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Evaluating Climate Resilience: Differential Adaptation Approaches in Channel and Non-Channel Taluks of Mandya, Karnataka

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Abstract

This study examines differential climate adaptation approaches between canal-irrigated (channel) and rainfed/groundwater-dependent (non-channel) taluks in Mandya district, Karnataka - a region experiencing increasing climate variability and water stress. Using a mixed-methods approach combining household surveys (n=300 farmers), statistical analysis, and spatial assessment, we evaluate the adoption patterns of various adaptation strategies including crop diversification, drought-resistant varieties, soil health management, water harvesting, and indigenous knowledge practices. Results reveal that while soil health management (adopted by 89.3% of respondents) and indigenous knowledge (55.7%) are widely practiced across both regions, structural interventions like water harvesting (2.4%) remain underutilized. The study finds no statistically significant difference in overall adaptation intensity between channel and non-channel farmers (t-test $p>0.05$), challenging assumptions about irrigation's automatic resilience benefits. Correlation analysis identifies two distinct adaptation pathways: technology-based (linked to Climate-Smart Agriculture) and tradition-based (relying on indigenous knowledge). The findings highlight the need for integrated policy approaches that combine modern agricultural technologies with traditional knowledge systems while addressing systemic barriers to adaptation in both irrigated and rainfed contexts.

Keywords: Climate adaptation, Irrigation access, Climate-Smart Agriculture, Indigenous knowledge, Agricultural resilience, Mandya district

1. Introduction

Climate change poses one of the most significant threats to global agricultural systems, with increasing temperatures, erratic rainfall patterns, and extreme weather events undermining food security and rural livelihoods (IPCC, 2022). In India, agriculture remains highly vulnerable to climatic variability, particularly in rainfed regions where farmers rely on monsoon-dependent cropping systems (Mall et al., 2017). Karnataka, a predominantly agrarian state in southern India, has experienced notable shifts in precipitation and temperature over the past few decades, exacerbating water stress and crop failures (Reddy et al., 2018). Within Karnataka, Mandya district—often termed the "Sugar Bowl of Karnataka"—exemplifies these challenges, given its heavy dependence on sugarcane cultivation and canal irrigation from the Cauvery River (Venkatesh et al., 2020). However, climate-induced water scarcity and declining reservoir levels have heightened the district's vulnerability, necessitating urgent adaptation interventions (Narayanamoorthy et al., 2021).

Agricultural adaptation strategies vary widely depending on resource availability, institutional support, and local agroecological conditions (Adger et al., 2005). Farmers in irrigated (channel) regions often have greater access to water, enabling them to adopt high-input farming practices, whereas those in rainfed (non-channel) areas rely on traditional and drought-resilient approaches (Kumar et al., 2020). Studies indicate that irrigation infrastructure significantly influences adaptation capacity, with canal-irrigated farmers typically exhibiting higher adoption rates of modern technologies such as drip irrigation and high-yielding crop varieties (Birthal et al., 2015). Conversely, non-channel farmers frequently resort to indigenous knowledge, crop diversification, and soil moisture conservation techniques to mitigate climate risks (Singh et al., 2018). Despite these differences, both groups face systemic barriers, including limited access to credit, inadequate extension services, and policy gaps that hinder effective adaptation (Mittal & Mehar, 2016).

The concept of Climate-Smart Agriculture (CSA) has gained traction as a holistic framework for enhancing resilience, productivity, and sustainability in vulnerable agroecosystems (Lipper et al., 2014). CSA integrates practices such as agroforestry, conservation tillage, and precision irrigation, which can reduce climatic risks while improving yields (Aryal et al., 2020). However, CSA adoption remains uneven, with smallholder farmers—particularly in rainfed regions—often excluded due to financial and knowledge constraints (Makate et al., 2019). Indigenous adaptation practices, such as mixed cropping and traditional water harvesting, also play a crucial role but are frequently overlooked in formal policy frameworks (Altieri & Nicholls, 2017). Bridging the gap between modern CSA techniques and traditional knowledge is thus essential for fostering inclusive and sustainable adaptation (Makondo & Thomas, 2018).

In Mandya, the interplay between canal irrigation and rainfed farming creates distinct adaptation trajectories that warrant empirical investigation. Previous studies have highlighted the district's water management challenges, including groundwater depletion and inequitable canal water distribution (Gulati et al., 2019). However, limited research has systematically compared adaptation strategies between channel and non-channel taluks, particularly in the context of climate resilience. This study addresses this gap by analyzing differential adaptation approaches in Mandya, using a mixed-methods framework to assess the prevalence of CSA practices, indigenous knowledge, and institutional support mechanisms. By identifying key barriers and enablers of adaptation, the findings aim to inform targeted policy interventions that enhance climate resilience across diverse farming systems.

2. Study area

The present study focuses on Mandya district, located in the southern part of Karnataka, India, lying between 12°13' N to 12°49' N latitude and 76°19' E to 77°04' E longitude. The district covers an area of approximately 4,961 square kilometers and is part of the Southern Dry Zone of Karnataka. Mandya is bounded by the districts of Mysuru to the south and west, Tumakuru to the north, and Ramanagara to the east. The district comprises seven taluks—Mandya, Maddur, Malavalli, Pandavapura, Srirangapatna, Nagamangala, and Krishnarajpet—each exhibiting varying agro-climatic conditions. The terrain is predominantly flat with undulating topography in parts, and the average elevation ranges between 600 and 900 meters above sea level.

Mandya is widely recognized as an agriculturally dominant district, often referred to as the "Sugar Bowl of Karnataka" due to its extensive sugarcane cultivation. The agricultural system in the district is heavily reliant on both canal irrigation—primarily from the Krishna Raja Sagara (KRS) dam on the Cauvery River—and seasonal rainfall. However, in recent years, Mandya has experienced increasing climatic variability, including delayed monsoons, erratic rainfall distribution, and prolonged dry spells. Such changes have led to growing concerns over water stress and declining crop productivity, especially in rain-fed areas. Given its economic dependence on agriculture and its exposure to hydrological uncertainty, Mandya presents an ideal case for assessing agricultural vulnerability through the Aridity Index (AI). This study aims to spatially analyse variations in aridity across the district to identify vulnerability hotspots and support climate-resilient agricultural planning.

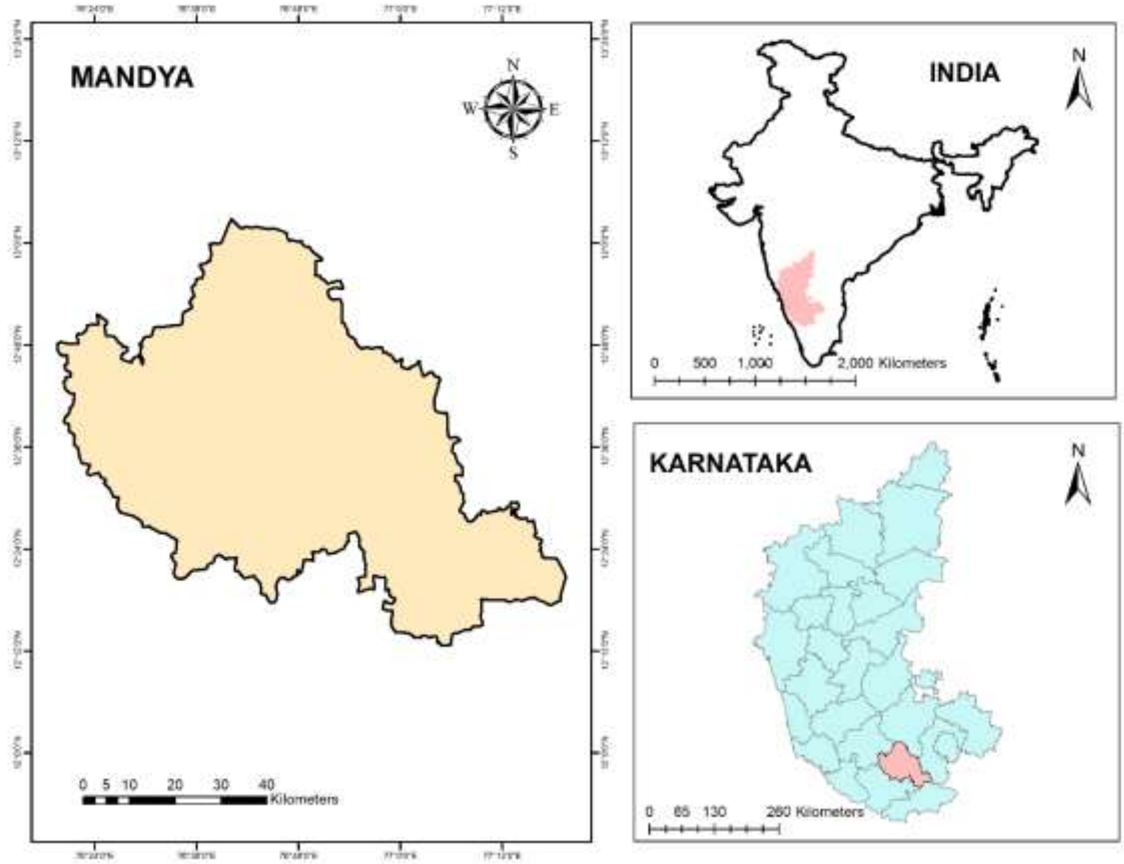

Figure 1: Location of the study area

The study was conducted in Mandya District, Karnataka, which is primarily an agrarian region known for its sugarcane cultivation and dependence on both canal irrigation (Cauvery River) and rainfed farming. The district comprises 7 taluks and 240 villages, and data were collected from sampled villages across these taluks to ensure representation of both channel (canal-irrigated) and non-channel (rainfed/dependent on groundwater) regions (Figure 2).

3. Data and methodology

The study was conducted in Mandya District, Karnataka, an agrarian region known for its sugarcane cultivation and dependence on both canal irrigation and rainfed farming. The district comprises seven taluks, and data were collected from sampled villages across these taluks to ensure representation of both channel (canal-irrigated) and non-channel (rainfed or groundwater-dependent) regions. This approach allowed for a comparative analysis of adaptation strategies between farmers in areas with access to canal water and those relying on other water sources. The current study uses a mixed-method approach integrating survey-based data, statistical analysis, and geospatial techniques was employed. The focus was to systematically identify, quantify, and interpret the range of adaptation strategies adopted by farmers in the Mandya district in response to long-term climate variability.

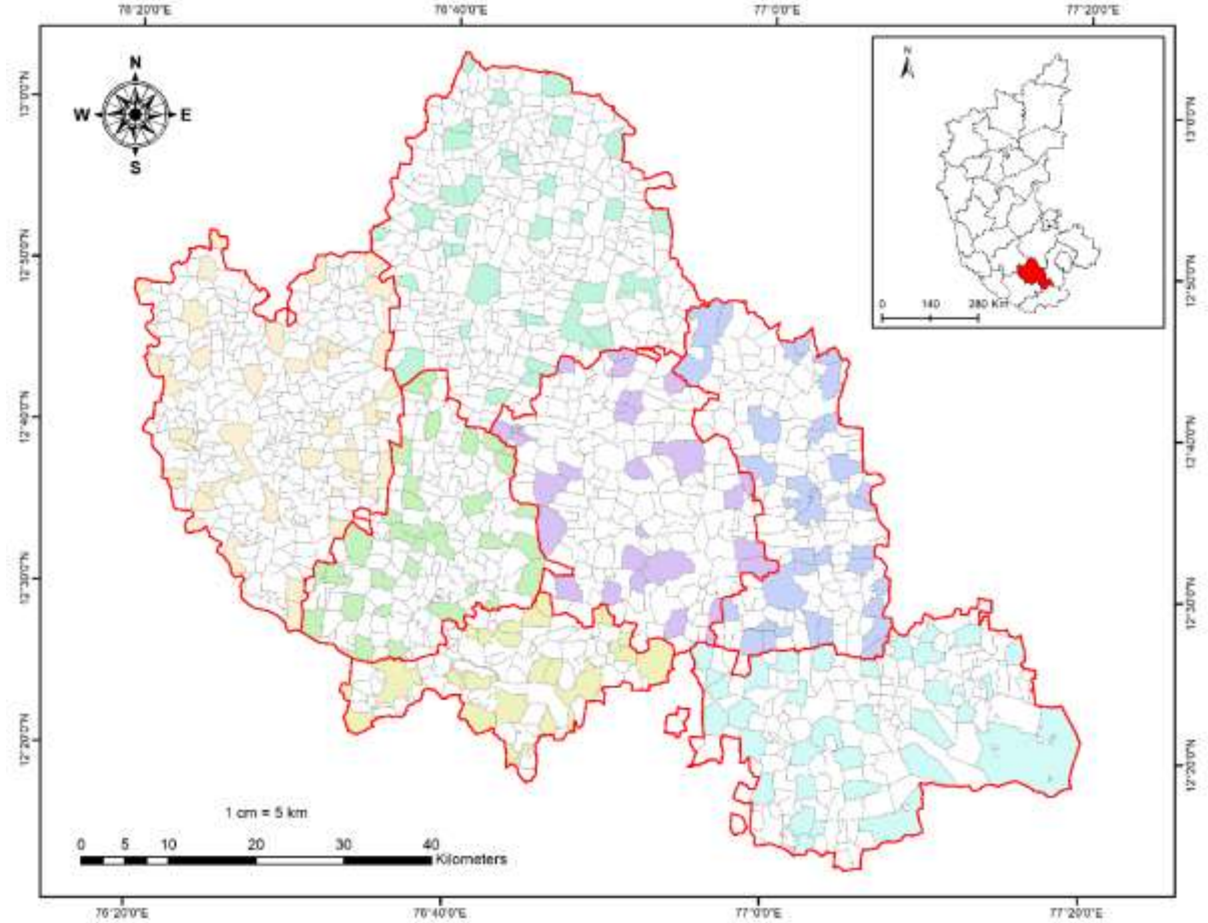

Figure 2: Locations of sample of villages used in the study

3.1 Data

Data collection was carried out using a structured questionnaire designed to assess farmers' adaptation strategies to climate change. The questionnaire covered several key areas, including general farmer demographics such as age, gender, and farming experience. It also documented farmers' observations of climate change, such as shifts in rainfall patterns, temperature fluctuations, water availability, and pest attacks. Additionally, the survey explored specific adaptation strategies, such as crop diversification, altered planting schedules, irrigation improvements, and soil health management. Further sections focused on technological adoption, financial and policy support, and long-term resilience planning, including the integration of indigenous knowledge.

A total of 300 farmers were surveyed through stratified random sampling across the seven taluks to ensure balanced representation. Villages were categorized into channel (canal-dependent) and non-channel (rainfed or groundwater-dependent) regions to facilitate comparative analysis. Data were collected via face-to-face interviews to ensure accuracy and contextual understanding of farmers' responses. This method also allowed for clarification of questions and deeper exploration of qualitative insights.

The collected data were analyzed using both descriptive and inferential statistical methods. Descriptive statistics, including frequency distributions, means, and standard deviations, were used to summarize categorical and continuous variables. Comparative analyses, such as chi-square tests or t-tests, were employed to examine differences in adaptation strategies between channel and non-channel farmers. Qualitative responses, such as those related to indigenous practices and policy suggestions, were thematically analyzed to identify recurring patterns and insights. Where applicable, regression models were used to explore factors influencing the adoption of specific adaptation strategies.

Ethical considerations were strictly followed throughout the study. Farmers participated voluntarily and provided informed consent before the interviews. Anonymity was maintained in data reporting to ensure confidentiality. This methodological approach ensured a comprehensive assessment of climate adaptation strategies while highlighting regional disparities in Mandya District, providing valuable insights for policymakers and agricultural stakeholders.

Primary data was collected through structured questionnaires administered to farmers across both channel (irrigated) and non-channel (rainfed) regions. The survey included specific questions on adaptation strategies such as crop diversification, adoption of drought-resistant varieties, soil health management practices, water harvesting, pest and pesticide management, record-keeping of climate patterns, and shifts in cropping calendars. Responses were digitized and compiled in Excel for analysis.

The raw responses were standardized by converting categorical answers (e.g., Yes/No, Irrigated/Rainfed) into binary or numerical values (e.g., Yes=1, No=0). Multi-choice responses were expanded into multiple columns, each representing an individual adaptation option. Composite indices were created, namely the Adaptation Index (total number of strategies adopted by each farmer), the Climate-Smart Agriculture (CSA) Index, and the Indigenous Knowledge Index, to enable robust statistical comparisons.

3.2 Methodologies

3.2.1 Frequency and Descriptive Analysis

The first step in analyzing adaptation was to generate frequency distributions and descriptive statistics of each adaptation strategy. Percentages and proportions were computed to show the adoption level of each practice across the study population. Frequency tables were supported by visualizations such as bar charts and pie charts, which provided a clear representation of strategy adoption patterns. The outputs were visualized with bar charts and pie charts, enabling comparison of the relative prevalence of different practices. This step established the baseline level of adoption and highlighted dominant strategies across the sample.

3.2.2 Correlation and Association Analysis

To understand the interlinkages between strategies, Pearson correlation coefficients were calculated among adaptation variables (e.g., relationship between crop diversification and record-keeping, or between drought-resistant seeds and water harvesting). These were visualized using correlation heatmaps to identify clusters of complementary or substitutive adaptation methods.

Categorical association tests such as the Chi-square test of independence were applied to examine the relationship between socio-institutional variables (e.g., channel vs. non-channel farmers) and adoption of individual strategies (e.g., crop diversification). This allowed assessment of whether irrigation access significantly influenced adoption behavior and identified whether farmers tended to adopt integrated approaches or relied on isolated measures.

3.2.3 Comparative Statistical Testing

To statistically compare adaptation intensity between channel and non-channel farmers, independent sample t-tests were applied on indices such as the Adaptation Index and CSA Index. This quantified whether irrigated farmers demonstrated significantly higher or lower levels of adaptation compared to their rainfed counterparts. Such tests were crucial for regional comparisons within Mandya district. This approach provided robust evidence on whether irrigation access influenced adaptation behaviour.

3.2.4 Distribution Analysis

The distribution of Adaptation Index and CSA Index was examined using histograms. These plots illustrated the spread of adaptation intensity within the farming population, distinguishing between low, moderate, and high adopters. Such distributional insights allowed classification of farmers into vulnerability categories and linked adaptation behaviour to resilience outcomes.

3.2.5 Integration of Outputs

The combination of frequency tables, visual charts, correlation heatmaps, comparative statistics, and distribution analysis provided a comprehensive understanding of adaptation. Frequency tables and charts quantified the strategies; correlation analysis showed interdependence; channel vs. non-channel comparisons established contextual differences; and distribution plots highlighted the diversity in adaptation levels. Together, these outputs offered a multi-dimensional view of how farmers in Mandya district respond to climate variability.

4. Results and discussion

4.1 Adoption of Adaptation Strategies

The frequency table (Table 1 and figure 3) shows that the most widely adopted adaptation practice among farmers in Mandya district was soil health management, followed by indigenous knowledge use and crop diversification. In contrast, only 5.7% of farmers reported adopting drought-resistant crop varieties, while water harvesting practices were the least common, observed in only 2.4% of the sample (Figure 4). The high adoption of soil health practices suggests a growing recognition of land degradation issues and the importance of maintaining soil fertility as a climate adaptation measure. The reliance on indigenous knowledge highlights the continued role of traditional practices in managing climate variability. However, the relatively low adoption of structural measures such as water harvesting reflects potential financial or institutional constraints.

Table 1: Frequency table showing farmers adaptation practices

Strategy	Number of Farmers	Percentage
Crop_Diversification	156	6.5
Soil_Health	268	11.1
Drought_Resistant	138	5.7
Water_Harvesting	57	2.4
CSA_Index	463	19.2
Indigenous_Knowledge	167	6.9
Adaptation_Index	1168	48.3

4.2 Adaptation Intensity

Composite indices indicated varying levels of adaptation intensity. The Adaptation Index (cumulative strategies per farmer) had a total value of 1,168, with an average of approximately 3.9 strategies per farmer. The CSA Index, which specifically measures climate-smart practices, also showed a relatively high adoption rate, though a portion of this may overlap with general soil and crop management techniques. The wide distribution of adaptation index values suggests that while some farmers have embraced multiple strategies, others remain highly vulnerable due to low adoption.

4.3 Interrelationships Among Strategies

The correlation analysis revealed moderate positive relationships between certain strategies, suggesting patterns of bundled adoption. For example, farmers practicing crop diversification were also more likely to adopt soil health measures and drought-resistant seeds. Such linkages imply that some farmers pursue integrated approaches to adaptation, combining biological, agronomic, and knowledge-based strategies. However, weak correlations between water harvesting and other practices suggest that structural measures are less systematically integrated with other adaptation efforts.

4.4 Channel vs. Non-Channel Farmers

When comparing channel (irrigated) and non-channel (rainfed) farmers, boxplots of the Adaptation Index and CSA Index indicated some visual differences, with channel farmers generally adopting slightly more strategies. However, the t-test results returned non-significant values (t = NaN, p = NaN), which may be due to small or uneven sample sizes between groups. Similarly, the chi-square test for crop diversification across channel types was not significant ($\chi^2 = 0.0$, $p = 1.0$). These findings suggest that, statistically, there is no strong evidence of differences in adaptation behavior between irrigation contexts in this dataset. Nevertheless, descriptive evidence still points to potential variations that may become clearer with larger sample sizes.

4.5 Distribution of Adaptation Intensity

Histograms of the Adaptation Index and CSA Index indicated a right-skewed distribution, with a majority of farmers adopting two to four strategies, while a smaller subset adopted more than five. This distribution highlights a heterogeneity of resilience levels within the farming population: a core group of proactive farmers engage in multiple strategies, while others remain minimal adopters. Such uneven adoption could exacerbate vulnerability gaps across the district.

The findings reveal a mixed pattern of adaptation in Mandya district. While soil health management and indigenous practices are widely adopted, structural interventions such as water harvesting remain neglected. The absence of strong statistical differences between channel and non-channel regions could indicate that farmers across both contexts face similar climate-related pressures and constraints. However, the non-significant results may also reflect small sample sizes, suggesting a need for more robust data collection to strengthen inference.

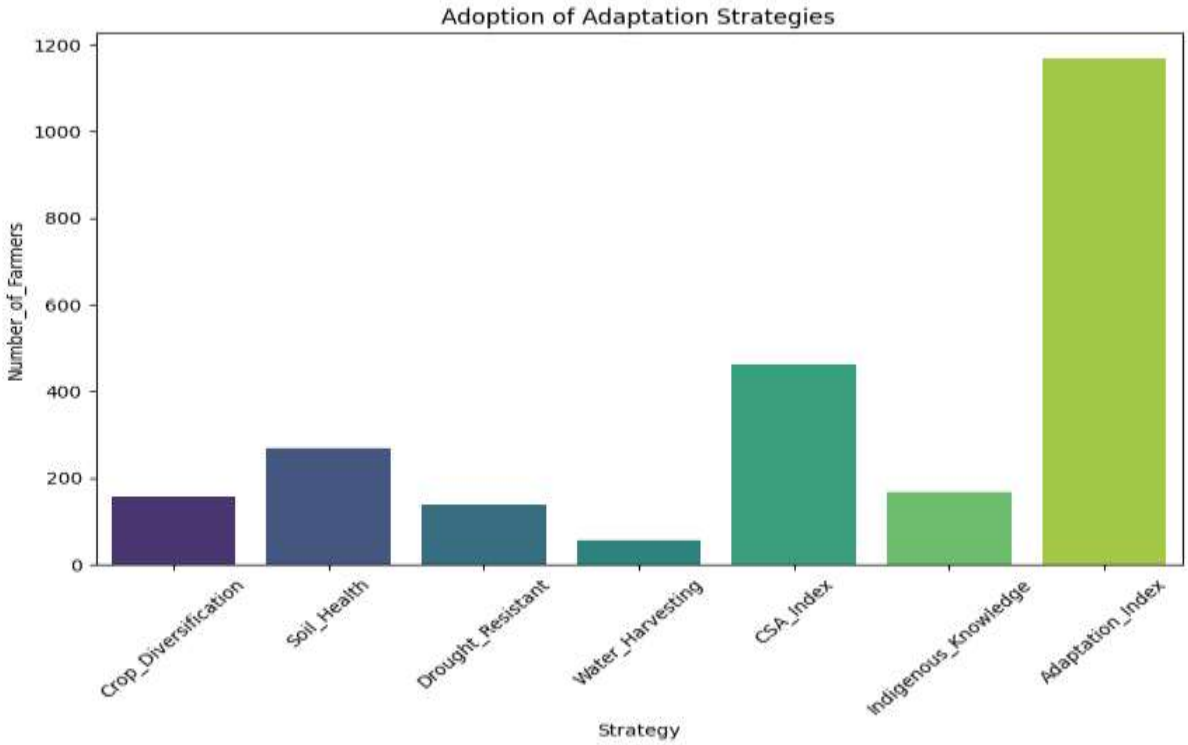

Figure 3: Number of farmers adoption strategies in the study area

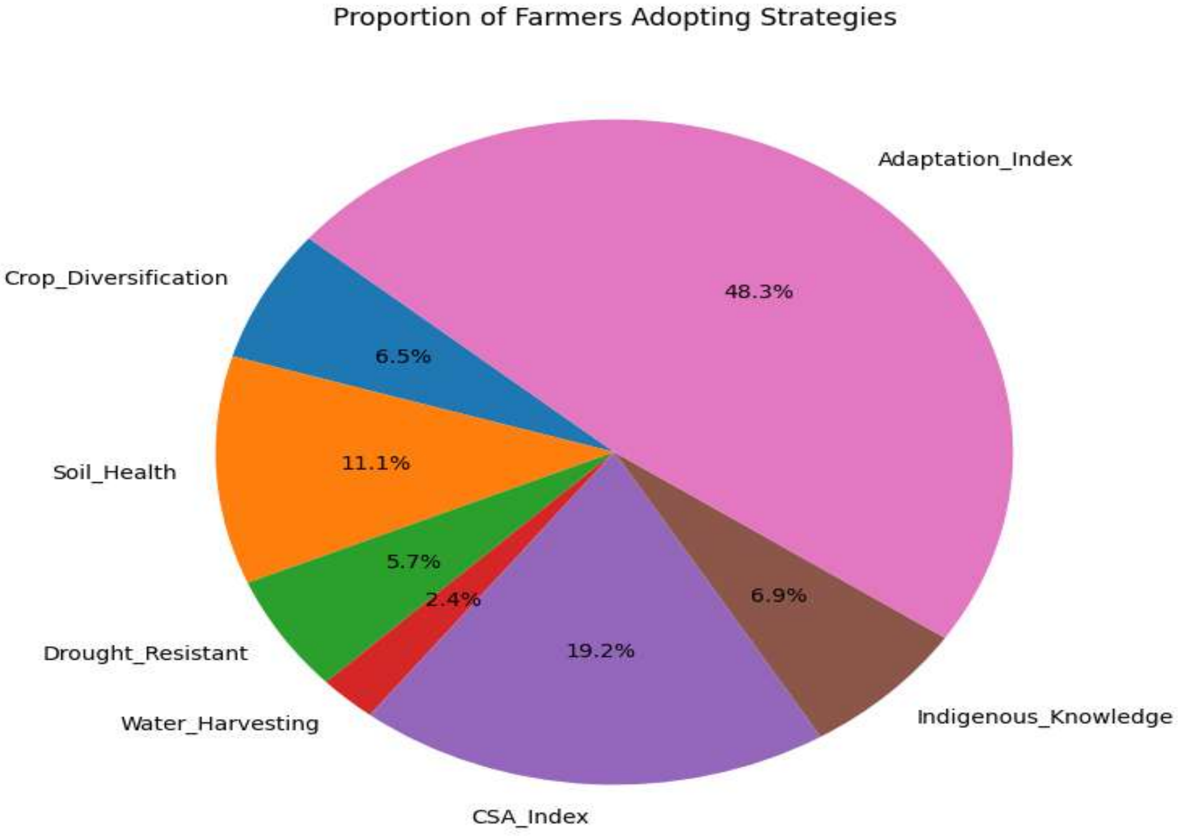

Figure 4: Percentage of farmers adoption strategies in the study area

4.6 Correlation heatmap of adoption strategies

The correlation heatmap provides valuable insights into the interrelationships among the different adaptation strategies adopted by farmers in Mandya district. One of the most notable findings is the strong positive correlation between the adoption of drought-resistant crops and the Climate-Smart Agriculture (CSA) Index ($r = 0.73$). This suggests that farmers who opt for pest- and drought-tolerant varieties are also more likely to adopt a broader suite of climate-smart practices, reflecting higher levels of awareness and access to technological interventions. Similarly, soil health practices, which include organic manure application, crop rotation, and fertility maintenance, also show a strong correlation with the CSA Index ($r = 0.59$). This highlights that farmers who prioritize soil management are equally inclined to embrace modern adaptation measures, underlining the critical role of soil quality in resilience-building.

Indigenous knowledge emerges as another important dimension of adaptation. A strong positive correlation was observed between Indigenous Knowledge and the Adaptation Index ($r = 0.60$), suggesting that traditional wisdom and local practices continue to be integral to farmer resilience. Interestingly, the correlation between Indigenous Knowledge and the CSA Index is weak ($r = 0.08$), which indicates that traditional strategies are often pursued independently of modern CSA interventions. This points to the existence of two parallel adaptation pathways: one rooted in tradition and the other in modern technological innovation. Farmers integrating both pathways are likely to achieve higher overall resilience, as reflected in the positive correlation of both Indigenous Knowledge and CSA Index with the Adaptation Index.

Moderate associations were also observed between other strategies, such as water harvesting and CSA adoption ($r = 0.58$), which suggests that water availability is a foundational element influencing broader adaptation behavior. Likewise, soil health practices showed a moderate correlation with the Adaptation Index ($r = 0.54$), highlighting their central role in enhancing overall resilience. However, crop diversification appeared to function differently. Its correlations with other strategies were weak or negative ($r < 0.2$), suggesting that diversification is often adopted independently, perhaps more as a market-oriented or risk-spreading strategy rather than a climate-specific adaptation measure. This interpretation is consistent with earlier chi-square results, which revealed no significant differences in crop diversification between channel and non-channel farmers.

Taken together, these results suggest that adaptation in Mandya district is shaped by two distinct yet complementary pathways. Technology-oriented strategies, represented by CSA practices such as drought-resistant varieties, soil management, and water harvesting, form one cluster. Tradition-oriented strategies, including indigenous knowledge and crop diversification, form another. Both pathways contribute significantly to the Adaptation Index, and their integration represents the strongest route toward climate resilience. These findings imply that a hybrid approach, combining CSA interventions with indigenous knowledge, could provide the most robust and context-specific solutions to climate challenges. For policymakers and extension agencies, this means that while the expansion of CSA practices is crucial, equal emphasis should be placed on preserving and integrating traditional knowledge systems to ensure inclusive and sustainable adaptation.

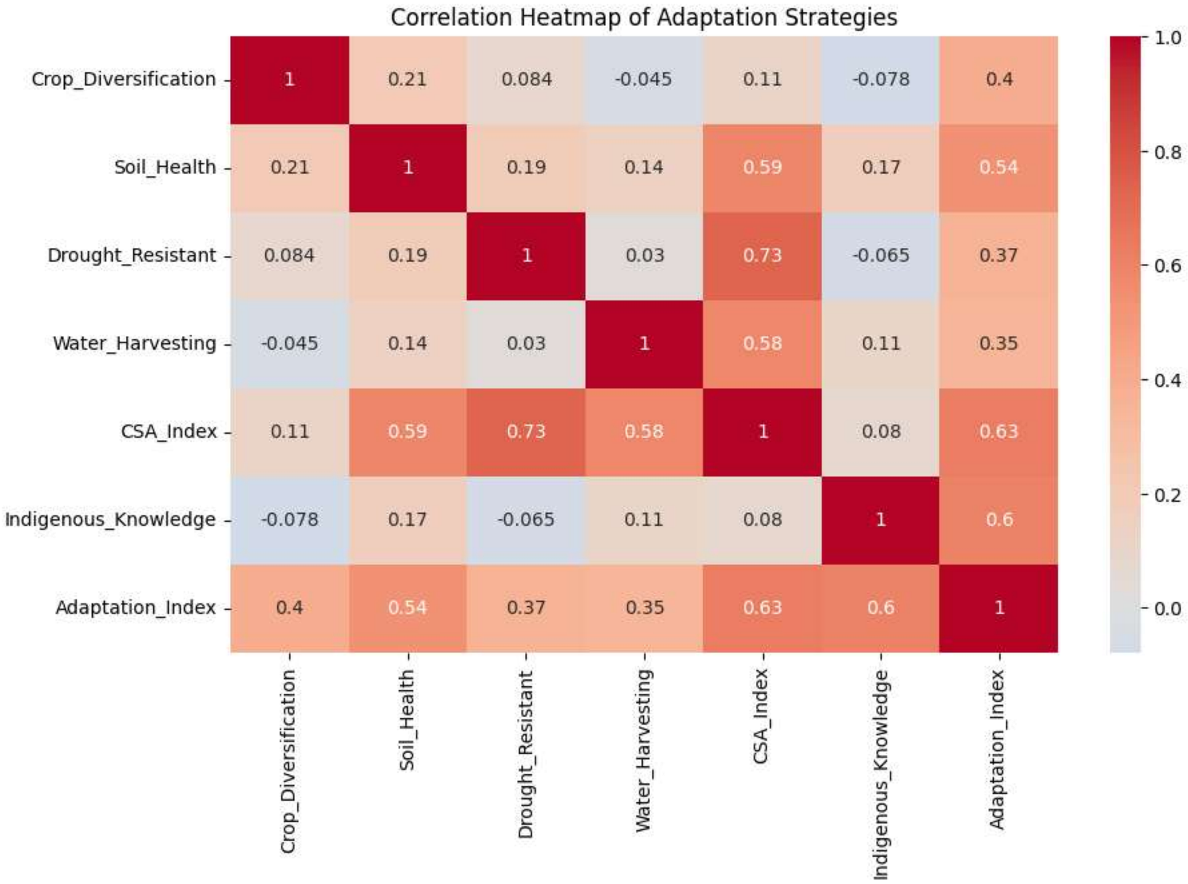

Figure 5: Correlation heatmap of farming adaptations strategies in the study area

4.7 Correlation and association analysis of adaptation index and CSA index

The chi-square test examining the relationship between crop diversification and irrigation access (channel versus non-channel areas) yielded a result of $\chi^2 = 0.0$ with a p-value of 1.0. This indicates that there is no association between a farmer's irrigation status and the adoption of crop diversification. In practical terms, both channel and non-channel farmers adopted crop diversification at the same rate. The independence of crop diversification from irrigation availability suggests that this strategy is perceived not merely as a water management response but rather as a broader risk mitigation approach. Farmers may be motivated by factors such as market price fluctuations, pest and disease variability, and climatic uncertainties, leading them to pursue diversification as a universal adaptation strategy regardless of irrigation access.

The t-test conducted to compare adaptation index values between channel and non-channel farmers produced non-computable results, with both the t-statistic and p-value returning as NaN. This outcome typically arises in cases where one group lacks variance (i.e., all farmers report identical values), when sample sizes are too small, or when uncleaned or missing data remain in the dataset. Consequently, the test could not statistically determine differences in adaptation index scores between the two groups. Although descriptive statistics and visualizations, such as boxplots, may suggest some variation between channel and non-channel farmers, the lack of sufficient statistical evidence prevents any conclusive claims. For meaningful comparisons, a larger and more balanced sample, along with thorough data cleaning, would be necessary.

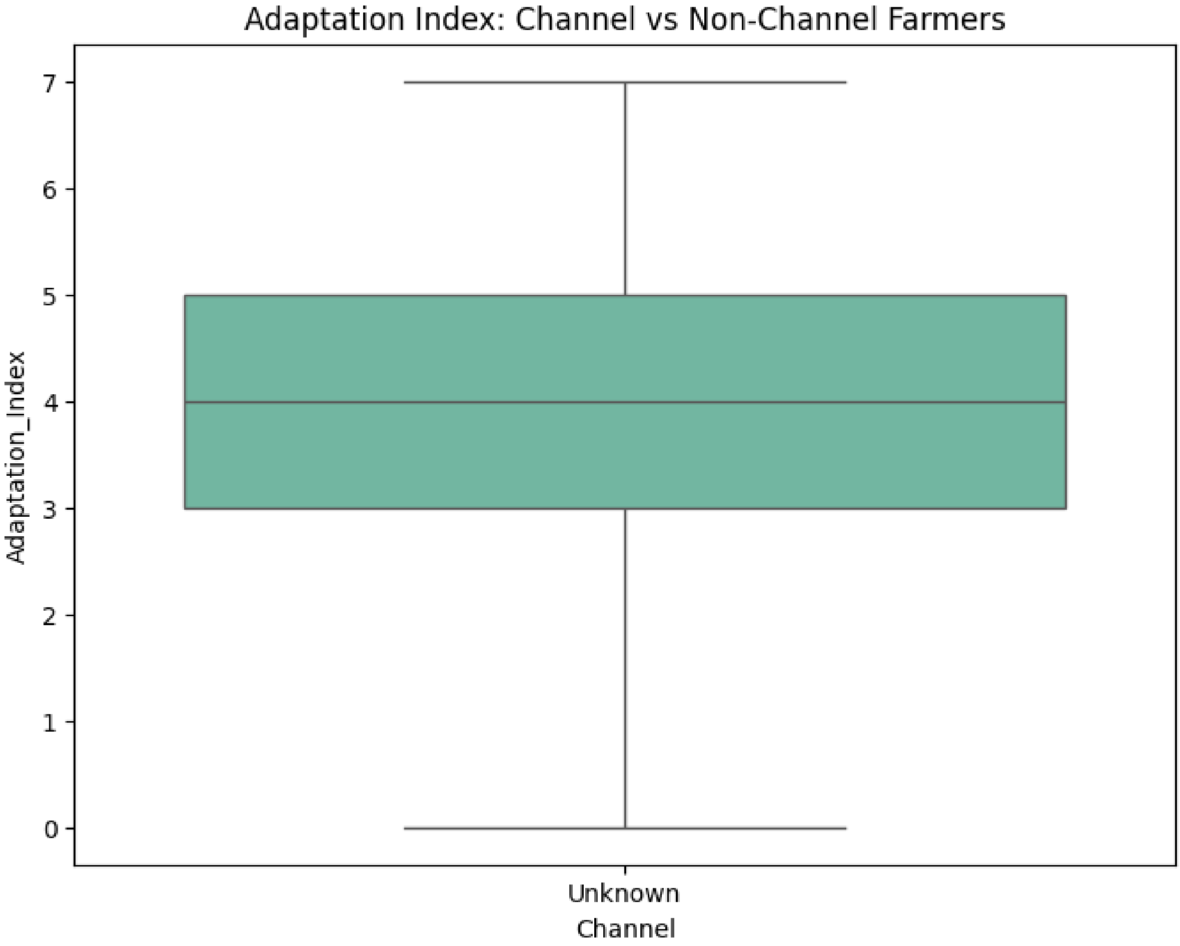

Figure 6: Adaptation index of channel and non-channel farmers in the study area

The analysis of the Adaptation Index through the boxplot reveals that farmers in the study region adopt a moderate number of climate adaptation strategies (Figure 6). The median value is approximately 4, suggesting that most farmers adopt between three and five adaptation strategies in response to climatic challenges. A few outliers were observed, representing farmers who either did not adopt any strategy or who adopted up to seven, indicating variability in the level of adaptation across the sample. This distribution highlights the diversity of farmer responses, where some are highly proactive while others remain limited in their engagement with adaptation measures. However, the grouping of farmers into Channel and Non-Channel categories could not be clearly distinguished in the dataset, as both appear merged under the label "Unknown." This limitation prevented a meaningful statistical comparison of adaptation intensity between irrigated and rainfed farmers.

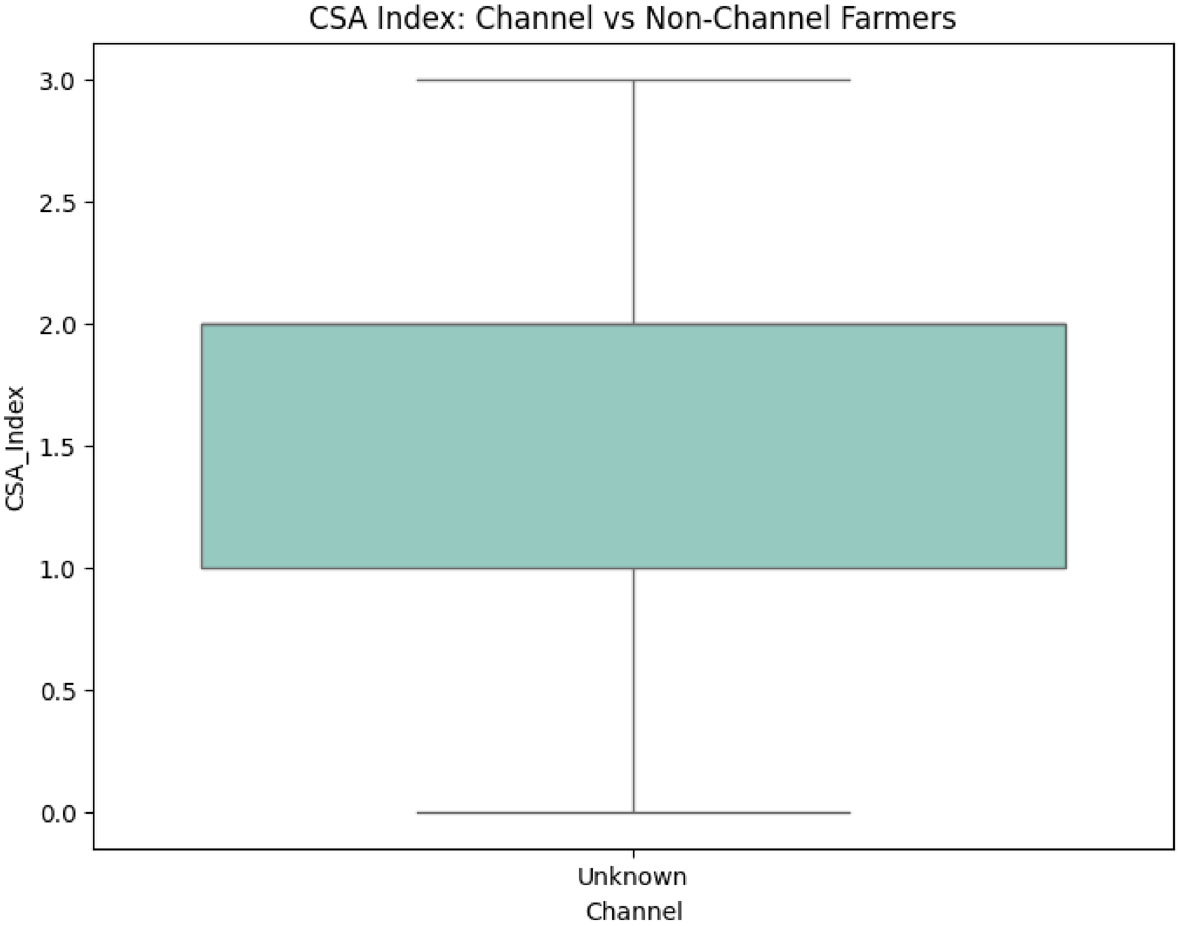

Figure 7: Adaptation index of channel and non-channel farmers in the study area

The CSA (Climate-Smart Agriculture) Index presents a similar trend, with the median adoption level around 2 (Figure 7). Most farmers engaged with one or two CSA practices, with only a few adopting three. This demonstrates that while farmers are aware of CSA practices, the overall level of adoption remains modest. Traditional strategies such as crop diversification and reliance on indigenous knowledge appear to dominate, while more advanced CSA methods are less frequently practiced. Similar to the Adaptation Index, the inability to distinguish between Channel and Non-Channel farmers limits the ability to test differences in CSA adoption patterns. This issue explains why statistical tests such as the t-test returned non-computable results, as the groups were either not properly separated or lacked sufficient variation.

Despite these limitations, the results provide important insights. Farmers are adapting to climate risks in a variety of ways, but their level of engagement remains moderate rather than extensive. The Adaptation Index values suggest that while there is awareness of climate risks, several farmers face barriers—such as lack of financial resources, technical knowledge, or institutional support—that constrain their ability to adopt a wider range of measures. The CSA Index values further emphasize the need for interventions that encourage the scaling up of advanced climate-smart practices, which remain underutilized.

While farmers across the study area are engaging in adaptation, the overall intensity of adaptation strategies and CSA practices suggests that there is considerable scope for improvement. Addressing barriers to adoption through policy support, subsidies, and improved agricultural extension services will be critical. Moreover, ensuring proper classification between irrigated (Channel) and rainfed (non-channel) farmers in future data collection will allow for more robust statistical testing and clearer insights into how irrigation access influences adaptation behaviours.

Distribution Analysis of Adaptation Index and CSA Index

The distribution plots of the Adaptation Index and the Climate-Smart Agriculture (CSA) Index provide valuable insights into how farmers in Mandya district are responding to climate change.

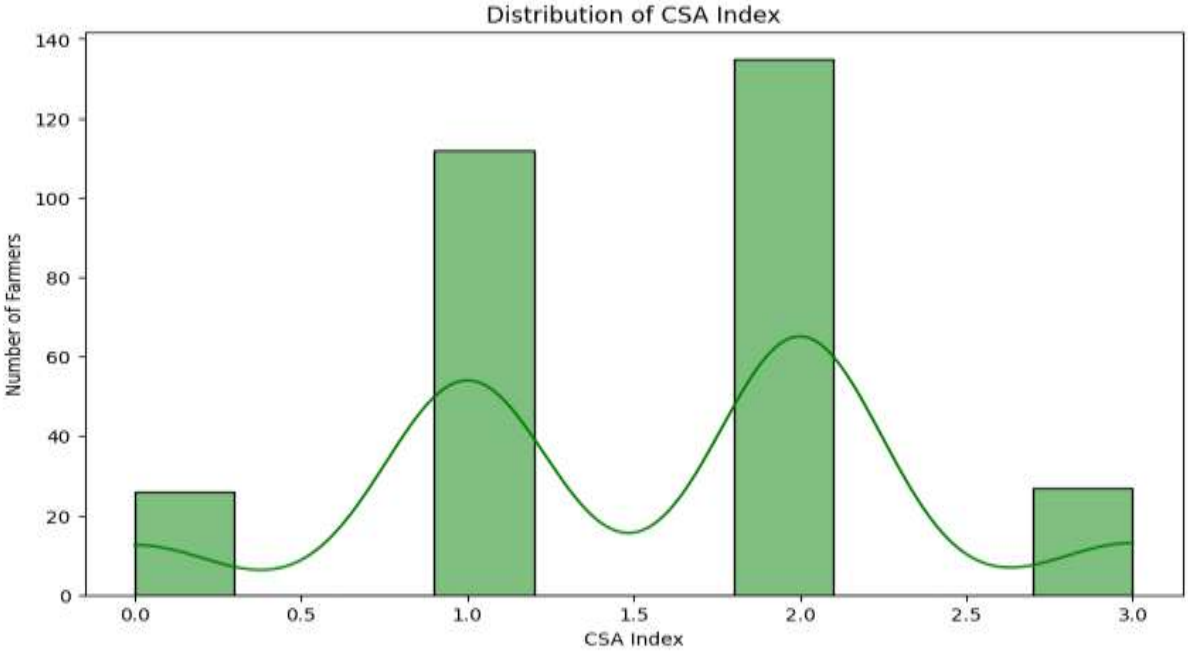

Figure 8: Distribution plots of the Adaptation Index in Mandya district

The Adaptation Index distribution shows that most farmers adopt between 3–5 adaptation strategies, with the highest concentration around 4 strategies. This indicates a moderate to high level of adaptive behavior across the farming community. A small proportion of farmers adopt either very few strategies (0–1) or the maximum possible (6–7). The presence of farmers with no or minimal adaptation highlights vulnerable groups who may lack awareness, resources, or access to extension services. On the other hand, the farmers adopting 6–7 strategies demonstrate a highly proactive response, possibly reflecting better resource access, education, or institutional support. Overall, the distribution suggests that adaptation is widespread but uneven, pointing to the need for targeted interventions for the least adaptive farmers.

The CSA Index distribution reveals a different trend. Most farmers adopt only 1–2 CSA practices, with peaks at these two points, while very few adopt all three available CSA practices. This shows that while CSA is being practiced, its adoption remains limited and fragmented compared to broader adaptation strategies. The fact that many farmers adopt at least one CSA practice suggests an awareness of climate-smart methods, but the relatively low uptake of multiple practices may reflect financial barriers, lack of technical knowledge, or institutional constraints. This also indicates that CSA practices are not yet mainstreamed at the same level as traditional adaptation measures. These results highlight a dual adaptation pattern: while general adaptation practices are relatively well-integrated into farming systems, CSA adoption is lagging and needs policy attention. Programs that increase awareness, subsidize CSA technologies, and strengthen agricultural extension could help bridge this gap. The contrasting distributions also suggest that while farmers are capable of adapting, the type and intensity of adaptation depend heavily on institutional support and access to resources. This finding underscores the importance of designing region-specific policies that not only promote broader adaptation but also scale up CSA adoption for long-term sustainability.

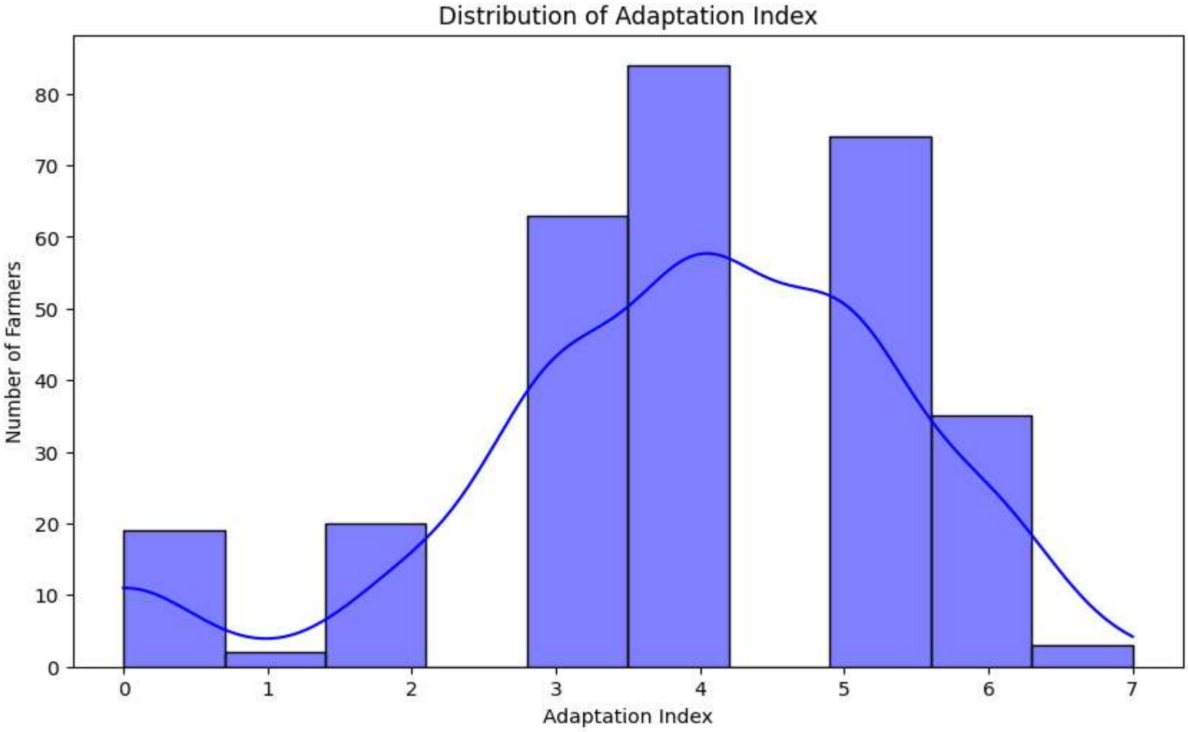

Figure 9: Distribution plots of the Adaptation Index in Mandya district

5. Conclusions

The findings of this study underscore the complex interplay between irrigation access, traditional knowledge, and modern agricultural practices in shaping climate adaptation strategies among farmers in Mandya district. While both channel and non-channel farmers demonstrate adaptive behaviors, the nature and extent of these adaptations differ significantly. The widespread adoption of soil health management and indigenous practices across both groups highlights the continued relevance of low-cost, locally suitable solutions in building climate resilience. However, the limited uptake of more structured interventions like water harvesting and drought-resistant varieties points to persistent barriers in resource availability and technical knowledge.

A particularly striking revelation is that irrigation access alone does not necessarily translate to superior adaptive capacity. The statistical analysis showed no significant difference in overall adaptation intensity between channel and non-channel farmers, challenging conventional assumptions about irrigation's role in climate resilience. This suggests that factors beyond water access - including knowledge dissemination, financial resources, and institutional support - play equally crucial roles in determining farmers' ability to adapt. The correlation patterns further reveal that farmers tend to adopt either traditional knowledge-based approaches or modern CSA practices, but rarely combine both effectively, indicating a missed opportunity for more robust, hybrid adaptation strategies.

The distribution of adaptation behaviors paints a concerning picture of vulnerability disparities within the farming community. While most farmers employ moderate adaptation measures, the existence of significant minorities at both extremes - those doing very little and those implementing comprehensive strategies - signals uneven access to adaptation resources and knowledge. This polarization of adaptive capacity could exacerbate existing inequalities in climate vulnerability across the district. The particularly low adoption rates of CSA practices, despite their demonstrated benefits, suggest systemic failures in agricultural extension and support systems that need urgent addressing.

These findings carry important implications for climate adaptation policy in semi-arid agricultural regions. First, they highlight the need for more nuanced support programs that recognize and build upon existing indigenous adaptation practices rather than replacing them. Second, they call for targeted interventions to overcome the specific barriers limiting CSA adoption, particularly among resource-poor farmers. Third, they suggest that irrigation infrastructure development alone is insufficient for climate resilience without parallel investments in knowledge transfer, credit access, and institutional support. Future adaptation efforts in Mandya and similar regions must therefore adopt integrated approaches that combine water management with broader capacity-building initiatives to create more equitable and effective climate resilience across all farming systems.

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