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

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:

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 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

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

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

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

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

As shown in Figure 1, the results indicate

3.2 Correlation Between Yield and Climate Variables

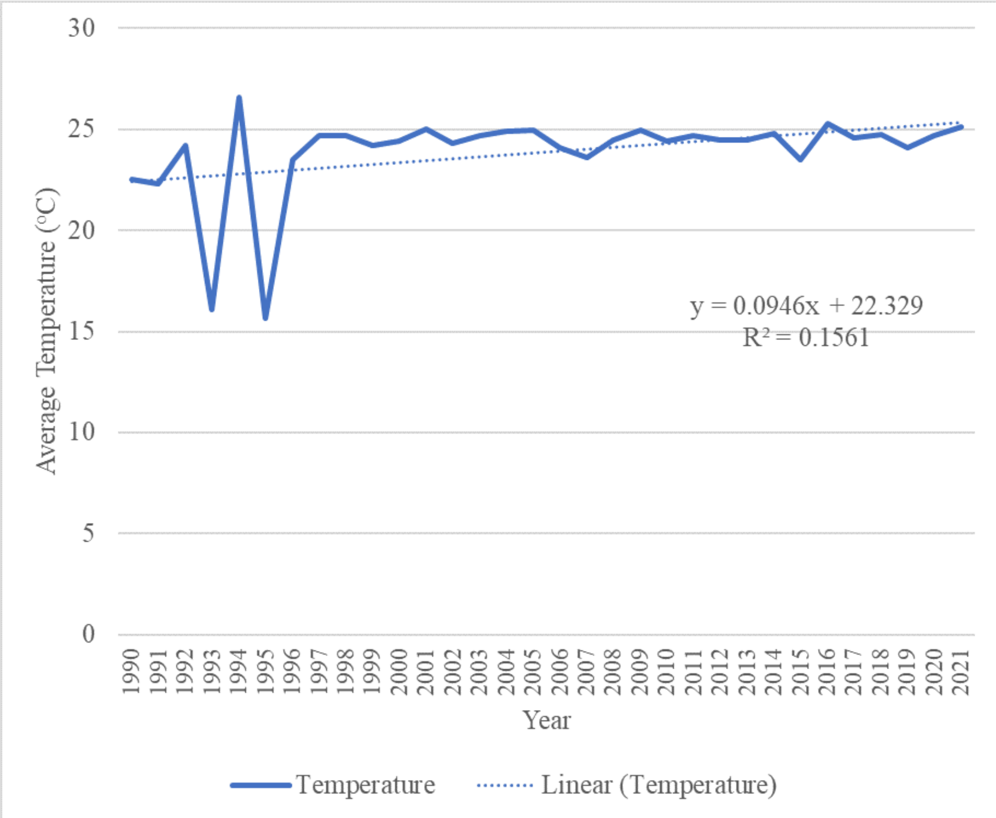
Table 7: Correlation Table between Yield and Climate Variables

	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

Figure 1: Average Temperature since 1990 to 2021



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

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.

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

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 1Karki 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.

4 Summary

References

References

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