International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 5, 2025
https://theaspd.com/index.php

# Role Of Multiple Stressors In Planned Adaptation To Climate Change In Semi-Arid Region In India

**Pradeep Kumar Mehta**[1]
[1]Assistant Professor, Amity University, Noida

***Abstract***
*With increasing challenges related to climate change, farmers living in harsh climatic conditions are experiencing an adverse impact on their livelihoods. Farmers need to respond to climate change in a more planned than reactive way to reduce their vulnerability to future climate changes. However, farmers confront with a range of multiple stressors, including climatic and non-climatic. The current study examines the role of non-climatic stressors on farmers' typology of adaptation. The study is conducted in an agriculturally dominated semi-arid region in India. The study includes a primary survey that encompasses 665 farmers. To ensure representation from each block, a proportionate stratified random sampling technique was applied in the selection process. Employing a mixed method approach, which combines quantitative and qualitative tools, the study reveals that farmers generally perceive climate change and attempt to adjust or adapt to changes in environmental conditions in various ways. However, in Nuh, only a few farmers are adopting planned measures to deal with climate change. The adoption of planned strategies is facilitated by access to formal credit, and affiliation with local organizations, while it is hindered by the incidence of non-climatic stressors. The existing non-climatic stressors play a critical role in farmers' adaptability to climate risks, constraining how farmers respond to climate change. There is a need to account for both climatic and non-climatic factors while planning and designing appropriate adaptation strategies.*
***Keywords***: *Climate change adaptation; non-climatic stressors; climatic stressor*

## 1. INTRODUCTION

Human-induced global warming, which has already caused a 1.1°C increase in global temperatures, is driving significant climate changes, as highlighted by the IPCC 2021 report. These changes are amplifying the frequency and intensity of extreme weather events, such as droughts and floods, which have severe impacts on water resources, food production, public health, and ecosystems (Shivanna, 2022). India, identified as a major hotspot for climate vulnerability, is particularly at risk, especially in its semi-arid regions where ecosystems are delicate and highly susceptible to both climate change and human activities (IPCC, 2022). In these regions, rising temperatures, erratic rainfall, and prolonged droughts threaten agricultural livelihoods (Revi et al., 2015; Huang et al., 2016; Jodha et al., 2012; Kattumuri et al., 2015; Singh et al., 2019). Climate change negatively impacts crop yields, biodiversity, and farming practices, exacerbating farmers' difficulties in managing pests and diseases, which in turn affects their income and increases risks (Mehta, 2020). Adaptation to climate change is crucial, with proactive, planned adaptation being vital for mitigating both current and future risks. However, farmers' responses to climate change are influenced not only by their awareness of climatic shifts but also by socio-economic conditions and local contexts, which can either facilitate or hinder adaptation (Ahmed et al., 2016; Antwi-Agyei et al., 2018).

Adaptation is essential for addressing the risks posed by climate change (Kidane et al., 2022). It is defined in various ways, with some definitions emphasizing responses to climate change and others focusing on the typology of adaptation strategies adopted by farmers (Ahmed et al., 2016; IPCC, 2021). Schipper (2020) highlights that not all adaptation measures reduce vulnerability; some may even exacerbate it, a phenomenon known as maladaptation. Therefore, it is important to understand the different types of adaptation strategies. Adaptation generally falls into two categories: response adaptation and planned adaptation. Response adaptation includes coping strategies that help manage past or current climate impacts, but these are often insufficient for addressing long-term climate challenges (Kidane et al., 2022). In contrast, planned adaptation is proactive and long-term, aiming to prepare for future climate shifts and hazards. Planned adaptation is generally more effective in reducing future vulnerability (IPCC, 2001). Farmers' ability to adapt depends not only on climate impacts but also on their capacity to respond, which is shaped by socio-economic conditions and local context (Lede et al., 2022). Vulnerability to climate change is determined by exposure, sensitivity, and adaptive capacity (Smit & Wandel, 2006), with human factors playing a crucial role in shaping adaptation decisions. Both climatic stressors (e.g., drought, erratic rainfall) and non-climatic stressors (e.g., economic, market, institutional factors) influence adaptation decisions, which can either reduce vulnerability or contribute to maladaptation (Bhatta et al., 2016; Lede et al., 2022). This study focuses on the role of non-climatic stressors in shaping farmers' adaptation strategies in the semi-arid Nuh district of Haryana, one of India's most economically disadvantaged regions. Climate change, particularly the rising groundwater salinity since the late 1990s, has compounded the district's challenges. The study aims to map climate changes in Nuh, explore the community's perceptions of stressors, identify the range of adaptation strategies used by farmers, and assess how non-climatic factors influence these strategies. It underscores the complexity of farmers' adaptation processes, driven by both climatic and non-climatic stressors, and calls for comprehensive adaptation strategies. The specific objectives of the study are: 1) To map the changes in significant climate variables in Nuh; 2) To analyze the community's perception of climate change and observed climatic and non-climatic stressors; 3) To explore the range of adaptation strategies (planned and responsive) adopted by farmers in response to climate change; and 4) To examine the role of various factors, including non-climatic stressors, on the typology of adaptation.

## 2. METHODOLOGY OF THE STUDY

The present study is conducted in Nuh district of Haryana, a semi-arid zone, where agriculture is the dominant livelihood. The study includes both primary and secondary data. To capture temperature and rainfall trends, secondary data from Indian Meteorological Department (IMD) and International Crops Research Institute for Semi-Arid Tropics (ICRISAT) for the last thirty years is used. Primary data collection from households occurred between May and June 2024. The household survey sample size was determined using the standard sample size formula:

Sample Size = N * [Z2 * p * (1-p)/e2] / [N – 1 + (Z2 * p * (1-p)/e2]

Where N is the population size (10,89,000), z is the z-score with a 99% confidence level (z=2.58), e is the margin of error with 5% (.05), and p is the standard of deviation where p is assumed to be 0.5 as it is unknown. Using the above probabilistic sample formula, the sample size of the study is 665 farmers. Selection of the farmers from each block is done using proportionate stratified random sampling (Table 1).

**Table 1: Sample Size**

| Blocks | Number of Households | Proportion of Households | Sample size |
|---|---|---|---|
| Tauru | 20117 | 14.37 | 96 |
| Nuh | 38714 | 27.66 | 184 |
| Punhana | 36531 | 26.10 | 174 |
| Firozpur Jhirka | 44613 | 31.87 | 212 |
| Total | | | 665 |

Source: Census 2011

For primary data analysis, the study combines quantitative methods (structured questionnaire) with qualitative methods (focus group discussions, climate mapping, and resource mapping) to encapsulate various dimensions. The factors that elucidate the typology of farmers' adaptation strategies are examined through the utilization of a binary logit model. This model integrates climate change adaptation strategies as dummy dependent variables with binary choices, distinguishing between farmers who have embraced anticipatory or planned strategies and those who have opted for reactive ones (where the value is 1 for farmers employing at least one anticipatory strategy and 0 for those not adopting any anticipatory strategies). The logistic distribution function governing the decision to adopt adaptation measures to climate change can be specified as follows:

Logit (P) = log ( P )

1-P

Let $P_i = Pr(Y=1 \mid X=x_i)$

then the model can be written as

$$Pr(y=1 \mid x) = \frac{\exp^{x'b}}{1+e^{x'b}} \; ; = \log\left(\frac{P_i}{1-P_i}\right) = Logit(P_i) = \beta_0 + \beta_1 x_i$$

where; Pi is a probability of deciding to adopt anticipatory adaptation strategies (dependent variable), xi's are the independent variables, β0 is the intercept and β1 is the regression coefficient.

We can write the model in terms of odds as;

$$\frac{P_i}{(1-P_i)} = \exp(\beta_0 + \beta_1 x_i)$$

The independent variables hypothesized to exert influence on the typology of farmers' adaptation include a combination of social, demographic, economic, and institutional characteristics, in addition to changes in climatic variables (rainfall and temperature) and the severity of non-climatic stressors (as shown in Table 2). Leveraging insights from previous research on adaptation strategies, the explanatory variables outlined in Table 2 were examined in this study to assess their impact on the typology of farmers' adaptation strategies to climate change.

**Table 2: Variables hypothesized to affect the typology of adaptation**

| Variable | Description | Value | Typology of Adaptation Decision (Sign) |
|---|---|---|---|
| Household Size | Number of family members | Number | - |
| Gender | Household head gender | 0=Female, 1= Male | +/- |
| Age | Age of Household Head in Years | Years | +/- |
| Education | Education of Household head | 0 illiterate, 1=literate | + |
| Experience | Farming Experience of household head | Years | + |
| Farm Size | Total landholding | Hectare | + |
| Access to Formal credit | Access to formal credit | 0=No, 1 =Yes | + |
| Perception of Climate Change | Perception of change in climatic variables | 0=No, 1 =Yes | + |
| The severity of non-climatic stressors* | An index value of the household experience of non-climatic stressors | 0=Less Severe and 1=Most severe | - |
| Institution Affiliation | Association with government or private organization | 0=No, 1 =Yes | + |

* The severity of non-climatic stressors is calculated based on farmer experience with non-climatic stressors. The list of twelve non-climatic stressors is given in Table 5. For any given stressor, there are only two categories for each household: either they experience (value 1) or do not experience (value 0) the stressor. The severity of non-climatic stressors for each household is the discrete value which is the sum of all stressors for that household which could be a minimum of 0 (no experience with any of the 12 stressors) or a maximum of 12 (have experience with all 12 stressors). The non-climatic stressor index is created by dividing the cumulative value of stressors experienced by the household by its maximum value in the following manner:

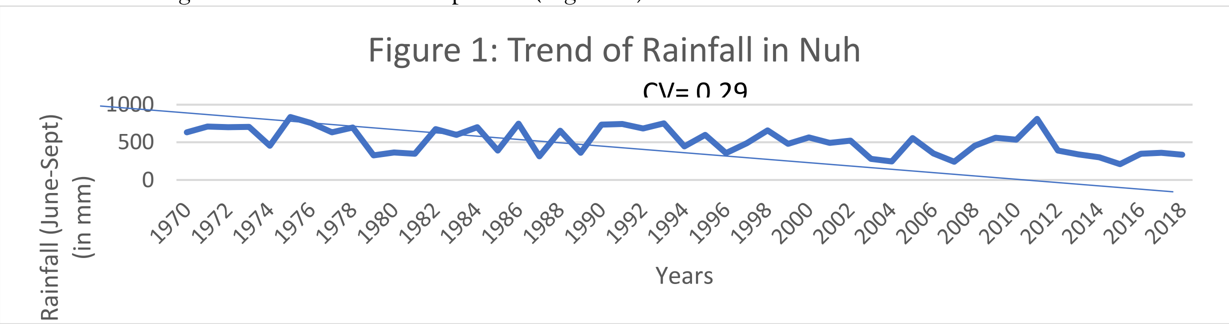
The non-climatic stressor index = $\frac{1}{n}\sum_{i=1}^{n} x_i$, where i is the number of stressors experienced by the household and n is 12.

The index value for the household will vary from 0-1; the higher the index for the household represents a higher incidence of non-climatic stressors or high severity level.

## 3. Study Region: Major Features and Trends in Climate Change

The Nuh region, previously known as the Mewat district, is one of the 22 districts of Haryana, India and is predominantly inhabited by Meo-Muslims. Covering an area of 1860 km², Nuh district comprises four blocks: Nuh, Tauru, Firozpur Jhirka and Punhana, with 431 villages and 297 panchayats (Census, 2011). Due to water scarcity and groundwater salinity, rain serves as the region's primary irrigation source. Despite harsh climatic conditions, agriculture remains the main livelihood option, with 86% of the population is dependent on agriculture (Government of Haryana, 2022). However, due to its geographically disadvantages, the crop yield per hectare in the district is lower compared to the rest of the state. Nuh district lags behind in several vital socioeconomic parameters and is among the country's most backward districts (Mehta, 2015).

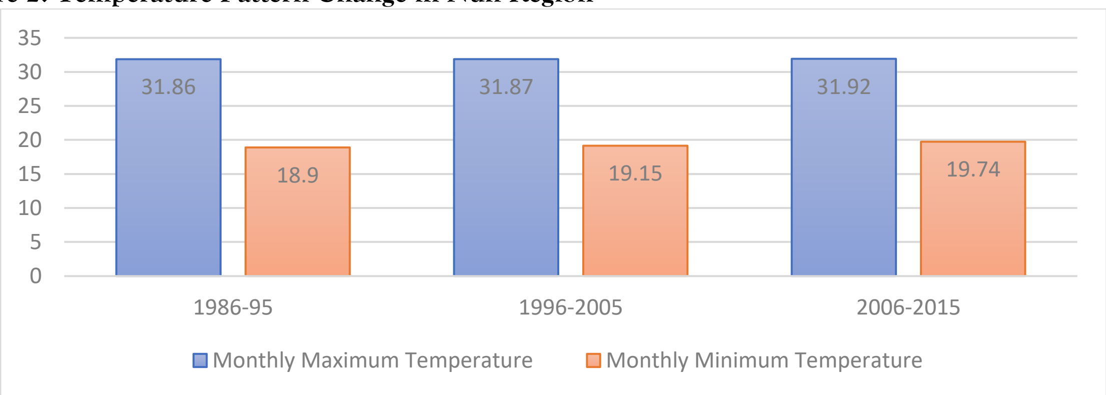
Nuh is situated within the subtropical semi-arid climatic zone, characterized by exceedingly hot temperatures during the summer months. May and June are the hottest months of the year, with temperatures ranging between 30°C to 48°C. January is the coldest month, with temperatures ranging between 2°C to 25°C (Government of Haryana, 2022). In the past 100 years, Nuh has experienced eighteen moderate and eight severe droughts (Kumar et al. 2016). Due to these extreme events and variable climate, community concerns over the groundwater table for agriculture and allied activities have increased (Mehta, 2020; Mitra et al. 2021). Changes in temperature and rainfall, along with their pattern, reflect changes in the region's climate, which have implications for farming. The rainfall data is collected for the four prime months when most of the rainfall occurs, i.e., June, July, August, and September. The data is obtained from the IMD from 1970 through 2019. The data has revealed a declining trend in rainfall with huge variabilities over the period (Figure 1).




Source: IMD, 2023

For the district, data on temperature for the maximum and minimum values are available only until 2000 from IMD and until 2015 from ICRISAT. Hence, the same trend was analyzed for the three decades from 1986 to 2015. The data revealed a continuous increase in the minimum temperature in the Nuh region, with the maximum temperature remaining almost the same over the last three decades (Figure 2). This trend has implications for cropping cycles and demand for water for growing crops in Nuh, which could affect farmers' income.

**Figure 2: Temperature Pattern Change in Nuh Region**



Source: IMD and ICRISAT, 2023

## 4. Farmers' perception of climate change and stressors

This section examines the socio-economic profiles of the respondents and their perceptions of climate change. The average household size in the Nuh region is 5.8 members, indicating relatively large families (Table 3). Most household heads (88%) are male, and the average landholding is 1.4 hectares, pointing to the dominance of small and marginal farmers. The majority of respondents are Muslim (73%), with an average age of 48.5 years for household heads. Over half (54%) of the household heads are literate, and the average farming experience is 39.6 years, highlighting extensive agricultural knowledge and adaptive strategies.

**Table 3: Socio-Economic Details of the Respondents**

| Variable | Description | Mean Value |
|---|---|---|
| Household Size | Average number of family members | 5.8 |
| Gender | Proportion of household head as male member | 88% |
| Age | Average Age of Household Head (in Years) | 48.5 |
| Education | Proportion of Household headed by literate | 54% |
| Experience | Average Farming Experience (in Years) | 39.6 |
| Farm Size | Average landholding (In Hectare) | 1.4 |
| Religion | Proportion of households being Muslims | 73% |

Source: Primary Data

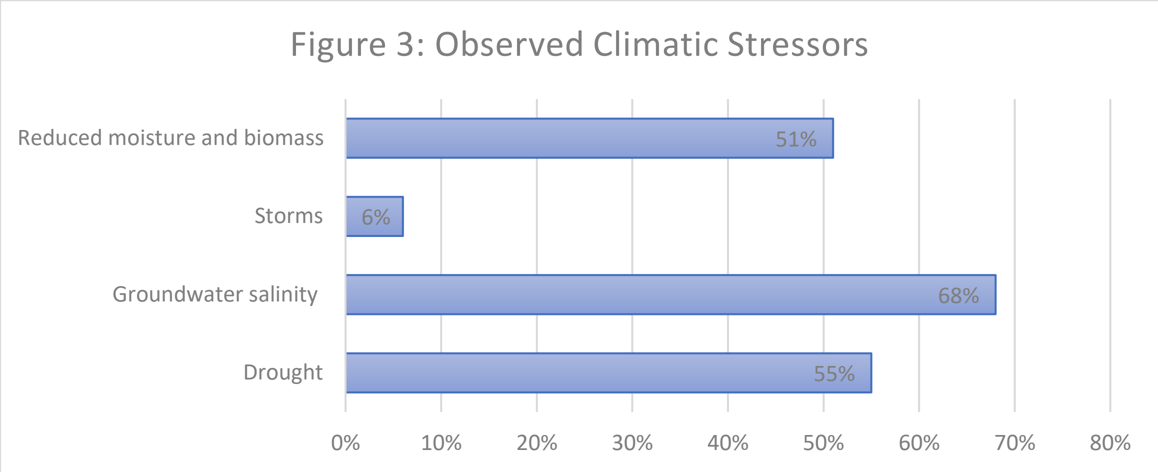
Local farmers perceive climate change through frequent changes and variability in rainfall and temperature (Alam et al. 2017; Banerjee, 2015; Datta et al. 2022). The previous section reveals that there have been eighteen moderate and eight severe droughts in Nuh in the last 100 years. Changes regarding increased minimum temperature and a decline in the rainfall trend have also been observed. We have elicited information from farmers regarding their awareness of changes in climatic variables pertaining to temperature and rainfall. The responses show that most community members (82%) have perceived changes in climatic variables in the last thirty years (Table 4), with the most severe being the perceived reduction in rainfall followed by an increase in temperature. Farmers' awareness of rainfall and temperature has also corroborated the macro (district) level trend in temperature and rainfall patterns. Farmers mentioned that along with the overall reduction in rainfall, there is an increase in episodes of intense rainfall, which adversely affects their crops. Change in temperature and rainfall pattern have implications for the production cycle, crop choices and crop productivity. Merely, eighteen percent of the sampled farmers reported no change in any of the listed climatic variables.

**Table 4. Farmer's perception of change in climatic variables over the last Thirty Years**

| | Yes | No |
|---|---|---|
| Increase in temperature | 72% | 28% |
| More intense rainfall | 58% | 42% |
| Reduced amount of rainfall | 78% | 22% |
| No change in the long-term trend of climatic variables | 18% | 82% |

Source: Primary Data

The changing rainfall and temperature patterns pose challenges for crop productivity and farming cycles. Climatic stressors, such as drought, storms, groundwater salinity, and reduced moisture and biomass availability, were identified as the major risks by the farming community (Figure 3). Groundwater salinity, in particular, severely impacts crop productivity. While storms are rare, the primary concern is groundwater salinity. Given that 86% of the population depends on agriculture, addressing these climatic stressors through effective adaptation policies is crucial for the region's agricultural sustainability.




Source: Primary Data

**5. Farmer's Adaptation to Climate Change**

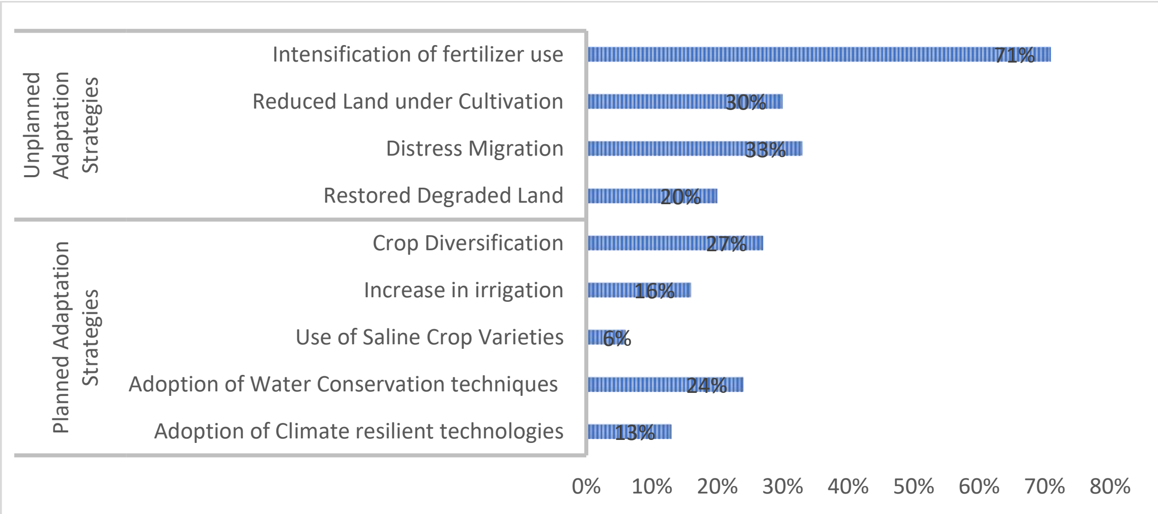
The perception of climatic changes serves as a precursor for adaptation actions by farmers (Alam et al. 2017). With the acknowledgement that climate change is real and has impacted their farm income, it is vital to explore how farmers respond to such changes. As critical climatic variables shift, farmers generally respond in multiple or numerous ways to climate change (Adger et al. 2003; Levina & Tirpak, 2006). Such responses depend on myriad factors, including the actual climate change, perceptions of changes in climatic variables, resources available to farmers, and support institutions (government and private), among others (Datta et al. 2022).

Vulnerability to future climate change is a critical issue. Farmers aim to adapt to climate change by taking many measures; however, only some of the measures they undertake are beneficial to reduce their vulnerability to future climate changes. Farmers with low adaptive capacity are also highly vulnerable to future changes in the incidence of extreme climate (Adger, 1996). Responding to climate change is a difficult decision that also entails trade-offs, as successful adaptation for the future may differ from responding to existing conditions. Adaptation should reduce various climate sensitivities; risk should be minimized or income should be more diverse; vulnerability should be reduced; or response should be more environmentally friendly (Kelly & Adger, 2000). Hence, adaptation must also be forward-looking to future changes in climate and should be more anticipatory than reactive (Schipper, 2007). As climate change is a phenomenon expected to remain a significant concern in the future, farmers must respond to climate change in a way that reduces their vulnerability to future climate change. Planned strategies improve farmers' resilience to future climate change more effectively than response strategies (IPCC, 2001).

In the Nuh region, farmers face challenges such as groundwater salinity and low crop productivity. To address these issues, they have adopted various strategies, including increased fertilizer use, irrigation, crop diversification, saline crop varieties, water conservation technologies, and utilization of degraded land. About 39% of farmers employ only one of these strategies. Based on these responses, we classify farmers' adaptations into planned and reactive strategies. Planned strategies include crop diversification, climate-resilient technologies, and water conservation, aimed at long-term climate resilience. Reactive strategies, such as intensified fertilizer use and distress migration, are short-term solutions that may not enhance future resilience and could increase vulnerability over time (Schipper, 2020).

The results highlight that the majority of farmers, constituting 71% have restored to the intensification of fertilizers in response to climate change (Figure 4). When interviewed, farmers revealed that given the increase in agricultural pests and diseases and low crop yields, they have no choice but to use more fertilizers to maintain crop productivity, despite the potential negative impact on farmers and animal health. It is important to note that approximately one-fourth of farm households even restored to restoring degraded land (less fertile) to compensate for the loss of income due to climate change. Moreover, a considerable number of farm families (33%) chose seasonal migration to work as labourers on lands in neighbouring districts or states. These distress migrants have also decreased the cultivated area, mainly due to a decline in the cultivation of indigenous commercial crops. Although most farmers (61%) have adopted multiple adaptation strategies, only a few (26%) have adopted planned or proactive strategies. Some measures, such as water conservation technologies, were adopted by 24% of farmers. Groundwater salinity is the major climatic stressor in the Nuh region; however, only 6% of sampled farmers have adopted saline seed varieties. Farmers revealed that saline varieties are available only for two crops, i.e., wheat and mustard, and to obtain these varieties, they need to visit other districts of the state which are nearly 200 km away from their location. The lack of availability of saline seeds in Nuh is hampering farmers' adoption, despite many being willing to adopt it due to the high incidence of salinity. Farmers associated with government extension services and a non-government organization (NGO) have adopted water conservation technologies such as laser levelling, sprinklers as well as climate-resilient technologies such as solar pumps, and sprayers.

**Figure 4: Adaptation Strategies adopted by Farmers in Nuh**




Source: Primary data

**6. Incidence of non-climatic stressors by farm households**

Farmers in Nuh have experienced groundwater salinity, drought, and soil moisture loss as major climate stressors. Along with these climatic stressors, they are also contending with several other non-climatic stressors crucial for their livelihoods. Table 5 lists the non-climatic stressors experienced by respondent farmers[2]. The incidence of these non-climatic stressors by farmers is depicted in Figure 7. The major non-climatic stressors identified by farmers include poor input and output market access, high level of indebtedness, lack of capital for farming, illness, and unemployment. Among the farmers surveyed, 51% of farm households in the Nub region face significant challenges accessing input markets. The region suffers from a scarcity of quality inputs such as fertilizers, seeds, and manure, exacerbating the issue. Timely procurement of these vital resources proves elusive for many farmers, causing delays in their farming operations. Consequently, farmers find it difficult to strategize and invest in their farms effectively, leading to a vicious cycle of poverty and low productivity. Additionally, a high incidence of indebtedness and a lack of capital for purchasing quality seeds and farming equipment are listed as significant stressors by 41% and 48% of farm households, respectively.

**Table 5: Indicators of non-climatic stressors**

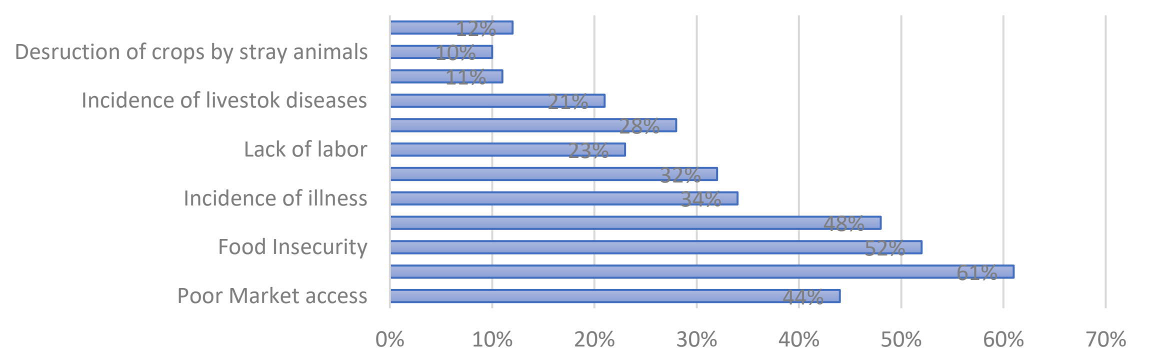
| S.No | Non-Climatic Stressor | Indicator |
|---|---|---|
| 1 | Indebtedness | Have outstanding payments due on either formal or informal loan |
| 2 | Land Conflict or Court case | Having any ongoing land conflicts or ongoing court case |

[2] The list is prepared in consultation with several focus group discussions with the farmers. In total, we have conducted twelve focus group discussions in all blocks to prepare the list of non-climatic stressors experienced by farmers in Nuh.

| | | |
|---|---|---|
| 3 | Crop loss through cattle destruction | Cattle destroyed crops on your farm last two years |
| 4 | Cattle Theft | Any of your cattle theft happened in the last two years |
| 5 | Livestock disease | At least one of your cattle had a disease in the last two years |
| 6 | Poor Input market access | Lack of timely availability of quality inputs such as seeds, fertilizers and manure |
| 7 | Poor Output Market Access | Selling crops to a middleman |
| 8 | No access to credit | Not able to get any loan (formal or informal) |
| 9 | Unemployment | At least one member (aged 18-60) in the household who is currently unemployed and actively seeking work |
| 10 | Illness | At least one member in the household who is severely sick and out-of-pocket expenditure is being incurred |
| 11 | Lack of Capital | You experience a lack of capital to purchase seeds, fertilizer or farming equipment |
| 12 | Lack of Labour | You experience a lack of labour for performing farming work |

Limited market access further weakens farmers' bargaining power, with 44% of farmers receiving low prices for their produce due to long distances to the market and inadequate storage facilities (Figure 5). Health issues and unemployment also impact farm households, with one-third experiencing illness or having unemployed members seeking work. Other non-climatic stressors include lack of credit access (28%), labor shortages (23%), livestock diseases (21%), land conflicts (12%), cattle theft (11%), and crop destruction by stray animals (10%).

Figure 5: Observed Non-Climatic Stressors by Farmers in Nuh




Source: Primary Data

When ranking stressors by importance, lack of input market access, groundwater salinity, intense rainfall, low crop prices, and access to capital are considered the most critical. Drought and lack of investment capital are of high incidence but lower importance, while indebtedness, unemployment, access to credit, and livestock diseases are of low incidence but high importance. Non-climatic stressors often have a greater impact on farmers' lives than climatic stressors, influencing their adaptation strategies to climate change. To cope, farmers adopt strategies such as seasonal migration, asset sales, consumption reduction, and informal loans. About 36% of households engage in seasonal migration to nearby districts or states as laborers, driven by low agricultural productivity and limited employment opportunities. Due to the absence of a robust banking system, 31% of farmers resort to high-interest informal loans. Additionally, 18% sell assets like land, livestock, or equipment, while 8% change diets or reduce consumption to manage both climatic and non-climatic stressors. These findings highlight the complex interplay of climatic and non-climatic stressors affecting farmers in Nuh, emphasizing the need for comprehensive policy interventions addressing both sets of challenges.

**7. Factors affecting adaptation strategies by farmers**

This section examines how various social, economic, institutional, and psychological factors, alongside non-climatic stressors influence farmers' adaptation typology. Among the ten independent variables in the model, four variables were found to be significant: literacy (coefficient= 2.322, $p < 0.05$; odd ratio=10.198), institutional association (coefficient= 1.578, $p < 0.05$; odd ratio=4.843), severity of non-climatic stressors (coefficient= -4.384, $p < 0.01$; odd ratio=0.012) and access to formal credit (coefficient= 2.125, $p < 0.01$; odd ratio=8.374) (Table 6). This suggests that farmers who have access to formal credit and are affiliated with institutions have a higher probability of adopting planned adaptation strategies compared to farmers without access to formal credit and institutional affiliation. Conversely, farmers experiencing a higher incidence of non-climatic stressors are less likely to adopt planned adaptation strategies. There is no observed association of farmers' planned adaptation with farm size, gender, age, household size, farm experience, and perception of change in climatic variables.

Interestingly, no significant associations were found between farmers' perceptions of changes in climatic variables (temperature and rainfall) and planned adaptation. Conversely, the prevalence of non-climatic stressors within households significantly undermines planned adaptation efforts, as evidenced by the negative coefficient and its statistical significance at the 1% level. This highlights the adverse impact of such stressors on farmers' ability to adopt planned strategies. Therefore, alongside endeavors to expand institutional reach and enhance credit accessibility, addressing non-climatic stressors assumes paramount importance in fostering planned adaptation among farmers in Nuh.

Overall, the findings highlight that upon perceiving changes in climate variables, farmers employ various adaptation measures. However, due to the lack of supportive mechanisms, most farmers resort to intensified fertilizer use, out-migration, or other coping strategies. A limited number of farmers opt for saline seeds and climate conservation technologies, which necessitate additional investment and resources. While access to climate information plays a pivotal role in shaping farmers' perceptions of climate change, the mere provision of information is insufficient for effective climate change management. It is crucial to comprehend the diverse non-climatic stressors in the region and discern those that prompt greater responses from farmers and influence their adaptation patterns. Furthermore, it is imperative for both government and non-government organizations to broaden their outreach so that more farmers can respond to changes in climatic conditions, thereby enhancing their resilience against future climate changes. Additionally, access to formal credit is crucial for farmers to embrace anticipatory strategies, which can be financially demanding. Even farmers with small farm sizes can adopt anticipatory strategies with the availability of low-cost credit, especially when they perceive the high impact of climate change on their income and risks.

**Table 6: Determinants of Farmer's Typology of Adaptation to Climate Change**

| Variables | Coefficient | Standard Error | Wald | P-Value | Odd-Ratio |
|---|---|---|---|---|---|
| AGE | -0.011 | 0.009 | 1.290 | 0.256 | .990 |
| GENDER | 0.069 | 0.387 | 0.032 | 0.859 | 1.072 |
| HOUSEHOLD SIZE | 0.019 | 0.077 | 0.063 | 0.802 | 1.019 |
| EDUCATION | 2.322 | 0.362 | 41.180 | 0.034** | 10.198 |
| EXPERIENCE | -0.005 | 0.017 | 0.109 | 0.742 | .995 |
| FARM SIZE | 0.052 | 0.319 | 0.027 | 0.870 | .949 |
| INSTITUTIONAL ASSOCIATION | 1.578 | 0.345 | 20.876 | 0.016** | 4.843 |
| PERCEPTION OF CLIMATE CHANGE | 0.360 | 0.359 | 1.006 | 0.316 | 1.433 |
| SEVERITY OF NON-CLIMATIC STRESSORS | -4.384 | 1.193 | 13.492 | 0.000* | .012 |
| FORMAL CREDIT | 2.125 | 0.347 | 37.416 | 0.000* | 8.374 |
| CONSTANT | -2.231 | 0.972 | 5.271 | 0.022 | .107 |

Notes: * and ** significant at 1% and 5% significance levels. Log likelihood = 256.307; Pseudo R2 (Cox and Snell R2 =0.381; Nagelkerke R2 =0.558).

## 8. DISCUSSION AND CONCLUSION

The long-term climate patterns in Nuh indicate a decline in precipitation and an increase in minimum temperatures over the past 30 years, leading to significant climatic stressors, such as groundwater salinity, which have depleted natural resources and harmed local farmers. The underdevelopment and marginalization of Nuh, combined with the threat of future climate change, highlight the urgent need for planned adaptation strategies. Unplanned, reactive strategies often result in maladaptation, increasing farmers' vulnerability.

The study shows that while farmers in Nuh have noticed changes in climate, their responses are primarily reactive due to short-term institutional focus on climate risks. These strategies address immediate agricultural losses and water scarcity but fail to prevent future vulnerabilities. For instance, over 70% of farmers have increased fertilizer use, which could lead to groundwater pollution and degrade soil health. Only around one-fifth of farmers have adopted planned, anticipatory strategies, such as water conservation and climate-resilient technologies, which could help reduce maladaptation. Barriers to adopting planned strategies include financial constraints, lack of extension services, and limited adaptation options. Farmers' responses to climate change are also shaped by their adaptive capacity and the presence of non-climatic stressors. Climate variability interacts with other societal challenges, exacerbating the difficulties farmers face. Non-climatic stressors, such as groundwater salinity, lack of land, skills, and industrial development, are more pressing for farmers' survival, often taking priority over climate change concerns. For example, many farmers are forced to purchase drinking water due to salinity or migrate for work to neighboring states to meet household needs.

Addressing non-climatic stressors is critical before scaling up planned adaptation strategies. Immediate issues, such as lack of employment, poor market infrastructure, inadequate potable water, and outdated farming technology, must be addressed by policymakers to enhance farmers' resilience to climate change. With projections of rising temperatures and reduced rainfall, farmers in semi-arid regions like Nuh could face heightened vulnerability. To mitigate this, it is essential to promote the adoption of climate-resilient technologies, water conservation measures, and saline-resistant varieties. Addressing non-climatic stressors, especially those impacting immediate needs, will help create a foundation for planned adaptation. Policymakers must consider these factors when designing adaptation strategies to improve farmers' resilience to future climate challenges.

**REFERENCES:**

1. Shivanna K. R. 2022, "Climate change and its impact on biodiversity and human welfare", Proceedings of the Indian National Science Academy. 88, 160–171. https://doi.org/10.1007/s43538-022-00073-6
2. IPCC 2022. "Climate change: a threat to human wellbeing and health of the planet. Taking action now can secure our future, https://www.ipcc.ch/2022/02/28/pr-wgii-ar6/. (Accessed on 02 April 2024)
3. Revi A., Bazaz A., Krishnaswamy J., Bendapudi R., D'Souza M. & Pahwa G.S. 2015, "Vulnerability and Adaptation to Climate Change in Semi-Arid Areas in India", ASSAR Working Paper, ASSAR PMU, South Africa. 1-20.
4. Huang J., Ji, M., Xie Y., Wang S, He, Y., & Ran, J. 2016, "Global semi-arid climate change over last 60 years", Climate Dynamics, vol 46, 1131–1150. https://doi.org/10.1007/s00382-015-2636-8
5. 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: Evidence from Indigenous Practices: Developing International Public" International Crops Research Institute for Semi-Arid Tropics, http://oar.icrisat.org/6071/ (accessed on 10 February 2025)
6. Kattumuri, R., Ravindranath, D. & Esteves, T. 2015, "Local adaptation strategies in semi-arid regions: a study of two villages in Karnataka, India" Climate and Development, pp. 1–14. ISSN 1756-5529. http://eprints.lse.ac.uk/64057/1/Climate%20resilience%20in%20India.pdf (accessed on 20 February 2025)
7. Singh C., Solomo D., Bedapudi R., Kuchimanchi B., Iyer S., & Bazaz A. 2019, "What shapes vulnerability and risk management in semi-arid India? Moving towards an agenda of sustainable adaptation", Environmental Development, Vol. 30, pp 35-50. https://doi.org/10.1016/j.envdev.2019.04.007
8. Mehta P.K. 2020, "Adaptive Strategies to Climate Change and Food Security: A Case Study from the Semi-arid Region of India. In "Climate Change Adaptation and Sustainable Livelihoods" Gavali R.S., Reddy K., Kakumanu V., Babu S. & Mishra S.K. NIRDPR Publications. ISBN: 978-81-944719-6-7, Hyderabad, India pp 40-54.
9. Ahmed Abubakari, Elaine T. Lawson, Adelina Mensah, Chris Gordon, Jon Padgham, 2016, "Adaptation to climate change or non-climatic stressors in semi-arid regions? Evidence of gender differentiation in three agrarian districts of Ghana", Environmental Development, Vol 20, pp 45-58. https://doi.org/10.1016/j.envdev.2016.08.002.

10. Antwi-Agyei Philip, Andrew J. Dougill, Lindsay C. Stringer, Samuel Nii Ardey Codjoe 2018, "Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana", Climate Risk Management, Vol 19, pp 83-93, ISSN 2212-0963, https://doi.org/10.1016/j.crm.2017.11.003.
11. Kidane R., Wanner T., Bray M.N., Kamal M.M.A., & Atampugra G. 2022, "The role of climatic and non-climatic factors in smallholder farmers adaptation responses: Insight from rural Ethiopia", Sustainability, 14, 5715. http://doi.org/10.3390/su14095715
12. IPCC 2021, "Annex VII: Glossary" [Matthews, J.B.R., V. Möller, R. van Diemen, J.S. Fuglestvedt, V. Masson-Delmotte, C. Méndez, S. Semenov, A. Reisinger (eds.)]. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2215–2256, doi:10.1017/9781009157896.022.
13. Schipper Lisa F. 2020, "Maladaptation: When Adaptation to Climate Change Goes Very Wrong" One Earth, 3 (4). 409-414. https://doi.org/10.1016/j.oneear.2020.09.014
14. IPCC 2001, "IPCC, Third Assessment Report". (https://www.ipcc.ch/report/ar3/wg1/) (accessed on 05 January 2025)
15. Lede E., Pearce T., Furgal C., Wolki M., Ashford G. & Ford J.D. 2022, "The role of multiple stressors in adaptation to climate change in the Canadian Arctic", Regional Environmental Change, 21–50, http://doi.org/10.1007/s10113-021-01769-z
16. Smit B, & Wandel J 2006, "Adaptation, adaptive capacity and vulnerability. Global Environmental Change", vol. 16, pp 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008
17. Bhatta G.D., Aggarwal P.K., Kristjanson P. & Shrivastava A.K. 2016, "Climatic and non-climatic factors influencing changing agricultural practices across different rainfall regimes in South Asia:, Current Science, 110 (7), pp. 1272-1281.
18. Census 2011, "Nuh District: Census 2011 Data", Registrar General and Census Commissioner of India Office, https://nuh.gov.in/document/nuh-district-census-2011-data/ (accessed on 16 January 2025)
19. Government of Haryana 2022, "Statistical abstract of Haryana 2020-21", Department of Economic and Statistical Analysis, http:// esaharyana.gov.in/Portals/0/Compilation/Abstract%202017- 18%20(English).pdf (accessed on 16 January 2025).
20. Mehta P.K. 2015, "Identifying Backwardness of Mewat Region in Haryana: A Block-Level Analysis", NITI Aayog, https://niti.gov.in/writereaddata/files/document_publication/Identifying%20Backwardness%20of%20Mewat%20Region%20in%20Haryana-%20A%20Block%20Level%20Analysis_final_0.pdf (accessed on 5 December 2024)
21. Mitra S., Mehta P.K, & Mishra S.K. 2021, "Farmers' Perception, Adaptation to Groundwater Salinity, and Climate Change Vulnerability: Insights from North India", Weather, Climate and Society, 13 (4). pp 797-811. https://doi.org/10.1175/WCAS-D-20-0135.1.
22. Indian Meteorological Data (IMD) 2023, "Data on Temperature and Rainfall", Data Supply Portal, Pune, India.
23. International Crops Research Institute for Semi-Arid Tropics (ICRISAT) 2023, "ICRISAT District Level Data for India (DLD)". http://data.icrisat.org/dld/ (accessed on 16 January 2025).
24. Alam G.M., Alam K., & Mushtaq S. 2017, "Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh", Climate. Risk Management, vol. 17, 52–63. http://doi.org/10.1016/j.crm.2017.06.006
25. 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), pp 2829–2845. http://doi.org/10.1007/s11069-014-1466-z
26. Datta P., Bhagirath B., Bahadur D, & Rahut B. 2022, "Climate change and Indian agriculture: A systematic review of farmers' perception, adaptation, and transformation, Environmental Challenges, vol. 8, pp1-12.
27. Adger W.N., Huq S., Brown K., Conway D, & Hulme M. 2003, "Adaptation to Climate Change in the Developing World", Progress in Development Studies 3 (3), pp. 179–195.
28. Levina, E. & Tirpak D. 2006, "Adaptation to Climate Change: Key Terms", OECD and International Energy Agency. https://one.oecd.org/document/COM/ENV/EPOC/IEA/SLT(2006)1/en/pdf. (accessed on 19 December 2022)
29. Adger W.N. 1996, "Approaches to Vulnerability to Climate Change", CSERGE Working Paper GEC 96-05, Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich, and University College London.
30. Kelly P.M., & Adger W.N. 2000, "Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation", Climatic Change, 47, pp 325–352.
31. Schipper Lisa F. 2007, "Climate change adaptation and development. Exploring the Linkages", Working Paper 107, Tyndall Centre for Climate Change Research.