, risk tolerance, and experiences with past interventions. If farmers perceive policies as irrelevant, extractive, or poorly aligned with their traditional practices, adoption rates for recommended sustainable practices decline sharply. In such cases,

even technically sound policies may become ineffective, highlighting the centrality of perception in the policy impact pathway.

5.3. The architecture of adoption- Behavioural, Institutional & Governance Factors

Scientific studies on sustainable practices and its adoption underlines that farmers' decisions are governed by cognitive heuristics and affective perceptions rather than solely rational cost-benefit calculations. In the Himalayan context, loss aversion, ambiguity aversion, and status quo bias are prominent, amplified by climatic unpredictability and historical mistrust in state-led initiatives. Risk perception, cultural congruence, and psychological biases (e.g., uncertainty avoidance, social conformity) profoundly influence farmer decision-making. Agricultural practices are deeply embedded within socio-cultural and religious frameworks, necessitating innovations that resonate with existing values and belief systems.

Weak or absent institutional infrastructures—such as non-functional extension systems, low credit penetration, insecure land tenure, and the absence of mountain-specific agricultural research—constitute critical impediments to innovation diffusion. The institutional void in remote and ecologically fragile regions contributes to the systemic marginalization of smallholders, especially women, Indigenous communities, and landless tenants. Conversely, regions with locally embedded and context-aware institutions show significantly higher adoption rates of sustainable practices, aligning with findings from institutional economics and agri-environmental governance literature.

Governance quality—operationalized through metrics of participation, accountability, and transparency—is a decisive factor. Decentralized and inclusive governance arrangements have the potential to democratize knowledge flows and policy ownership, fostering grassroots innovation. However, institutional fragmentation, jurisdictional overlaps, and elite capture continue to undermine the equity and legitimacy of policy processes in several Himalayan states, reflecting global concerns on governance in resource-scarce, multi-level systems.

5.4. Towards a Systems-Based Policy Paradigm

The research emphasizes that sustainable agricultural transitions in the Himalayas cannot be decoupled from the social and cognitive realities of farming communities. Future policy trajectories must integrate behavioural economics, cultural congruence, and local knowledge systems into the core of agricultural planning. For instance, policy incentives and messaging that align with traditional ecological values and practices are far more likely to be adopted than those perceived as externally imposed or misaligned with local belief systems. Moreover, long-term programmatic continuity and institutional trust are critical to overcoming farmers' risk

aversion and skepticism, particularly in regions with a history of policy inconsistency. Thus, the outlook for sustainable agriculture in the Himalayas hinges on **three interrelated imperatives**: (1) designing policies that are **contextualized**, participatory, and grounded in socio-cultural realities; (2) fostering **trust and continuity** through long-term programmatic support, transparent governance, and local institutional strengthening; and (3) incorporating **behavioural and institutional insights** into extension, training, and communication strategies to align new practices with existing norms and values.

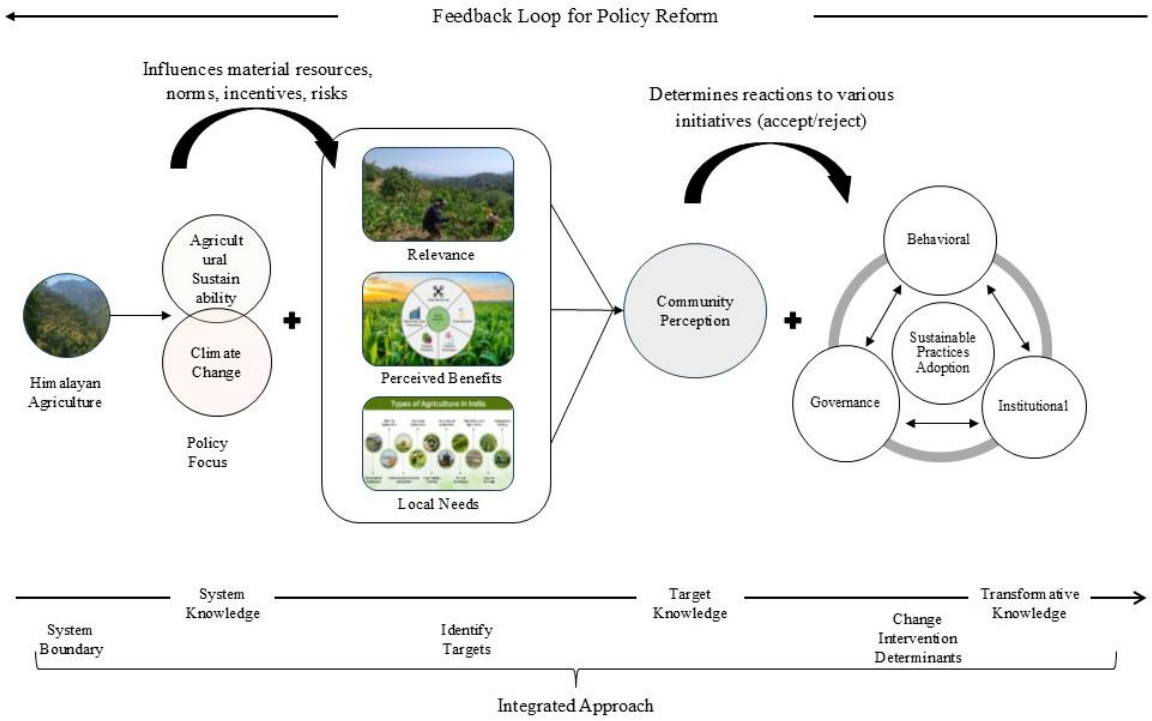

Figure 3: Feedback loop generated from the results of three articles, showing the need for an integrated approach.

By foregrounding the causal and cyclical interdependence of these factors, this study underscores the imperative of systems-thinking in agricultural sustainability discourse and aligns with global calls for integrated adaptation strategies in mountain ecosystems (as emphasized by the IPCC, FAO, and UNDP). The insights presented here advance the scientific understanding of how policy, perception, and institutional quality interact in shaping adaptive capacity and sustainable development in climate-sensitive agrarian regions. This integrated approach also emphasizes a shift from a linear model of technology transfer—where innovations are generated by experts and passed down to passive farmers—to a co-creation model of innovation. In this model, farmers are active agents of the feedback loop, who adapt,

reshape, and reinvent agricultural practices based on their own knowledge systems, needs, and aspirations. Feedback loops ensure that farmers' experiences and behaviours influence policy redesign for greater fit over time. Policies must, therefore, be flexible, participatory, and iterative, allowing for learning, adaptation, and contextual variation. Thus, a fragmented understanding that isolates policy, perception, or adoption factors would miss the systemic nature of the challenges facing Himalayan agriculture. Only by viewing these elements as dynamically interconnected can we hope to design and implement interventions that are not only technically effective but socially acceptable, economically viable, and environmentally sustainable.

Another major contribution of this research is towards the broader corpus of Himalayan agricultural science and climate adaptation studies by demonstrating that the interaction among policy frameworks, socio-cognitive perceptions, and institutional architectures constitutes a dynamic and co-evolutionary system. This research also contributes to a broader theoretical and empirical understanding of sustainability transitions in climate-sensitive ecosystems. It aligns with global calls for systems-based approaches to adaptation and resilience, such as those articulated in the IPCC Sixth Assessment Report and the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land). This study also contributes to a growing body of scholarship that argues for **transdisciplinary, community-led, and equity-focused agricultural governance** in ecologically fragile and culturally diverse regions. The Himalayan region, given its role in India's food, water, and climate security, offers a critical opportunity for piloting innovative governance models that integrate scientific, indigenous, and policy knowledge systems.

Finally, the urgency of climate change underscores the necessity of this integrated perspective. The Himalayas are warming faster than the global average, and their agricultural systems are already experiencing the consequences: altered growing seasons, increased pest and disease pressures, and heightened risk of extreme weather events (Rasul et al., 2021). Without robust, interconnected strategies that link policy innovation, community engagement, and systemic institutional reform, efforts to build climate resilience will remain piecemeal and insufficient.

In sum, the synthesis of this research points to a singular imperative: agricultural sustainability in the Himalayas demands not isolated technical fixes, but systemic transformations that align policy frameworks, community perceptions, and behavioural, institutional, and governance realities into a coherent, integrated strategy.

6. Conclusion:

This research underscores the critical importance of viewing sustainable agriculture in the Himalayas through a systems lens that integrates agricultural policy, community perception, and the enabling behavioural, institutional, and governance factors. The findings demonstrate that the transformation toward sustainable and climate-resilient agriculture is not merely a technical challenge but a deeply social and political one—intertwined with the everyday realities, perceptions, and aspirations of Himalayan farming communities. As climate change accelerates and socio-ecological vulnerabilities deepen, the limitations of fragmented, technocratic, and top-down policy interventions become increasingly evident.

For the Indian western Himalayan context, agricultural policies have undergone significant shifts in recent years. Initiatives such as the **National Mission on Sustainable Agriculture (NMSA)**, **Paramparagat Krishi Vikas Yojana (PKVY)**, and **Rashtriya Krishi Vikas Yojana (RKVY)** reflect a growing policy emphasis on organic agriculture, agroecological approaches, climate adaptation, and soil health. Several Indian Himalayan states, including Uttarakhand, and Himachal Pradesh, have explicitly promoted organic and traditional agricultural systems, aligning policy narratives with sustainability goals. However, despite this rhetorical alignment, these policies often fall short in their practical implementation—particularly in addressing the socio-economic and cultural dimensions of adoption.

Future research in Himalayan agriculture should prioritize a more holistic and inclusive approach that addresses the disconnect between policy goals and local realities. There is a critical need to integrate socio-cultural dimensions into agricultural studies, particularly examining how factors such as gender, caste, ethnicity, and customary land rights influence access to resources and participation in decision-making. Research should also focus on documenting and validating indigenous ecological knowledge and traditional agroecological practices, which are often overlooked despite their relevance to sustainable farming in the region's fragile environments. Understanding the perceptions and experiences of marginalized groups—especially women and smallholders—toward existing agricultural policies can offer valuable insights into issues of exclusion and inequity. Moreover, future studies should explore context-sensitive, decentralized policy models that reflect the unique agroecological conditions of the Himalayas, moving away from top-down approaches that are perceived as externally imposed and short-term. Strengthening the capacity of local extension services, investing in

mountain-specific agricultural research, and securing land tenure for smallholder farmers are essential preconditions for sustainable uptake.

Evaluating the long-term sustainability and environmental impact of productivity-focused interventions is equally essential to ensure that short-term yield gains do not compromise ecological resilience. Finally, research should identify effective mechanisms for community engagement in policy development, emphasizing participatory governance and co-creation of knowledge to enhance the legitimacy, acceptance, and impact of agricultural initiatives. These must be complemented by financial and infrastructural mechanisms that reduce the transaction costs of adopting climate-resilient practices. The research also calls for a rethinking of how authority, participation, and accountability are distributed in agricultural policymaking. Empowering local institutions, such as Panchayati Raj bodies, cooperatives, and women's self-help groups, to co-design and implement agricultural programs can enhance legitimacy, ownership, and equity. Equally important is the need to streamline overlapping mandates and institutional fragmentation that currently hinder the implementation of integrated and adaptive governance.

The future of agriculture in the Himalayas depends not only on scientific and technological innovation but on building adaptive, inclusive, and trusted institutions that can navigate complexity and foster sustainable, long-term transformation. Future policy design should move beyond top-down frameworks and actively engage with the socio-cultural and behavioral realities of Himalayan communities. Policies influence community perceptions not only through material incentives such as subsidies but also through symbolic mechanisms, including the alignment of interventions with traditional knowledge and practices. To foster meaningful change, policy design must account for local norms and values, leveraging both tangible and intangible tools to shift community behaviors. Importantly, community perceptions should not be treated as passive or static; rather, they are dynamic and deeply embedded in a feedback-rich policy cycle. Building trust, ensuring continuity, and establishing cultural legitimacy are essential for effective policy communication and long-term adoption. Moreover, behavioral, institutional, and governance reforms must be viewed as central—rather than peripheral—to policy success. These dimensions form the foundational enabling environment for sustainable agricultural practices and climate adaptation and must be integrated intentionally into both policy planning and implementation processes.

References:

Agricultural Policy Design and Implementation. (2008, February 29). *OECD*. https://www.oecd.org/en/publications/agricultural-policy-design-and-implementation_243786286663.html

Ayanlade, A., Radeny, M., & Morton, J. F. (2017). Comparing smallholder farmers' perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather and climate extremes*, 15, 24-33.

Baraj, B., Mishra, M., Sudarsan, D., Silva, R. M. da, & Santos, C. A. G. (2024). Climate change and resilience, adaptation, and sustainability of agriculture in India: A bibliometric review. *Heliyon,* 10(8), e29586. https://doi.org/10.1016/j.heliyon.2024.e29586

Bradshaw, B., Dolan, H., & Smit, B. (2004). Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. Climatic change, 67(1), 119-141.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental science & policy*, 12(4), 413-426.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. J*ournal of environmental management*, 114, 26-35.

Cariappa, A. A. G., & and Krishna, V. V. (n.d.). Carbon farming in India: Are the existing projects inclusive, additional, and permanent? *Climate Policy,* 0(0), 1–16. https://doi.org/10.1080/14693062.2024.2416497

Celio, E., Flint, C. G., Schoch, P., & Grêt-Regamey, A. (2014). Farmers' perception of their decision-making in relation to policy schemes: A comparison of case studies from Switzerland and the United States. *Land Use Policy*, 41, 163–171. https://doi.org/10.1016/j.landusepol.2014.04.005

Chakraborty, R., Daloz, A. S., Kumar, M., & Dimri, A. P. (2019). Does Awareness of Climate Change Lead to Worry? Exploring Community Perceptions Through Parallel Analysis in Rural

Himalaya. *Mountain Research and Development,* 39(2), R35–R54. https://doi.org/10.1659/MRD-JOURNAL-D-19-00012.1

Chakraborty, R., Rampini, C., & Sherpa, P. Y. (2023). Mountains of inequality: Encountering the politics of climate adaptation across the Himalaya. *Ecology and Society*, 28(4). https://doi.org/10.5751/ES-14399-280406

Chaudhary, P., & Bawa, K. S. (2011). Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology Letters*, 7(5), 767–770. https://doi.org/10.1098/rsbl.2011.0269

Crane, T. A., Roncoli, C., & Hoogenboom, G. (2011). Adaptation to climate change and climate variability: The importance of understanding agriculture as performance. *NJAS-Wageningen Journal of Life Sciences,* 57(3-4), 179-185.

Creemers, S., Van Passel, S., Vigani, M., & Vlahos, G. (2019). Relationship between farmers' perception of sustainability and future farming strategies: A commodity-level comparison. Agriculture and Food, 4(3), 613-642.

Das, S., & Mishra, A. J. (2023). Climate change and the Western Himalayan community: Exploring the local perspective through food choices. *Ambio*, 52(3), 534–545. https://doi.org/10.1007/s13280-022-01810-3

Datta, P., Behera, B., & Rahut, D. B. (2022b). Climate change and Indian agriculture: A systematic review of farmers' perception, adaptation, and transformation. *Environmental Challenges,* 8, 100543. https://doi.org/10.1016/j.envc.2022.100543

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American journal of agricultural economics*, 93(3), 829-846.

de Jalón, S. G., Iglesias, A., & Neumann, M. B. (2018). Responses of sub-Saharan smallholders to climate change: Strategies and drivers of adaptation. *Environmental science & policy*, 90, 38-45.

Director Land Records H.P. (n.d.). Annual Season and Crop Report for 2018-19. GoHP. https://himachal.gov.in/WriteReadData/l892s/13_l892s/1694856925.pdf

Dorward, P., Osbahr, H., Sutcliffe, C., & Mbeche, R. (2020). Supporting climate change adaptation using historical climate analysis. *Climate and Development*, 12(5), 469-480.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global environmental change*, 19(2), 248-255.

Food miles to assess sustainability: A revision—Van Passel—2013—Sustainable Development—Wiley Online Library. (n.d.). Retrieved 21 January 2025, from https://onlinelibrary.wiley.com/doi/full/10.1002/sd.485?casa_token=weu7-2t6PMsAAAAA%3AjZrQ33r0_2ICdt9OOoeMSl9ORrq6KGTuCSFV9F7pZK66N6QoK0Wbg4AuLTAiCtDS94cLfha8613UN9U

Gbetibouo, G. A. (2009). Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. IFPRI Discussion Paper 00849, no. February: 52. https://doi.org/10.1068/a312017.

Groß, M., & Stauffacher, M. (2014). Transdisciplinary Environmental Science: Problem-oriented Projects and Strategic Research Programs. *Interdisciplinary Science Reviews*, 39(4), 299–306. https://doi.org/10.1179/0308018814Z.00000000093

Guntukula, R. (2020). Assessing the impact of climate change on Indian agriculture: Evidence from major crop yields. *Journal of Public Affairs*, 20(1), e2040.

Hazrana, J., & Birthal, P. S. (2023). Cropping System Diversification for Higher Productivity and Resilience of Agriculture: Evidence from India. In *Managing Risk in Agriculture: A Development Perspective* (pp. 264-281). GB: CABI.

Huang, K., & Sim, N. (2021). Adaptation may reduce climate damage in agriculture by two thirds. *Journal of Agricultural Economics,* 72(1), 47-71.

Jha, S. K., Mishra, S., Sinha, B., Alatalo, J. M., & Pandey, R. (2017). Rural development program in tribal region: A protocol for adaptation and addressing climate change vulnerability. *Journal of Rural studies*, 51, 151-157.

Jha, C. K., & Gupta, V. (2021). Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India. *Environmental and Sustainability Indicators*, 10, 100112. https://doi.org/10.1016/j.indic.2021.100112

Jodha, N. S., Singh, N. P., & Bantilan, M. C. S. (2012). Enhancing Farmers' Adaptation to Climate Change in Arid and Semi-Arid Agriculture of India: Evidences from Indigenous practices: Developing International Public Goods from Development-oriented Projects. Working Paper Series no. 32.

Khan, N., Ray, R. L., Sargani, G. R., Ihtisham, M., Khayyam, M., & Ismail, S. (2021). Current Progress and Future Prospects of Agriculture Technology: Gateway to Sustainable Agriculture. *Sustainability*, 13(9), Article 9. https://doi.org/10.3390/su13094883

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science,* 7(S1), 25–43. https://doi.org/10.1007/s11625-011-0149-x

Macchi, M., Gurung ,Amanda Manandhar, & and Hoermann, B. (2015). Community perceptions and responses to climate variability and change in the Himalayas. *Climate and Development*, 7(5), 414–425. https://doi.org/10.1080/17565529.2014.966046

Negi, V. S., Thakur, S., Dhyani, R., Bhatt, I. D., & Rawal, R. S. (2021). Climate Change Observations of Indigenous Communities in the Indian Himalaya. *Weather, Climate, and Society,* 13(2), 245–257. https://doi.org/10.1175/WCAS-D-20-0077.1

Ojo, T. O., & Baiyegunhi, L. J. S. (2020). Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. *Land Use Policy,* 95, 103946.

Omerkhil, N., Kumar, P., Mallick, M., Meru, L. B., Chand, T., Rawat, P. S., & Pandey, R. (2020). Micro-level adaptation strategies by smallholders to adapt climate change in the least developed countries (LDCs): Insights from Afghanistan. *Ecological Indicators*, 118, 106781.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., ... & van Ypserle, J. P. (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change (p. 151). Ipcc.

Pandey, R., Aretano, R., Gupta, A. K., Meena, D., Kumar, B., & Alatalo, J. M. (2017). Agroecology as a climate change adaptation strategy for smallholders of Tehri-Garhwal in the Indian Himalayan region. *Small-scale forestry*, 16, 53-63.

Pandey, R., Kumar, P., Archie, K. M., Gupta, A. K., Joshi, P. K., Valente, D., & Petrosillo, I. (2018). Climate change adaptation in the western-Himalayas: Household level perspectives on impacts and barriers. *Ecological Indicators,* 84, 27–37. https://doi.org/10.1016/j.ecolind.2017.08.021

Pathak, H. (2022a). Impact, adaptation, and mitigation of climate change in Indian agriculture. *Environmental Monitoring and Assessment,* 195(1), 52. https://doi.org/10.1007/s10661-022-10537-3

Patnaik, U., & Das, P. K. (2017). Do development interventions confer adaptive capacity? Insights from rural India. *World Development,* 97, 298-312.

Pattanayak, A., Kumar, K. S. K., & Anneboina, L. R. (2021). Distributional impacts of climate change on agricultural total factor productivity in India. *Journal of the Asia Pacific Economy,* 26(2), 381–401. https://doi.org/10.1080/13547860.2021.1917094

Paudel, B., Acharya, B. S., Ghimire, R., Dahal, K. R., & Bista, P. (2014). Adapting agriculture to climate change and variability in Chitwan: Long-term trends and farmers' perceptions. *Agricultural Research*, 3, 165-174.

A Review on Climate Change and its Impact on Agriculture in India. (n.d.). Retrieved 18 March 2025, from https://www.researchgate.net/publication/348542910_A_Review_on_Climate_Change_and_its_Impact_on_Agriculture_in_India

Platt, R. V., Ogra, M., Kisak, N., Manral, U., & Badola, R. (2021). Climate change perceptions, data, and adaptation in the Garhwal Himalayas of India. *Climate and Development*, 13(2), 95–106. https://doi.org/10.1080/17565529.2020.1724069

Praveen, B., & Sharma, P. (2020). Climate change and its impacts on Indian agriculture: An econometric analysis. *Journal of Public Affairs*, 20(1), e1972.

Schwenck, C., Pfendtner-Heise, J., & von Wehrden, H. (2025). Unveiling local knowledge: A case study on inner development and sustainable transformation in rural areas. Discover Sustainability, 6(1), 225. https://doi.org/10.1007/s43621-025-00999-z

Singh, S. (2020). Farmers' perception of climate change and adaptation decisions: A micro-level evidence from Bundelkhand Region, India. *Ecological Indicators*, 116, 106475.

The Impact of Climate Change on Agricultural Practices in India by Pavittarbir Saggu: SSRN. (n.d.). Retrieved 18 March 2025, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4880148&utm_source=chatgpt.com

Tienhaara, A., Niemi, J., Vainio, A., & Pouta, E. (2024). The future of agriculture and agricultural policy: Perceptions of non-farmers and farmers: Future images. *Agricultural and Food Science*. https://doi.org/10.23986/afsci.137790

Tiwari, K. R., Awasthi, K. D., Balla, M. K., & Sitaula, B. K. (n.d.). Local people's perception on Climate Change, its impact and adaptation practices in Himalaya to Terai regions of Nepal.

Van Passel, S. (2013). Food miles to assess sustainability: A revision. *Sustainable Development*, 21(1), 1–17. https://doi.org/10.1002/sd.485

Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What Is Sustainable Agriculture? A Systematic Review. *Sustainability*, 7(6), Article 6. https://doi.org/10.3390/su7067833

Venkateswarlu, B., Shankar, A. K., & Gogoi, A. K. (2011). Climate change adaptation and mitigation in Indian agriculture. Climate Change Adaptation Strategies in Agriculture and Allied Sectors. *Scientific Publishers India*, 85-95.

Vijhani, A., Sinha, V. S. P., Vishwakarma, C. A., Singh, P., Pandey, A., & Govindan, M. (2023). Study of stakeholders' perceptions of climate change and its impact on mountain communities in central Himalaya, India. *Environmental Development*, 46, 100824. https://doi.org/10.1016/j.envdev.2023.100824