

The socio-economic impacts of climate variability on agricultural livelihoods: Perspectives from the past and present of agricultural communities

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ABSTRACT This study examines the impacts of climate variability on agricultural livelihoods in Rambewa, Anuradhapura District, Sri Lanka, where paddies, cereals, vegetables, and fruits form a critical economic base. A mixed-methods design integrated climatic data analysis with a questionnaire survey of 100 farmers and 15 in-depth interviews conducted from March to July 2023. Quantitative data were analysed using the Kruskal-Wallis H and Mann-Whitney U tests, with Holt's Relative Importance Index applied to rank perceived impacts. Annual Rainfall Anomaly Index calculations revealed pronounced inter-annual variability, with negative anomalies corresponding to drought years and positive anomalies to flood events. Qualitative insights, including oral histories, were thematically analysed using Braun and Clarke's framework. Farmers' recognition of climate shifts was primarily experiential, with impacts differing by farming type. The findings highlight the importance of integrating indigenous ecological knowledge with climate-smart practices to strengthen agricultural extension services, improve water management, and enhance resilience to future climatic uncertainties.

KEY WORDS agricultural livelihood – Anuradhapura – climate variability – drought – flood – indigenous knowledge

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1. Introduction

Climate variability has serious impacts on agricultural families in South Asia, particularly in Sri Lanka, where agriculture is the backbone of its economy and livelihood. An important staple crop in Sri Lanka, paddy agriculture is particularly vulnerable to climate variability. Higher temperatures and erratic rainfall patterns have led to both decreased yield and increased crop failure. Studies have argued that climate conditions of expected temperature increase of 1.0 °C and warming trends of 0.02–0.03 °C/year look to be common within the next 30 years and also negatively impact paddy growth (Wimalasiri et al. 2022).

Variability of rainfall during critical growth periods magnifies the impact of climate variability and has led to crop failure, which is even higher in rainfed areas (Chandrasiri et al. 2023). Smallholder farmers dominate agricultural production in Sri Lanka; they face a sizable challenge with climate variability. Since smallholder farmers often have limited access to resources, education and technology, they find it difficult to adapt to changes. Limited adaptation has occurred – such as the adoption of drought-tolerant crop varieties and adjusted sowing times – but farmers continue to face significant obstacles, including the cost of changes and limited access to information on those changes (Menike, Arachchi 2016; Herath, Thirumarpan 2017; Gunathilaka, Samarakoon 2022). Climate variability steadfastly creates socio-economic losses for agricultural families. Loss of yield and crop failure leads to loss of income, and food security issues are heightened. The impact of climate variability on paddy cultivation in Sri Lanka, highlighting that increased rainfall positively affects paddy production during the Maha season, though this benefit is not uniformly distributed. Conversely, rising temperatures negatively impact paddy yields (Dananjaya, Shantha, Patabend 2022).

Farmers adapt in numerous ways: planting short-duration crops, using climate-resilient seeds, and managing their water resources more effectively. However, limitations such as finances and access to information frequently hinder these adaptations. Educational programming and access to climate data are crucial for facilitating adaptability (Menike, Arachchi 2016; Herath, Thirumarpan 2017; Gunathilaka, Samarakoon 2022). To address these challenges, comprehensive policy approaches are necessary, which include strengthening agriculture extension services and promoting climate-smart agriculture and insurance programs. Vulnerability mapping can facilitate targeted interventions to ensure support for those areas that are impacted the most (Niranjan et al. 2015; Scognamillo et al. 2022; Amarnath et al. 2023). Climate variability is a significant issue for the agricultural sector of Sri Lanka, particularly with regard to paddy farming and smallholder farmers. Therefore, comprehensive, clearly defined educational, resource, and policy interventions are needed to respond to or adapt to increased climate variability and enhance farmer resilience as well as food security.

The area cultivated for paddy is around 34,000 ha during the Maha season¹. The area cultivated for supplementary food crops is around 10,000 ha during the Maha season and around 6,000 ha during the Yala season. This area can be considered as one of the leading areas for maize, black gram, sesame, big onion, soya bean and chilly cultivation in Sri Lanka.

Climate variability is a serious threat to agricultural livelihoods due to changes in rainfall patterns, temperature fluctuations, droughts, and flooding events in Rambewa, which is situated in Anuradhapura district, Sri Lanka. In the study area, agricultural households have faced the impacts of climate variability, including reduced crop yield, food insecurity, and economic uncertainty. The research and literature to support these adaptation efforts remains limited, especially on the impacts of climate variability and adaptation efficacy on agricultural-based livelihoods in the area. As farming and agriculture are essential to the livelihoods in this locality, not addressing this knowledge gap limits targeted interventions as support for farmers to adapt. Although previous research suggested traditional knowledge and agrometeorological advisories as adaptation strategies, there are limited research studies that apply these strategies to localize them to agricultural practices in Rambewa.

This study illustrated the need for additional research on the practicality and efficacy of combining traditional farming practices with modern climate-resilient practices, especially in terms of being located in the Rambewa area. Various studies have identified changes in rainfall patterns in the Anuradhapura District (Jayawardene, Sonnadara, Jayewardene 2015; Ekanayake, Amaratunga 2017; Wijesinghe, Jayawardena, Sonnadara 2020) but relatively little has been known about how rainfall patterns directly affect the crop yield and food security within this context – in Rambewa. For example, analyses using the Standardized Precipitation Index (SPI) have revealed distinct variability patterns across selected regions in Anuradhapura. However, existing research has generally focused on regional-scale rainfall variability without assessing its localised impacts on agricultural yields, food security, and farming practices in Rambewa (Marambe et al. 2015).

The present study addresses this gap by systematically examining the effects of climate variability on agricultural livelihoods in Rambewa, integrating meteorological data, farmer surveys, and indigenous ecological knowledge. In particular,

¹ Maha season: The agricultural cultivation season from September to March linked to the Northeast monsoon, with more continuous and abundant rainfall, supporting major crop cultivation, especially rice) and around 24,000 ha during the Yala season.

Yala season: The agricultural cultivation season in Sri Lanka from May to August associated with the Southwest monsoon, characterized by shorter and less abundant rainfall, supporting minor crop cultivation (Department of Census and Statistics, Sri Lanka, 2023).

the research examines the effects of climate variability, looks at impacts from droughts and floods, and considers the perception of effectiveness of adaptation strategies of agricultural households. Ultimately while quantitative data are used with qualitative understanding, the research is intended to inform for specific adaptation planning in the area, as it assesses the overall impacts of climate.

We test in our study following hypotheses:

- H₀₁: There is no significant difference in the consequences of climate variability among agricultural households.
- H₁₁: There is a significant difference in the consequences of climate variability among agricultural households.
- H₀₂: There are no differences in the impacts for each of the consequences in the drought season compared to the flood season.
- H₁₂: There are statistically significant differences in the consequences in the drought season compared to the flood season.
- H₀₃: There is no significant difference in farmers' perceptions of the effectiveness of different adaptation strategies.
- H₁₃: There is a significant difference in farmers' perceptions of the effectiveness of different adaptation strategies.

2. Materials and methods

Anuradhapura District consists of six agroecological regions where climate change is strongly felt through rainfall variations. The district is known for its tank-based irrigated agriculture systems, especially with minor rainfed tanks at village levels that render agriculture heavily dependent on seasonal rainfall. Since April is the only rainy month in the Yala season, rainfed cultivation is not possible during the Yala season. However, as the capacity of some of the major tanks in these areas is augmented with the diversion of the Mahaweli River, irrigated agriculture under major tanks has built resilience to climate change. In mid-May, pre-monsoon disturbances from the Bay of Bengal can lead to flooding along either side of the major rivers. Rambewa Divisional Secretariat is located in the Anuradhapura District of the North Central Province of Sri Lanka (Department of Census and Statistics, Sri Lanka 2023; Fig. 1). It serves as an administrative section and is considered a local governance section of rural region (Bandara, Sanjeevani 2020). The area consists of agricultural undertakings highly reliant on the influence of monsoonal rainfall patterns typical of Sri Lanka's dry zone (Jayasinghe, Wickramasinghe, Herath 2019). The Rambewa area includes several Grama Niladhari divisions that support else local agricultural production and rural livelihoods (De Silva 2018). Local climate and soil type and water resource availability heavily influence agricultural research, integrating traditional and modern farming practices for

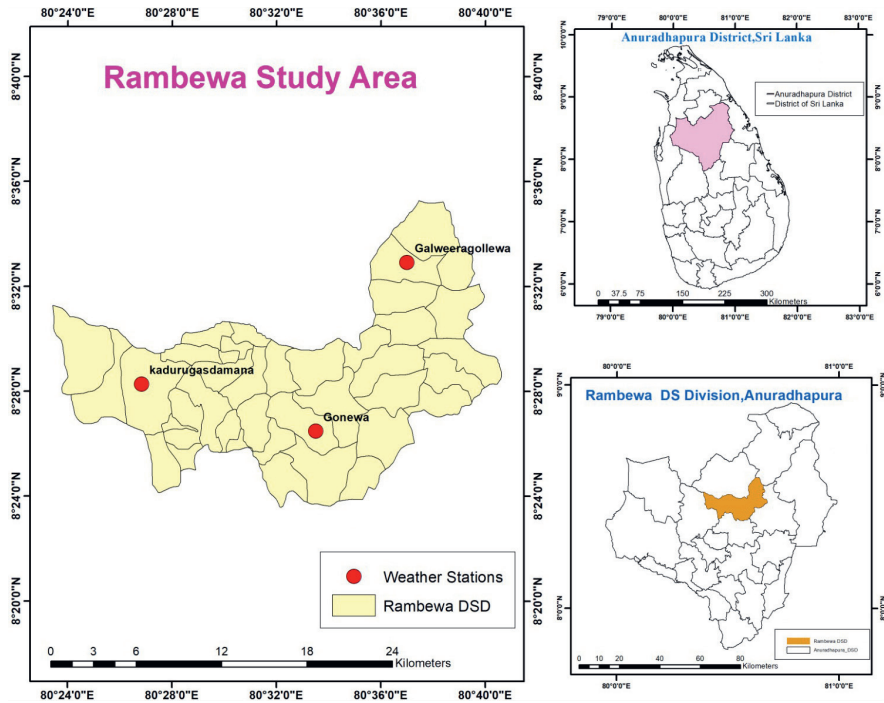


Fig. 1 – Study area: Rambewa Divisional Secretariat Division. Source: Compiled by author, 2025.

climate resilience. The Rambewa Divisional Secretariat (DS) division is located at approximately latitude 8.47°N and longitude 80.58°E . The soil in Rambewa mainly consists of alluvial soils along the Kanadara Oya and predominantly Aluthwewa Series in gentle undulations. Water resource availability includes part of the Anuradhapura North Water Supply Scheme, which provides safe drinking water to the area through facilities such as water treatment plants, reservoirs, and elevated water towers sourced mainly from the Nuwarawewa reservoir system (Fernando, Karunaratne 2021). Due to climate change, flooding has become more intense and frequent in recent years. Interviews were conducted in Rambewa due to the increasing trend of carbon emissions. Between 2001–2023, as a result of tree cover loss in Rambewa, an average of 14.8 kt per year was released into the atmosphere. In total, 340 kt of CO_2 was emitted during this period. Furthermore, in 2010, Rambewa had 7.01 kha of tree cover extending over 26 of its land areas. In 2023, it lost 91 hectares of tree cover, equivalent to 21.1 kilotons of CO_2 emissions (www.globalforestwatch.org, 2024). Due to climate change, flooding has become more intense and frequent in recent years. Interviews were conducted in Rambewa due to the increasing trend of carbon emissions. Between 2001–2024, as

a result of tree cover loss (1.69 kha) in Rambewa, an average of carbon emissions 14.8 kt per year was released into the atmosphere. In total, 380 kt of CO₂ was emitted during this period (www.globalforestwatch.org, 2024).

This research surveyed a total of 100 individual respondents (50 males, 50 females) from agricultural households. Participants' ages ranged from 18 to 72 years (mean age: 44.3 years; standard deviation: 11.2 years), with 28% aged 18–30 years, 47% aged 31–50 years, and 25% aged above 50 years. Respondents were chosen through purposive and snowball sampling, both of which are well-established sampling strategies for qualitative and mixed-method studies to identify information-rich participants (Palinkas et al. 2015; Naderifar, Goli, Ghaljaie 2017). Purposive sampling allowed for the recruitment of participants who had significant experience in agriculture, and knowledge of climate variability. In contrast, snowball sampling facilitated reaching participants possessing specialized indigenous ecological knowledge through referrals within the community.

Both primary and secondary data were utilised to ensure a robust analytical foundation. Data were collected using semi-structured interviews and surveys from March to July 2023, focusing on participants' understanding of climate variability, its impacts on livelihood, and the importance of indigenous knowledge for adaptation. Oral histories were used to reflect on community memory of environmental change over the longer haul.

This study used a mixed methods approach to integrate quantitative and qualitative methodologies. We used the Kruskal–Wallis H test (Kruskal, Wallis 1952) and the Mann–Whitney U test (Mann, Whitney 1947) to understand differences among demographic groups in the quantitative data. It was based on Holt's (2014) Relative Importance Index (RII) for ranking perceived impacts of climate variability. We used Braun and Clarke's (2006) descriptive and thematic framework to analyse the qualitative data including oral histories. This combination of analytical tools allowed for a comprehensive examination of the relationship between climate variability and indigenous ecological knowledge.

2.1. The Kruskal-Wallis method

All the data are pooled and ranked from smallest (1) to largest (5), then the sums of ranks in each subgroup are added up, and the probability is calculated.

Given k independent samples with sizes n_1, n_2, \dots, n_k , total $N = \sum n_i$, and rank sums R_i for each group, the Kruskal-Wallis test statistic H is calculated as:

$$H = (12 / (N(N + 1))) \times \sum (R_i^2 / n_i) - 3(N + 1) \quad (\text{Equation 1})$$

where: R_i = sum of ranks for the i -th group; n_i = sample size of the i -th group; N = total sample size across all groups ($N = n_1 + n_2 + \dots + n_k$).

Under the null hypothesis, H approximately follows a chi-square distribution with $k - 1$ degrees of freedom.

The value of H is tested against the chi-square distribution for $k - 1$ degrees of freedom, where k is the number of groups. If there are tied ranks a correction is used but makes very little difference. A p-value can also be calculated based on the H statistic and compared to the significance level (e.g., 0.05).

Reject H_0 : $H \geq$ critical value.

Accept H_0 : $H <$ critical value.

2.2. Mann-Whitney U test

Given two independent samples $X = \{x_1, x_2, \dots, x_{n_1}\}$ and $Y = \{y_1, y_2, \dots, y_{n_2}\}$, the Mann-Whitney U statistic is calculated as:

$$\begin{aligned} U_1 &= n_1 n_2 + n_1 (n_1 + 1) / 2 - R_1 \\ U_2 &= n_1 n_2 + n_2 (n_2 + 1) / 2 - R_2 \end{aligned} \quad (\text{Equation 2})$$

where: n_1 and n_2 are the sample sizes of groups 1 and 2; R_1 is the sum of the ranks for sample 1; R_2 is the sum of the ranks for sample 2. The smaller of U_1 and U_2 is used as the test statistic U .

2.3. Relative Importance Index (RII)

This index helps to determine the relative importance of different factors or indicators based on survey responses or other data.

$$RII = \Sigma w / (A \times N) \quad (\text{Equation 3})$$

w (Weight): This shows the importance rating each factor received from survey participants through a Likert scale ranging from 1 to 5.

X (Frequency): The X metric shows how frequently respondents chose a particular weight (w).

A (Highest weight): The scale's maximum weight value is represented in this parameter (e.g., maximum value of 5 in a 5-point Likert scale).

N (Total respondents): The count of participants who took part in the survey or data collection is represented by this number.

Σ (Sigma): The symbol represents the total value of all numbers enclosed by parentheses.

Source: Roy (2020)

Table 1 – Rainfall categories based on RAI values

RAI category	RAI range
Extreme Humid	Above 4
Very Humid	2 to 4
Humid	0 to 2
Dry	-2 to 0
Very Dry	-4 to -2
Extremely Dry	Below -4

Source: Costa, Rodrigues 2017

2.4. Rainfall Anomaly Index (RAI)

Annual RAI was calculated using the “Precintcon” package in the R programme for daily rainfall data from 1993 to 2023. Equations 4 and 5 calculated positive and negative rainfall anomalies for seven rainfall stations covered by the study area.

$$RAI (Positive) = 3 (N - \bar{N}) / (\bar{M} - \bar{N}) \quad (Equation 4)$$

$$RAI (Negative) = -3 (N - \bar{N}) / (\bar{X} - \bar{N}) \quad (Equation 5)$$

where: N = present rainfall (monthly/seasonal/yearly) current monthly/seasonal/yearly rainfall, in order words, of the month/seasonal/year when RAI will be generated (mm); \bar{N} = monthly/seasonal/yearly average rainfall of the historical series (mm); \bar{M} = average of the ten highest monthly/seasonal/yearly precipitations of the historical series (mm); \bar{X} = average of the ten lowest monthly/seasonal/yearly precipitations of the historical series (mm); and positive RAI have their values above average, and negative RAI have their values below (Costa, Rodrigues 2017). The values of RAI have categorized six regimes (Table 1).

3. Results

3.1. Rainfall patterns

The Rainfall Anomaly Index (RAI) data for the area of interest demonstrate a considerable amount of variability over time in rainfall activity. The analysis of the RAI at three contributory stations (Galweeragollewa, Gonewa, and Kadurugasdamana) in the Rambewa DS division demonstrate the variability of precipitation in this area and the effect of extreme weather patterns on the rainfall amounts in the area (Table 2).

Positive rainfall anomalies occurred in the periods 2009–2012 and 2014–2015, particularly in the very humid years (RAI > 2) of 2011 and 2014. Negative anomalies

Table 2 – Characteristics of meteorological stations

Location	Latitude (°N)	Longitude (°E)	Elevation (m)	Period of measurement
Galweeragollewa (Station 82)	8.54	80.63	106	1993–2023
Gonewa (Station 71)	8.45	80.54	106	
Kadurugasdamana (Station 70)	8.45	80.45	80	

Source: Compiled by author, 2025

occurred in the two depressed periods of rainfall, 1995–2003 and 2016–2020. It should be emphasized that Galweeragollewa is subject to large deviations from normal (Fig. 2). Gonewa demonstrates alternating periods of positive and negative anomalies (Fig. 3).

Most notably, this station experienced a significant number of negative anomalies during 1994–1998 and 2016–2020, reflecting the extent of dry to very dry conditions (RAI between -2 and -4) and, in some years, approaching extremely dry conditions (RAI below -4). Particularly dry years included 1995 and 2016, both classified as dry to very dry (RAI < -1.5). In contrast, positive anomalies occurred during 2009–2012 and 2014–2015, with this station recording the greatest positive anomalies among all stations in the period assessed. The very humid years of 2011 and 2014 (RAI between 2 and 4) were especially notable. Gonewa also exhibited considerable sustained variability around the baseline of cumulative anomaly, fluctuating between extremes of positive and negative anomalies.

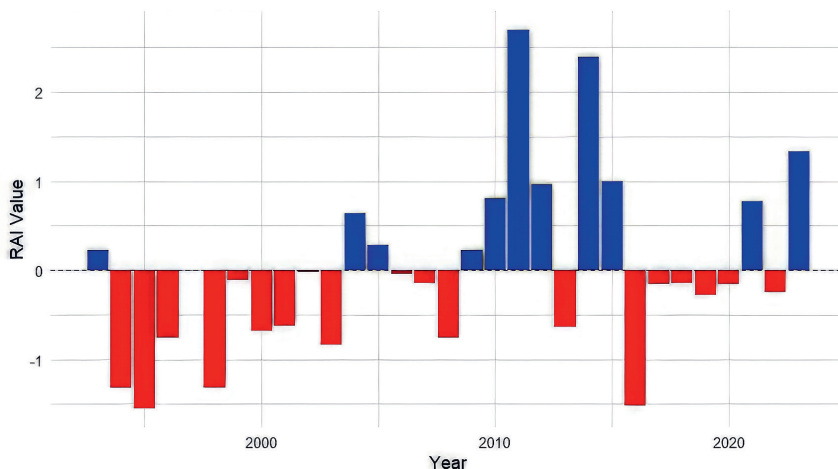


Fig. 2 – Rainfall anomalies in Galweeragollewa, Rambewa DS division (station no. 82). Source: Compiled by author using RAI in R software, 2025.

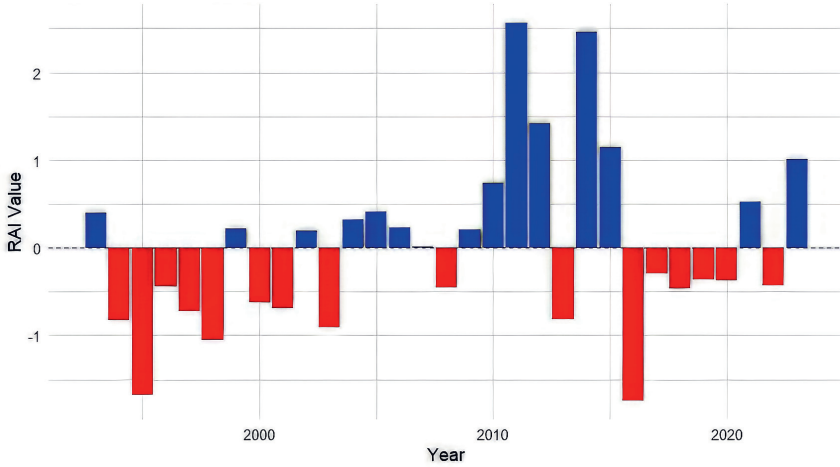


Fig. 3 – Rainfall anomalies in Gonewa, Rambewa DS division (station no. 71), Source: Compiled by author using RAI in R software, 2025.

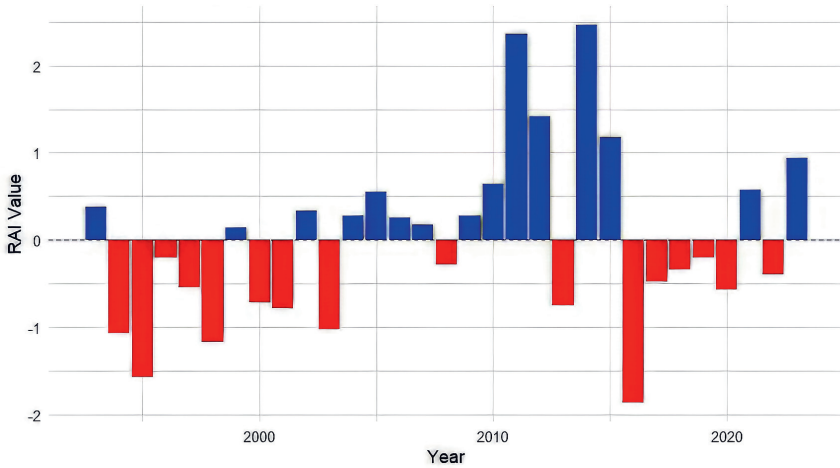


Fig. 4 – Rainfall anomalies in Kadurugasdamana, Rambewa DS division (station no. 70). Source: Compiled by author using RAI in R software, 2025.

Compared to the other stations, Kadurugasdamana exhibits moderate deviations for both positive and negative annual rainfall anomalies (Fig. 4).

Very humid anomalies (RAI between 2 and 4) occurred in 2011 and 2014. Conversely, a negative anomaly approaching very dry conditions (RAI < -1.5) was recorded in 2016, reflecting below-average rainfall. Overall, Kadurugasdamana

displayed a more moderated trend throughout the assessed period, with balanced anomalies and fewer extreme deviations compared to other two stations.

The long-term patterns of alternating positive and negative anomalies demonstrate variations between wet and dry periods. The years of negative anomalies represent major drought years; for example, 1995, 2003, 2013, 2016, and 2022. These years saw moderate departures from average rainfall (below average), which coincided with lower water availability for many local agricultural enterprises. On the contrary, positive anomalies indicate rain falling during periods of flooding or excessive rainfall, which are also recorded during years that are affected by flood events (2011, 2014, and 2023). The positive anomalies may correspond with low rainfall as well, which may question the intensity and frequency of these extreme conditions relative to climatic variability.

The RAI figures at these stations (in the Rambewa a DS division) frequently demonstrate similar trajectories. That said, geographic proximity, regional climate patterns, and annual variability all contribute to such correlations. The figures do indicate, however, an increasing trend in the frequency of negative anomalies in recent years, indicating a shift to drier or drought years for either climate change reasons or regional phenomena we would not be aware of and formally consider. The long-term drivers of rainfall anomaly, whether positive or negative, would provide insight into the ability to predict or forecast events which can and do affect the region.

The long-term patterns of rainfall anomalies provide crucial insights into climate variability in the region. Understanding these patterns is essential to interpreting the influence of agricultural livelihoods and improving agricultural, water resource and disaster risk reduction practices. The variations identified suggest a need to adapt to the influence of extreme variability in rainfall, which could threaten the long-term establishment of localities.

3.2. Awareness of climate variabilities and their impacts on agricultural livelihood

The study conducted in the area revealed a high level of awareness for climate variability. According to the findings, 96.5% of the respondents reported that they were aware of changes in climatic conditions. From observation and experience, many agricultural families in the study area perceive climate variability, and they can build their adaptive capacity on this foundation to help them cope with climate fluctuations. When considering how the respondents had gained knowledge of climate variability, most of the respondents have gained awareness. In particular, 70% noted that they learned about drought from their experiences, identifying the capacity of experience-based learning as a local understanding and response to climate stress. In addition, the 20% who learned of drought at school indicates the

role of formal education in climate literacy. A smaller proportion of farmers in the area became aware of drought through either traditional learning or the Internet, and these two categories of respondents together represented less than 10% of the responses. However, farmers are directly dependent on natural conditions, so they rely heavily upon their observations and previous experiences of extreme weather events to anticipate and prepare for droughts and floods. However, some respondents said that rainfall patterns have changed and cannot be predicted as previously. Overall, these findings reveal the importance of experience-based learning processes to climate adaptation in agricultural families.

The Kruskal-Wallis test was conducted to determine whether the consequences of climate variability significantly differ based on farming type (Table 3). The results indicate that some consequences exhibit statistically significant differences, while others do not.

From the factors examined, yield decline ($p = 0.035$), delay in harvesting ($p = 0.024$), disease and pest damage ($p = 0.018$), delay in planting crops ($p = 0.025$), decline in harvest quality ($p = 0.016$), drying up of water sources ($p = 0.004$), dryness around ($p = 0.047$), loss of livestock ($p = 0.004$), food prices ($p = 0.002$) and impact on livelihoods ($p = 0.002$) were significant ($p < 0.05$). Moreover, this indicates that the impacts of climate variability are very much different by types of farming. That said, different farming sectors are feeling these. This suggests that these consequences of climate variability significantly differ among farming types. In other words, different farming groups experience these impacts to varying extents, possibly due to differences in location, farming practices, resource availability, or crop and livestock dependency.

Table 3 – Consequences of climate variability on agriculture families

Consequence variables	Farming type (p-value)
Increase food prices	0.002
Impact on livelihoods	0.002
Drying up of water sources	0.004
Loss of livestock	0.004
Decline in harvest quality	0.016
Disease and pest damage	0.018
Delay in harvesting	0.024
Delay in planting crops	0.025
Yield decline	0.035
Dryness around	0.047
Poor health/malnutrition of people	0.118
Poor health of livestock	0.194
Declining the prices of livestock	0.393

However, people's poor health/malnutrition ($p = 0.118$), livestock poor health ($p = 0.194$), and livestock declining prices ($p = 0.393$) were not significantly different between farming types. These findings suggest that the factors are more uniformly experienced by different farmer typologies, indicating that climate variability affects them in a broader way rather than being contingent upon specific farming contexts.

In particular, the results show how, overall, some effects of climate variability vary by the type of farming requiring attention to farmers' adaptation in this sense, especially vegetables and cereal crops, compared to paddy crops. Other effects seem to hit all farmers equally. The notable dissimilarities indicate that group-specific risk factors need to be considered when designing targeted interventions and adaptive approaches, especially with respect to water availability, yield reductions, livestock welfare and economic consequences. On the other hand, for the impacts that do not have large differences, larger, more universal policy measures may be needed to address the overall impact of climate variability on agricultural households.

The results revealed the impact of drought and flooding on various socio-economic and psychological consequences (Table 4). Therefore, the following hypotheses are proposed and tested:

(H₀₂): There were no differences in impact for each of the consequences in drought season compared to flood season.

(H₁₂): There will be statistically significant differences in the consequences in drought season compared to flood season.

The consequences are compared based on Likert-scale ratings of residential households during drought and flood seasons. The p-values provide significance

Table 4 – Impact of drought and flooding on various socio-economic and psychological consequences

Impact	Drought seasons (p-values)	Flood seasons (p-values)
Threatened household food security	0.037	0.036
Food shortages	0.000	0.041
Nutrient deficiencies	0.068	0.088
Health problems	0.074	0.042
Unemployment	0.000	0.000
Household income decreased	0.000	0.067
Reduced spending on festivals	0.023	0.050
Migration	0.012	0.083
Children's school trips were affected	0.000	0.000
Feelings of hopelessness	0.000	0.000
Conflicts over water in society	0.016	0.125
Farmers commit to suicide	0.043	0.078

values to determine whether there is a statistically significant difference between the two climatic conditions.

Concerning food security and nutritional conditions, threats to household food security are substantial in both drought ($p = 0.037$) and floods ($p = 0.036$), showing that extreme climate events affect food availability in any condition. Food shortages are, however, substantially different in both conditions ($p = 0.000$ in drought, $p = 0.041$ in floods), suggesting that drought conditions have a more immediate and severe consequence on food availability than floods. Both nutrient shortages ($p = 0.068$ in drought, $p = 0.088$ in flooding) and health ($p = 0.074$ in drought, $p = 0.042$ in flooding) are not statistically significant, suggesting that the nutritional and health conditions could be equally experienced during these climate events.

Economic impacts, which include unemployment ($p = 0.000$ for both drought and floods) and decreases in household income ($p = 0.000$ during drought and $p = 0.067$ during floods), are all significantly impacted by climate occurrences. This infers that financial strain is likely a prominent outcome of these events, regardless of what specific climate is identified. Likewise, it is inferred that reductions in household income are likely to be more related to droughts than floods. Reductions in expenditures on festivals ($p = 0.023$ for drought, $p = 0.050$ for floods) show that the extreme events led to limitations in disposable income, thereby restricting the spending of discretionary income. Social and mobility effects can be identified through migration, which is the only indicator of significant impact during drought ($p = 0.012$). However, again, the impact during floods is not as significant ($p = 0.083$). It can be inferred with confidence that migration patterns related to climate events may have more effects when related to drought than to temporary displacement in floods. The impacts on school trips also demonstrate that changes in climate events lead to disruptions in children's educational and extracurricular activities ($p = 0.000$ for both events).

The droughts and flood events impact the psychological and social stability of the residents. The sense of hopelessness ($p = 0.000$ for both drought and floods) suggests that psychological distress is an important consequence of climate variability, no matter the time of year. The same can be said for conflicts over water resources ($p = 0.016$ during drought, $p = 0.125$ during floods). However, these conflicts are more significant with droughts, illustrating that water scarcity increases social tensions. There are several extreme outcomes, such as farmer suicides ($p = 0.043$ during drought, $p = 0.078$ during floods), which are significant, with drought being even more significant, because these consequences refer to extreme financial distress and psychological stress in farming communities from prolonged water shortages and failed harvests.

The results show that drought and floods pose significant impacts on household food security, economic stability and psychological well-being. At the same time,

drought appears to have a far stronger impact on food shortages, migration, water conflicts, and farmer suicides. Floods still have significant impacts, especially on economic well-being and health. Policymakers and disaster relief agencies should act on tailored interventions that address the vulnerabilities that flood vs drought are presenting.

3.3. Assessing current knowledge of potential strategies to mitigate drought

In the study area, drought has a common impact on agriculture, affecting agricultural families and their day-to-day lives. Therefore, they have taken some mitigation and adaptation strategies to overcome the drought impacts (Table 5). The following table illustrates how they rank mitigation and adaptation measures according to the importance of the strategy.

Farmers have displayed proactivity towards drought conditions while employing activities such as water conservation and water use-efficient practices. Water conservation was the adaptation strategy most frequently used to cope with drought with a (RII) of 0.9813. Immediately after water conservation, the second-highest rank is presented upon multi-cropping (crop rotation) with a high relative importance index of 0.9750. It reflects that farmers will diversify crops to conserve soil fertility and, hence, in the long run, reduce their vulnerability to drought and water shortage. Other very important strategies also include proper management of irrigation and canals (0.9500), which ranks high. This indicates that the farmers are willing to recognize the need for water management, especially for the sustainability of crops.

On the other hand, the conservation of forest areas (0.7813) and limiting groundwater use (0.76) are ranked as moderately important and lower than water conservation techniques. Proper control of animal husbandry ranks lowest with an index of 0.7125, indicating that animal husbandry is relevant but implicitly given the least importance when compared to other water-conservation methods.

Table 5 – Measures taken by farmers to mitigate and adapt to drought conditions

Action	Relative importance index	Rank
Water conservation	0.9813	1
Crop rotation	0.9750	2
Proper management of irrigation/canals	0.9500	3
Conservation of forest areas	0.7813	4
Limit the groundwater use	0.7625	5
Proper control of animal husbandry	0.7125	6

Source: Compiled by author, 2025

Table 6 – Coping strategies of farmers for preparing for a potential drought during normal years

Follow action taken	Relative importance index	Rank
Early sowing	0.7875	1
Saving money	0.7725	2
Crop storage	0.7600	3
Growing crops that use less water	0.7450	4
Crop residue storage for livestock	0.6775	5
Finding an alternative source of income	0.6725	6
Migrating for work	0.5775	7
Withdrawal from farming activities	0.5025	8
Selling a certain amount of livestock	0.4075	9

Source: Compiled by author, 2025

In general, it indicates that in response to the effects of drought, farmers tended to favor water-saving interventions and efficient agricultural practices more than environmental conservation.

Coping strategies of farmers for preparing for a potential drought during normal years in a ranking demonstrate the need for proactive measures (Table 6).

The most important among them is early sowing (0.7875), which indicates the first preference for farmers toward timely planting to make the most of crop growth and yield before the onset of possible dry periods. Saving money (0.7725) and crop storage (0.7600) rank second and third, respectively, to indicate that future drought impacts are prevented by financial preparedness as well as food security. Growing crops requiring less water (0.7450) and storing crop residues for livestock (0.6775) also contribute significantly to agricultural sustainability in the long run.

On the other hand, withdrawing from farming activities (0.5025) and migrating for employment (0.5775) are less proactive or reactive measures. Farmers prefer not to look for alternate sources of livelihood rather than seek other fields of activity in agriculture. It clearly indicates that this last one is the least popular strategy – to sell a certain number of livestock (0.4075) – and illustrates that farmers view livestock as precious assets which they would not part with unless necessary. Very clearly, these results suggest that normal years are a time when farmers can really make an effort to make mass savings, diversify crops, and hoard resources, thus becoming less victimized by future drought conditions.

The data demonstrates clear changes in dependency on water sources, depending on dry conditions or normal conditions, with drought impacting the availability and use of water (Fig. 5).

When conditions are normal, the primary water sources are tanks and rivers (Oya) (38%), shallow wells (31%), and irrigation canals (24%). Deep wells have the least contribution, at only 7%. This shows that surface water and shallow

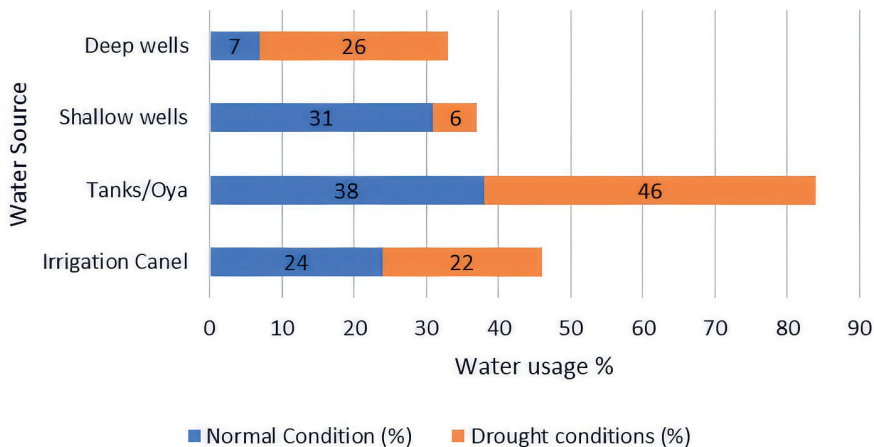


Fig. 5 – Changes in dependency on water sources. Source: Compiled by author, 2025

groundwater sources should be relied on with available rainfall or normal conditions. In drought conditions, there is a significant change in dependency on different sources. Shallow wells drop from 31% to 6%, showing their susceptibility to water availability. Deep wells shoot up from 7% to 26%. As the shallow wells dried up, the deeper groundwater source became an alternative dependency, if available. Tanks and oya have an increased dependency from 38% to 46%, which is shown as a buffer against normal conditions. Irrigation canals decreased dependency usage from 24% to 22%, and this could be attributed to the decrease in the flow of water in the canals during dry conditions.

The data illustrates the leading irrigation methods that farmers utilize for cropping and the reliance on traditional water distribution systems (Fig. 6).

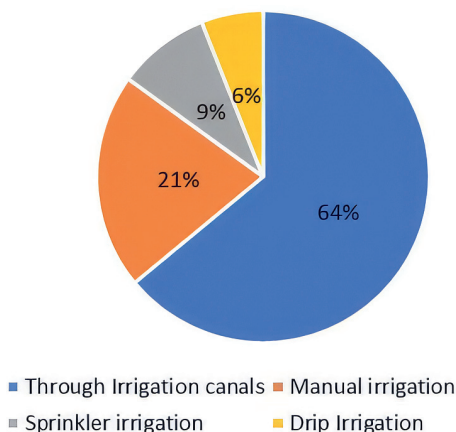


Fig. 6 – Irrigation methods that farmers utilize for cropping. Source: Compiled by author, 2025.

Irrigation canals are the predominant method (64%), suggesting that large-scale surface water management systems play a significant role in the agricultural water supply; large-scale surface water management systems are likely to support extensive paddy and field crop production. The significant reliance on irrigation canals indicates that many farmers are dependent on a centralized distribution of irrigation rather than localized or improved methods, especially in paddy farming. Manual irrigation is the second most popular (21%). Manual methods indicate that a significant number of farmers also rely on labor-intensive methods, like carrying water in a bucket or using a small pump to distribute water. This is likely most commonly in areas that do not have access to irrigation canals or in crops where efficiency is not as important to the water application. Modern irrigation methods such as sprinkler irrigation (9%) and drip irrigation (6%) were used least as primary methods. While these are considered valuable for water conservation and targeted water application, the low use of these methods suggests barriers to entry, such as high costs to start, lack of knowledge of methods available or lack of technical support for such methods. The low use of water shows an opportunity to promote sustainable irrigation methods, which potentially increase water efficiencies and minimize water scarcity during drought conditions.

The results from the Mann-Whitney U test provide insights into farmers' perceptions of various adaptation strategies under drought conditions (Table 7).

All tested adaptation strategies showed significant p-values (0.001–0.037), indicating variation in farmers' perceptions of their effectiveness. (H_{03} : There is no significant difference in farmers' perceptions of the effectiveness of different adaptation strategies. H_{13} : There is a significant difference in farmers' perceptions of the effectiveness of different adaptation strategies.) Given that all the p-values are below the significance threshold of 0.05, the null hypothesis (H_0) is rejected for each adaptation strategy. This rejection supports the alternative hypothesis

Table 7 – Farmers' perceptions of various adaptation strategies under drought conditions

Adaptations measure	p-values
Changing crop calendar	0.001
Transform into modern irrigation practices	0.001
Switching to crops that consume less water	0.004
Manage waterlogging and erosion	0.005
Integrated pest and pathogen management	0.005
Diversify income	0.005
Diversify crops	0.006
Agroforestry	0.007
Keeping land fallow during drought and flood seasons	0.021
Collecting water through the farm pond, using in-situ conservation methods	0.037

(H₁), which states that there is a significant difference in farmers' perceptions of the effectiveness of different adaptation strategies under drought conditions. The strategies include changing crop calendars, switching to water-efficient crops, modern irrigation practices, agroforestry, and others. The fact that all strategies show significant results indicates that farmers recognize the value of diverse approaches to managing drought.

The rejection of the null hypothesis across all strategies highlights the importance of considering multiple adaptation methods. It suggests that farmers do not perceive all strategies as equally effective or relevant, which could be due to factors like resource availability, climate variability, or past experiences. This understanding can help policymakers and agricultural advisors tailor support and guidance to better match the needs and perceptions of farmers. By acknowledging these differences in perceived effectiveness, more targeted and effective drought management plans can be developed to support agricultural resilience.

3.4. Climate change adaptation and indigenous knowledge

Locals have adapted their knowledge over the past in livelihood for agriculture, countering climate change effectively. Sri Lankans of civilized antiquity were highly resourceful with respect to environmental changes and had developed plans to mitigate the impacts. In this context, with the identification of climate change, there was a practice of seasonal growing called 'yala maha kanna' in which Yala is associated with rice and other crops planting and cultivation from April to September caused by the South-West monsoon and Maha associated with sowing rice and harvesting rice from October to February caused by North East monsoon. Notably, natives in the period of Anuradhapura were adept in the practice of rice farming endemic to wetlands, termed 'chena cultivation', which floods fields during the yala monsoon to encourage rice growth. However, rains were not reliable during this season, with the risk of drought and floods. Moreover, another strategy was the cascade system, which was built as a solution for both seasonal and long-term environmental challenges with an understanding of the region's climate. According to the Mahawansa, even during the reign of King Dewanampiyatissa in the 3rd century BCE, tanks and reservoirs were constructed to sustain agriculture during dry spells. Centuries later, during the reign of King Parakramabhahu I in the 12th century CE, the irrigation system and rice cultivation techniques were further expanded to withstand climate variability (Mahawansa, chapter 34). Other than innovative irrigation techniques, religious and cultural events, crop diversification, and communal cooperation led people to face environmental and climate challenges. These adaptation strategies were passed down through generations.

It was revealed through environmental observations how ancestors were knowledgeable about climate change. Particularly, they were aware of the environmental clues and symbols, which are called 'traditional ecological knowledge'. This showcases their bond with the environment in which they live. Even today, farmers recall monsoon indicators to predict monsoons. Significantly, the behaviour of certain animals and the appearance of flowers. When all the Jackfruit trees started blooming, a male farmer aged 75 said: "If the Jackfruit trees bloom, it indicates an early Yala monsoon." A 53-year-old farmer asked us to come out and said: "In the old days, my father used to tell me that a Mango tree would have flowers when the rain came. It always happened at just the right time. When the tables would bloom, we would start sowing Haars so that the rains would come near. Now, we do not see that flowering as regularly, which makes it harder to plan." Not only flora but also people used animal behaviour as indicators. As a female farmer aged 62 expressed: "If you see the Kingfisher birds flying low and close to the water, that is a sign that rain is near. My father always said that when the termites start working on their mounds at the start of the season, the rain will soon come. This was the natural calendar." Another male farmer, aged 79, stresses that "In our grandfather's time, they knew when to expect rain just by looking at the sky or feeling the wind. However, today, the weather has changed. Sometimes it rains too much, and other times we do not get enough."

Religious and cultural events play a crucial role in climate change. Particularly, there are temples dedicated to rain deities to invoke rainfall and protect against droughts. A female farmer aged 69 stressed: "In the past, there were rain ceremonies at the temple to ask for blessings. People believe that by performing rituals with sincerity by the monks, nature listens. Now, although the world has changed, we continue these ceremonies." The Date reveals that even though technology has developed, they still believe in the traditional knowledge of observing the wind and clouds to make their decisions."

According to one of the male farmers, aged 78, "our ancient kings built major tanks with foresight, as weather is unpredictable and in the times of drought water is saved. Thus, there was a great interference in water management despite these inherent climate challenges. The majority of the research sample emphasizes the continuation and preservation of these practices from the old glorious days." One female farmer (age 71) expressed that, "without water, we cannot properly do agriculture. In this case, we are still dedicated to protecting these practices. Those practices we get from our earlier generation, and we must pass them to future generations."

Anuradhapura, the hub of the culture of agriculture in Sri Lanka, experienced unpredictable weather throughout the year. It includes severe droughts, erratic monsoons, and extreme heat, which directly impact agriculture. During the off-season, rice, maize, and groundnuts are planted in addition. As one of the male

farmers aged 68 voiced, “Rice is the most important primary food crop. However, what to do in the dry season? During this dry season, we plant maize and ground-nuts. So, this is how we adapt to survive through many climate challenges.” Another female farmer, aged 63, said: “We used to grow maize alongside the rice paddies because it needed less water. If the rains were late, at least we would have some crops ready to harvest. My mother always said, ‘Do not put all your hope in one crop.’ We grew coconut and cashew nuts as backup, too.” These drought-resistant crops rely significantly on the diversification of crops grown in the region. Crop rotation is one of the major solutions to prevent the risk of crop failure. It was rotated between rice and legumes, ensuring a stable agricultural output despite climate change.

However, climate change has become one of the reasons farmers abandon agriculture. According to one male farmer, “I abandoned agriculture a few years back as I was not able to gain a considerable profit in the past. However, I rejoined agriculture as it was very much familiar to me, unlike doing some other jobs. Not only I but also a number of people from our village who follow and seek other jobs. Due to climate change, we faced many problems in harvesting.” Thus, interview data shows that farmers are thoroughly hesitant to abandon agriculture, admiring their historical legacy. Another male farmer, aged 75, mentioned that “the regular pattern of rainfall now has changed. Significantly, as we have experienced, the rain starts in the maha season, which means in the 9th month of the year, and it continues, albeit in contrast, now the dry season starts from the 9th month a few years back. This has led to the delay in cultivating paddy. As usual, it was in the 9th month, but due to the dry season, we have to start from October, delaying it a one month.” Another female farmer, aged 61, stressed that “according to my knowledge, since a few years ago, the six-month rainfall season has shifted from one to two months.”

However, traditional medicine was also closely related to knowledge of climate change. According to one female farmer aged 63, “When the rains come, the air becomes heavy with moisture, and that’s when people start getting sick with fevers. My grandmother taught me to make an herbal mixture of ginger and turmeric to treat cold-related illnesses. These herbs grow best when the weather starts to change, and the ground becomes damper.”

Interview data showcase how Anuradhapura people used traditional knowledge to adapt to climate change. Moreover, data revealed how traditional knowledge has been preserved and passed through generations over centuries. From this point of view, despite modern forecasting systems, traditional knowledge is profound, giving valuable lessons on adaptability and sustainable living.

4. Discussion

This research indicates the large significance of climate variability for agricultural families in the Rambewa DS division of Sri Lanka concerning paddy farming and at a broader South Asian level with respect to climate change and agriculture. The Rainfall Anomaly Index (RAI) data collected from Galweeragollewa, Gonewa, and Kadurugasdamana stations reported substantial variation in rainfall that was distinguished by alternating patterns of positive and negative anomalies. These correspond to wet and dry periods in years that included troubling drought years in 1995, 2003, 2013, 2016, and 2022, as well as flood years in 2011, 2014 and 2023. These observations supported claims made in the introduction that poor rainfall patterns contributed to lower yield and increased crop failure (Chandrasiri et al. 2023).

The findings from the study suggest that there is a high level of awareness of climate variability among respondents, with 96.5% of them indicating awareness of changes in climatic conditions, which is mainly experience-based, as 70% learned about rainfall and temperature variabilities from their own experience. This finding underscores the importance of local knowledge and experience in understanding and responding to climate stress, as also noted by Menike and Arachchi (2016), Herath and Thirumarpan (2017) or Gunathilaka and Samarakoon (2022).

The Kruskal-Wallis test revealed significant differences in the consequences of climate variability based on farming type, with yield decline, delays in harvesting and planting, disease and pest damage, decline in harvest quality, drying up of water sources, dryness around, loss of livestock, impacts on food prices, and livelihoods all showing significant differences ($p < 0.05$). This suggests that the impacts of climate variability are experienced differently by different farming groups, highlighting the need for targeted interventions and adaptive approaches. However, factors such as people's poor health/malnutrition, livestock poor health, and livestock declining prices were not significantly different between farming types, indicating that these impacts are more uniformly experienced across different farmer typologies, suggesting the need for broader policy measures.

In addition, a more in-depth consideration of the impacts of flooding and drought revealed clear differences in their consequences on food security in households, economic stability, and psychological health. Droughts seem to have a more pronounced effect on food shortages, migration, water conflict, and farmer suicides, while flooding has a much clearer impact on economic well-being and health. All of this analysis suggests the need for more targeted interventions that consider the specific vulnerabilities created by droughts and floods (see e.g. Niranjana et al 2015; Scognamiglio et al 2022; Amarnath et al 2023).

Furthermore, this study highlights the importance of integrating local knowledge and scientific data in order to develop effective adaptation strategies. The farmers displayed a high level of awareness around climate variability, and this is a clear indication of the possibilities of farmers bringing valuable input into the effects of climate change and mechanisms of adaptation. This connects to the concept of co-production of knowledge, which is the process of local communities and scientists working in tandem to produce context-specific solutions (Armitage, Berges, Doubleday 2011). This type of approach involves the partnership to produce solutions that policy-makers can leverage to create more effective and sustainable interventions based on the needs and challenges of specific farming communities.

Finally, the study results reporting differential impacts of drought and flooding events on household dependence signal the need for a nuanced policy response. A policy response should address emergency relief in relation to the event while further engaging with longer-term strategies that aim to build resilience. Longer-term strategies could include climate-resilient crop cultivars and improvements to irrigation capacity and efficiency, as well as early warning systems to provide advance notice of extreme weather events, all as examples (Barnett, O'Neill 2010). Given climate change impacts, any climate-related development initiation ought to consider climate-change relations.

5. Conclusion

Overall, the study's findings reinforce the urgency for comprehensive policy approaches, including strengthening agriculture extension services, promoting climate-smart agriculture, and implementing insurance programs to enhance farmer resilience and food security in the face of increasing climate variability. By combining local knowledge with scientific research and policy support, it is possible to develop effective strategies that mitigate the impacts of climate change on agriculture and improve the livelihoods of farming communities. In conclusion, the discussion highlights the complex interplay between climate variability, agricultural practices, and community resilience. Addressing these challenges requires a multifaceted approach that considers both the specific vulnerabilities of different farming groups and the broader socio-economic context in which they operate. Future research should focus on developing and implementing adaptive strategies that are grounded in local realities and supported by scientific evidence, ultimately contributing to more sustainable and resilient agricultural systems.

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