

Climate change adaptation of smallholder farmers in South Asia: Potential strategies for agricultural transformation

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Abstract

Purpose – Climate change significantly increases the vulnerability of agriculture in South Asia. This has led to decreased agricultural yields, resulting in lower incomes, heightened food insecurity and increased poverty levels. Thus, the purpose of this study is to explore the current climate change adaptation measures used by hazard-prone farming communities in South Asia.

Design/methodology/approach – The most relevant documents from the Web of Science and Scopus databases were retrieved using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Findings – Across the reviewed literature, South Asian smallholder farmers are reported to face recurrent climate hazards – particularly floods, drought/heat stress, riverbank erosion and pest/disease outbreaks – that



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shape the adaptation priorities described in empirical studies. The reported adaptation responses cluster into six domains: livelihood diversification, agricultural diversification, risk management, land and crop management, farm and income management and conservation practices. Overall, the reviewed evidence most frequently reports agronomic and risk-oriented adjustments, whereas conservation-oriented and ecosystem-based practices are less frequently reported, often in contexts constrained by credit, information, infrastructure and institutional support.

Research limitations/implications – Future research should concentrate on a specific South Asian region using primary data. In addition, adaptation strategies may vary because of demographic characteristics. This study could not highlight the influence of demographic characteristics on adaptation strategies because of its specific focus. Future studies should consider the influence of demographic attributes such as land size, household size, gender, education level and membership in farmer associations, training in agricultural production, access to extension services and the use of improved varieties of adaptation strategies by South Asian farmers. Furthermore, future studies should focus on the negative effects of technology-assisted adaptation techniques, traditional and local knowledge, livelihood variety, government and organization aid, food and water security, social and recreational activities and physical infrastructure.

Originality/value – Prior systematic reviews of adaptation strategies among South Asian farmers have lacked transparency regarding their review processes. This has made it challenging for subsequent researchers to replicate studies, verify interpretations or evaluate their thoroughness. This study aims to address this gap by clearly outlining our review methodology.

Keywords Climate change mitigation, Adaptation, Agricultural vulnerability, Resilience, Adaptive transformation, Climate-smart agriculture

Paper type Research paper

1. Introduction

South Asia, the world's most densely populated region, encompasses eight countries: Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka. Although the agricultural industry in South Asia is still expanding, it is becoming less significant overall in terms of its contribution to gross domestic product and labor force participation (Bhatta *et al.*, 2017; Aryal *et al.*, 2020a, 2020b). Farm families are expanding their sources of revenue beyond agriculture as urbanization continues to increase. According to projections, by 2050, nearly half of the Indo-Gangetic Plains, the primary food source for South Asia, may be too hot for agricultural output (Aryal *et al.*, 2021). Climate change exacerbates food insecurity and poverty in South Asian nations by affecting farm production and the availability of natural resources (Sahoo *et al.*, 2025). This will harm the lives of millions of people in the area. According to projections, the cost of food will increase by 1.5 times for livestock goods and by 2.5 times for main food crops between 2000 and 2050 because of climate change (Adeagbo *et al.*, 2021). Therefore, South Asia could lose an equivalent of 1.8% of its yearly gross domestic product by 2050 and 8.8% by 2100 if no adaptation measures are taken (Ahmed and Suphachalasai, 2014).

To increase agricultural viability and develop policies that protect South Asia's most vulnerable farmers from the impacts of climate change (Aryal *et al.*, 2020a, 2020b), a deeper understanding of climate change effects and adaptation strategies is crucial. This review draws on foundational frameworks that conceptualize adaptation as determined by factors such as vulnerability, exposure and adaptive capacity (Smit and Wandel, 2006), as well as by institutional and social processes that mediate adaptation (Adger, 2003). To situate our analyses within broader climate adaptation theories while also supporting smallholder strategies within those theories, we also engage with resilience thinking to add considerations. In addition, we engage with resilience thinking (Folke, 2016) and transformational adaptation (Kates *et al.*, 2012) to interpret how adaptation strategies not only buffer climate risk but also potentially contribute to long-term system shifts in

smallholder agriculture. This aligns with the notion of adaptive transformation, which refers to deliberate, systemic changes that enhance adaptive capacity and promote more resilient, sustainable agricultural systems in response to climate stressors.

Climate change has been shown to negatively affect the yields of most crops (Quiroga *et al.*, 2020). Long-term climate change also increases the frequency of extreme weather events (Kabir *et al.*, 2017; Singh *et al.*, 2021a), affects the timing of pest and disease outbreaks (Brown *et al.*, 2021), reduces water-use efficiency and fertilizer use and increases yield variability (Below *et al.*, 2012). These consequences are anticipated to exacerbate agricultural production problems and imperil worldwide efforts to meet three of the United Nations' Sustainable Development Goals (SDGs): no poverty (SDG 1), zero hunger (SDG 2) and climate action (SDG 13) (UN, 2018). Climate change is predicted to intensify in South Asia, where temperatures are expected to rise dramatically across the continent's interior. Between 1990 and 2005, rainfall in northern and central South Asia increased substantially, whereas precipitation in southern South Asia decreased (Aryal *et al.*, 2020a, 2020b).

Recent region-specific studies, including those by Lamichhane *et al.* (2022), have provided us with more insight into this phenomenon, further exploring how South Asian smallholder farmers adapt through location-specific combinations of crop diversification, irrigation management and livelihood reorganization to climate change – illustrating both the urgency and contextual diversity of adaptation pathways across the region. The IPCC (2022) noted regional variations in the effects of climate change on food production across South Asia. With climate change now widely acknowledged, adaptation research has become a focus (Naz *et al.*, 2018). Numerous studies have investigated the factors that affect agricultural adaptation to climate change (Lungarska and Chakir, 2018; Chen *et al.*, 2018; Suresh *et al.*, 2021; Ali *et al.*, 2025). The impacts of climate change have been felt most acutely by developing countries, where agriculture plays a vital role. Climate change has increased both the frequency and intensity of extreme climate events in South Asian nations (Bhatta *et al.*, 2017). However, they lack an understanding of adaptation strategies (Khan *et al.*, 2021). Despite many studies on farmers' adaptation to climate change, comprehensive evaluations of farmers' perspectives in South Asia are lacking. This study aims to fill this knowledge gap by identifying and defining the patterns of climate change adaptation among South Asian farmers.

The objective of this research is to examine the literature on how South Asian farmers adapt to climate change. The main research question of this systematic review is as follows:

RQ1. How are South Asian farmers adapting to the impacts of climate change?

This study focuses on human adaptation strategies and specifically targets South Asian farmers, who are the most vulnerable to climate change because of their dependence on natural stability for socioeconomic activities (Bhatta *et al.*, 2017). Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, the Maldives and Sri Lanka are included in this research study. However, the review focuses on smallholder farmers and farm households; accordingly, studies were retained when aquaculture or other allied production activities formed part of a smallholder household's agricultural livelihood system, whereas large-scale commercial fisheries or stand-alone industrial aquaculture operations were outside the scope.

This review contributes in three ways. First, it provides an open, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-guided synthesis explicitly designed for South Asian smallholder farmers, advancing over broader regional analyses, such as those presented by Shaffril *et al.* (2018). Second, it develops a sixfold typology that more clearly differentiates key adaptation domains from the general economic-technological groupings used by Aryal *et al.* (2020a, 2020b). Third, it highlights less explored areas, such

as conservation practices and farm income strategies, to help identify gaps that require targeted policy and research.

2. Materials and methods

2.1 Research design

An extensive systematic review was conducted, including the creation of a protocol and the search of the literature for relevant data, using PRISMA as the framework for gathering this information (Page *et al.*, 2021). Sierra-Correa and Cantera Kintz (2015) argued that applying the PRISMA protocol yields three distinct benefits. First, it helps researchers formulate concise research queries for conducting systematic analyses. Second, it establishes explicit inclusion/exclusion criteria for studies relevant to systematic analyses. Third, it seeks to investigate existing scientific literature within a predetermined timeline constraint.

2.2 Eligibility criteria

The present study focuses on South Asian nations that have been subject to scrutiny in the literature. Only original research articles published between January 2000 and August 2025 in English were eligible. Review articles, editorials, conference proceedings, gray literature and review journals were excluded to maintain analytical focus and data quality. Eligible studies had to focus on climate change adaptation in smallholder agricultural livelihood systems in South Asia, including crop, livestock, poultry and aquaculture activities where these formed part of the farm household economy.

2.3 Search strategy

The primary search string was constructed after several commonly used databases were reviewed in accordance with each database's specific requirements. We used terms such as climate change adaptation, farming, smallholder farmers, adaptation strategies, agricultural adaptation and natural hazards to gather literature for the document selection process. We used well-established databases, including Scopus and Web of Science, to gather the literature. The search and selection criteria used in this investigation are outlined in Table 1. The full database-specific search strings, fields, run dates and retrieval counts are provided in Supplementary Table S1.

2.4 Document selection

2.4.1 Document selection process. Figure 1 summarizes the screening and selection process following PRISMA 2020 (Page *et al.*, 2021). Database searching identified 1,788 records (Web of Science $n = 1,239$; Scopus $n = 549$), and 17 additional records were identified through reference checking (total records before deduplication = 1,805) (Supplementary Table S2). We removed 1,135 duplicates, leaving 670 unique records for title and abstract screening. During screening, 313 records were excluded as out of scope/off-topic. We then sought full texts for the remaining 357 reports, of which 126 reports could not be retrieved. The remaining 231 full-text reports were assessed for eligibility; 129 were excluded because they did not focus on South Asian countries. This yielded a final sample of 102 studies included in the qualitative synthesis. To balance recall and screening feasibility, we used a broader regional query in Web of Science and supplemented it with regional plus country-specific searches in Scopus, together with backward reference checking.

2.4.2 Selected literature. The PRISMA process yielded 102 studies for review (Supplementary Table S3), covering all eight South Asian countries. Bangladesh contributed the largest number of studies ($n = 29$), followed by Pakistan ($n = 22$), India ($n = 18$), Sri

Table 1. Research protocol

Items	Details
Databases	Web of Science and Scopus
Publication	Peer-reviewed original journal article
Language	English
Time duration	From January 2000 to August 2025
Search terms	South Asia, climate change, adaptation, farming, adaptation strategy, agricultural adaptation, Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka
Search areas	Title, abstract and keywords
Inclusion criteria	Papers focused on farmers' adaptation to changing climate
Exclusion criteria	Non-English article, duplication, no access to full text, out of fields, no focus on South Asia
Regional focus	South Asian countries

Source(s): Authors' own creation

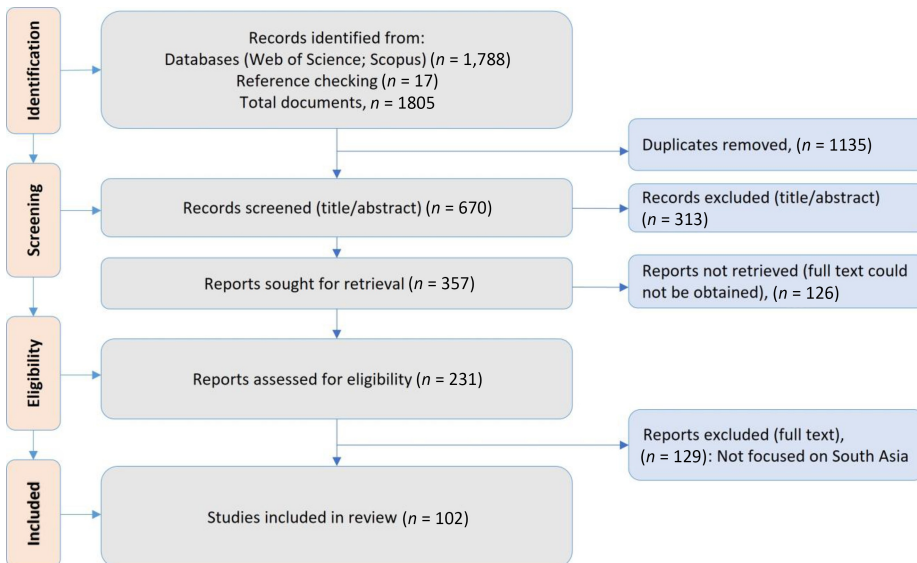


Figure 1. PRISMA 2020 flow diagram of document selection

Source: Authors' own creation

Lanka ($n = 9$), Afghanistan and Nepal ($n = 8$ each), Bhutan ($n = 3$) and the Maldives ($n = 1$); two studies had a broader South Asia focus. Publications increased notably during 2022–2024, indicating growing scholarly attention to climate change adaptation among smallholder farmers in the region.

2.5 Data extraction

We coded adaptation actions at the article level via the predefined six-domain coding manual (definitions, inclusion/exclusion rules and boundary cases). In the coding process,

“smallholder farming systems” were interpreted to include mixed household production systems in which crop cultivation could be combined with livestock, poultry or aquaculture activities. Each study could contribute to multiple domains but was counted only once per domain; accordingly, frequencies reflect reported prevalence across studies rather than practice instances or effectiveness. Two reviewers independently coded all 102 studies, resolved disagreements through discussion and referred unresolved cases to a third reviewer. Cohen’s κ was not calculated; instead, dual-coding coverage and adjudication procedures are reported in Supplementary Table S4. We also applied a conservative transformational-adaptation flag when studies explicitly described durable system reconfiguration, such as livelihood reorientation, shifts to agroforestry or perennial systems, long-term water-control investments or collective institutional reorganization.

2.6 Quality appraisal and risk of bias

Given the methodological heterogeneity of the included corpus, we conducted a structured quality appraisal to avoid treating all evidence as methodologically equivalent. We applied the Mixed Methods Appraisal Tool using design-appropriate criteria for qualitative, quantitative descriptive, quantitative nonrandomized and mixed-methods studies (Supplementary Table S5). Two reviewers independently appraised each study, with discrepancies resolved through discussion and, when necessary, adjudication by a third reviewer. Appraisal outcomes were not used to exclude studies *a priori*; rather, they informed confidence calibration in the narrative synthesis. Accordingly, frequency counts are interpreted as the prevalence of reported practices rather than evidence of effectiveness, domains in which inferences are disproportionately supported by lower-confidence studies are explicitly flagged, and stratified/sensitivity summaries contrast patterns observed in higher-confidence studies with those in the full corpus.

3. Results

3.1 Farmers’ adaptation strategies in South Asia

This study highlighted six important domains for adaptation to climate change, namely, livelihood diversification, agricultural diversification, risk management, land and crop management, farm and income management and conservation practices. Each of these domains encompasses a range of strategies used by smallholder farmers across South Asia (Table 2).

Among the 102 studies, most were from India ($n = 18$), Bangladesh ($n = 29$), Nepal ($n = 8$) or Pakistan ($n = 22$). Land and crop management was the most reported strategy (73 studies), followed by risk management (51), agricultural diversification (45), livelihood diversification (41), farm and income management (35) and conservation practices (22). Multiple strategies are frequently combined. These adaptation categories parallel those of the Food and Agriculture Organization (FAO) of the United Nations (FAO) (FAO, 2017) and Lipper *et al.*’s (2014) principles of climate-smart agriculture (CSA) and are further refined for smallholder farmers in South Asia.

Figure 2 illustrates the distribution of adaptation strategies across the 102 reviewed studies. Land and crop management emerged as the top adaptation strategy ($n = 73$), followed by risk management (51), agricultural diversification (45), livelihood diversification (41), farm and income management (35) and conservation practices (22). This pattern suggests that the reviewed studies most frequently report agronomic and risk-oriented measures, with conservation-oriented practices remaining relatively underrepresented in the empirical literature.

Table 2. Key areas of adaptation strategies

Key areas	Key strategies	Sources
Livelihood diversification	Inter-cultivation operations	Bhatta <i>et al.</i> (2017)
	Access to finance	Menike and Arachchi (2016), Kuchimanchi <i>et al.</i> (2021) and Kafle <i>et al.</i> (2022)
	Agro-technical support	Angom <i>et al.</i> (2021), Ali <i>et al.</i> (2021) and Jatav (2024)
Agricultural diversification	Agricultural mechanization	Hussain <i>et al.</i> (2018), Jha and Gupta (2021), Haque <i>et al.</i> (2023) and Sahoo <i>et al.</i> (2025)
	Off-farm income generation	Kuchimanchi <i>et al.</i> (2021), Shahzad and Abdulai (2020), Ali <i>et al.</i> (2021), Sargani <i>et al.</i> (2023) and Irshad Ahmad <i>et al.</i> (2024)
	Crop rotation	Aliyar <i>et al.</i> (2022), Sam <i>et al.</i> (2020) and Angom <i>et al.</i> (2021)
	Cultivating a short-term crop	Naz <i>et al.</i> (2018), Singh (2020) and Anik <i>et al.</i> (2021)
	Low irrigation required varieties	Jawid and Khadjavi (2019), Kadiyala <i>et al.</i> (2021) and Jha and Gupta (2021)
	Sufficient irrigation	Hossain <i>et al.</i> (2022), Aryal <i>et al.</i> (2020a, 2020b) and Baruah <i>et al.</i> (2021)
	Rainwater harvesting	Muench <i>et al.</i> (2021) and Paudel <i>et al.</i> (2022)
Risk management	Farmyard manure application	Omerkhil <i>et al.</i> (2020a, 2020b), Alauddin and Sarker (2014) and Iqbal and Aziz (2022)
	Insurance	Bahinipati and Venkatachalam (2015) and Ali <i>et al.</i> (2021)
	Allocation of resources	Tripathi and Mishra (2017) and Dagdeviren <i>et al.</i> (2021)
	Government subsidy	Chalise and Naranpanawa (2016)
Land and crop management	Agricultural technology transfer	Azhoni and Goyal (2018), Singh <i>et al.</i> (2021a, 2021b) and Kuchimanchi <i>et al.</i> (2021)
	Support from agricultural extension agent	Khanal <i>et al.</i> (2018), Khanal and Wilson (2019) and Shahzad and Abdulai (2020)
	No tillage	Abdur Rashid Sarker <i>et al.</i> (2013) and Hossain <i>et al.</i> (2016)
	Low tillage	Islam <i>et al.</i> (2021a) and Rahman <i>et al.</i> (2021)
	Adjustment of varieties	Dubey <i>et al.</i> (2017) and Swami and Parthasarathy (2020)
	Adjustment of planting/harvesting time	Khanal <i>et al.</i> (2021)
	Adjustment of planting methods	Abid <i>et al.</i> (2016) and Khanal <i>et al.</i> (2018)
	Cropping time adjustment	Naz <i>et al.</i> (2018) and Suresh <i>et al.</i> (2021)
Suitable crop variety selection	Abid <i>et al.</i> (2019), Sam <i>et al.</i> (2020), Kuchimanchi <i>et al.</i> (2021) and Bhuyan <i>et al.</i> (2024)	
		Abid <i>et al.</i> (2019), Jha and Gupta (2021), Singh <i>et al.</i> (2021a, 2021b), Aqib <i>et al.</i> (2024) and Bhuyan <i>et al.</i> (2024)

(continued)

Table 2. Continued

Key areas	Key strategies	Sources
Farm and income management	Drought-tolerant varieties	Ali and Erenstein (2017) and Aftab et al. (2021)
	Flood-tolerant varieties	Qazlbash et al. (2021) and Ali et al. (2021)
	Pest tolerant varieties	Khan et al. (2021) and Mahmood et al. (2021)
	Irrigation	Kabir et al. (2017) , Khan et al. (2020) and Ahmed et al. (2021)
	Reserving water	Ahmed and Diana (2015) and Rana and Moniruzzaman (2021)
	Using rainwater	Bremer et al. (2019) and Islam et al. (2021b)
	Using pesticides and growth hormone	Bhatta et al. (2017) and Hasan and Kumar (2019)
	IPM (integrated pest management)	Islam and Nursey-Bray (2017)
	Agroforestry	Abdur Rashid Sarker et al. (2013) , Rana and Moniruzzaman (2021) and Baruah et al. (2021)
	Cover cropping	Hossain et al. (2016) and Ahmed et al. (2021)
Conservation practices	Store water in a place on the crop field	Alauddin and Sarker (2014)
	Cover the ridge of the crop field after seed sowing	Jawid and Khadjavi (2019)
	Mulching	Hossain et al. (2016) , Khanal and Wilson (2019) and Mahmood et al. (2021)
	Hedging surrounding the crop field	Daigneault et al. (2016)
	Planting medicinal	Ngwenya et al. (2017) and Rana and Moniruzzaman (2021)
	planting around the crop field	

Source(s): Authors' own creation

We linked dominant hazards to the six adaptation domains to show hazard–strategy relationships (Supplementary Table S6). Flood studies most often pair land/crop management with risk management; drought/heat studies emphasize water-saving irrigation, water storage/harvesting and tolerant varieties; riverbank erosion studies frequently combine livelihood and farm income diversification with crop/calendar adjustments; salinity studies highlight salt-tolerant varieties and crop switching plus freshwater management; and pest/disease studies most often report IPM, resistant varieties and crop rotation. Because hazard reporting is uneven, these are evidence-map linkages (reported pairings), not adoption rates or effectiveness.

Most reported adaptations are incremental (calendar, variety, input and routine irrigation adjustments). Several studies indicate greater structural change consistent with agricultural transformation – livelihood reorientation beyond farming, shifts toward diversified/perennial systems (e.g. agroforestry) and longer-horizon water-security investments (e.g. irrigation/storage) when finance and institutional support are available (Supplementary Table S7).

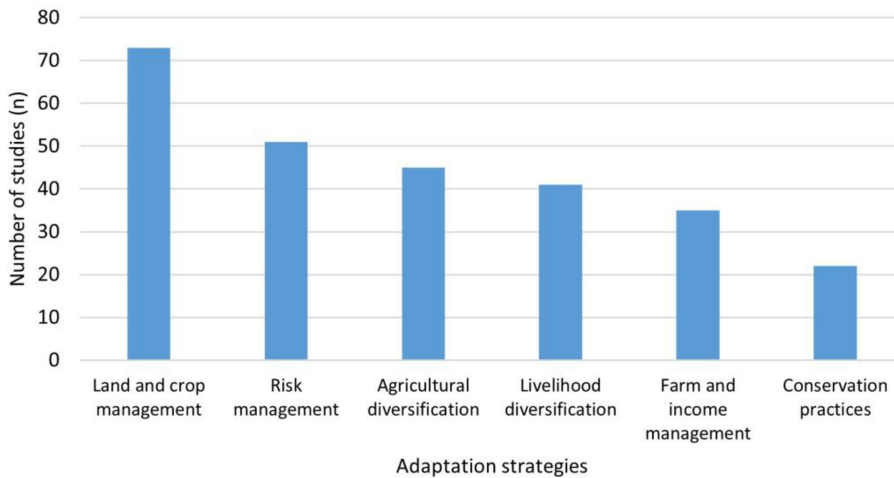


Figure 2. Distribution of adaptation strategies reported in the reviewed studies

3.2 Common barriers to adaptation

South Asian farmers must adapt to climate change but face many obstacles in doing so. These obstacles can be divided into six groups: knowledge and awareness; access to technology/inputs/infrastructure/financial resources/policy support; and social and cultural factors (Table 3).

Key barriers include water scarcity (48 studies), limited credit (45), weak institutional support (38) and climate uncertainty (33), as well as land tenure insecurity, price fluctuations and limited adaptive knowledge among women and other marginalized groups.

4. Discussion

4.1 Common adaptation strategies of South Asian farmers

4.1.1 Livelihood diversification. The diversification of income sources also means that farm families will have stable incomes, as younger family members are involved in farming activities in other regions (Baruah *et al.*, 2021). Income diversification may also help ensure stable finances for such households. Families who live on agricultural land can share their successful experiences on the land. Research has also revealed that the concept of livelihood diversification can serve as an adaptive mechanism, depending on the time period (Jawid and Khadjavi, 2019; Chowdhury *et al.*, 2022). During periods of suffering, communities often abandon their agricultural resources as sources of revenue that favor food resources instead. The use of diversified livelihoods to offset the negative impacts of climate variability (such as flooding, drought and animal illness) is an adaptive strategy (Kuchimanchi *et al.*, 2021); research indicates that farmers use a variety of approaches when diversifying their livelihoods to adjust to it: adjusting crop variety (Abid *et al.*, 2019), water and fertilizer management (Aryal *et al.*, 2020b), access to agricultural loans (Faisal *et al.*, 2021), agrotechnical support (Shaffril *et al.*, 2018), farming tools and nonagricultural output (Dagdeviren *et al.*, 2021; Suresh *et al.*, 2021).

4.1.2 Agricultural diversification. The diversification of agriculture has helped develop more ecologically and economically sustainable practices. Diversity enhances resilience by

mitigating outbreaks and reducing transmission by slowing pest propagation and transmission rates, which are expected to increase under future climate conditions (Baruah *et al.*, 2021). Farm diversification can be an effective solution that enhances food security and builds resilience against environmental shocks and climate change. Diversification is an effective strategy for increasing food security. Sustainable agriculture refers to expanding traditional crop and livestock activities while adhering to environmental sustainability principles (Singh *et al.*, 2019). Diversification can also help conserve natural resources while mitigating adverse environmental impacts. Agricultural diversification involves adding activities or products to already established farms or animal enterprises.

4.1.3 Risk management. Risk management systems can successfully stabilize farm output and income, reduce catastrophic occurrences and overcome adoption hurdles (Singh *et al.*, 2019). Climate adaptation strategies such as indicator-based insurance rely on weather indicators correlated with agricultural losses, such as rainfall, yield or vegetation; these strategies help farmers avoid moral hazard issues, such as adverse selection or excessive loss verification costs, protect assets against adverse climate hazard impacts that impact financial availability and encourage improved agricultural technology (Naz *et al.*, 2018).

4.1.4 Land and crop management. Land management plans are innovative ideas and activities designed to promote or preserve soil health. One such practice, minimum/zero tillage, encourages reduced disturbance of the soil structure to minimize adverse effects, such as fertility restoration, erosion prevention, increased water-holding capacity and increased carbon storage, all of which contribute to overall improvements in the structure and fertility of agricultural soils (Mahmood *et al.*, 2021). However, zero tillage is associated with significant tradeoffs that can significantly reduce yields when it is used exclusively.

4.1.5 Farm and income management. The rapidly changing climatic conditions in South Asia have created several unpredictable obstacles that negatively affect agricultural productivity and economic viability. The implementation of effective farm management and income management is the key to resolving these problems. Research has examined the effects of climate change on agricultural yields and profits among smallholder farmers in developing countries (Kabir *et al.*, 2017; Robert *et al.*, 2018; Abeysekera *et al.*, 2023), showing that the nutritional aspects of inorganic fertilizers and manures are crucial to the texture and fertility of the soil (Singh *et al.*, 2021b) and have a greater impact on yield when used simultaneously (or independently).

4.1.6 Conservation practices. Farmers around the world face an ongoing struggle to meet population growth requirements, protect natural resources, adapt to climate change and develop sustainability strategies that preserve these resources (Singh *et al.*, 2019). Crop rotation is an invaluable conservation technique used by conservationists to increase soil health, decrease erosion and retain water (Khanal and Wilson, 2019). Cover crops constitute another powerful conservation technique that farmers can use to reduce soil erosion while also covering disturbances during planting and harvesting. Water and nutrient management are vital for promoting sustainable agriculture while simultaneously protecting the environment (Robert *et al.*, 2018).

4.2 Challenges in adaptation practices

4.2.1 Policy-related support. Farmers may struggle to adjust to climate change without sufficient institutional frameworks and regulations (Bhatta *et al.*, 2017). For example, without policies prioritizing climate-resilient agricultural investments or providing incentives to do so (such as policies that prioritize this approach or provide incentives), investment may decrease, as accessing essential supplies and markets for smaller farms becomes more difficult (laws that favor large-scale over small-scale farming can make this

Table 3. Common challenges of the CCA for South Asian farmers

Major challenges dimension	Specific causes	Sources
Poor policy and governance	Inadequate policies	Islam and Nursey-Bray (2017), Rahman <i>et al.</i> (2021) and Muench <i>et al.</i> (2021)
	Poor institutional frameworks	Kabir <i>et al.</i> (2017), Sam <i>et al.</i> (2020) and Angom <i>et al.</i> (2021)
	Lack of good governance	Singh <i>et al.</i> (2019), Bremer <i>et al.</i> (2019) and Omerkhil <i>et al.</i> (2020b)
Financial resources	Lack of financial capital	Rahman <i>et al.</i> (2021) and Muench <i>et al.</i> (2021)
	Low access to institutional finance	Truelove <i>et al.</i> (2015)
	High-interest rate of local lenders	Singh <i>et al.</i> (2019) and Sam <i>et al.</i> (2020)
Information	Inability to access expensive agricultural inputs	Kabir <i>et al.</i> (2017), Rana and Moniruzzaman (2021) and Aftab <i>et al.</i> (2021)
	Lack of access to information and knowledge	Abid <i>et al.</i> (2019) and Suresh <i>et al.</i> (2021)
	Poor understanding of adaptation strategies	Bhatta <i>et al.</i> (2017) and Abid <i>et al.</i> (2019)
Technology and inputs access	Lack of access to technology	Fahad and Wang (2018) and Jha and Gupta (2021)
	Low access to inputs like seeds, fertilizer, pesticides and intercultural operation tools	Bahinipati and Venkatachalam (2015) and Omerkhil <i>et al.</i> (2020a)
	Low access to agricultural mechanization	Bhatta <i>et al.</i> (2017), Hussain <i>et al.</i> (2018) and Kuchimanchi <i>et al.</i> (2021)
Infrastructure	Inadequate infrastructure (road and communication network)	Omerkhil <i>et al.</i> (2020a) and Khan <i>et al.</i> (2020)
	Low access to market	Fahad and Wang (2018) and Abid <i>et al.</i> (2019)
Sociocultural aspect	Gender inequalities	Naz <i>et al.</i> (2018) and Aryal <i>et al.</i> (2020a, 2020b)
	Poor attitude toward new technology	Shahzad and Abdulai (2020) and Baruah <i>et al.</i> (2021)
	Negative social norms	Hussain <i>et al.</i> (2018), Kuchimanchi <i>et al.</i> (2021) and Rahman <i>et al.</i> (2021)

Source(s): Authors' own creation

more challenging still). In contrast, a lack of cooperation across organizations or sectors may reduce the effectiveness of adaptation strategies (Robert *et al.*, 2018).

4.2.2 Knowledge and understanding of climate change effects. A significant obstacle to adaptation is farmers' limited awareness of climate risks and responses: many in South Asia (and related industries) lack an understanding of climate impacts on livestock, yields and livelihoods and of practical options such as drought-resistant varieties, adjusted planting calendars and water-efficient practices (Li, 2023). Information gaps threaten sound decision-making, whereas issues such as internet access, literacy levels and language barriers limit access to relevant guidance.

4.2.3 Technological and resource constraints faced by farmers. South Asian farmers face significant challenges, as they lack access to advanced technologies and resources to help them respond to climate change. Jellason *et al.* (2021) suggested that farmers could increase agricultural yields by adopting modern seed varieties, water management practices

and other technical advances. However, having access to these essential instruments is a challenge for many South Asian farmers. Farmers may be unable to access markets and finance because of a lack of information. As a result, their adaptation to agricultural practices is challenging.

4.2.4 Poor infrastructure. Farmers across South Asia suffer from inadequate infrastructure in markets, transportation and irrigation systems (Islam and Nursey-Bray, 2017), restricting their access to markets and affecting agricultural practices. Poor road networks create access issues, making it harder than before to find fair prices for their produce. Natural disasters damage markets and infrastructure essential to agricultural production, leaving farmers struggling to access finance, agricultural inputs and markets. In these uncertain circumstances, they might find it challenging to determine the appropriate strategies (Fischer, 2021).

4.2.5 Lack of financial resources. Financial restrictions are hindering an increasing number of small farms from adopting climate-resilient practices and technologies or adapting to climate change impacts, with the costs of installing irrigation infrastructure or growing drought-tolerant crops financially straining some farmers. People living in poverty typically do not have access to financial institutions that could help them invest in improving climate resilience, thereby hindering adaptation efforts and heightening vulnerability to its effects.

4.2.6 Barriers to social and cultural practices. Cultural and social factors, including gender inequality in decision-making and resource access, constrain South Asian adaptation. According to Feola *et al.* (2015), cultural beliefs or customs could prevent farmers from adopting new technologies or methods. To alleviate these difficulties, more access must be gained; climate-resilient projects must be invested in; supportive policies must be created, cultural or social restrictions must be removed; and weather forecasting services must be prioritized by governments to improve farmers' access to information, markets and services (Aryal *et al.*, 2021).

Overall, barriers such as limited credit and high input costs, weak extension/institutional support, infrastructure gaps and gendered constraints on information and resources keep adaptation largely incremental and agronomy-focused. These same constraints likely explain why ecosystem-based and conservation practices are less frequently reported, as they typically require longer time horizons, secure land access and sustained advisory support.

4.3 Implications for agricultural transformation

This research's adaptation pathways draw upon CSA while adding specific South Asian elements. While CSA emphasizes productivity, resilience, emission reduction and farmer information systems, our six domains of adaptation strategies – livelihood diversification, agricultural diversification, risk management, land and crop management, farm and income management and conservation practices – show how these strategies can be operationalized for smallholder farmers. Linking all six previous strategy domains also serves as an effective bridge between global frameworks and local realities. Overall, these priorities most directly advance SDG 2 (Zero Hunger) and SDG 13 (Climate Action), with strong co-benefits for SDG 1 (No Poverty) and SDG 5 (Gender Equality) through income stability and more equitable access to information, finance and services. Operationally, the reviewed adaptation pathways imply several linked priorities for agricultural transformation: scaling drought-, heat- and flood-tolerant varieties; improving water security through efficient irrigation and water-saving practices; strengthening soil health via conservation-oriented management (e.g. crop rotation, cover crops, reduced tillage and mulching); diversifying production systems and income streams to spread climate risk; and expanding reliable climate information services to support timely planting, irrigation and harvesting decisions. For future research, this gap suggests prioritizing rigorous evaluation of ecosystem-based and conservation

practices in South Asian smallholder settings, including comparative evidence on yield stability, soil moisture/erosion control, pest suppression, labor and cost tradeoffs and distributional effects for women and resource-poor farmers.

Figure 3 illustrates how climate stressors activate six domains of adaptation strategies, which, supported by information, resources, institutions and social capital, strengthen farmers' adaptive capacity and resilience. These interactions, mediated by policy and cross-sectoral (water–energy–food) linkages, cumulatively drive agricultural transformation toward more productive and climate-resilient smallholder systems in South Asia.

Some commonly reported actions (e.g. intensified irrigation/input use) can reduce short-term risk yet create maladaptation via groundwater depletion, energy dependence, debt burdens or ecological degradation. To operationalize Figure 3, we propose a small indicator set (e.g. yield variability, adoption by domain, irrigation dependence/groundwater stress proxies, insurance penetration, extension reach and gender/asset gaps in uptake).

5. Conclusion

This study examines how the reviewed literature portrays climate change adaptation among smallholder farmers in South Asia and what these reported adaptations imply for agricultural

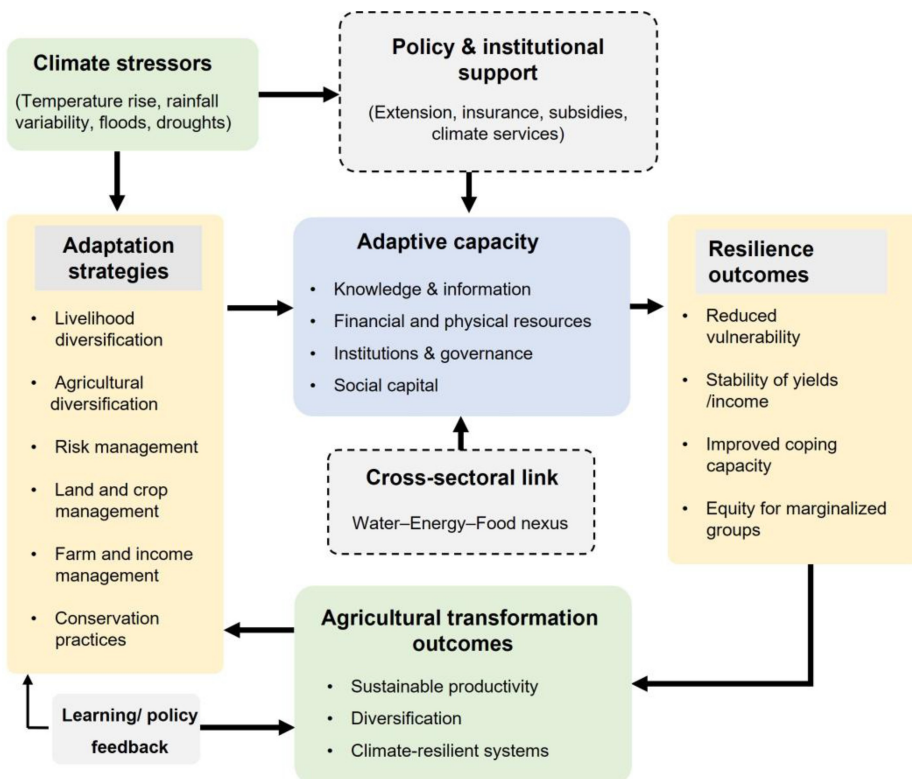


Figure 3. Conceptual model linking adaptation strategies, adaptive capacity and agricultural transformation in South Asia

transformation in the region. Using a PRISMA-guided protocol, we identified six core domains of adaptation – livelihood diversification, agricultural diversification, risk management, land and crop management, farm and income management and conservation practices – which together constitute the main repertoire of responses reported in the reviewed studies to floods, droughts, riverbank erosion and increasing pest and disease pressures. The reviewed literature most frequently reports agronomic and risk-oriented measures, whereas conservation-oriented and ecosystem-based practices remain comparatively underrepresented.

Our findings highlight that incremental, coping-oriented strategies dominate the reviewed literature on adaptation among South Asian smallholder farmers. These reported strategies include frequent adjustments to cropping calendars, varietal selection, irrigation practices and input management, which are commonly described as helping to stabilize yields and incomes in the short term. However, the potential for more transformative adaptation is constrained by a combination of structural factors – including poor policy and governance arrangements, limited and unequal access to financial services and climate-smart technologies, inadequate infrastructure and entrenched sociocultural barriers. Moreover, gender inequalities further limit who can benefit from emerging adaptation options, including financial instruments and risk management services. Policymakers in agriculture and other stakeholders need to intensify efforts to promote adaptation strategies that farmers can use to respond to specific climate extremes. Governments and development partners should also focus on policies that help farm families and communities with vulnerable status gain access to the social services and financial resources needed to implement strategies to adapt to climate change.

Although PRISMA-based, this review has several limitations. First, South Asia's marked geographic and socioecological diversity limits uniform regional generalization, and adaptation patterns may vary across countries, subregions and demographic groups. Second, our focus on English-language, peer-reviewed studies from Scopus and Web of Science may also have excluded relevant gray or non-English literature; additionally, because Web of Science used a broader regional query while Scopus included country-specific queries, some country-specific studies indexed only in Web of Science may not have been captured. Third, some countries, especially Bhutan, the Maldives and Afghanistan, remain underrepresented, and reliance on published studies may have introduced publication bias by overlooking informal or locally documented adaptation knowledge. Finally, because 126 reports sought for retrieval could not be obtained in full text, some incompleteness in the evidence base cannot be ruled out. Future research should expand coverage to underrepresented settings and non-journal sources, use primary data in specific subregions and examine demographic, institutional and gendered dimensions of adaptation more systematically.

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Supplementary material

The supplementary material for this article can be found online.

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