Socio-Economic Impacts of Climate Change on Farming Communities in Hisar District, Haryana

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Abstract : Climate change poses a significant challenge to agriculture in semi-arid regions of India, where rising temperatures, erratic rainfall, and groundwater depletion threaten the socio-economic stability of farming communities. This study examines the livelihood impacts of climate change on agricultural households in Hisar District, Haryana, focusing on income stability, irrigation costs, food security, and adaptation responses. Primary data were collected from 240 farming households across five blocks representing varying levels of climatic and hydrological vulnerability. Descriptive and regression analyses were employed to assess block-wise differences in socio-economic outcomes. Results indicate that farmers in groundwater-stressed blocks face higher irrigation costs, greater income volatility, and increased dependence on credit compared to those in canal-supported areas. Climate-induced yield variability has adversely affected food security, particularly among small and marginal farmers, while labor shifts toward non-farm activities reflect coping responses. The study highlights the need for geographically differentiated, livelihood-centered climate adaptation strategies to strengthen resilience in semi-arid agricultural systems.

***IndexTerms* - Climate change impacts, Farmer livelihoods, Groundwater depletion, Agricultural adaptation.**

I. INTRODUCTION

Climate change has emerged as one of the most critical challenges confronting agricultural systems worldwide, particularly in semi-arid and water-stressed regions [1,2]. Rising temperatures, increased frequency of heat extremes, and growing uncertainty in rainfall patterns have significantly altered agro-climatic conditions, thereby affecting crop productivity, water availability, and the livelihoods of farming communities [3,4]. In developing countries such as India, where agriculture remains a primary source of employment and income for a large proportion of the population, these climatic stresses pose serious risks to food security and rural development [5].

India's agricultural sector is highly sensitive to climate variability due to its strong dependence on monsoon rainfall and uneven access to irrigation resources [6]. Recent decades have witnessed noticeable warming trends, increased rainfall variability, and a rising incidence of extreme weather events across northern and northwestern India [7,8]. These changes have disrupted traditional cropping systems and intensified reliance on groundwater for irrigation, particularly in semi-arid states such as Haryana [9]. While groundwater extraction has temporarily buffered agricultural production against rainfall uncertainty, it has simultaneously led to widespread aquifer depletion, raising concerns about the long-term sustainability of irrigated agriculture [10,11].

Within this broader context, Hisar district of Haryana represents a critical case of climate–agriculture–livelihood interaction. Empirical studies in the district have documented statistically significant warming trends, declining rainfall, and severe groundwater depletion over the past three decades [12,13]. These climatic and hydrological changes have resulted in differential impacts on crop productivity, with cool-season crops such as wheat and mustard exhibiting higher sensitivity to rising temperatures, while increased groundwater dependence has escalated irrigation costs and resource stress [14]. However, despite growing evidence on biophysical impacts, relatively little attention has been paid to how these climate-induced changes translate into socio-economic outcomes for farming households at the district level.

Understanding the socio-economic dimensions of climate change is essential because agricultural vulnerability is shaped not only by exposure to climatic stress but also by household-level characteristics such as farm size, access to irrigation, income diversification, and institutional support [15,16]. Climate-induced yield variability, rising irrigation costs, and groundwater depletion can directly affect farm incomes, food security, labor allocation, and indebtedness, thereby influencing farmers' adaptive capacity and resilience [17,18]. These impacts are often unevenly distributed, with small and marginal farmers facing disproportionately higher risks [19].

Against this backdrop, the present study examines the socio-economic impacts of climate change on farming communities in Hisar district, Haryana. Building upon earlier district-level evidence on climate-induced crop productivity decline and groundwater stress, this paper focuses on livelihood outcomes, including income stability, cost of cultivation, food security, labor dynamics, and adaptation responses [12,13,20]. By integrating household-level survey data with spatial vulnerability patterns, the study aims to provide policy-relevant insights into how climate change reshapes rural livelihoods in semi-arid agricultural regions.

Figure 1. Geographical representation of Haryana showing position of Hisar

Objectives

The specific objectives of this study are to:

1. Assess the impact of climate-induced crop yield variability on farm income and livelihood stability of agricultural households in Hisar district.
2. Examine the socio-economic implications of groundwater depletion, particularly in terms of irrigation costs and household indebtedness.
3. Analyze variations in livelihood vulnerability across blocks with differing levels of climatic and hydrological stress.
4. Identify adaptation strategies adopted by farmers and the constraints affecting their adaptive capacity.

II. Study Area and Methodology

2.1 Study Area

Hisar district is located in the western part of Haryana between 29°05′–29°49′ N latitude and 75°26′–76°15′ E longitude, covering an area of approximately 3,983 km². The district lies in the semi-arid agro-climatic zone of northwestern India and is characterized by hot summers, mild winters, and highly variable monsoon rainfall. The mean annual rainfall is around 420 mm, nearly 80 per cent of which is received during the southwest monsoon season (June–September), while potential evapo-transpiration exceeds rainfall by nearly threefold, making agriculture heavily dependent on irrigation [7,20].

Agriculture is the principal livelihood activity in the district, with wheat and mustard dominating the rabi season and cotton and bajra prevailing during the kharif season. Although canal irrigation historically supported agricultural production, declining canal inflows and increasing climatic variability have resulted in a marked shift toward groundwater-dependent irrigation over the past three decades [13,14]. Previous studies have documented significant warming trends, declining rainfall, and severe groundwater depletion in the district, leading to spatially uneven agricultural vulnerability, particularly in southern blocks such as Adampur and Narnaund [8,12].

Given its semi-arid climate, intensive agricultural practices, and increasing groundwater stress, Hisar district provides a suitable case for examining the socio-economic impacts of climate change on farming communities and livelihood sustainability.

2.2 Sampling Design and Data Collection

The study is based on primary data collected through a household-level survey conducted during 2024–2025. A stratified sampling approach was adopted to capture socio-economic variation across areas with differing levels of climatic and hydrological vulnerability. Based on earlier assessments of crop productivity decline and groundwater stress, five blocks—Adampur, Narnaund, Hisar, Uklana, and Barwala—were selected to represent high, moderate, and low vulnerability zones [20,13].

A total of 240 farming households were surveyed, with approximately 40–50 households selected from each block using random sampling. The sample included marginal, small, medium, and large farmers to ensure representation across farm-size categories.

Data were collected using a structured questionnaire covering socio-demographic characteristics, cropping patterns, irrigation practices, income and expenditure trends, food security status, labor dynamics, and adaptation responses to climate variability. The questionnaire incorporated a mix of close-ended, Likert-scale, and limited open-ended questions, allowing both quantitative analysis and contextual interpretation. Similar household survey approaches have been widely used in climate–livelihood studies to assess vulnerability and adaptive capacity at the local level [16,17].

2.3 Analytical Framework and Methods

The analysis combines descriptive, comparative, and inferential statistical techniques to examine the socio-economic impacts of climate change on farming households. Descriptive statistics were used to summarize household characteristics, income sources, irrigation costs, and adaptation practices. Comparative analysis was carried out to assess differences in socio-economic outcomes across blocks with varying levels of groundwater stress.

To evaluate the relationship between climate-induced stress and livelihood outcomes, regression analysis was employed, with indicators such as income variability, irrigation expenditure, and indebtedness used as dependent variables. Independent variables included farm size, irrigation source, perceived climate variability, and access to institutional support. In addition, a composite livelihood vulnerability index was constructed by integrating indicators of income instability, irrigation cost burden, food security, and adaptive capacity, following established vulnerability assessment frameworks [1,15].

The methodological approach allows for identification of both direct and indirect socio-economic impacts of climate change, while highlighting spatial disparities in livelihood vulnerability within the district. All statistical analyses were performed using standard statistical software, and results are interpreted in conjunction with existing empirical literature on climate change, groundwater stress, and rural livelihoods.

III. Results and Discussion

4.1 Impact of Climate Variability on Farm Income and Irrigation Costs

The results of the household survey reveal that climate-induced variability in crop productivity has had a pronounced impact on farm income and cost of cultivation across Hisar district. A large proportion of respondents reported increased year-to-year income fluctuations over the past decade, which they attributed to rising temperatures, erratic rainfall, and declining crop yields. Farmers located in groundwater-stressed blocks such as Adampur and Narnaund reported significantly higher irrigation expenditures compared to those in canal-supported blocks like Uklana and Barwala. On average, irrigation costs in high-vulnerability blocks were 30–40 per cent higher, primarily due to increased groundwater pumping depth and rising energy costs [9,11,14].

Regression analysis indicates a strong positive relationship between groundwater depth and irrigation expenditure, confirming that groundwater depletion directly translates into higher production costs. These findings are consistent with earlier studies highlighting the economic burden of groundwater over-extraction in semi-arid regions of northwestern India [10,19]. Although groundwater-based irrigation has helped farmers buffer rainfall uncertainty, it has also intensified cost pressures, thereby reducing net farm income and increasing economic vulnerability.

4.2 Livelihood Stability, Indebtedness, and Food Security

Climate-induced income instability has had significant implications for livelihood security among farming households. Survey results show that a substantial share of small and marginal farmers reported increased dependence on credit to meet cultivation expenses, particularly during drought and low-rainfall years. Indebtedness levels were markedly higher in groundwater-stressed blocks, where repeated crop losses and escalating irrigation costs have weakened repayment capacity. Similar patterns have been reported in other parts of semi-arid India, where climate stress and groundwater depletion jointly exacerbate rural indebtedness [10,18].

Food security outcomes also varied spatially across the district. Households in high-vulnerability blocks reported shorter periods of food sufficiency and greater reliance on market purchases, reflecting reduced on-farm production and income uncertainty. Small and marginal farmers were particularly vulnerable, corroborating findings from livelihood vulnerability assessments that emphasize the disproportionate impact of climate change on resource-poor households [15,19]. These results underline that climate change affects not only production systems but also household-level welfare and nutritional security.

4.3 Labor Dynamics and Livelihood Diversification

The analysis further reveals notable changes in agricultural labor dynamics as a response to climate stress. Many households reported a gradual decline in on-farm labor demand during years of poor crop performance, accompanied by increased engagement in non-farm activities such as wage labor, construction work, and small-scale services. This trend was more pronounced in blocks experiencing higher climatic and hydrological stress, suggesting that livelihood diversification has emerged as a key coping strategy.

While diversification can enhance resilience, it also reflects distress-driven adaptation, particularly among smallholders lacking access to irrigation and financial resources. Previous studies have similarly observed that climate variability accelerates shifts away from agriculture in vulnerable rural regions, raising concerns about the long-term sustainability of agrarian livelihoods [5,16].

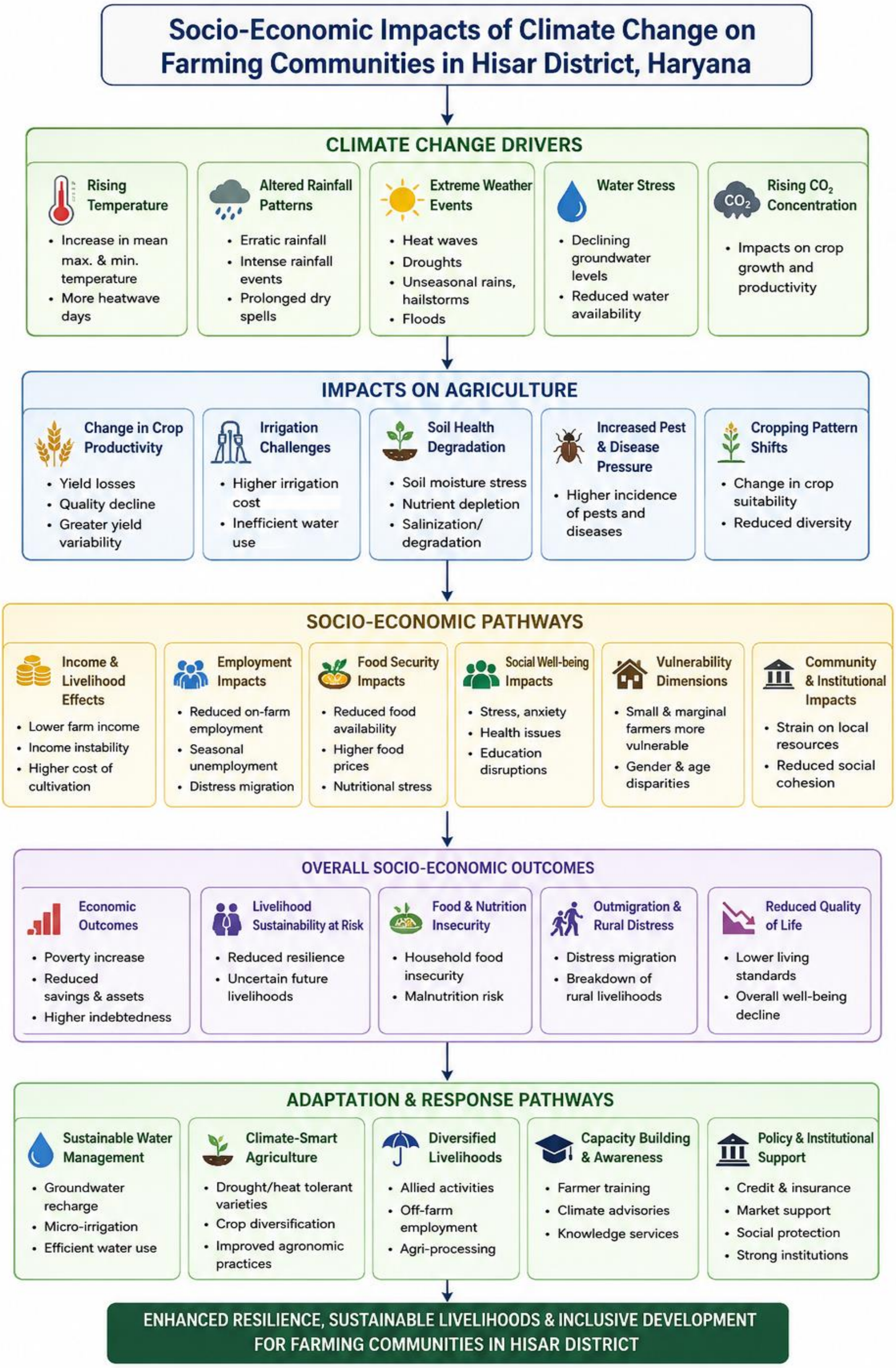

Figure 2. Conceptual framework of the socio-economic impacts of climate change on farming communities in Hisar

4.4 Adaptation Strategies and Constraints

Farmers across Hisar district have adopted a range of adaptation measures to cope with climate variability. Common strategies include changes in sowing time, crop diversification toward relatively drought-tolerant crops, increased use of groundwater irrigation, and adoption of improved seed varieties. However, the adoption of resource-intensive measures such as micro-irrigation and climate-resilient technologies remains limited, particularly among small and marginal farmers.

The analysis indicates that adaptive capacity is strongly influenced by access to irrigation, farm size, and institutional support. Farmers in canal-assisted blocks exhibited relatively higher adaptive capacity compared to those in groundwater-dependent areas. Key constraints identified by respondents include high investment costs, limited access to credit, inadequate extension services, and uncertainty regarding government support schemes. These findings align with broader evidence emphasizing that unequal access to resources and institutions shapes differential adaptation outcomes under climate change [16,17,18].

Overall, the results demonstrate that climate change operates through interconnected biophysical and socio-economic pathways, with groundwater depletion acting as a critical mediator linking climatic stress to livelihood vulnerability. The observed spatial disparities underscore the need for location-specific adaptation strategies that address both environmental and socio-economic dimensions of agricultural resilience.

Table 1. Block-wise socio-economic vulnerability of farming communities to climate change in Hisar District, Haryana, based on irrigation cost, income volatility, debt incidence, and overall vulnerability level.

Block	Irrigation Cost ↑	Income Volatility	Debt Incidence	Vulnerability Level
Adampur	High	High	High	Very High
Narnaund	High	Moderate–High	High	High
Hisar	Moderate	Moderate	Moderate	Moderate
Uklana	Low	Low	Low	Low
Barwala	Low	Low	Low	Low

IV. Policy Implications

The findings of this study carry significant implications for climate adaptation planning and agricultural policy in semi-arid regions such as Hisar district. First, the strong linkage between groundwater depletion and rising irrigation costs highlights the urgent need for integrated groundwater governance. Regulatory measures aimed at controlling over-extraction, combined with incentives for micro-irrigation and water-use efficiency, are essential to reduce long-term vulnerability [10,11,20]. Promotion of drip and sprinkler irrigation systems, particularly in groundwater-stressed blocks, can substantially lower pumping requirements while enhancing water productivity.

Second, the observed income instability and rising indebtedness among small and marginal farmers underscore the need for income stabilization mechanisms. Strengthening climate-linked crop insurance schemes, expanding access to institutional credit at affordable rates, and improving risk-transfer instruments can reduce distress borrowing and enhance financial resilience [5,18]. Policies should prioritize vulnerable farmer categories and ensure timely compensation during drought and heat-stress years.
Third, the spatial heterogeneity in livelihood vulnerability suggests that uniform district-level interventions may be ineffective. Block-specific adaptation strategies should be designed based on groundwater stress levels, irrigation infrastructure, and socio-economic conditions. In highly vulnerable blocks such as Adampur and Narnaund, targeted support for crop diversification, promotion of less water-intensive crops, and capacity-building programs can enhance adaptive capacity [15,16].

Fourth, institutional strengthening is critical. Improved extension services, climate information dissemination, and farmer training programs can facilitate the adoption of climate-resilient technologies and agronomic practices [1,17]. Integrating scientific climate projections with local advisory systems will enable farmers to make informed decisions regarding sowing time, crop choice, and irrigation scheduling.

Finally, adaptation policies must adopt a livelihood-centered approach that recognizes the interconnected nature of climate, water, agriculture, and rural welfare. Coordinated action across water governance, agricultural development, rural credit systems, and social protection programs is necessary to prevent deepening socio-economic inequalities under climate change. Such integrated strategies can enhance long-term resilience of farming communities in semi-arid agro-ecosystems.

V. Conclusion

This study examined the socio-economic impacts of climate change on farming communities in Hisar district, Haryana, by linking climatic variability and groundwater depletion with livelihood outcomes at the household level. The findings demonstrate that climate change influences rural livelihoods not only through declining and variable crop productivity but also through rising irrigation costs, increased indebtedness, and growing income instability. Groundwater depletion emerges as a critical intermediary mechanism through which climatic stress translates into higher production costs and heightened economic vulnerability [9,11,14].

The analysis reveals pronounced spatial disparities within the district. Farmers in groundwater-stressed blocks experience significantly greater livelihood insecurity compared to those in canal-assisted areas, underscoring the importance of location-specific adaptation strategies. Small and marginal farmers are disproportionately affected, reflecting structural inequalities in access to irrigation, credit, and institutional support [15,16]. While livelihood diversification and agronomic adjustments provide short-term coping mechanisms, they do not fully offset the long-term risks associated with sustained groundwater decline and climate variability.

Overall, the study highlights that climate change in semi-arid agricultural systems operates through interconnected environmental and socio-economic pathways. Enhancing resilience therefore requires integrated interventions that address water governance, income stabilization, technological access, and institutional strengthening simultaneously. By providing district-level empirical evidence on livelihood impacts, this study contributes to the growing body of research emphasizing that effective climate adaptation must move beyond production-centric approaches and adopt a comprehensive, livelihood-centered framework for sustainable rural development.

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