SClimate 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 of this research is Janaki Rural Municipality of Nepalgunj, Banke (Figure). The elevation of Janaki Rural Municipality is 165m above sea level. It is bordered by Nepalgunj Sub Metropolitan in the east, Kohalpur Municipality in the north, Khajura Rural Municipality in the west, and India in the south (Janaki Rural Municipality, 2075). The region experiences a temperate climate, characterized by flat terrain. According to the meteorological department records, the average annual rainfall is 1445.58 mm. The maximum recorded temperature reaches 46°C, while the minimum temperature is 4.5°C (Janaki Rural Municipality, 2075). Farming is the primary income source for most families. Of the 5,063 ha of cultivable land, only 2,532 ha is utilized, with 1,798 ha as farmland and 774 ha as upland.

In Janaki Rural Municipality, 1,294 households own less than 0.167 ha, 1,222 own 0.2–0.33 ha, 2,338 own 0.37–0.67 ha, 1,512 own 0.7–1 ha, and 973 own more than 20 ha, while 52 households are landless. Of the land, only 321 ha is irrigated year-round, and 1,871 ha lack irrigation. The municipality has 50 ponds, some used for irrigation. Despite abundant arable land, limited irrigation and technological support prevent commercial farming, leading many to rely on India for food supplies (Janaki Rural Municipality, 2075).

Janaki Rural Municipality consists of six wards in total, out of which three wards were randomly sampled and included in the research study as follows (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)

2.2 Methods of Data Collection

2.2.1 Primary Source of Data

A comprehensive household survey and intensive field research were carried out in Janaki Rural Municipality's wards 01, 03, and 04, which included a total of 47 villages. Structured interviews and direct observations were used to collect data on agriculture, irrigation, food security, and perceptions of climate change. Village sample sizes were assessed using household ratios, and then systematic sampling was conducted.

2.2.2 Secondary Source of Data

The secondary data were taken from literature reviews relevant to the research topic, where the majority of reviews were collected from desk studies, i.e., the internet. Various knowledge and data were achieved through reference books, recently published national newspapers, international journals, reports, records, past literature, reviews of various websites, and so on.

2.2.3 Sampling Frame

Stratified random sampling was utilized in a survey conducted in Janaki Rural Municipality, where wards 1, 3, and 4 were chosen by lottery out of six wards. Villages were sampled proportionally, whereas households within each village were systematically selected based on municipality-provided household data. Janaki Rural Municipality, divided into six wards, had wards 1, 3, and 4 selected for the study using a lottery method. Ward 1 includes 5 villages, while wards 3 and 4 have 21 villages each, as identified by an internal survey in 2075 B.S. Villages were proportionately sampled through stratified random sampling to ensure diversity and minimize sampling errors. Observations were also conducted to gather information on homes within each village.

The details of the household distribution are provided in Table 2.

Table 2: Household Distribution by Ward

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

2.3 Sample Size Determination

Total household population was obtained from the report obtained from Janaki Rural Municipality from the internal survey conducted in 2075 B.S. The sample size of the population to conduct the questionnaire survey was calculated at a 95% confidence level using the formula:

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

Source: Dahal, 2021

Where:

- n = Sample size
- N = Total number of households of selected wards
- z = Confidence level at 95%, $z = 1.96$
- p = Expected rate of occurrence = 0.9
- $q = 1 - p = 0.1$ (expected rate of non-occurrence)
- e = Degree of error = 0.05

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

$$n = 133.9 \approx 134$$

The selection of households from each ward was calculated using the following formula:

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

Source: Dahal, 2021
Where:

- n_h = Sample size for each ward
- N_h = Population size of each ward
- N = Total population size = 4221
- n = Total sample size = 134

2.4 Sample Size of Selective Wards

The sample size for each ward is calculated as follows:

Table 3: Sample Size of Selective Wards

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

2.5 Sample Size of Selective Villages

The sample size for selective villages of ward 1 (Saigaun) is shown in Table 4:

Table 4: Sample Size of Selective Village of Ward 1 (Saigaun)

Village	**Household Number**	**Sample Size**	**Sample Size Cumulated**
3	414	13	13
5	331	10.39	10
Total	1242	39	39

The sample size for selective villages of ward 3 (Indrapur) is shown in Table 5:
The sample size for selective villages of ward 4 (Khajura Khurda) is shown in Table 6:

Table 5: Sample Size of Selective Village of Ward 3 (Indrapur)

Village	Household Number	Sample Size	Sample Size Cumulated
1	127	4.02	4
3	85	2.69	3
19	149	4.71	5
Total	1929	61	61

Table 6: Sample Size of Selective Village of Ward 4 (Khajura Khurda)

Village	Household Number	Sample Size	Sample Size Cumulated
3	50	1.57	2
10	62	1.95	2
15	87	2.73	3
Total	1050	33	33

2.5.1 Data Collection and Calculation

The initial step was to collect the necessary data and the extractions of pertinent factors in order to accomplish the main goal of the examining the production trend and climatic scenario along with other variables and their correlation in the research area. Subsequently, these factors were scrutinized to identify their inter relationship and trends. The data used for this analysis were sourced from a variety of outlets, encompassing both primary and secondary data, along with ancillary data, to ensure a comprehensive and high-quality analysis. The process of gathering data involved accessing a rich pool of information from government reports, academic literature, and books, thereby offering a more expansive context and historical viewpoint for the research. Moreover, adding information from trustworthy websites and internet sources improved the dataset's currency and depth. This diverse approach to data collection ensured the study's dependability and thoroughness while also enhancing its richness. Important contextual facts were acquired from reputable organizations including DHM, and MOALD. These details contributed to a thorough understanding of the issues influencing the research region. The primary, secondary, and auxiliary sources were all covered by this comprehensive data collection methodology. These many techniques for gathering data have enabled this thesis to get an accurate outcome to address the objectives. IBM SPSS statistical 27 tool and Microsoft Excel was used to carry statistical analysis.

Pearson Correlation Coefficient Pearson correlation coefficient is used for yield, sunshine hour, and accumulated rainfall to calculate the linear relationship between them before simple linear regression, where total yield is the dependent variable, and sunshine radiation, accumulated rainfall, and average temperature are the independent variables.

Pearson correlation coefficient (r) is a popular method for calculating a linear correlation. The degree and direction of the relationship between two variables are indicated by the correlation coefficient, which has a range of -1 to 1 Turney2022.

A perfect positive correlation ($r = 1$) means that as one variable rises, the other rises in proportion. A complete negative correlation ($r = -1$) means that as one variable rises, the other falls proportionately. ($r = 0$) indicates no linear correlation between the variables.

The formula for the Pearson correlation coefficient (r) between two variables (X) and (Y) with (n) data points is given by:

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

Where:

- X_i and Y_i are individual data points for variables X and Y, respectively.
- $\bar{X}$ and $\bar{Y}$ are the means (average) of the variables X and Y, respectively.
- $\sum$ represents the summation symbol, indicating that you need to sum the quantities inside it across all data points.

Source: Turney2022

Simple Linear Regression Analysis Simple linear regression analysis is used in this study to establish the relationship between the dependent variable (Yield) and independent variables (climate data). This statistical technique allows for the examination of how changes in one variable (independent variable) affect changes in another variable (dependent variable) through the estimation of a linear relationship between them Mali2023.

The equation of simple linear regression is:

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

Where:

- Y_i represents the dependent variable; X_i represents the independent variable.
- The intercept, denoted by β_0, indicates the value of Y when X equals 0.

- β_1 is the slope of the line, representing the change in Y for a unit change in X.
- ϵ represents the error term, accounting for the differences between the observed and predicted values.

T-test The T-test is used to compare the average yields (in kilograms per hectare) of two groups categorized by different irrigation methods: year-round irrigation and rainfed irrigation during the monsoon season.

- **Year-round Irrigation:** Agricultural plots where irrigation is consistently applied throughout the year.
- **Rainfed Irrigation:** Agricultural plots relying solely on rainfall during the monsoon season for irrigation.

Statistical software package (SPSS) is used for analysis. The t-test is performed to compare the average yields between the two irrigation groups. The significance level (α) is set a priori to 0.05.

$$H_0 : \text{There is no difference in yields between the two groups.}$$

$$H_1 : \text{There is a difference in yields between the two groups.}$$

A statistical test for comparing the means of two groups is called a t-test. It is frequently employed in hypothesis testing to ascertain whether two groups are distinct from one another or whether a procedure or treatment genuinely affects the population of interest Bevans2020.

The t-test statistic is given by the formula:

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

Where:

- $\overline{x_1}$ and $\overline{x_2}$ represent the means of the two samples.
- S^2 represents the pooled variance of the two samples.
- $\frac{1}{n_1} + \frac{1}{n_2}$ represents the sizes of the two samples.

Source: Student1908, Zabell2008

Index Model An index model determines the index value for every unit area and uses those values to create a ranking map. An index model and a binary model are comparable in that they both rely on overlay operations for data processing and require multicriteria assessment. However, an index model generates an index value, not just a yes or no, for every unit area OneStopGIS2020.

Two tiers of evaluation are applied to certain variables:

- Considering relative significance and weighing.
- Values that are seen are assessed and assigned scores OneStopGIS2020.

Climate Change and Production Trend Analysis The simple linear regression analysis was carried out using IBM SPSS Statistical 27 tool to identify the relationship between the dependent and independent variables. In this data, production yield data is the dependent variable, and climatic variables such as accumulated precipitation data, average temperature, and sunshine radiation are the independent variables.

Initially, the correlation between these variables was computed, and afterward, the linear relationship between climate variables (sunshine hours, temperature, and rainfall) and yield was analyzed through simple linear regression analysis.

Climate Change Trend Three variables for climate change were studied, which included Accumulated Rainfall, Average Temperature, and Sunshine hours of the study area for the last thirty years, from 1990 to 2021. The data were obtained from the Department of Hydrology and Meteorology. Excel was used for plotting the linear trend graph.

Climate Change Perception An index model has been used to evaluate the perception of farmers towards climate change and its impact on agricultural production. Understanding of climate change and its impacts is deeply rooted in the perception of farmers towards climate change. A total of 134 respondents were asked to give their opinion on the following statement.

A three-point scale was used with the frequency of agreement/approval as +1, frequency of disagreement/disapproval as -1, and "don't know/absent" was given as 0.

The following formula by Dahal (2021) has been used for calculating the index for binary variables:

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

Where:

- FA: Frequency of agreement/approval
- FDA: Frequency of disagreement/disapproval
- FDK: Frequency of "don't know/absent"
- N: Total number of respondents = 134

For variables with multiple categories, the following formula has been used to calculate the index based on a data normalization technique (Nguyen 2019):

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

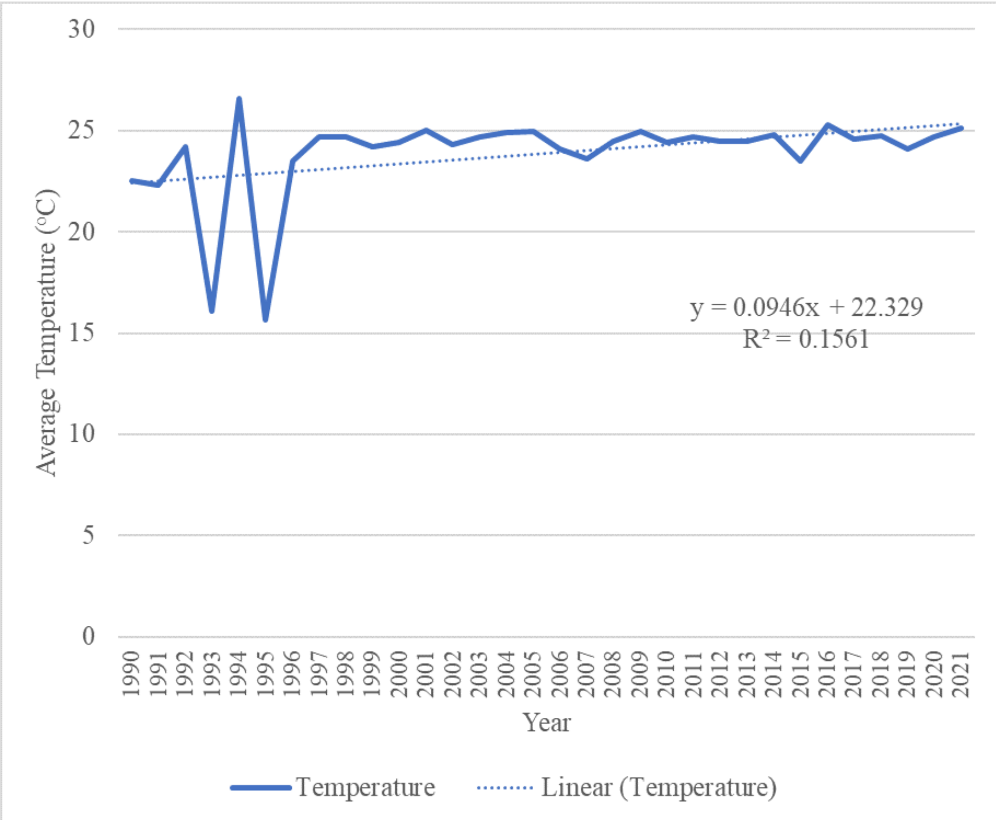
Where X is the value of a particular category.

3 Results and Discussion

3.1 Climate and Production

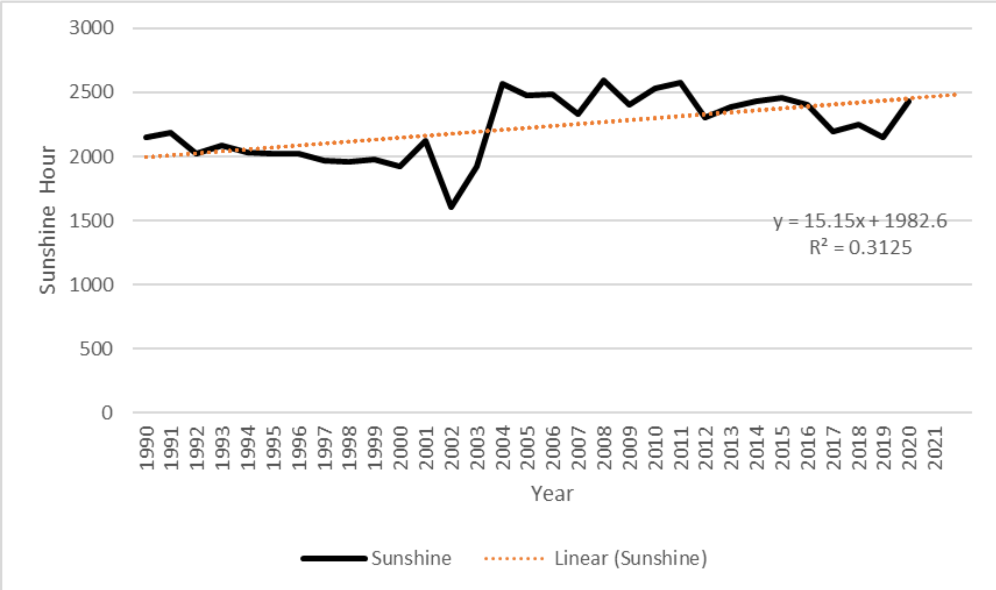
3.1.1 Climate Change Trend

Figure 1: Average Temperature since 1990 to 2021



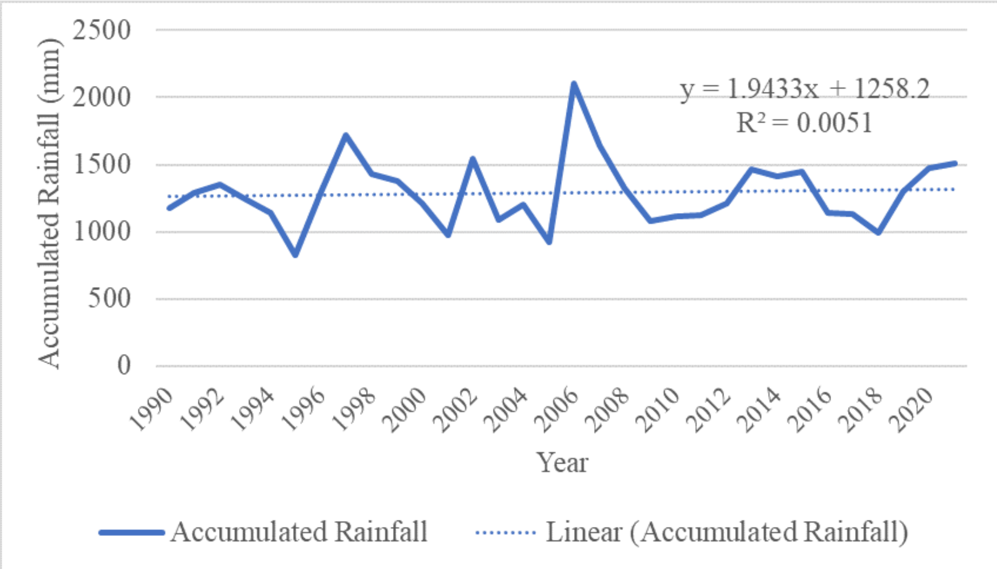
As shown in Figure 1, the results indicate that between 1990 and 2020, the average temperature showed a minor positive trend, averaging 0.0946 degrees Celsius each year, with 15.61% of the variability explained by the linear trend $y = 0.0946x + 22.329$. The positive trend might be due to global warming. 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 7: 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 8: 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 9: 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 9 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 10 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 11 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 10: 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 12). 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 13).

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 14 presents the results of the t-test examining the effect of different irrigation categories on crop yield.

Table 11: 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 12: 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 13: 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 14: 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 14). 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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