Climate Adaptation Strategies for Sustainable Agriculture: A Case Study of Janaki Rural Municipality, Banke, Nepal

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Abstract

This study analyzed (Aryal et al., 2020) space and time.
Keywords:

1 Introduction

Climate change significantly impacts agriculture by altering key climatic factors such as temperature, carbon dioxide (CO_2) levels, and precipitation patterns. While moderate increases in temperature and CO_2 may enhance crop productivity in certain regions, extreme climate variations—such as more frequent droughts and floods—pose serious challenges to farmers. These climatic disruptions exacerbate existing stressors, including population growth and resource scarcity, amplifying their adverse effects on agricultural productivity and food security(Paudel, 2015). According to Kang et al. (2009) Food security depends on four key factors: food availability, stability, access, and utilization. Increased climate variability, along with more frequent and intense weather events, puts significant pressure on food stability. Additionally, climate change impacts food quality by raising temperatures and shortening crop growth periods. Food security is impacted by climate change, especially in areas and populations where rain-fed agriculture is the primary source of food. Plants and crops have thresholds that when exceeded impair yield and growth (Muluneh, 2021). Climate change is expected to intensify the frequency and severity of extreme weather events, leading to increased climate variability and uncertainty. Farmers in low-income countries are particularly vulnerable to these changes due to their high exposure to climate risks and limited adaptive capacity. As climate extremes become more frequent, the ability of farmers in these regions to sustain agricultural productivity and food security will be increasingly challenged (Budhathoki et al., 2020). One of the most significant issues in the 21st century is to supply enough food for the growing population while maintaining the already strained ecosystem, which is endangered by climate change (Kang et al., 2009).With the global population steadily increasing, the need to enhance production to meet the growing demand for food has become crucial. However, this imperative has prompted a quest for "sustainable" agricultural approaches that not only boost productivity but also prioritize the preservation of resources for the benefit of future generation (Singh et al., 2022). The effects of climate change on agricultural output frequently interact with those on water availability productivity and soil water balance. Climate change affects temperature and precipitation, which immediately affect the state of soil moisture and groundwater levels. Crop types, planting locations, soil degradation, the growing environment, and the availability of water throughout the crop growth period all have an impact on crop production (Risal et al., 2022). Nepal's geographical diversity, ranging from the Terai plains to the Himalayan peaks, makes it highly vulnerable to climate change. Agriculture is a critical sector in Nepal, forming the backbone of the economy and providing livelihoods for nearly two-thirds of the population. However, it faces numerous challenges, including poverty, limited access to resources, and climate change. Climate change significantly impacts agriculture by altering temperature and precipitation patterns, leading to shifts in soil moisture and groundwater levels (Gyawali & Khanal, 2021). In particular, the Western Terai region, known as the "breadbasket" of Nepal, has experienced observable shifts in climate patterns, including an annual temperature rise of approximately 0.040°C (Karn 2014). Erratic weather events and climate variability significantly threaten agriculture, which forms the backbone of the region's economy (Max 2023). In order to improve agricultural resilience, production, food security, and sustainability, adaptive research should concentrate on creating crop varieties that can withstand drought, heat, and floods, including locally grown, indigenous, disease- and pest-resistant cultivars. It should also invest in resource centers, adjust sowing timing based on rainfall, encourage early maturing cultivars, ensure high-quality seeds and planting materials, and implement food production and self-reliance initiatives in rural, food-deficient areas (Dahal & Khanal 2010). In the Banke district, challenges such as limited irrigation infrastructure and agricultural constraints have exacerbated food deficits. For instance, in 2015-16, Banke faced a food deficit of -1767 MT, highlighting the growing issue of food insecurity

(SINA 2017). Janaki Rural Municipality, situated in Banke, exemplifies the urgent need to understand the interplay between climate change impacts, agricultural resilience, and food security dynamics. This study seeks to address the knowledge gap regarding the impact of climate change on agriculture in Banke. By examining the relationship between climatic variables (temperature, precipitation, and sunshine hours) and crop yields over the past three decades, the research aims to provide a comprehensive understanding of the region's vulnerabilities. Additionally, the study explores farmers' perceptions of climate change, food security scenarios, and the current state of irrigation. It also investigates how these factors collectively influence agricultural resilience and food production. The findings from this study can inform strategic planning and policy-making to enhance agricultural resilience and food security in Banke. By identifying the key challenges and opportunities, the research aims to support local and provincial governments in developing targeted interventions, such as promoting drought-resistant crops, improving irrigation systems, and providing training on adaptive farming practices. These measures are essential to ensuring sustainable agricultural development and improving the livelihoods of farmers in Janaki Rural Municipality, Banke.

2 Study area, Data and Methods

2.1 Study Area

The study area for this research is Janaki Rural Municipality, located in Nepalgunj, Banke District, Nepal (Figure??). Situated at an elevation of 165m above sea level, it is bordered by Nepalgunj Sub-Metropolitan City to the east, Kohalpur Municipality to the north, Khajura Rural Municipality to the west, and the international boundary with India to the south (Janaki Rural Municipality). The region features a temperate climate and flat terrain. Meteorological records indicate an average annual rainfall of 1445.58 mm, with temperatures ranging from a minimum of 4.5°C to a maximum of 46°C (Janaki Rural Municipality).

Agriculture is the primary livelihood for most households in Janaki Rural Municipality. Of the 5,063ha of cultivable land, only 2,532ha are utilized, comprising 1,798ha of farmland and 774ha of upland. Land ownership varies widely: 1,294 households possess less than 0.167ha, 1,222 hold 0.2–0.33ha, 2,338 own 0.37–0.67ha, 1,512 control 0.7–1ha, and 973 own more than 20ha, while 52 households are landless (Janaki Rural Municipality, 2075). Irrigation remains limited, with only 321ha irrigated year-round and 1,871 ha lacking consistent water access. The municipality contains 50 ponds, some of which support irrigation. Despite abundant arable land, inadequate irrigation and limited technological resources hinder commercial agriculture, resulting in dependence on food imports from India

(Janaki Rural Municipality, 2075).

Janaki Rural Municipality is divided into six wards, of which three were randomly selected for this study (Table 1).

Table 1: Study Area with elevation and coordinates

S.N.	Study Location	Elevation (m)	Coordinates
1	Janaki Rural Municipality – 01, Saigaun	164	28°02'42"N 81°34'05"E
2	Janaki Rural Municipality – 03, Indrapur	172	28°05'02"N 81°36'20"E
3	Janaki Rural Municipality – 04, Khajura Khurda	163	28°06'26"N 81°36'00"E

Source: (Janaki Rural Municipality, 2075)

2.1.1 Methods of Data Collection

Primary Data Sources A comprehensive household survey and intensive field research were conducted across wards 1, 3, and 4 of Janaki Rural Municipality, encompassing 47 villages. Structured interviews and direct observations were employed to gather data on agricultural practices, irrigation access, food security, and perceptions of climate change. Village sample sizes were determined based on household ratios derived from municipal records, followed by systematic sampling of households within each village to ensure representativeness.

Secondary Data Sources Secondary data were sourced from a literature review pertinent to the research objectives. Desk-based research, primarily utilizing online resources, provided the majority of the data. Additional information was obtained from reference books, recently published national newspapers, peer-reviewed international journals, government reports, historical records, and relevant websites.

2.1.2 Sampling Frame

The study employed stratified random sampling to select wards 1, 3, and 4 from the six wards of Janaki Rural Municipality, using a lottery method for ward selection. These wards were chosen to represent the municipality's diversity, with ward 1 comprising 5 villages and wards 3 and 4 each containing 21 villages, as documented in an internal survey from 2075 B.S. Villages within each ward were sampled proportionally using stratified random sampling to enhance diversity and reduce sampling bias. Households within selected villages were then systematically chosen based on household data provided by the municipality. Field observations complemented the survey by providing additional insights into household conditions and local agricultural practices.

Details of the household distribution across the sampled wards are presented in Table 2. The table summarizes the number of households and soil samples collected from wards 1, 3, and 4 of Janaki Rural Municipality, providing a foundation for the study's analysis of agricultural and environmental conditions.

Table 2: Household and Soil Sample Distribution by Ward in Janaki Rural Municipality

Ward	Household	Soil Sample
1	1242	8
3	1929	8
4	1050	8
Total	7391	24

2.2 Sample Size Determination

The total household population was derived from an internal survey conducted by Janaki Rural Municipality in 2075 B.S. (Janaki Rural Municipality). The sample size for the questionnaire survey was calculated at a 95% confidence level using the following formula (Dahal 2021):

$$n = \frac{N \cdot z^2 \cdot p \cdot q}{(N-1) \cdot e^2 + z^2 \cdot p \cdot q}$$

where:

- n = sample size,
- N = total number of households in selected wards (4,221),
- z = z-score for 95% confidence level (1.96),
- p = expected prevalence (0.9),
- $q = 1 - p$ (0.1),
- e = margin of error (0.05).

Substituting the values:

$$n = \frac{4221 \cdot (1.96)^2 \cdot 0.9 \cdot 0.1}{(4221-1) \cdot (0.05)^2 + (1.96)^2 \cdot 0.9 \cdot 0.1} = 133.9 \approx 134$$

The sample size for each ward (n_h) was determined proportionally using the formula (Dahal 2021)

$$n_h = \frac{N_h}{N} \cdot n$$

where:

- n_h = sample size per ward,
- N_h = number of households in the ward,
- N = total household population (4,221),
- n = total sample size (134).

2.3 Sample Size of Selected Wards

The proportional sample sizes for wards 1, 3, and 4 are presented in Table 3.

Table 3: Sample Size of Selected Wards in Janaki Rural Municipality

Ward	N_h	N_h/N	$N_h/N \cdot n$
1	1242	0.29	39
3	1929	0.457	61
4	1050	0.249	33
Total	4221		134

2.3.1 Data Collection and Calculation

This study aimed to examine production trends, climatic scenarios, and their interrelationships within the research area. Data collection involved integrating primary, secondary, and ancillary sources to ensure a robust and comprehensive analysis. Primary data were gathered through household surveys and field observations in Janaki Rural Municipality, as detailed in earlier sections. Secondary data were sourced from government reports, academic literature, books, and reputable organizations, including the Department of Hydrology and Meteorology (DHM) and the Ministry of Agriculture and Livestock Development (MOALD). Ancillary data from credible websites enhanced the dataset's timeliness and depth. This multifaceted approach ensured the reliability, richness, and contextual relevance of the data. Statistical analyses were performed using IBM SPSS Statistics (version 27) and Microsoft Excel.

Pearson Correlation Coefficient The Pearson correlation coefficient (r) was calculated to assess the linear relationship between crop yield (dependent variable) and climatic factors—sunshine hours, accumulated rainfall, and average temperature (independent variables)—prior to regression analysis. This coefficient, ranging from -1 to 1, quantifies the strength and direction of linear associations. A value of $r = 1$ indicates a perfect positive correlation, $r = -1$ a perfect negative correlation, and $r = 0$ no linear correlation. The formula is:

$$r = \frac{n \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where x_i and y_i are individual data points, $\bar{x}$ and $\bar{y}$ are the means of variables X and Y, and n is the number of observations.

Simple Linear Regression Analysis Simple linear regression was employed to model the relationship between crop yield (Y_i, dependent variable) and individual climatic variables (X_i, independent variables). This method estimates the linear effect of an independent variable on the dependent variable. The regression equation is:

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon$$

where β_0 is the intercept, β_1 is the slope, and ϵ is the error term capturing unexplained variation.

T-test A two-sample t-test was conducted to compare average crop yields (kg/ha) between plots with year-round irrigation and those reliant on rainfed irrigation during the monsoon season. Year-round irrigation refers to plots with consistent water supply, while rainfed irrigation depends solely on seasonal rainfall. The null hypothesis (H_0) posits no difference in yields between groups, against the alternative (H_1) of a significant difference. The significance level was set at $\alpha = 0.05$, and analysis was performed in SPSS. The t-test statistic is:

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{s^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where $\overline{x_1}$ and $\overline{x_2}$ are group means, s^2 is the pooled variance, and n_1 and n_2 are sample sizes.

Index Model An index model was developed to assign index values to unit areas, facilitating the creation of a ranking map. Similar to binary models, it employs overlay operations and multicriteria assessment but generates continuous index scores rather than binary outcomes. The process involved two stages:

(1) assigning weights to variables based on relative importance,

(2) scoring observed values.

Climate Change and Production Trend Analysis Simple linear regression, implemented in IBM SPSS Statistics (version 27), was used to model the relationship between crop yield (dependent variable) and climatic variables—accumulated precipitation, average temperature, and sunshine radiation (independent variables). Pearson correlation coefficients were first calculated to assess linear associations, followed by regression analysis to quantify trends over time. This dual approach provided insights into both the strength and direction of relationships between yield and climate factors.

Climate Change Trends Three climatic variables—accumulated rainfall, average temperature, and sunshine hours—were analyzed over a 30-year period (1990–2021) in the study area. Data were sourced from the Department of Hydrology and Meteorology (DHM). Linear trends were visualized using Microsoft Excel, with graphs illustrating changes in each variable over time.

Climate Change Perception An index model evaluated farmers' perceptions of climate change and its impact on agricultural production, recognizing that such perceptions shape adaptation strategies. A survey of 134 respondents assessed opinions on climate change using a three-point scale: +1 for agreement/approval, -1 for disagreement/disapproval, and 0 for "don't know/absent." For binary variables, the perception index was calculated using the formula by (Dahal2021):

$$\text{INDEX} = \frac{FA(+1) + FDA(-1) + FDK(0)}{N}$$

where:

- FA = frequency of agreement/approval,
- FDA = frequency of disagreement/disapproval,
- FDK = frequency of "don't know/absent,"
- N = total respondents (134).

For variables with multiple categories, a normalized index was computed based on (Banerjee et al., 2023):

$$\text{INDEX} = \frac{(\text{Max value} - \text{Min value}) \times X}{(\text{Max value} + \text{Min value}) \times \text{Max value}}$$

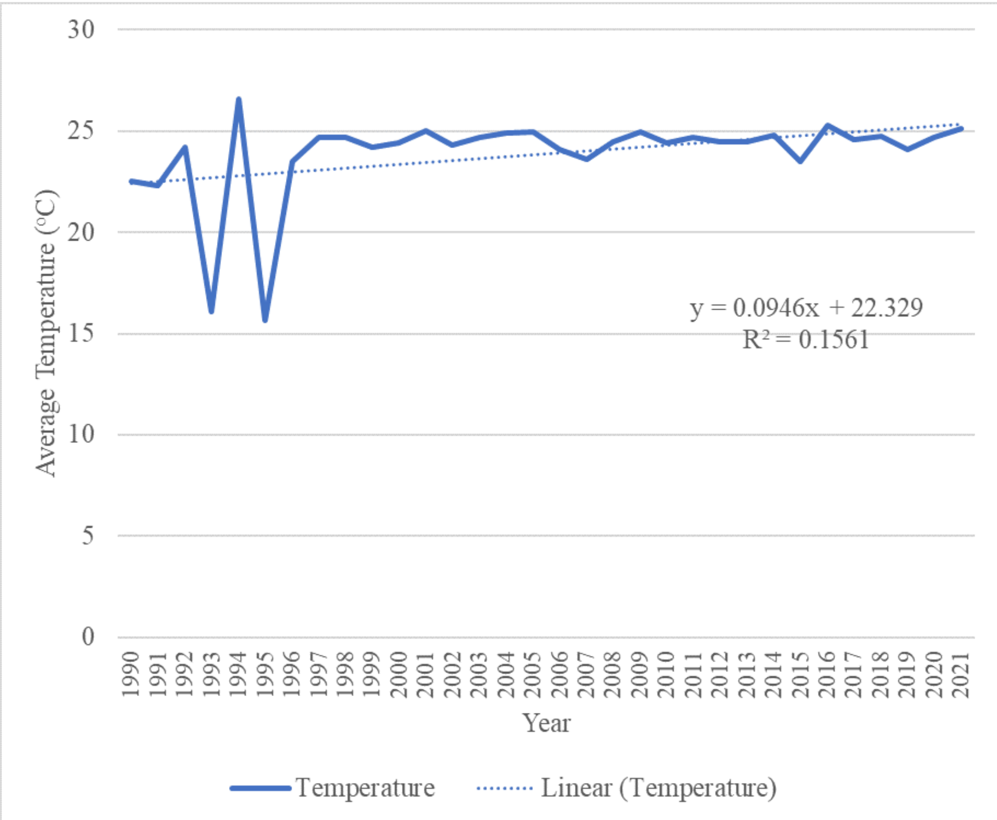
where X is the observed value of a specific category, and Max/Min values define the range of responses.

3 Results and Discussion

3.1 Climate and Production

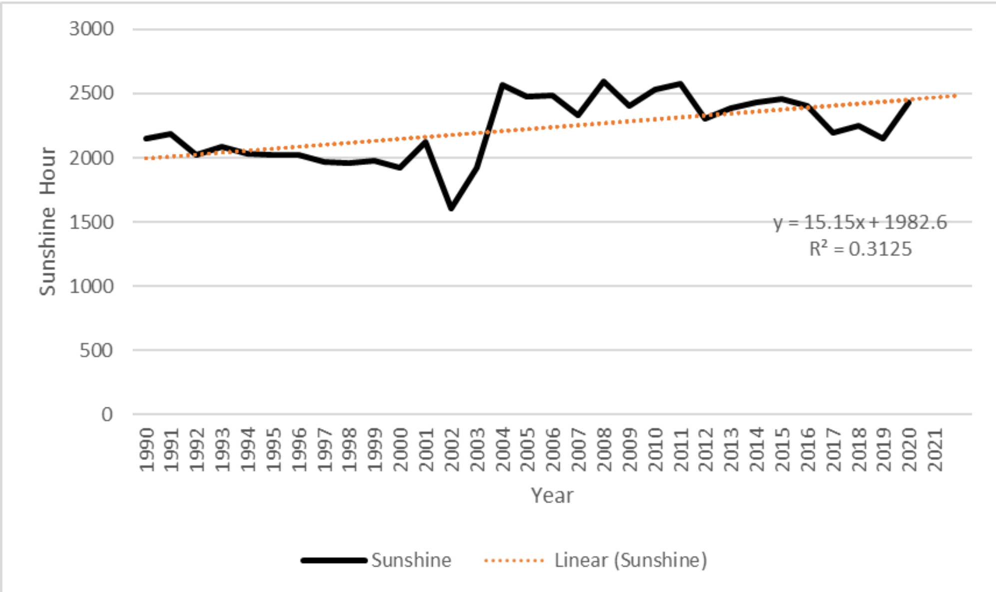
3.1.1 Climate Change Trend

Figure 1: Average Temperature since 1990 to 2021



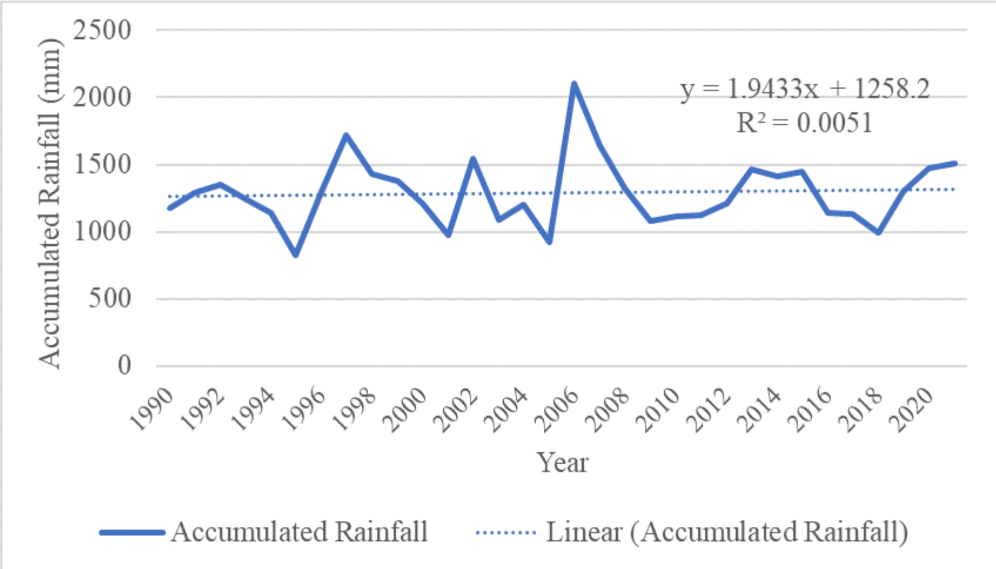
As shown in Figure 1, the results indicate that between 1990 and 2020, the average temperature showed a minor positive trend, averaging 0.0946 degrees Celsius each year, with 15.61% of the variability explained by the linear trend $y = 0.0946x + 22.329$. The positive trend might be due to global warming. The temperature increase could have a significant impact on crop production, as it may affect crop growth, development, and yield. The temperature increase could also lead to changes in the distribution of pests and diseases, which could further affect crop yield.

Figure 2: Average Sunshine Hour since 1990 to 2021



The average sunlight hours from 1990 to 2020 showed a positive slope of 15.15 hours/year with an intercept of 1982.6 in the linear trend analysis. This indicated an overall rise in sunshine hours, and the trend's R-squared value of 0.3125 indicates that it accounts for 31.25% of the variability (Figure 2). The increase in sunlight hours that Banke experienced between 1990 and 2020 might had been caused by variations in the weather, patterns of land use, and climate variability, all of which might had been impacted by local and global climate change.

Figure 3: Accumulated Rainfall since 1990 to 2021



The graph 3 revealed a slight positive trend in accumulated rainfall $y = 1.9433x + 1258.2$, with an annual increase of around 1.9433 millimeters per year. Changes in local weather patterns, air circulation, land use, and the effects of climate change might all be contributing factors to the increase in rainfall in Banke, Nepal.

3.2 Correlation Between Yield and Climate Variables

Table 4: Correlation Table between Yield and Climate Variables

	Sunshine Hours	**Accumulated Rainfall (mm)**	**Average Temperature (°C)**
Yield (mt/ha)	0.417*	-0.074	0.287
(p-value)	0.017	0.686	0.112

Table 5: Linear Regression Model Summary for Yield and Climate Data

Dep. Variable	Yield
Adjusted R-squared	0.161
Significance (p-value)	0.048
F-statistic	2.981
R-squared	0.242

Table 6: Regression Coefficients for Yield and Climate Data

Model	Unstandardized Coefficients		Standardized	t	Sig
	B	Std. Error	Beta		
(Constant)	-99.061	903.331	-	-0.110	0.913
Sunshine	0.670	0.291	0.391	2.306	0.029
Accumulated Rainfall	-0.279	0.279	-0.168	-0.999	0.326
Average Temperature	43.825	32.148	0.232	1.363	0.184

$$\begin{aligned} \text{Crop Yield} = & -99.061 + 0.670 \times \text{Sunshine} \\ & - 0.279 \times \text{Accumulated Rainfall} \\ & + 43.825 \times \text{Average Temperature} \end{aligned} \tag{1}$$

Table 4.1 presents the correlation between crop yield and key climate variables, including sunshine hours, accumulated rainfall, and average temperature. The results indicate:

Sunshine hours show a significant positive correlation with yield (r = 0.417, p = 0.017), suggesting that increased solar exposure contributes to higher crop productivity. Accumulated rainfall exhibits a weak negative correlation with yield (r = -0.074, p = 0.686), indicating that rainfall variability does not have a statistically significant effect on crop production. Average temperature has a moderate positive correlation with yield (r = 0.287, p = 0.112), although the relationship is not statistically significant. These findings suggest that sunshine hours play a more influential role in determining crop yield than rainfall or temperature variations.

Linear Regression Analysis The linear regression model for yield and climate variables reveals an R-squared value of 0.242, indicating that approximately 24.2% of the variability in crop yield can be explained by sunshine hours, accumulated rainfall, and average temperature. The adjusted R-squared value of 0.161 suggests a moderate explanatory power after adjusting for the number of predictors.

The regression model equation derived from the analysis is:

Regression Coefficients and Statistical Significance Examining the individual regression coefficients:

Sunshine hours $\beta = 0.391$, $p = 0.029$ show a significant positive effect on yield, confirming that increased sunlight exposure enhances productivity. Accumulated rainfall $\beta = -0.168$, $p = 0.326$ has a negative but non-significant effect, indicating that excessive or inconsistent rainfall does not significantly contribute to yield improvement. Average temperature $\beta = 0.232$, $p = 0.184$ has a positive but non-significant effect, suggesting that temperature variations alone are not a strong predictor of yield changes. Discussion Influence of Climate Factors on Crop Yield

The findings in Table 6 indicate that sunshine hours are the most influential climate variable affecting crop yield. The significant positive correlation and regression coefficient confirm that higher solar radiation enhances photosynthesis, leading to better crop growth and productivity. This aligns with prior studies conducted in Nepal and South Asia, which found that solar radiation is a key determinant of agricultural output (Thapa & Devkota, 2016).

Conversely, rainfall does not show a significant impact on yield, which may be due to erratic precipitation patterns in the Banke district. Similar studies in Nepal have reported that uneven rainfall distribution can reduce soil moisture availability, affecting crop health despite high total precipitation levels (Regmi et al., 2019). This suggests that rainfall variability, rather than total rainfall, may be more critical for crop yield determination.

The moderate but non-significant relationship between temperature and yield suggests that while temperature fluctuations impact crop growth, their effect is less direct than sunshine exposure. Previous research has found that higher temperatures may accelerate crop maturation but also increase evapotranspiration, reducing soil moisture levels and affecting plant growth (Shrestha et al., 2022). This could explain why the temperature variable, though positively correlated with yield, does not exhibit strong statistical significance.

Comparing with Previous Studies Compared to previous studies in Nepal's Terai region:

Devkota & Paija (2020) found that a 1% increase in rainfall improved rice yield by 0.45%, while this study indicates a negative but weak relationship between rainfall and yield. The inconsistency may stem from differences in soil properties, irrigation availability, and crop types across districts. Karki et al. (2021) reported that sunshine hours significantly influenced wheat productivity, supporting this study's findings that higher solar exposure enhances crop output. Risal et al. (2022) noted that temperature increases beyond optimal thresholds negatively impact yield, whereas this study does not find a strong negative effect, possibly due to regional climate adaptations. Implications for Agricultural Adaptation Strategies The results underscore the importance of optimizing sunshine exposure through improved crop management techniques such as: Selecting drought-resistant crop varieties that can capitalize on high sunlight conditions. Enhancing irrigation infrastructure to mitigate the negative impacts of inconsistent rainfall. Adopting precision agriculture technologies to optimize planting schedules based on temperature and solar radiation patterns.

Additionally, policymakers should focus on climate-resilient agricultural practices, particularly in districts like Banke, where rainfall unpredictability poses challenges for farmers.

Limitations & Future Research Directions Although this study provides valuable insights, some limitations should be considered:

The relatively low R-squared value (0.242) suggests that other non-climatic factors (e.g., soil quality, pest outbreaks, irrigation methods) also influence yield and should be included in future models. The study does not account for extreme weather events (e.g., floods, droughts), which could significantly affect yield trends. Future research should incorporate long-term climate projections and soil moisture analysis to improve yield prediction accuracy. Conclusion This study highlights the strong positive impact of sunshine hours on crop yield, while rainfall and temperature have weaker, non-significant effects. The findings suggest that improving water management and leveraging sunshine exposure are key to sustaining agricultural productivity in Nepal's Banke district. Future studies should integrate broader climate and agronomic factors to develop more comprehensive yield forecasting models.

subsubsectionClimate Change Perception

Table 7 shows the farmers' perception towards questions related to climate change. The results indicate that all the farmers in the study area were aware of the ongoing general climate change, with an index value of 1. However, there was almost no awareness about the range of temperature experienced in the locality and its effects on agricultural productivity, both having an index value of -0.88.

Farmers were highly unaware of the effects of climate change regarding untimely monsoons and their impact on production, with an index value of -0.75. On the other hand, farmers had slight awareness about the effects of pests and insects, abnormalities in crops due to climate change, and extreme weather events in the locality, with index values of 0.28, 0.275, and 0.155, respectively.

Even though all farmers were aware of the ongoing climate change, there was only an average level of awareness about the evidence of climate change. The detailed calculations are presented in Annex 5.

3.2.1 agriculture and Food Scenarios

Table 8 presents the production-related data obtained from the household survey conducted in the study area. The findings indicate that mixed farming and crop combination were almost nonexistent, with 97.8% of households not practicing either method.

The study further revealed that 92.5% of families produced enough food for themselves, while 3% of families met their food deficit by purchasing from the market. Despite the minimal institutional support, recorded at only 4.5%, a significant portion (97.8%) of the population had sufficient food stock. This was primarily sourced from their own production (95.5%), with the remaining 4.5% obtained from markets.

Table 7: Farmer's Perception on Climate Data

Statement / Variables	**Index**
Climate change is happening	1.00
Aware about the range of temperature experienced in locality	-0.88
Climate change affects agricultural productivity	-0.88
Effect of untimely monsoon on production	-0.75
Climate change affects the spread of pests and insects over crops	0.28
Abnormalities in crops	0.275
Extreme events in locality	0.155
Evidence of climate change	0.47

**Higher the index, stronger the perception.*
Frequency of agreement/approval: +1, Frequency of disagreement/disapproval: -1, Frequency of don't know/absent: 0.

As a result, the majority of the population (99.3%) was well-nourished, with only 0.7% identified as undernourished (Annex 6.7).

subsubsectionCrop Calendar Farmers in the study area have shifted their sowing and harvesting times over the past five years (Table 9). The primary reason behind this shift in cropping time is attributed to irregular monsoons and climatic changes. However, for seasonal fruits and vegetables, no significant changes were observed.

3.3 Irrigation

3.3.1 irrigation Status

Numerous irrigation sources are used in the research region. During the monsoon season, 93.3% of the land relies on rainfed irrigation, while only 26.9% of the land has irrigation available throughout the year. The entire study area is covered by gravity-fed surface irrigation, which includes both flood and furrow techniques. Additionally, respondents reported that there were no significant issues related to irrigation in the study area (Table 10).

3.3.2 Irrigation and yield

The different categories of irrigation used in the study area were categorized into two irrigation groups: year-round irrigation, used by 9 respondents, and rainfed irrigation, used by 125 respondents (Annex 6.3). Table 11 presents the results of the t-test examining the effect of different irrigation categories on crop yield.

Table 8: Agricultural and Food Scenario Characteristics

Characteristics	**Variables**	**Percentage**
Mixed Farming	Yes	2.2
	No	97.8
Crop Combination	Yes	2.2
	No	97.8
Food Production	Enough	92.5
	Not Enough	7.5
Food Deficit	Purchase from the market	3.0
	Not Deficit	97.0
Undernutrition	No	99.3
	Yes	0.7
Food Stock Present or Absent	Yes, Present	97.8
	No, Absent	2.2
Sources	Own Production	95.5
	Markets	4.5
Institutional Support	Yes	4.5
	No	95.5

Table 9: Crop Calendar Based on Major Changes in Cropping Time

Crop	**Before 5 Years**		**Recent Time (After 5 Years)**		**Reason**
	Sowing Month	**Harvesting Month**	**Sowing Month**	**Harvesting Month**	
Paddy	June (3rd week)	September (1st week)	August (1st week)	November (Mid-week)	Irregular Monsoon / Climatic Shift
Wheat	December (1st week)	April (Last week)	January (Mid-week)	April (2nd week)	Climatic Shift
Mustard	November (Mid-week)	April (Mid-week)	November (3rd week)	March (2nd week)	Climatic Shift
Lentils	October (3rd week)	March (3rd week)	December (1st week)	April (Last week)	Climatic Shift
Pigeon Pea	June (Last week)	January (2nd week)	July (3rd week)	February (2nd week)	Climatic Shift
Vegetables	All months	All months	All months	All months	No Change
Fruits	All months	All months	All months	All months	No Change

Source: Questionnaire survey conducted in the study area.

Table 10: Frequency Table for Land and Irrigation Data of Survey

Characteristics	**Variables**	**Percentage**
Irrigation Source	Ground water + Canal irrigation + Rainfall	23.9
	Ground water + Drainage Pond + Rainfall	59.0
	Ground water + Rainfall	1.5
	All	15.7
Land Quality Irrigation	Khet	73.1
	Upland and Khet	26.9
Irrigation Type	Natural	38.1
	Artificial	48.5
	Both	13.4
Irrigation Category	Year-round irrigation (whole year)	6.7
	Rainfed Irrigation (monsoon)	93.3
Season of Availability	All Season	26.9
	Monsoon	73.1
Irrigation Technique	Gravity-fed surface (flood and furrow)	100.0

Table 11: t-test of Between-Subjects Effects

	Year-Round Irrigation		**Rainfed Irrigation**		t(132), p	
Yield (kg/ha)	**Mean**	**SD**	**Mean**	**SD**	**t**	**p**
Crop Yield	7868.63	3756.38	5450.43	2505.86	2.696	0.008

The t-test results compare the mean yield between two irrigation methods, year-round irrigation and rainfed irrigation, in Janaki Rural Municipality (Table 11). The findings indicate that for year-round irrigation, the mean yield is 7868.63 kg/ha with a standard deviation of 3756.38, while for rainfed irrigation, the mean yield is 5450.43 kg/ha with a standard deviation of 2505.86.

The higher crop yield in year-round irrigation can be attributed to the fact that individual household crop yields were computed separately and then aggregated to determine the overall yield. The analysis revealed a statistically significant difference in mean yields between the two groups, $t(132) = 2.696, p = 0.008$, suggesting that year-round irrigation significantly enhances crop yield compared to rainfed irrigation.

4 Summary

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