

**CLIMATE CHANGE AND ITS IMPACT ON FARMING
SYSTEMS OF WEST KAMENG DISTRICT, ARUNACHAL
PRADESH**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY**

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MZU REGISTRATION NO.: 2200629

Ph.D. REGISTRATION NO.: MZU/Ph.D./2071 of 31.08.2022



**DEPARTMENT OF GEOGRAPHY & RESOURCE
MANAGEMENT
SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCES
MANAGEMENT
SEPTEMBER, 2025**

**CLIMATE CHANGE AND ITS IMPACT ON FARMING SYSTEMS OF WEST
KAMENG DISTRICT, ARUNACHAL PRADESH**

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**In partial fulfillment of the requirement of the Degree of Doctor of Philosophy
in Geography & Resource Management of Mizoram University, Aizawl.**



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SEPTEMBER, 2025

I **NORBU JAMCHU THONGDOK**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

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Acknowledgement

Initially, I pay homage to the Lord Buddha for keeping me mentally and physically safe and sound throughout my Ph.D. journey.

I am grateful to my society, the Shertukpen community, for their endless support and deliberations during my research.

I express my heartfelt sense of gratitude to the Department of Geography and Resource Management, in particular, and Mizoram University as a whole for infrastructural and financial assistance and support.

Most importantly, I am blessed to have my supervisor, Sr. Prof. Vishwambhar Prasad Sati, who, since the very first day, has encouraged me and lifted me to do hard work, and guided me every day as I can remember till today. He made me capable of executing and achieving numerous things in life. His teachings and guidance are what I will always remember and cherish throughout my life. Therefore, I pray to the almighty Lord Shiva to look after him and keep him healthy and safe all the time.

In addition, I am indebted to all the people who cooperated with me during the field visit and data collection, such as all the farmers, members of the village council, NGOs, and scientists of Krishi Vigyan Kendra (KVK) Dirang, West Kameng District, Arunachal Pradesh, and the Office of the District Agricultural Office, Bomdila, West Kameng District, Arunachal Pradesh, for providing me with necessary information about agricultural production. Furthermore, I am obliged to my friends, Mr. Vikrant Kumar, for helping me out with the map preparations, and Mr. Dorjee Khandu Wangja (Chumbi) for helping me with my data collection process, also my friend Debashis Sarma. Lastly, I am thankful to my beloved Ms. Subu Yatung, who played an important part in helping me achieve this feat. Without her, my journey would not have been completed.

I am also grateful to my brother Puia, who had sheltered me when I first came to Mizoram; without him, my Ph.D. journey would not have been possible. Every individual has played an important role in my Ph.D. life.

Lastly, and most notably, I am thankful to my parents in particular and my family as a whole, who stood with me in my every struggle. I would dedicate my Ph.D. work and all its success to my parents and my family. May god keep pouring blessings on my family and every step of my endeavors.

(NORBU JAMCHU THONGDOK)

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CHAPTER 1

INTRODUCTION

Climate change is a comprehensive term and a burning issue at present. It is a crucial driver that greatly affects agricultural practices (Enete & Amusa, 2010). It affects agriculture in many ways, such as variations in rainfall, temperatures, and extreme events, with an important impact on soil erosion, resulting in a variation in the growing season (World Bank, 2008). The agricultural sector and climate change are closely intertwined (IPCC, 2007). Various prominent authors have distinctively defined climate change. Costello et al. (2009) defined climatic variation is an immense threat of the 21st century. Similarly, Tol (2009) stated that climate change is the most adverse phenomenon; it is larger, more complex, and unpredictable than any other environmental issue.

Climate change greatly affects the socioeconomic activities of an area, most importantly farming patterns and other agricultural activities. Owing to the drastic change in climate, the agriculture sector and farming practices are under threat, as a consequence of increase in anthropogenic activities such as industrialization, urbanization, deforestation, change in land use patterns, etc. Agriculture is an economic activity that is largely dependent upon weather and climate to produce the food, fibre, and other necessary things to sustain human life (Praveen & Sharma, 2019). The crop yield shows a strong relationship with climate change (Hoffmann, 2013). Climate change is much faster and poses a higher potential threat to agricultural practices (Mahato, 2014). Agricultural activity is expected to be vulnerable to climate variability (Vuuren et al. 2009).

Climate affects numerous socioeconomic activities, particularly farming patterns and allied activities. Change is imminent, and it is bound to occur; such change in a certain amount of rainfall, temperature, and humidity controls the nature of the soil and greatly affects agricultural output in mountain regions.

Climate change poses a great threat to mountainous regions (Sati, 2015); besides, its change and its hydrological consequences may result in the significant

modification of soil conditions (Várallyay, 2010). Numerous studies have been conducted with regard to climate change and crop suitability; its impact on food production has been examined, particularly with crop yields. Nevertheless, climate affects all elements of crop production and productivity (Iizumi & Ramankutty, 2015), as such fluctuations in weather patterns can elevate the crop susceptibility and the consequences of extreme climate events like high temperatures, droughts, and incessant rainfall. Moreover, consecutive climate events, such as abnormal flooding and rains, are disastrous and are intensified by environmental effects that also distress human and agricultural activities (Rosenzweig et al., 2001).

In particular, under rain-fed conditions, the potential of crop to produce solely determine by the climatic setting of an area (Chemura et al., 2020); consequently, respective crop will flourish within a specific climatic condition that can be improved by management—however, climate change will modify the satisfaction of these requirements of the components of crop suitability (Travis, 2016). Directly or indirectly, climate change affects crop production; thus, land capability is expected to decrease under climate change, and crops grown in summer are anticipated to be more sensitive to its change than winter season crops (California Department of Food and Agriculture, 2013). Crop suitability assessment models can indicate the best locations to grow different crops and, in doing so, support efficient use of land to leave space for or share space with nature (Gardner, 2021). Thus, assessing agricultural suitability and yield under climate change is essential for eco-friendly agricultural production (Abd-Elmabod et al., 2020). Due to climate change, several traditional crops (mostly cereal grains) have now completely disappeared, and those crops are being replaced by commercial cash crops that are resilient to climate variability (Thongdok and Sati, 2024).

Climate controls agriculture in numerous aspects, such that the plant mechanisms, and therefore yields, are influenced by several ecological factors, such as humidity and temperature, which affect either directly or indirectly with other factors, in defining the agricultural productions (Waggoner, 1983). It is the primary factor of agricultural practices. Despite the crucial role of agriculture, concern has been raised about the latent effects of its change on agricultural production and productivity.

Climate change is projected to determine crop and livestock practices, water bodies, and other elements of agricultural patterns (Adams et al., 1998). Moreover, variations in temperature and rainfall will affect the dispersal of agroecological zones. Changes in soil moisture and the content will vary during the period and length of growing seasons of different crops (Darwin, 2011).

India is highly vulnerable to climate change, mainly in the agriculture sector. (Bhattacharya, 2019). In India, many studies have provided experimental indication that climate change has resulted in a deterioration in agricultural productivity (Praveen & Sharma, 2020). Farming is the main occupation and major source of livelihood in the West Kameng district of Arunachal Pradesh. The agro-climatic conditions are rich for the cultivation of various crops. Some crops, such as potatoes, are largely grown (APSAPCC, 2011). Meanwhile, there is a large change observed in climatic conditions in the recent past, which is affecting farming systems in the region.

Furthermore, through this study, the pivotal role of assessment of the soil would help us in a precise and comprehensive understanding of the crop pattern and suitability for cultivation. Moreover, analyzing climate data, such as temperature, rainfall, and humidity, would help illuminate the trend of climate variability and its implications for agricultural practices. Overall, the study would help our interpretation of the in-depth relationship between the underlying physical setting and agriculture, it would also envisage the vision of sustainable farming practices and management of natural resources (Thongdok and Sati, 2024).

This study will explore the current situation of the farming system and climate variability and change in the West Kameng district of Arunachal Pradesh. The major research queries stressed for this study are: What are the climatic conditions and farming systems that prevail in the region? And what are the implications of its change on farming systems? The study will also focus on understanding the agroecological condition: climate, vegetation, soil, water availability, and their relationship with agriculture.

1.1. Study area

Arunachal Pradesh is located in Northeast India, between 26° 0' 30" N and 29° 0' 30" N, and 91° 0' 30" E and 97° 0' 30" E. It covers an area of 83,743 km² (1.18% of India's total area). It is bounded by Bhutan in the West, China in the North, and Burma in the East, and the state of Assam in the South. Altitude ranges from 150 m to 7,000 m. The major types of climates are monsoon climate, subarctic climate, alpine climate, and humid subtropical climate. The average temperature in the state ranges from -6 °C to 35 °C. It receives a mean annual rainfall of 300 cm. Over four thousand species of flowering plants, 600 bird species, 200 fish species, and 42 amphibian species. The state has a total population of 1,383,727 (3.34% of India's total population) and comprises 26 major tribes and more than a hundred sub-tribes (Census of India, 2011).

The West Kameng district is in the westernmost region of Arunachal Pradesh (Fig. 1.1). It is bordered by Bhutan in the West, Assam in the South, the East Kameng district in the East, and Tibet (China) in the North. The vegetation is subtropical, broad-leaved, pine forests, evergreen, and dense. Loamy, clay, and sandy loam are the three major types of soils found in the district. Various types of fruit are extensively grown, such as Kiwi, Plum, Pears, Chestnut, Cherry, Walnut, and Persimmon. Apart from that, the cultivation of tomatoes, Cabbage, Chilli, and Potatoes by the people of Rupa, Bomdila, Singchung, Dirang, Nafra, Shergaon, and Kalaktang is the main occupation of the people of West Kameng District. The inhabitants of the district are comprised mainly of Aka (Hrusso), Bugun (Khowa), Monpa, Sajolong (Miji), Sartang, and Shertukpen ethnic groups. There are 260 villages, 5 administrative blocks, and 13 administrative circles in the district. The administrative circles are Balem, Bhalukpong, Bomdila, Dirang, Jamiri, Kalaktang, Kamengbari-Doimara, Nafra, Rupa, Shergaon, Singchung, Thembang, and Thrizino (District Statistical Handbook, 2011).

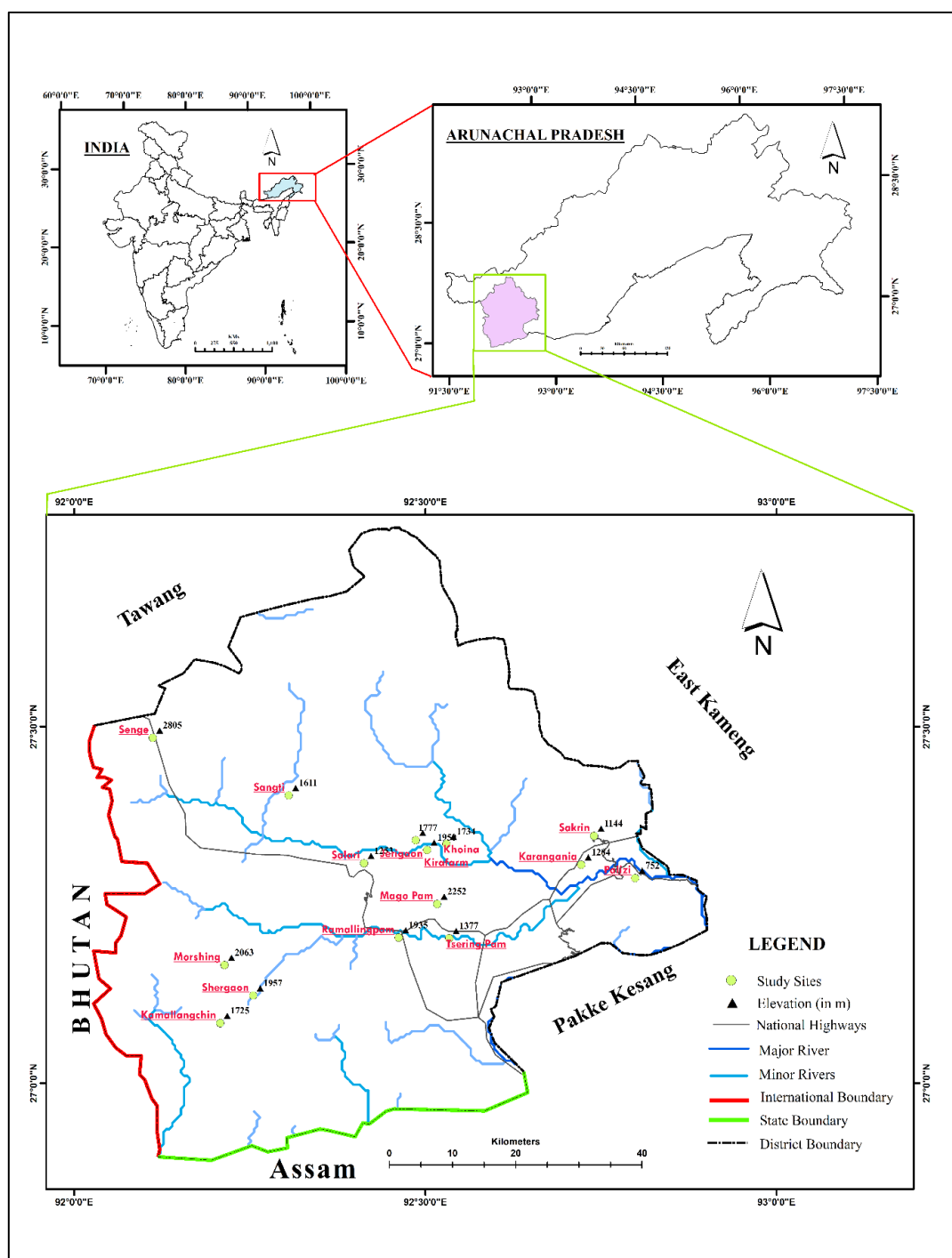


Fig. 1.1. Study area map of the West Kameng District

1.2. Materials and methods

1.2.1. Data collection

The data has been collected through both primary and secondary sources. The primary data has been collected by selecting 15 villages for the case study; a total of 5 administrative blocks, and 3 villages from each administrative block were selected (Table 1.1). The villages were selected based on their location, altitude, accessibility, and population size. The sampling size was determined at 35.48 % of the total population of each village, and a purposive sampling method was used to obtain the data from the farmers. A structured questionnaire was constructed, and questions were asked on the farming systems, agro-climatic conditions, climate change, socio-economic conditions, and people's perception of the impact of climate change on farming systems. The other questions inquired about the crops' area, production, and productivity.

Table 1.1. Household-level survey of the case study villages

Village	CD Block	Number of the HHs surveyed	Total number of HH	% of HH surveyed	Elevation (in m)	Location
Morshing	Kalaktang-Rupa Block	13	35	35	2063	27°10'26''N;92°12'23''E
Kamallangchin		19	54	35	1725	27°09'58''N;92°15'76''E
Shergaon		38	106	35	1957	27°14'71''N;92°27'95''E
Ramallingam	Sinchung Block	7	20	35	1935	27°18'38''N;92°46'51''E
Tsering Pam		11	30	35	1377	27°20'24''N;92°49'47''E
Mago Pam		14	40	35	2252	27°24'96''N;92°52'34''E
Salari	Dirang Block	53	149	35	1253	27°32'58''N;92°43'76''E
Sangti		74	210	35	1611	27°24'10''N;92°16'40''E
Senge		56	160	35	2805	27°44'75''N;92°17'95''E
Jerigaon	Nafra Block	41	117	35	1777	27°33'94''N;92°47'95''E
Kirafarm		12	35	35	1950	27°35'50''N;92°47'69''E
Khoina		13	36	35	1734	27°35'75''N;92°48'61''E

Karangania	Thrizino Block	11	29	35	1284	27°17'56''N;92°42'26''E
Sakrin		21	59	35	1144	27°21'03''N;92°43'35''E
Palizi		40	112	35	752	27°17'30''N;92°46'46''E
	Σx=	423	1192	35.48		

Source: Primary field survey 2023

The secondary data has been used to gather sufficient insight into the research problem through relevant literature reviews available in published books and journal articles. Besides, censuses, governmental reports, unpublished doctoral theses, and different government websites have been used to obtain pertinent information related to the research problem. Moreover, the data on temperature, rainfall, and humidity of the last 21 years have been obtained from the NASA Data Access Viewer or Power NASA <https://power.larc.nasa.gov/>. In addition, information from the Office of the District Agriculture Officer, the Directorate of Economic and Statistics, Arunachal Pradesh, and the District Statistical Handbook was used to generate socio-economic data of the study area.

1.2.2. Data analysis

Various quantitative techniques and statistical measures were used in the study. Such as simple mean, trend analysis, linear regression analysis, *Pearson* correlation (*r*), two-tailed ANOVA, multiple regression analysis, per-capita income (PCI), per-capita production (PCP), and growth rate of the production.

1.2.2.1. Mean

In statistics, the mean, often referred to as the average, is calculated by summing all values in a dataset and then dividing by the total number of values. It is the average of a set of numbers.

Mean,

$$\bar{x} = \frac{\sum x_i}{n}$$

Where, $\bar{x}$ = is the Mean

$\sum x_i$ = Sum of all data points

n = is the number of data points

1.2.2.2. Trend analysis

A trend analysis is a statistical method of attempting to determine the past, present, and future behaviors of the variables by analyzing historical data sets. Whereas, for the study, Parametric or linear trend analysis has been applied to understand the variables' trend.

Trend (Linear) regression or analysis,

$$Y = mX + b$$

Where Y : dependent variable or the variable whose value is being predicted or explained based on the relationship with the independent variable (x)

mX : represents the product of the slope (m) and the independent variable (x)

b : represents the slope of the fitted line, indicating the average change in the dependent variable (Y) for every one-unit increase in the independent variable (x)

1.2.2.3. Correlation

Correlation analysis is a statistical method used to measure and evaluate the strength and direction of the relationship between two or more variables. Whereas, for the study, *Pearson* correlation (r) has been used.

Pearson (r) correlation,

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where,

r = Pearson correlation coefficient

n = the number of pairs of data

Σxy = the sum of the products of paired scores

Σx = the sum of x scores

Σy = the sum of y scores

Σx^2 = the sum of squared x scores

Σy^2 = the sum of squared y scores

1.2.2.4. Two-tailed ANOVA

ANOVA (Analysis of Variance) is a statistical test used to analyze the difference between the means of more than two groups.

Two-tailed Anova,

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \epsilon_{ijk}$$

Where,

Y = dependent or response variable in the data set

i = level of factor A

j = level of factor B

k = level of factor c

μ = average value of all observations

A_i = specifically denotes the mean value for the i group or level of the independent variable

AB = represents two different independent variables

ϵ_{ijk} = represents the random error term associated with a specific observation

1.2.2.5. Multiple regression analysis

Regression is a statistical technique used to determine the relationship between two variables. Whereas, Multiple linear regression is used to estimate the relationship between two or more independent variables and one dependent variable.

Multiple regression analysis,

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots + b_pX_p + \varepsilon$$

Where,

b_0 (*Intercept*) = predicted value of Y value

b_1 (*Coefficient for X_1*) = estimated change in Y value

b_2 (*Coefficient for X_2*) = estimated change in Y for a one-unit increase in X_2

b_p (*Coefficient for X_p*) = estimated change in Y for a one-unit increase in X_p

$X_1, X_2, \dots, X_p$ (*Independent Variables*) = predictor variables

ε (*Error Term*) = part of Y that is not explained by the independent variables in the model

1.2.2.6. Per-capita income (PCI)

Per capita income (PCI) is the average amount of money earned per person in a given area over a specific period. It's usually calculated by dividing the total income of an area by its population.

Per-capita income,

$$PCI = \text{Total Income} / \text{Population}$$

Where,

Total income = income earned by a population in a year

Population = total population of an area

1.2.2.7. Per-capita production

Per capita production refers to the output or production of goods and services measured per person within a specific population or area.

Per-capita production,

$$\text{Per capita production} = \text{Total Production} / \text{Population}$$

Where,

Total production = total production of goods in a year

Population = total population of an area

1.2.2.8. Growth rate

A growth rate is a metric that expresses the percentage change of a variable over a specific period.

$$\text{Growth Rate} = (\text{Current Yield} - \text{Previous Yield}) \div \text{Total Yield} * 100$$

1.3. Statement of the problems

In recent years, the West Kameng district has attained the name ‘agriculture bowl’ of the state of Arunachal Pradesh due to its high agricultural productivity. However, over the years, the region has been experiencing a drastic climate variability; changes in rainfall patterns and increasing temperature. It is proven that climate change poses a huge threat to agriculture and allied activities, whereas, often, climate change tends to have short-term positive impacts on agricultural productivity. Crops require certain climate conditions for their growth and yield; therefore, the increasing trend of temperature may lead to the introduction of new crops, and such a case has been witnessed across the region. The district is experiencing an increasing trend of temperature and a decreasing trend of rainfall over the last 21 years.

The farming patterns and systems of the region are changing; the farmers have superseded the traditional crops like maize and cereals with cash or non-conventional

crops like tomato, potato, chilies, cabbage, etc. These crops are commercial. The change in climate conditions, like an increase in temperature, has resulted in the abandonment of traditional crops and the adoption of such crops, which are climate resilient and have the potential for high productivity. Moreover, the farmers have ceased practicing the water-intensive crops due to decreasing rainfall patterns in the region.

The problems of the study arise from the fact that the climate in the region is changing at a fast pace, resulting in both positive and negative impacts on the environmental and societal aspects. It was also found that the introduction of these cash crops holds high potential to enhance the standard of living or livelihood of the farmers due to their economic viability. Therefore, the primary objectives of the study are to examine the changing climate pattern and its implications on the farming systems in the district. Besides, such changes in farming systems and patterns have resulted in livelihood enhancement in the region.

1.4. Scope of the study

Climate is inevitable and dynamic; thus, climate is bound to change and occur. Variability in climate conditions in day-to-day life is becoming more evident. It directly influences various socio-economic activities, most importantly, agricultural practices and productivity. Whereas mountain ecosystems are important yet very fragile to climate change. The rural population dwelling in mountainous regions is more vulnerable to climate change, with changes in agricultural practices and patterns due to climate change and variability.

Over the recent years, the Himalayan state of Arunachal Pradesh has been witnessing a drastic change in conditions like fluctuating rainfall, increasing temperature, and drought-like situations across various regions in the state. The maximum percentage of the population in the state is still dependent upon agriculture and its allied activities as a primary source of income and occupation. The West Kameng district in the state is most vulnerable to climate change, as it has been evident in recent years with changes in farming patterns in the region.

This study focuses on climate change and its impact on the farming systems of the West Kameng district of Arunachal Pradesh. Agriculture is the main occupation of the people of West Kameng, also the region is known as the agricultural bowl of the state. It has a suitable climatic condition that favors the growth and practices of varied agricultural and horticultural crops. However, in recent years, the region has been witnessing a shift in agricultural production and practices, perhaps due to variations in climatic conditions. This study endeavors to chalk out a meaningful strategy to comprehend the impact of climate change on the farming system and endorse sustainable and climate-resilient farming practices in Arunachal Pradesh in general and the West Kameng district in particular.

1.5. Objectives

The main objectives of the study are as follows-

1. To examine the climatic conditions and farming systems in the West Kameng district of Arunachal Pradesh.
2. To study the impact of climate change on farming systems.
3. To analyze the socio-economic status of farming communities due to changes in farming systems.
4. To suggest sustainable and climate-resilient farming systems.

1.6. Hypothesis

The present study's hypothesis is the Null hypothesis of the general analysis of the regional climate indicates that the climatic condition over the last 21 years has been constant, and there is no change; whereas, the Alternative hypothesis of the study of the climate of past 21 years indicates that there is significant variations and changes in the climatic condition over the region. The hypothesis of the study is as follows.

1. Climate change has a significant impact on the growth, production, and productivity of crops, mainly in the Himalayan region.
2. It also has an impact on the socio-economic and livelihood sustainability of the farmers.

1.7. Research questions

1. What are the farming systems and patterns in the West Kameng district?
2. What is the impact of climate change on the agricultural growth, production, and productivity in the district?
3. Is the introduction of commercial crops enhancing the livelihood of people?

1.8. Chapterization of the study

The chapters in the study have been organized as follows-

Chapter I: Introduction

The introduction chapter comprises the background of the study, such as introductory aspects of the study, statement of the problems, study area, scope or significance of the study, aims and objectives, hypothesis, and research questions.

Chapter II: Literature Review

This chapter consists of various literature concerning climate change and its implications on farming systems across the globe. The review has been done in the following manner: International level, National level, regional level, and local level for a clear and better understanding of the climate implications on agriculture and its allied sectors.

Chapter III: Geo-Environmental Setting

This chapter covers the Geographical and Socio-economic aspects and backgrounds of the study area. Physical factors like Geology, altitude, flora and fauna, drainage, soil moisture, soil texture, valley, and forest. Moreover, it also includes climatic aspects like average temperature, humidity, and rainfall. Besides, socio-economic aspects like people, tribe, religion, occupational structure, literacy rate, and festivals.

Chapter IV: Climate variability and change

This chapter deals with the analysis and understanding of the changing trend of climate change and the variability of the time series data on climate parameters, viz, temperature (monthly and annual), humidity (monthly and annual), and rainfall

(monthly and annual) for the period of 2002-2022, i.e., of the last 21 years. The chapter presents the way the climate is changing and its trend over the last 21 years in the study area with the help of a statistical technique called Trend (linear) analysis.

Chapter V: Climate change and its impact on farming systems

This chapter involves the implications of climate change on farming systems and patterns like growth, production, productivity, and yield. Production and area of major crops and climate data of the last 9 years have been analyzed using various statistical techniques to determine the correlation and effect of climate on crop production, such as correlation, two-tailed ANOVA, and multiple regression analysis to understand the relationship between crop production and climate variables. Moreover, the chapter also deals with the determination of a relationship between the elevation and crop production, to underline whether altitudinal variations are affecting the crop production.

Chapter VI: Socio-economic status of the farming communities

This chapter encompasses the socio-economic aspects of the farmers in the study area. Such as their occupation, literacy rate, crop production, yield, and area. In addition, the chapter presents how cash crops benefit farmers in terms of livelihood enhancement and sustainability. Moreover, this chapter covers the per-capita income of farmers and the per-capita production of crops.

Chapter VII: Sustainable and climate-resilient farming practices

This chapter includes the formulation and construction of different strategies and measures for the adaptation and enhancement of sustainable livelihood and means to promote sustainable and climate-resilient agriculture in the study area.

Chapter VIII: Summary and Conclusions

This chapter deals with the summary and conclusions of the research work.

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CHAPTER 2

LITERATURE REVIEW

A literature review is an integral part of research, providing a better vision and insight into the researcher's topic. It is essential in any research and study, as a good review of the literature would pave the way for a better understanding of the problems and prospects of the field of research.

Numerous studies concerning climate and its implications for various social systems and activities have been conducted at the international, national, regional, and local levels. It is essential to construct the knowledge base of distinct studies on climate variability and its implications on social activities, primarily on agricultural practices. The review of the pieces of literature highlights the overall framework of the implications of climate change on societal impacts, particularly agriculture practices and systems.

2.1. International level

UNEP (2021) in its report ‘The Effects of Climate and Air Quality on Diverse Communities’, based in North America, reported the rapid change in the region's climate, such as extreme climatic events resulting in frequent droughts and forest fires. They also focused on how much change can potentially drive the change in land use patterns over the region.

Edition (2016) reported a study on ‘Climate change indicators in the United States’ which explained climate change and its impact on the environment in the United States of America (USA), in their study, they extensively reported the adverse effects of climate change due to human activities resulting in heavy snowfall, rising temperatures, shifting rainfall, and more extreme climate events – like heavy rainstorms and record high temperatures – are becoming more common.

Lane et al. (1999) conducted a significant study titled ‘Indicators of impacts of global climate change on US water resources’, highlighting climate change and its negative implications for water resources in the United States of America (USA). The

study primarily focused on regional reservoir storage vulnerability, regional water supply systems, and water resources under a climate change scenario with an economic growth scenario.

Houghton et al. (1996) in their work ‘Climate Change 1995: The Science of Climate Change,’ reported that over the last century, the Earth's average temperature has already gone up by between 0.3 and 0.67 degrees Celsius. Particularly concerning is that the rate of this increase has accelerated significantly in recent decades, and it will also affect the changing temperatures and climate. Moreover, evaporation is also expected to increase in the coming years.

Motha & Baier (2005) in their study ‘Impacts of present and future climate change and climate variability on agriculture in the temperate regions of North America’ argued that the United States and Canada’s potential impact of climate change on agricultural production and yield. Moreover, they stated the Southern crop areas are expected to have the worst declines because of rising temperatures and decreased water availability.

Calzadilla et al. (2013) in their monumental work entitled ‘Climate change impacts on global agriculture’ argued that Climate change is expected to decrease global agricultural production. In the short term, the loss is slight, at about 0.5%, but it rises to about 2.3% over time. Furthermore, adjustments in rainfed and irrigated production are caused by anticipated changes in the water supply for these types of agriculture. The yield gap between rainfed and irrigated crops is reduced in the 2020s by moderate precipitation increases, increasing global rainfed production. This leads to a decline in irrigated crop production, primarily in the United States, the Middle East, North Africa, and South Africa, as well as in regions where irrigated production makes up a significant portion of total crop production and has high negative yield responses to temperature changes.

Marengo et al. (2014) worked on ‘Climate change in Central and South America: recent trends, future projections, and impacts on regional agriculture’ and discussed important components of vulnerability including a lack of resilience and the

ability to foresee, manage, and adjust to extremes. For instance, depending on where and when they make landfall, hurricanes and tropical cyclones can have quite diverse effects. Similar to this, the effects of heat waves and heavy rains can vary greatly among various demographic groups based on their exposure and susceptibility, as well as their income and educational attainment. Therefore, severe weather or climatic events, non-extreme events with high exposure and susceptibility, or a combination of events or their effects like flash floods, and landslides can all have extreme effects on human, ecological, and agricultural systems.

Ziervogel et al. (2014) conducted a study on ‘Climate change impacts and adaptation in South Africa’ where they emphasized the key concerns of climate change and its probable impact on agriculture practices in hilly regions. Moreover, they talked about the adaptation and mitigation measures to be adopted for sustainable and climate-resilient farming practices in the region. Furthermore, they stressed the importance of assessing climate change to support farming and agricultural development.

Kotlarski et al. (2023) in their work ‘21st Century Alpine climate change’ in the European Alps, meaningfully explained the climate change and global warming scenario in the 21st century, and its present societal implications and prospects as well. Moreover, the entire Alpine region will face a warmer climate in the twenty-first century for all emission scenarios.

Führer and Gobiet (2014) in their work ‘Implications of climate change scenarios for agriculture in Alpine regions—A case study in the Swiss Rhone catchment’ conducted in the Alpine Mountain region stressed the awareness and knowledge of climate change and its effect on various agriculture practices and development. And also deteriorating agro-climatic conditions and probable implications on agricultural development.

Behringer (2000) discussed in a study entitled ‘Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture’ executed in the Alpine region, they significantly highlighted the

importance of mountain agriculture and how climate change is also impacting the pivotal socio-economic activities like agriculture and its allied activities. Moreover, they stated that agriculture is highly sensitive to climate change.

Brosse et al. (2022) conducted a study on ‘The importance of the indirect effects of climate change adaptations on alpine and pre-alpine freshwater systems’ in the Alpine Mountain region of Europe. They emphasized how freshwater systems and bodies are affected. Interestingly, they also highlighted how susceptible agriculture is to changing climates. They also discussed mitigation measures to tackle climate change's impact on freshwater bodies and agriculture practices.

Tasser et al. (2017) organized a study on ‘Climate change versus land-use change—What affects the mountain landscapes more’ in the Alpine region. They emphasized the importance of climate change and variability and their immense effect on land use, particularly agriculture. Besides, the impact of changes in land use and climate warming on a typical Alpine landscape and its transformation.

Bibi & Rahman (2023) executed a significant study on ‘An overview of climate change impacts on agriculture and their mitigation strategies’ in this work they explained the dreadful implications of climate change on various socio-economic activities. They specifically stressed its adverse effect on agriculture and soil, as abiotic stresses such as salinity, drought, and temperature fluctuations are devastating to crops.

Blanc & Reilly (2017) conducted a work on ‘Approaches to assessing climate change impacts on agriculture: an overview of the debate’ they discussed how negative implications of climate change are transforming the agriculture scenario across the globe. Most importantly they stated concerning the adoption of mitigation measures, such as approaches to climate-resilient farming practices to cope with climate variability.

Ivanova's (2020) work entitled ‘Impact of Climate Changes, Timber Harvesting, and Fires on Boreal Forests (Example of the Ural Mountains, Russia)’ in the Ural Mountain ranges argued how climate change not only affects agriculture rather it also has a greater implication on timber harvesting, and issues of climate

change-induced forest fire over the region. Also, reasoned that the influence of climate leads to a shift in the range of forest types, which makes it quite vulnerable to climate variability and change.

Lioubimtseva et al. (2005) conducted a work 'Impacts of climate and land-cover changes in arid lands of Central Asia', they argued that despite the mounting understanding of global warming and climate change, there is a great dilemma regarding the climate change response to arid regions. On how these changes might affect the socio-economic activities of the region, such as agriculture and its allied practices. They also stressed future predictions and planning on how to tackle climate change in the arid region of Central Asia in response to agriculture.

Mendelsohn's (2014) work entitled 'The impact of climate change on agriculture in Asia' primarily focused on Central China and discussed that Asian agriculture is responsible for two-thirds of global agricultural GDP; however, in recent years, changing climate has led to an increase in the global temperature, resulting in global warming. The study stresses the effect of excessive warming on crop production and yield. This drastically lessened the agricultural production over the years. Additionally, the study suggested that India is likely to be the most vulnerable country.

Habib-ur-Rahman et al. (2022) conducted a study on 'Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia' They argued that climate change is threatening agricultural output in areas with food insecurity, particularly in Asian nations, the farmer's livelihood has also been negatively impacted by drought, heat waves, storms, floods, unpredictable and heavy rainfall patterns, and emerging insect pests. Furthermore, their study also examined the future climate predictions, which show extreme climatic events like an increase in temperature and abnormal rainfall, which pose a threat impacting the crops and production over the region.

Lozano-Povis et al. (2021) stressed a study on 'Climate change in the Andes and its impact on agriculture: a systematic review' a study based on the mountain region of the Andes in South America, deliberates that Agriculture in the Andes has

become more vulnerable to climate change in recent years, favoring processes like soil erosion, glacier retreat, forest cover loss, higher rainfall intensity, and changes in the dynamics of local crops like corn, quinoa, and potatoes.

De Salvo et al. (2013) conducted work on ‘The impact of climate change on permanent crops in an Alpine region’, particularly focusing on the Italian Alpine region, where they stated climate change is affecting the cultivation of major crops over the region in recent years. The study also argued for the need for systematic management for sustainable and climate-resilient agriculture.

Chen et al. (2016) worked on ‘Impacts of climate change on agriculture’, a study conducted in China reveals the adverse effect of climate variability on agriculture development over the years, thus this variability has immensely altered the agriculture practices over the region, transforming farming systems and patterns of the major crops. Moreover, their study also advocates for agriculture to effectively adapt to climate change in the ensuing decades, for the overall benefit of the farming community.

Ruane & Rosenzweig (2019) a study on ‘Climate change impacts on agriculture’ the study validates that agricultural systems are currently undergoing rapid shifts due to climate change, such changes lead to social advancement, population expansion, technological advancement, economic opportunity, changing commodity demand, and the need for sustainability in the face of environmental change on a worldwide scale. The study also states that the biggest challenge faced by the world in the 21st century is climate change and how it drives the transformation in various socio-economic activities and environmental settings.

Praveen & Sharma (2019) stressed a work ‘A review of literature on climate change and its impacts on agriculture productivity’. Their study mainly focuses on climate change effects on agricultural productivity; it says that agriculture is directly influenced by the climate due to its dependency on climate variables. The most significant natural hazard that harms agricultural output is climate change, which might have a long-term or short-term effect. Therefore, programs and policies

concerning climate change and suggesting sustainable and climate-resilient agriculture have become an important and integral aspect in the present day.

2.2. National level

Sati (2024) deliberately argued under a work titled ‘Climate Change and Its Impact on Farming Systems. In Farming Systems and Sustainable Agriculture in the Himalayas’ the study reported on the serious implications of climate change, particularly in agriculture and farming practices of the Central Himalayas. Additionally, the study advocates that climate change is proving to be a fundamental aspect driving these transformations in the farming systems of the Central Himalayan region. Furthermore, warming trends in the region are contributing to the alarming drying of natural springs, posing a direct threat to the agricultural practices that rely on these water sources.

Mahato (2014) stressed in a study entitled ‘Climate Change and its Impact on Agriculture’ an overall outlook on the implications of climate variability and its negative impact on the agricultural systems in India. The study argued that the drivers of climate change may be an increase in surface and atmospheric temperature, and the surge in the carbon concentration in the atmosphere; whereas these alterations will immensely affect food production by directly impacting the plant physiology. In addition, the warmer temperature will also affect crop growth and yield in the long run.

Kumar & Gautam (2014) in their work ‘Climate change and its impact on agricultural productivity in India’; discussed that climate change is a serious issue that has an immense impact on water and agriculture. Moreover, such changes in the atmosphere are also affecting human health in numerous aspects. They also explained the need for future climate predictions for sustainable and climate-resilient agriculture.

Kumari et al. (2020) conducted a study on ‘A review on climate change and its impact on agriculture in India’ They argued that the Agricultural sector is the most important sector of the Indian economy, however, it is also the most vulnerable entity to climate change. According to their study, climate change is greatly deteriorating

Indian Agricultural production and yield, they have also argued based on the IPCC report, that 21st-century temperature in India is likely to increase by 3-4° C, which would lead to a loss of 3-26% in net agricultural revenues.

Negi et al. (2012) reported in their study ‘Impact of Climate Change on the Western Himalayan Mountain Ecosystems: An Overview’ that they presented an overview of climate change impacts on agriculture, water, and forest ecosystems in the western Himalayan. They also reported that agriculture is the primary occupation of the majority of the farmers in the Western Himalayas, however, it is also most susceptible to the consequences of adverse climate variability. Apart from this, they also argued that the increasing rate of depleting snow cover is due to warming and the increase in temperature over the region.

Negi et al. (2017) conducted a study on ‘Climate change impact in the Western Himalaya: people’s perception and adaptive strategies’ they deliberated that the mountain region across the globe is affected by climate change. Whereas, the climate change in the Himalayan region is distinctive and its major implications are on agriculture, water resources, livestock, and melting glaciers. They also reported the negative impact of climate change on livelihood and other socio-economic activities. Therefore, they have urged the need for people’s perception towards climate change, which can be an important asset in the adoption and mitigation of climate change events.

Dahal et al. (2022) executed a work on ‘Climate change impacts and adaptation in a hill farming system of the Himalayan region: climatic trends, farmers’ perceptions, and in their study, they extensively deliberated that the farming community in hilly regions are most vulnerable to climate change, therefore understanding the parameters of climate change as well as perception of farmers towards the climate change is essential in tackling and adoption of climate resilient farming practices. Moreover, the farmers are adapting to climate change by altering their farming systems and practices, however, there is still a need to bridge the gap between the farmers and crop production as most of the farmers have lesser knowledge

concerning changing climate and which climate resilient crops to be adopted for sustainable and resilient farming practices.

Chhogyel et al. (2020) in their work titled ‘Perception of farmers on climate change and its impacts on agriculture across various altitudinal zones of Bhutan Himalayas’ study describe how climate change is affecting the agricultural development in the Bhutan Himalaya. They found that these climate change impacts were assessed to be responsible for 10–20 % of crop damage, resulting in crop losses. Additionally, they have diagnosed climate change adaptation strategies applied by the farmers, which will help understand the climate change implications, it will also boost the food security and production of the region. The study also suggests identifying and formulating an integrated, sustainable, and climate-proof farming support system.

Kc et al. (2022) in their work on ‘Himalayan ecosystem services and climate change driven agricultural frontiers: a scoping review’ deliberated the climate as a pivotal driver in determining the ecosystem and agriculture practices. Besides, their study also suggests that the Himalayan region is seeing a disproportionate impact on food and water security, habitat health, and agricultural output due to climate change, rising temperatures, snow melts, and more frequent droughts and floods. At lower elevations, the yield of staple crops like rice, maize, and wheat is being adversely affected by these climate changes.

Rawat (2012) executed a study on ‘Impacts of climate change and hydrological hazards on monsoon crop patterns in the Lesser Himalaya: A watershed-based study.’ The study discussed how crop patterns and yield are induced and controlled by varying climatic conditions over a region. Moreover, the study also focuses on how extreme climate events like torrential rainfall during the monsoon season affect the cropping pattern in the Lesser Himalayas. In addition, climate change, as new threats emerge as threats to food security and livelihood, agricultural production, and public health.

Sharma et al. (2017) conducted a study on ‘Climate change & North-West Himalaya: prioritization of agriculture-based livelihood actions’ and stated that the

Himalayan region supports one-third of the water resources of the country however, the region is also fragile to climate change melting of snow cover, affecting various socio-economic aspect; due to their reliance on natural resources, mountain societies are increasingly at risk from processes fuelled by climate change. The heavy reliance on agriculture and other natural resources for subsistence makes this vulnerability even worse. About sixty percent of agriculture in the Himalayan region is rainfed, making it susceptible to variations in the frequency and timing of rainfall. Crop output is influenced by a variety of biophysical processes, factors, and their intricate interactions in addition to the availability of water.

Rani et al. (2022), in his work ‘Climate change, its impacts, and sustainability issues in the Indian Himalaya’ indicates major implications of climate change on various sustainability issues. The study also proves that climate change poses threats to society and offers the toughest challenges for economic development in the present-day context. It also suggests that climate change and its inevitable impacts on the physical and cultural environment, most importantly, food production and food security. As well, the study also recommends that it is important to study and understand the impacts and responses of the mountainous region toward climate change for sustainable planning and adaptability of the climate-resilient agriculture practices.

Sati & Kumar (2023) in their study on ‘Declining agriculture in Garhwal Himalaya: Major drivers and implications’ the study report on the declining agriculture practices over the Garhwal region of the Himalaya. The article exclusively discusses how agriculture is the main occupation of the rural population of the region, in the meantime how climate change is proving to be an imminent factor in the declining trend of subsistence agriculture practices. Henceforth, climate change, severe geohydrological disasters, wildlife-damaged crops, population growth, shrinking landholdings, low soil fertility, low arable land productivity, monocropping, and a lack of utilization of contemporary technology were the main causes of the decline.

Shrestha & Aryal (2011) study on ‘Climate change in Nepal and its impact on Himalayan glaciers’ advocates that climate change often proves harsh for the

population inhabiting the Himalayan region, as the population is mostly reliant on natural resources, therefore, it greatly affects the local economy and livelihood of the populous. The warming climate has resulted in the rapid shrinking of a majority of glaciers in Nepal; besides, such warming has also stalled the agricultural practices and challenged the agricultural pattern of the region.

Isaac & Isaac (2017) work on ‘Vulnerability of Indian agriculture to climate change: A study of the Himalayan region state’ deliberated on the vulnerability of Himalayan states to climate variability and extreme climatic events. The study also highlighted the challenges posed to the agriculture sector due to climate variability. Besides, it also argued concerning the growing population and food security. Moreover, it observed a noticeable change in cropping patterns, crop productivity, and land use; it also suggested that adaptation and mitigation strategies are necessary to ensure sustainable and climate-resilient agriculture.

Shekhar et al. (2010) conducted a study on ‘Climate-change studies in the western Himalayas’. In their study, they significantly discussed that the Himalayan region plays an important role in maintaining distinct climate features over the Indian sub-continent as well as the Himalayas. Moreover, the study also stated that mountain ecosystems play a significant role in maintaining dimensions of interaction between the environment and society; whereas it is important at the same time mountain regions are exposed to extreme consequences of climate change, the change affects a wide range of societal and environmental aspects, particularly agriculture being the most susceptible to climate variability.

Chaudhary et al. (2011) work on ‘Consistency of local perceptions of climate change in the Kangchenjunga Himalaya landscape’ highlights the implications of climate change on the livelihood of the Kangchenjunga region of the Himalaya. The study argued that rapid climate change in the Himalayas is expected to have a major effect on local biodiversity, ecosystems, agriculture, and human health. Their findings of the study demonstrate that residents of the Kangchenjunga Himalaya region are well-informed about climate change and how it affects ecosystems, agriculture, biodiversity, and weather.

Batool et al. (2019) executed a study on ‘Rainfall variability and Dynamics of cropping pattern in Kashmir Himalayas: A Case Study of Climate Change and Agriculture.’ They highlight how the components of climate, such as rainfall variability, greatly determine the agricultural activities of a region. The study validates that all aspects of existence are negatively impacted by climate change. Climate change has the greatest impact on agriculture of all human endeavors. According to their report, rainfall has been declining over the past few decades, which has affected the region's farming patterns and yields. Additionally, it was noted that the region's crops have displayed varying relationships with rainfall; thus, the area planted for some crops has grown, while the area planted for others has decreased.

Deb et al. (2015) worked on ‘Evaluation of climate change impacts and adaptation strategies for maize cultivation in the Himalayan foothills of India’ the study reports the climate change scenario of the Indian state of Sikkim; it mainly deals with the impact of climate change on maize (*Zea mays*) cultivation in the state. The study particularly deals with how the climate over a region determines the growth and yield of crops. Their study also indicates that early seeding, reducing the rate at which farm yard manure is applied, adding supplemental watering, and switching to heat-tolerant maize cultivars could all help counteract the anticipated drop in maize yield in the era of climate change.

Poonia et al. (2021) study on the ‘Impact of climate change on crop water and irrigation requirements over eastern Himalayan region’ validates that due to climate change has impacted various socioeconomic activities and agricultural development over the Eastern Himalayan region of India, their study investigates the regional implications of climate change on crop yield and crop water requirements of maize, paddy, and wheat over the Himalayan state of Sikkim. It also discusses that a growing number of factors are influencing agricultural and social growth, including possible shifts in climate variability and its extremes.

2.3. Regional level

Bawa & Ingty (2012) stressed a work titled ‘Climate change in Sikkim: a synthesis’ that discusses how climate change is having a significant impact on the

biodiversity, natural resources, and society in the Himalayas. The study once more highlights the critical need for comprehensive data on the present impacts of climate change on both society and the environment. The several methods for vulnerability assessments are evaluated in the fourth part. The following section provides a summary of current approaches to mitigating the adverse effects of climate change. Moreover, to create and execute a state-wide framework for climate change adaptation and mitigation in Sikkim.

Deb & Babel (2015) deliberated in their work on ‘Assessment of impacts of climate change and adaptation measures for maize production in East Sikkim, India’ that exclusively validates the climate change impacts on maize (*Zea Mays*) in the hilly terrain of East Sikkim district of the Indian state of Sikkim. The study deals with the investigation of maize cultivation in rainfed areas, as their findings suggest the declining level of rainfall in the region, which has resulted in the lower yield capacity of the maize over the region. Besides, by adjusting planting dates, supplying supplemental irrigation, and controlling the right amount of nutrients, the same variety's maize yield in future climate conditions can be preserved or increased from its current level of production to cope with climate change as a resort for sustainable agriculture.

Feroze et al. (2018) conducted a study on ‘Impact of climate variability on farming: What the farmers of Meghalaya perceive?’ which focuses on the climate change perspective on the farmers of Meghalaya. It primarily deals with the rainfall variability pattern in Meghalaya over the last thirty years. Their findings suggest that the farmers' perspective is that the rainfall is decreasing and the temperature is increasing; moreover, the production and yield of potato, ginger, paddy, and pineapple have been greatly reduced due to scarce rainfall over the region in the recent years. The study also advocated that planned or systematic adaptation measures to curb the negative impact of climatic variability on agriculture practices.

Singh & Feroze (2020) their study on ‘Impact of climate change on animal husbandry: a gender perspective study in Meghalaya’ examines not only climate change impact on agriculture, the study cites that it has been already proven by

numerous literature regarding the climate change impact on agriculture, whereas, their work deliberates how it also effects the livestock rearing or animal husbandry, the climate change impact on livestock in Meghalaya is a matter of concern, unprecedented scare rainfall leads to low rainfall affecting the fodder cultivation subsequently the livestock farmers. Their study suggests initiating the new measures for livestock management techniques and high-yielding breeds of small and big animals to encourage the livelihood of the livestock farmers to alleviate and tackle the climate change impacts.

Chakraborty & Hazari (2017) executed a study on ‘Impact of climate change on yields of major crops in Tripura’, the study deals with climate change impacts on major crops in the state of Tripura, the study found that the rate of evaporation and relative humidity is high which is greatly affecting the production and yield of the major crops like paddy, potato, and pineapples over the region. The study also discussed that the annual rainfall was found to have a significant impact on rice productivity, and the temperature trend was increasing, affecting the crop lines of maize and groundnut cultivation.

Kuki (2023) studied under the title ‘A study on the Climate change in Tripura: With a focus on small growers of plantation crops’ argued that due to climate change; rice paddy cultivation on plain land has significantly diminished as a result of plantation farming; additionally, even in isolated settlements, access to bamboo and trees was challenging. As the canal's water level dropped, the temperature rose due to low rainfall intensity in the state, which has resulted in poor plant health and growth in the region.

Sati & Vangchhia (2018) in their study on ‘Changing agriculture and cropping pattern in Mizoram, Northeast India’ significantly expressed a concern over the changing pattern of farming in the state of Mizoram, their study suggests a decrease in production of permanent agriculture due to climate variability and change, however, increased production in Jhum cultivation (shifting cultivation) was witnessed. As climate change is imminent, their study prospects shifting of agriculture systems from

Jhum to permanent agriculture to enhance and improve the livelihood sustainability of the farmers.

Saitluanga et al. (2021) in their work titled ‘Analysis of Climate Variability and Agricultural Productivity in Mizoram, Northeast India’ reflect that the mountain regions are prone to climate change. Their study mainly focuses on the rainfall variability and temperature fluctuation and their impact on the agricultural productivity in Mizoram. Additionally, the study's temperature trend analysis also shows a sharp rise in temperature of more than 2°C during the last three decades. Finally, linear regression analysis demonstrates that production is significantly impacted by variations in climate variables.

Roy et al. (2018) in their work ‘Climate resilient agriculture in Manipur’, a significant study contributing to climate change and its impact on farming practices; Manipur is endowed with rich biodiversity and abundant natural resources, however the in recent years the state has been facing a severe consequence of climate change and its negative impact on agriculture and its allied activities. The study validates that the region is projected to experience extreme rainfall and a reduction in crop production and yields in the coming years. Hence, there is an urgent need to initiate a climate-resilient plan and climate-ready policy to tackle climate change and enhance agricultural development in the state.

Ahamed et al. (2025) stressed a study on ‘Community perceptions of climate change in Manipur, India’, the study primarily focuses on how the local communities perceive climate change, such as causes, implications, and consequences. Besides, the study also discusses the intensity of implications of climate change on the local economy, which is mostly driven by agriculture. The rainfall is decreasing and the temperature is increasing with each passing year, therefore, the farmers and the common people need to understand how climate change would enable policy-makers to improve local adaptation measures and formulate an effective mitigation strategy that efficiently tackles the negative impact of climate change.

Jamir et al. (2013) in their study on ‘Farmers’ vulnerability to climate variability in Dimapur district of Nagaland, India’ reported that several parts of the Indian state of Nagaland have been receiving deficit rainfall over the recent years, leading to severe drought affecting farming patterns and activities, due to climate variability and change. Their study also suggests that regional vulnerability assessment should be strictly carried out concerning formulation and mitigation measures for the program and policymakers to alleviate the effects of climate change on the agriculture sector.

Schröder et al. (2024) reported in their study on ‘Managing uphill cultivation under climate change—An assessment of adaptation decisions among tribal farmers in Nagaland state of India’, deliberating the management strategies to enhance the uphill cultivation on the Jhum field in the state of Nagaland. The study elaborates that most of the farmers have observed and experienced rising temperatures and a decreasing rainfall pattern over the region. Besides, it discusses that tribal farmers are more vulnerable to climate change as they are dependent on rainfed agriculture. Therefore, the study also advocates that agricultural training is the most influential factor for adaptation and mitigation measures for sustainable agriculture.

2.4. Local level

Thongdok & Sati (2024) in their study on ‘Impact of Climate and Soil on Agriculture in West Kameng District, Arunachal Himalaya’ reported that climate change navigates every sphere of the earth's surface, wherein, agriculture is the most affected entity and adverse climate variability in the West Kameng district of Arunachal Himalaya. Their results reveal that the climate factors like rainfall, temperature, and humidity are greatly affecting the production and yield of the major cash crops in the region. Their study paves the way for a comprehensive understanding of how certain crops respond to particular soil types and underlying climatic conditions for their growth and yield. Besides, the study also envisages sustainable and eco-friendly farming systems in the region.

Maiti et al. (2017) deliberated in their work, ‘An assessment of social vulnerability to climate change among the districts of Arunachal Pradesh, India’, their

study highlights the status of climate change-induced social vulnerability particularly on agriculture practices of the districts of Arunachal Pradesh. It also discusses farmers' perception on climate variability and changes and how it affects the farming patterns of the region; therefore, the study reveals most of the marginal farmers are highly vulnerable to climate change as farmers are dependent on the monsoon, hence, rainfall deficit and fluctuation immensely affect the major crops in the region.

Bharali & Khan (2011) reported in their study on 'Climate change and its impact on biodiversity; some management options for mitigation in Arunachal Pradesh', the study reports on various implications of climate change in the environment; the study significantly suggests that the climate change is not only affecting the agriculture but biodiversity as a whole. In addition to endangering biodiversity, climate change will have an impact on the socioeconomic standing of the state's indigenous population.

Rehman et al. (2023) conducted a study on 'Livelihood vulnerability assessment and climate change perception analysis in Arunachal Pradesh, India' they explained how Agro-based rural livelihoods are seriously threatened by the frequent calamities brought on by climate change. Their study also advocates some recommendations provided to improve local communities' adaptation sustainably, including government support and sustainable livelihood methods to promote climate-resilient and sustainable livelihood practices through environmentally friendly agriculture.

Bhagawati (2017) executed a 'Review on climate change and its impact on agriculture of Arunachal Pradesh in the Northeastern Himalayan region of India' in their work, which discusses Arunachal Pradesh's climate change situation and how it affects the state's farming system and agricultural output. The state is observing climate variability with the upsurge in average temperature, particularly the minimum temperature, and a decrease in annual rainfall. The study also reveals that the state is extremely vulnerable to climate change, due to its fragile ecosystems and farming practices.

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CHAPTER 3

GEO-ENVIRONMENTAL SETTING

3.1. Geo-environmental background

Geographical or geo-environmental background is an important aspect of the geographical study of any domain. Comprehending and highlighting the background, such as soil moisture, soil texture, annual rainfall, annual humidity, annual temperature, drainage, and people, is essential for overall research studies. It provides a significant base for executing any research tasks; determining research designs, and the degree of research. Understanding the extant climate and people is prominent in agricultural research, as cropping patterns and the regional underlying climatic conditions strongly determine productivity. Moreover, the investigation of the socioeconomic characteristics of farmers, such as occupation, literacy rate, and income, is crucial in Geographical studies.

3.2. Physical background

Physical background is natural features like rivers, plains, mountains, plateaus, drainage, etc., which is essentially the geographical landscape of a region. It is important to understand the characteristics of these features; such features involve entities without involving any human activities, the physical background can also be described as the study of physical Geography, which focuses on Earth's physical features rather than human aspects. In the meantime, background factors such as temperature, humidity, rainfall, soil moisture, soil texture, and drainage are crucial for the study.

3.2.1. Geology

Geology, in layman's terms, refers to rock science or the study of rock formation, which deals with the physical structure and substance of the earth. The geological composition of the study area is found to be of Subansiri Formation, Dirang Formation, Bomdila gneiss formation, Tenga Formation, Chillipam Formation, Bichom Formation, Bhareli Formation, Dafla Formation, and Kimin Formation.

3.2.2. Elevation

Elevation measures the vertical distance of a point or object from the mean sea level. The vertical distance or elevation of the study areas or villages surveyed ranges from 752 m up to 2805 m from the MSL (Table 3.1 & Fig. 3.1).

Table 3.1. Elevation of the study villages

Village	Elevation
Morshing	2063
Kamallangchin	1725
Shergaon	1957
Ramallingpam	1935
Tsering Pam	1377
Mago Pam	2252
Salari	1253
Sangti	1611
Senge	2805
Jerigaon	1777
Kirafarm	1950
Khoina	1734
Karangania	1284
Sakrin	1144
Palizi	752

Source: Primary field survey 2023

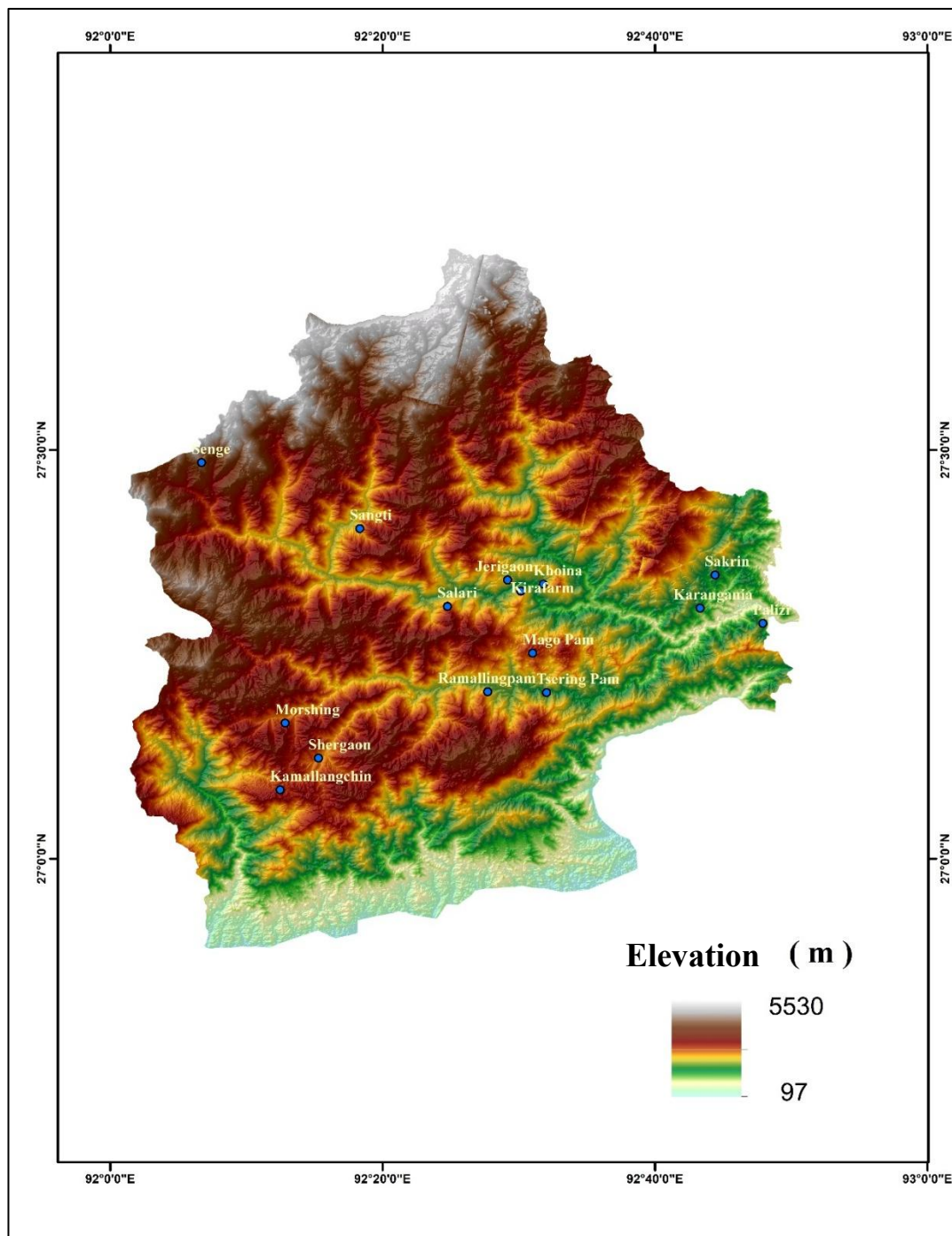


Fig. 3.1. Elevation map of the West Kameng District

3.2.3. Flora and Fauna

In simple terms, the flora and fauna refer to the diversity of the plants and animals over an area or ecosystem. The district is adorned with rich floral and faunal diversity. There are two national parks: the Namdapha National Park and the Mouling

National Park. Besides, there are eight wildlife sanctuaries, followed by the Eaglenest Wildlife Sanctuary, the Dibang Wildlife Sanctuary, the Mehao Wildlife Sanctuary, the Kamlang Wildlife Sanctuary, the Pakhui Wildlife Sanctuary, the Daying-Earing Wildlife Sanctuary, the Talley valley Wildlife Sanctuary, and the Itanagar Wildlife Sanctuary.

The district is home to over 500 species of birds and more than 200 species of mammals, moreover, Arunachal Pradesh is also known as '*Orchid Paradise of India*', there are around six hundred twenty-two species of orchids in the state, additionally, it is also home to many species of reptiles, butterflies, and insects.

3.2.4. Valley

Valleys are the flat, elongated plains or an area between the two elevated hilly areas. Valleys are characterized by flat areas which can be found in high altitudes as well as low-lying areas. The following are the valleys of the district: the Bichom River Valley; the Tammaphu River Basin; the Tenga Valley; the Bhairabkund River Valley, and the hills of the district.

3.2.5. Forest

A habitat with a high tree density is called a forest. Plants, animals, and microorganisms make up this intricate community that interacts with both their surroundings and one another. The district has 25527 hectares of total reserve forest and 455 hectares of Anchal or village reserve forest. The district's forest falls into one of the following categories.

- i) Reserve forests
- ii) Protected forests
- iii) Anchal Reserve Forests
- iv) Unclassed forests

3.2.6. Drainage

The West Kameng district is enriched with various resources, particularly in terms of water resources. The region is festooned with small streams, brooklets, and rivers, which makes the district a hotspot for tourism. Rivers such as the Bichom River,

which passes through Dirang, Salari, and Bichom, generally originate from the Kangto Glacier in the district, Ziding-Kho, Dinik-Kho, and Doblo-Kho are three major rivers that pass through Rupa and Tenga towns, and the Mighty Kameng River which is the largest river in the district the name of the district Kameng derived its name from this river, the river passes through two districts the East-Kameng and West-Kameng, and when it enters the state of Assam it transforms into Jia-Bharali river, which is an important tributary of the mighty Brahmaputra River (Fig. 3.2).

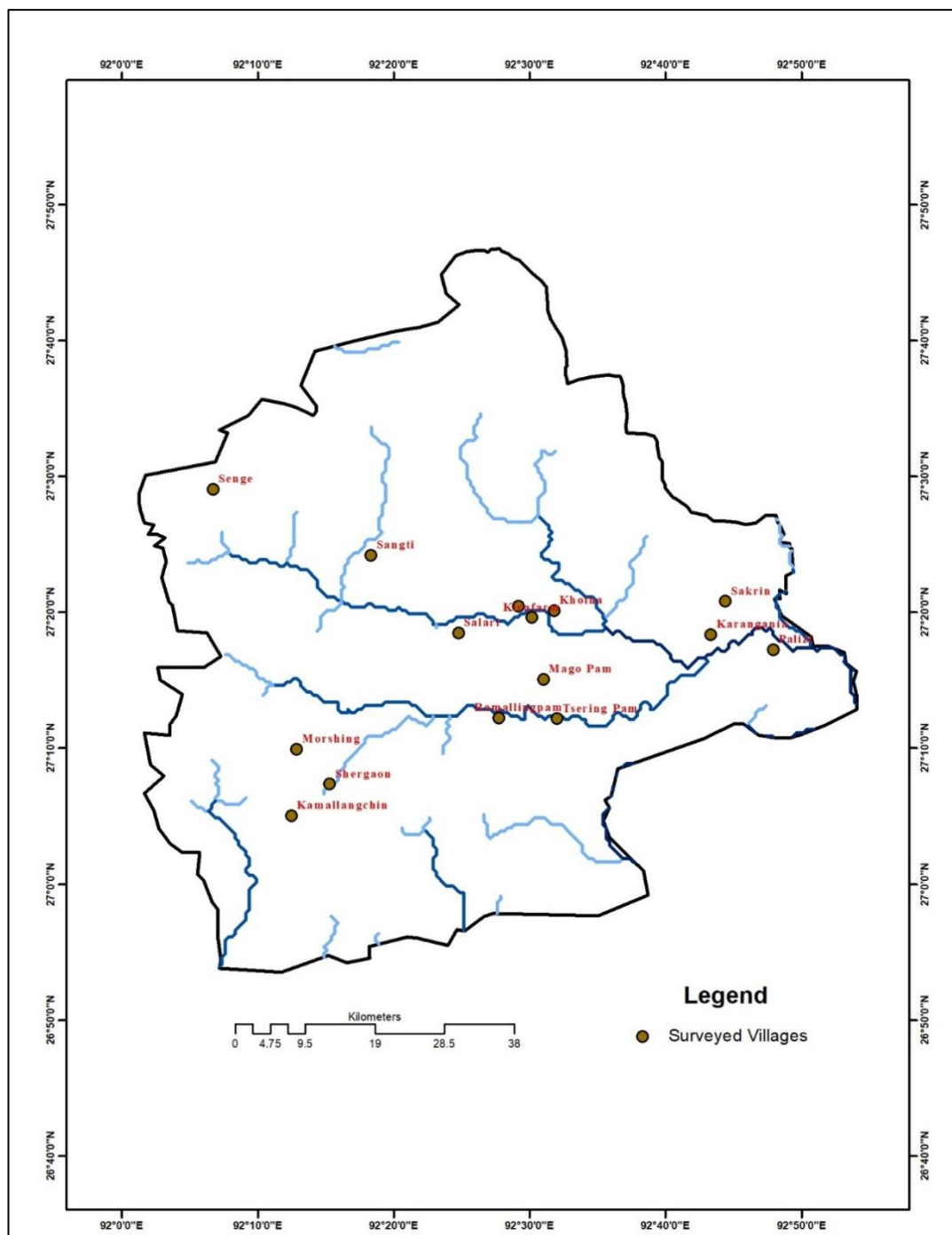


Fig. 3.2. Drainage map of the West Kameng District

3.3. Climate

In simple terminology, climate refers to a long-term weather condition over a place or a region; the main components of climate are temperature, humidity, rainfall, and wind. These components hold a pivotal role in determining various environmental and social activities on the Earth. The variation of these components greatly affects agriculture and its allied activities, their intensity, production, and yield. Moreover, certain types of climatic conditions regulate different types of soils, such as soil moisture and soil texture; thus, understanding the climatic conditions of a region is of utmost importance.

3.3.1. Temperature

In layman's terms, temperature measures the degree of hot and cold. The study examined the temperature of the West Kameng district for the last twenty-one years, starting from 2002-2022. An average of the last twenty years was calculated; the average value was categorized in an interval of 14-16 °C, 17-18 °C, 19-20 °C, 20-22 °C, and 23-28 °C (Table 3.2 & Fig. 3.3).

Table 3.2. Mean annual temperature (2002-2022)

Sl. No	Annual temperature (in °C)
1	14-16
2	17-18
3	19-20
4	20-22
5	23-28

Source: Primary field survey, 2023

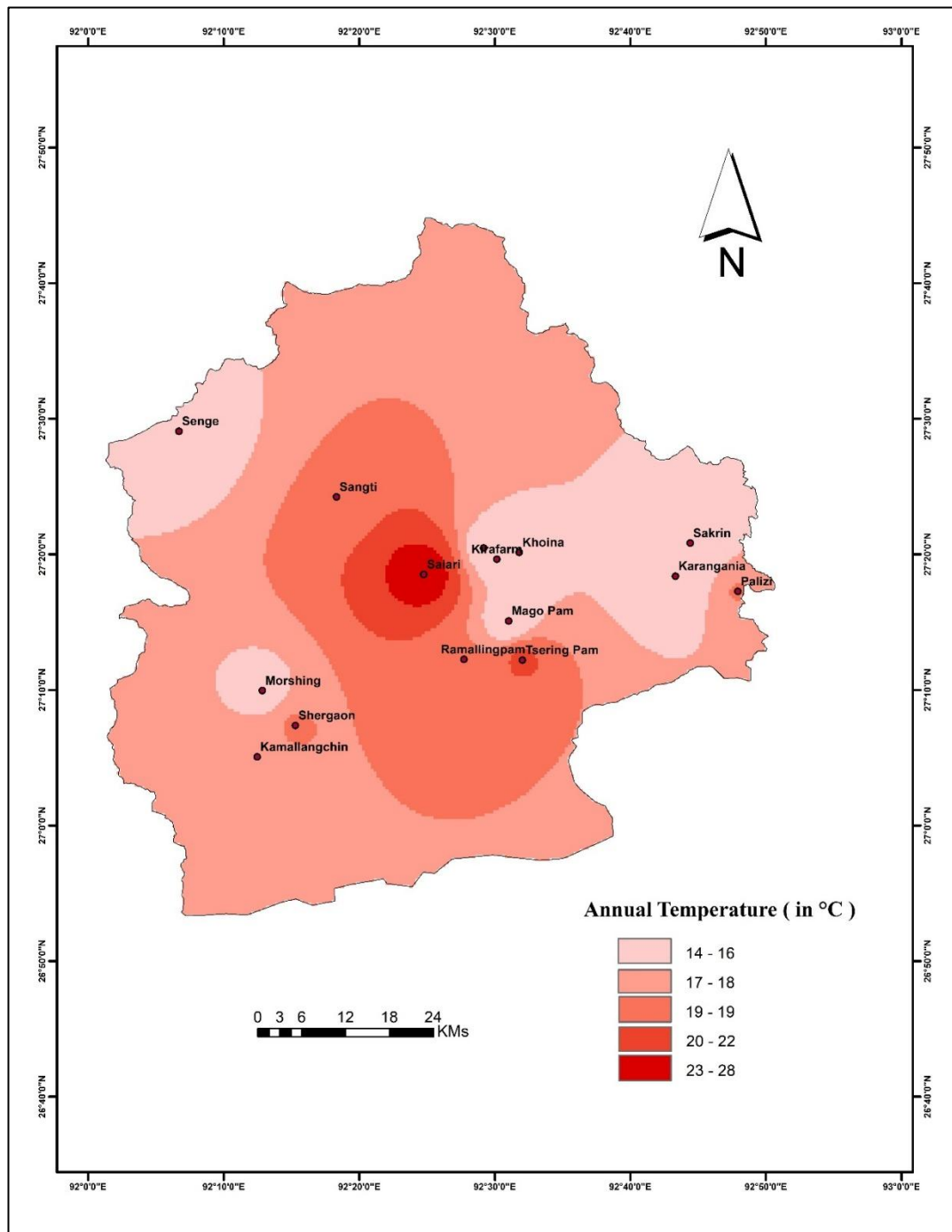


Fig. 3.3. Temperature map of the West Kameng district

3.3.2. Humidity

In simple words, humidity is the presence of water vapor or moisture in the air. The study analyzed the humidity of the last twenty-one years, starting from 2002-2022. Hence, an annual average or mean was calculated; an average value was categorized

in an interval of 77-79 %, 79-80 %, 80-81%, 81-82 %, and 82-84 % (Table 3.3 & Fig. 3.4).

Table 3.3. Mean annual humidity (2002-2022)

Sl. No	Annual humidity (in %)
1	77-79
2	79-80
3	80-81
4	81-82
5	82-84

Source: Primary field survey, 2023

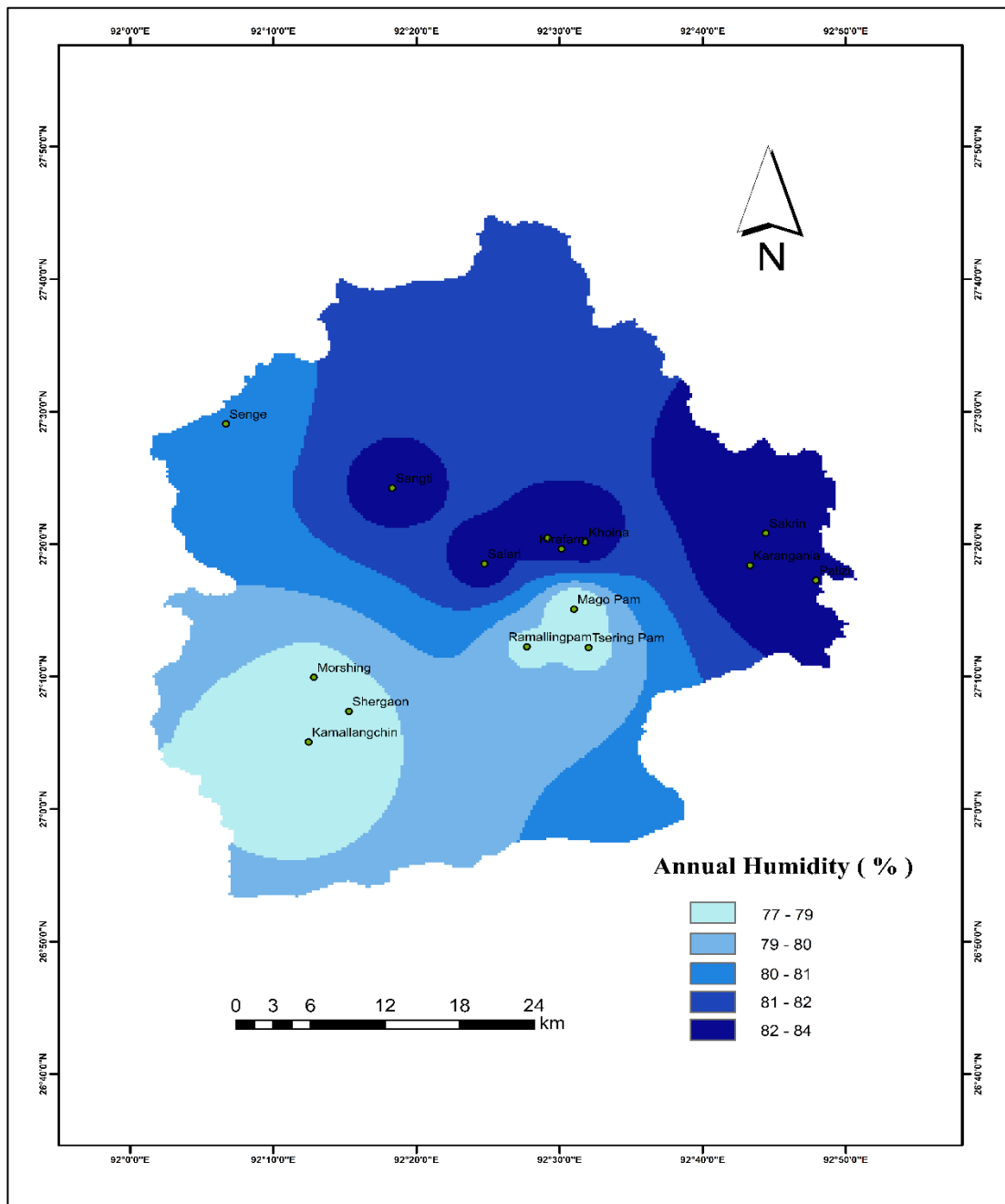


Fig. 3.4. Humidity map of the West Kameng District

3.3.3. Rainfall

In layman's terms, rainfall is the amount of water that falls in a specific place and period in the form of rain. The study analyzed the humidity of the last twenty-one years, starting from 2002-2022. Hence, an annual average or mean was calculated; an

annual average was categorized in an interval of 91-115 cm, 116-130 cm, 131-148 cm, 149-167 cm, and 168-191 cm (Table 3.4 & Fig. 3.5).

Table 3.4. Mean annual rainfall (2002-2022)

Sl. No	Annual rainfall (in cm)
1	80-100
2	100-150
3	150-200
4	200-250
5	250-300

Source: Primary field survey, 2023

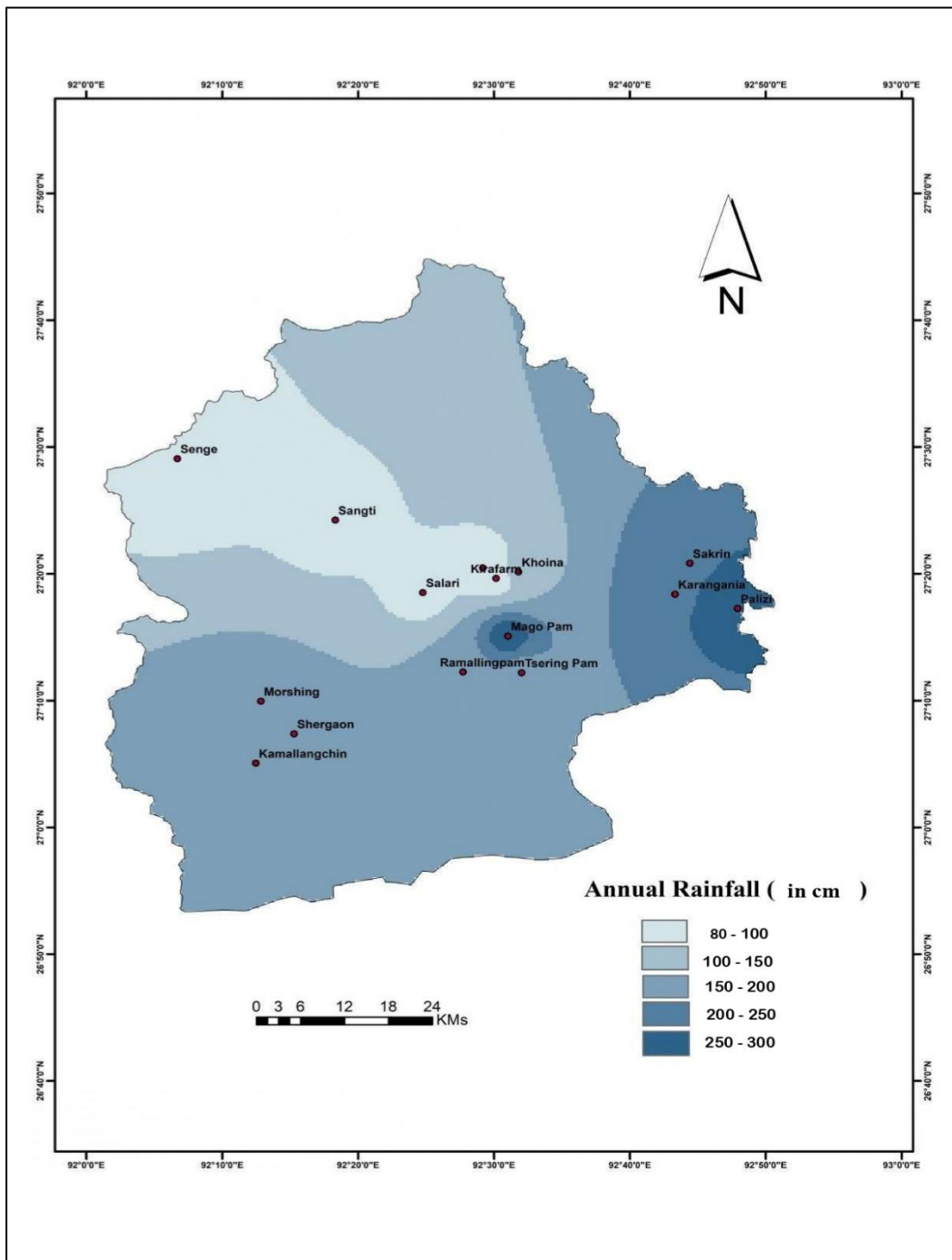


Fig. 3.5. Rainfall map of the West Kameng District

3.3.4. Soil moisture

Soil moisture is the capacity of soil to retain a certain amount of moisture or water vapor in the soil. Soil like peaty and loamy has a high potential to retain moisture; whereas, sandy and silty soils have less water-holding capacity. The study

collected the primary soil sample from fifteen villages and examined its moisture content using the ‘Oven Dry Method’, and categorized the moisture content as 30-35 %, 46-52 %, 53-56 %, 57-61 %, and 62-70 % (Table 3.5 & Fig. 3.6).

Table 3.5. Soil moisture

Sl. No	Soil moisture (in %)
1	30-35
2	46-52
3	53-56
4	57-61
5	62-70

Source: Primary field survey, 2023

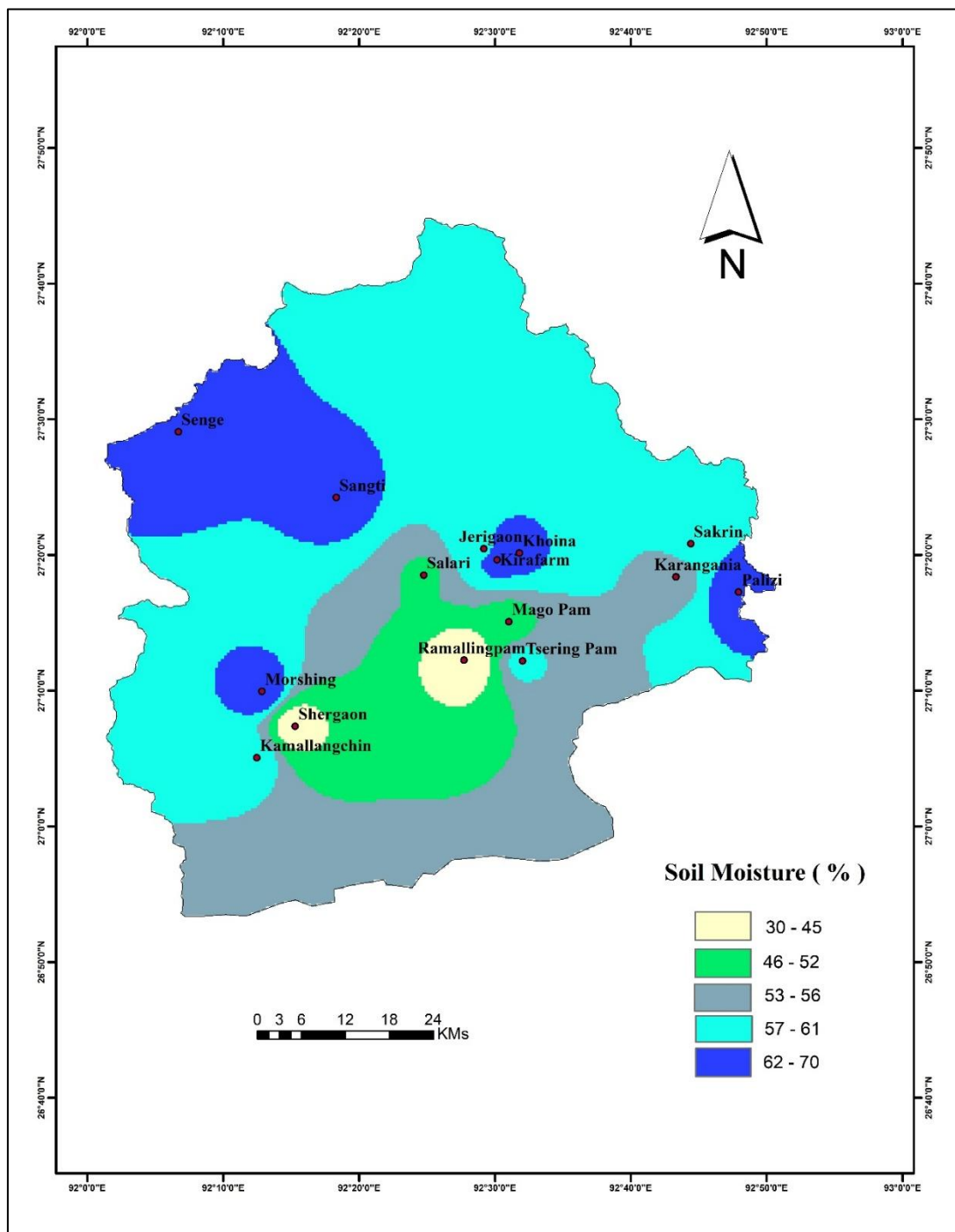


Fig. 3.6. Soil moisture map of the West Kameng District

3.3.5. Soil texture

Soil analysis is an essential process to determine the soil's physical and biological properties. Also, knowing the precise soil texture and moisture requirements for growing crops is momentous and beneficial because it provides a tool to

acknowledge whether the soil is suitable or not. According to the USDA (United States Department of Agriculture), the basic soil texture requirement for agriculture is loamy, and textured soil is considered the most suitable. Whereas, the basic soil moisture requirement is between 20-60 %, which is overall considered suitable for all kinds of crops. The soil samples collected during the study were analyzed using rigorous methods, and the results showed a positive indication because most of the textures found were loamy and clayey loam, similarly, the analyzed soil moisture was also found suitable ranging between 22.2 % to 57.06 % (Table 3.6 & Fig. 3.7).

Table. 3. 6. Soil texture attributes of the study villages

Sl. No	Village	Sand (in %)	Clay (in %)	Silt (in %)	Texture
1.	Mago-Pam	20	60	20	Clay
2.	Salari	4	60	56	Silty clay
3.	Kamallangchin	92	94	2	Loamy sand
4.	Morsing	96	98	2	Clay
5.	Shergaon	94	98	4	Clay
6.	Jerigaon	60	92	32	Silty clay
7.	Ramallingam	92	98	6	Clay
8.	Khoina	30	96	66	Silt loam
9.	Sangti	70	40	30	Sandy loam
10.	Senge	20	92	72	Silt loam
11.	Tsering-Pam	20	98	78	Silt loam
12.	Kirafarm	10	96	86	Silt loam
13.	Karangania	94	96	2	Clay
14.	Sakrin	92	96	4	Clay
15.	Palizi	86	98	12	Clay

Source: Primary field survey 2023

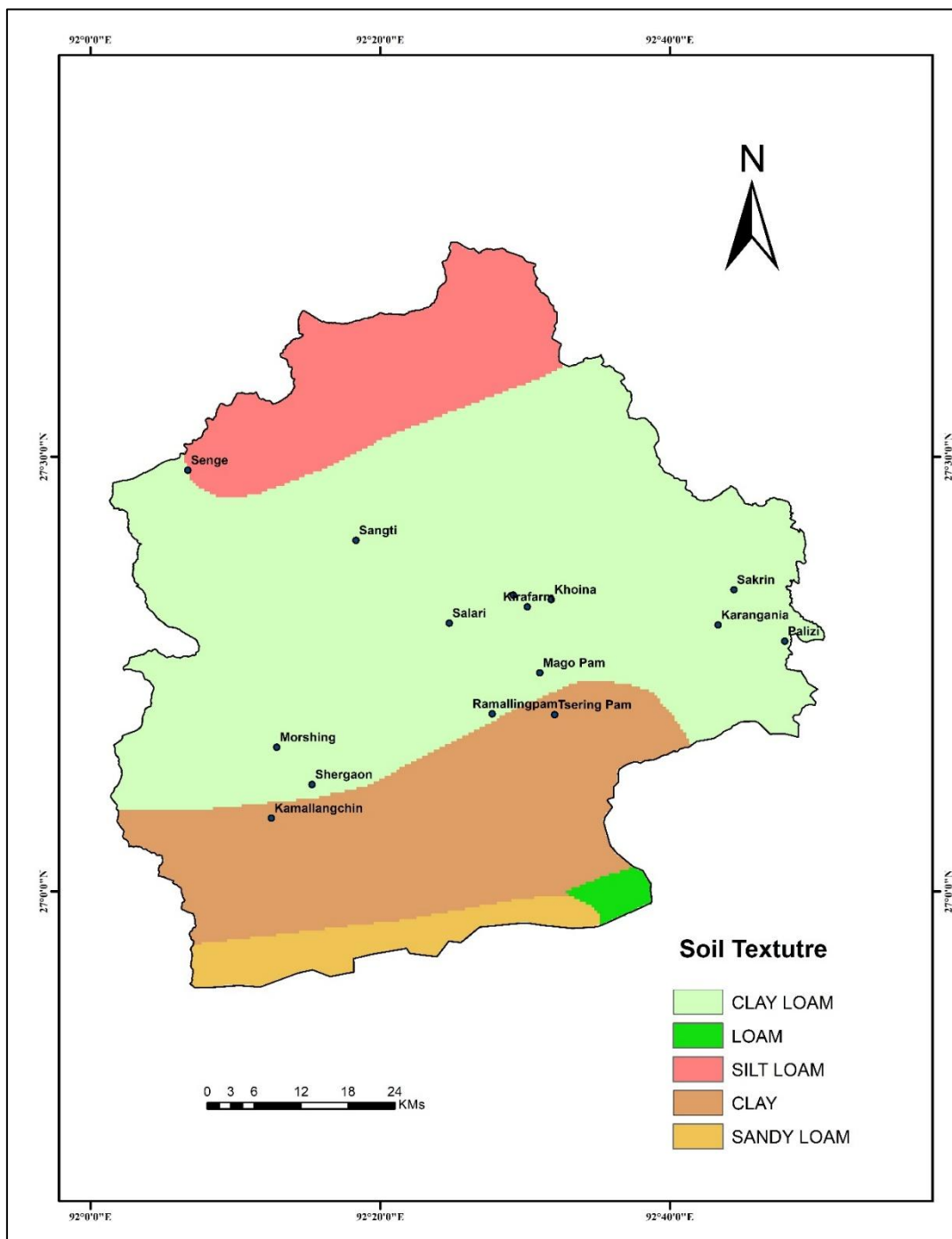


Fig. 3.7. Soil texture map of the West Kameng District

3.4. Cultural background

3.4.1. Tribes

Arunachal Pradesh is also termed a mini-India due to its socio-cultural diversity. There are twenty-six major tribes and more than a hundred sub-tribes.

Meanwhile, the West Kameng district comprises five major tribal communities: Shertukpen, Bugun (Khowa), Monpa, Aka (Hrusso), and Sartang. Each tribe is adorned with cultural practices such as customs, traditions, and food habits. Besides, the Bugun (Khowa) is the smallest tribe in the district with a population of approximately two thousand individuals according to the 2011 census. The Monpa tribe has the highest population as they comprise 77 % of the district population, with approximately sixty thousand individuals based on the 2011 census reports.

3.4.2. Festivals

The entire tribal community of Arunachal Pradesh has its unique festivals. The tribes of West Kameng, like Shertukpen, have Khiksabha, where they worship the nature idols, such as the river, the forest, and the mountain deities; the Bugun (Khowa) have Pham-Kho-Sowai, which is celebrated every year during the harvesting season. The Monpa tribe has Losar, which is the Buddhist New Year celebrated every year during February and March, which is also celebrated by the Shertukpens. The Aka (Hrusso) have the Nyethrii-Dow festival, which is celebrated to cleanse villages, drive away evil spirits, and worship deities for protection, prosperity, and peace of the community. The Sartang tribe has the Tang festival, which is celebrated every year in September, which is a pre-harvesting festival, and offerings are made to the local deities to protect and prosper the community.

3.4.3. Religion

Religion is a system of practice, belief, and value, where every community, regardless of caste and creed, has its belief systems. Therefore, the tribes of West Kameng have their own identity and religion, such as Buddhism, Christianity, Hinduism, and Bon-tradition or Donyi-Polo (nature worship) (Census, 2011). The table below shows the percentage of religious composition (Table 3.7).

Table 3.7. Religious composition of the West Kameng District

Sl. No	Religion	Percentage (in %)
1	Buddhism	42.99
2	Hinduism	37.24
3	Christianity	10.08
4	Donyi-Polo	6.86
5	Others	2.82

3.4.4. Literacy rate

According to the 2011 census, 83,947 people were living in West Kameng in 2011, with 46,155 men and 37,792 women. Of the 74,599 people living in West Kameng, 42,542 were men and the remaining 32,057 were women, according to the 2001 census. The average literacy rate of West Kameng in 2011 was 67.07, compared to 67.07 in 2001. Whereas, the female literacy rate is slightly higher than that of the male, which is 70.29, and the female is 73.45. Besides, the sex ratio in West Kameng stood at 940 per 1000 males (Census, 2011).

References

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CHAPTER 4

CLIMATE VARIABILITY AND CHANGE

4.1. Introduction

Climate variability refers to short-term changes in weather patterns, whereas climate change refers to long-term changes in weather patterns. Climate change is a significant threat to humanity, and its impacts on natural and human systems have already been observed (IPCC, 2021). Mountain regions are highly vulnerable to climate change, as they are ecologically fragile, tectonically and seismically active, and geologically sensitive (Sati, 2015). With other global challenges, climate action demands global and local collaboration and must be addressed in a revolutionary, systemic, and comprehensive manner that prioritizes short-term targeted action and long-term ecological and human well-being, in fact, many environmental systems, especially those that extend well beyond the mountain limits, depend heavily on meteorological and climatic phenomena in mountainous locations. Whereas, mountain climates are primarily influenced by four factors: terrain, altitude, latitude, and continentality (Beniston, 2006; Cabré et al., 2024). However, it is generally accepted that high mountain ecosystems are especially susceptible to changes in the climate (Markham et al., 1993; Beniston, 1994).

Climate change affects fluctuations in the hydrological cycle, increasing atmospheric moisture capacity and precipitation rate (Huntington, 2006; Mokhov & Ch, 2014). Whereas, the mountainous regions in Europe, particularly the Alps, exhibit the greatest sensitivity to climate change (Bocchiola & Diolaiuti 2010; Diolaiuti & Smiraglia & Diolaiuti, 2016; Fugazza et al., 2021). Additionally, the severe consequences of climate change will affect seasonal shifts in precipitation, temperatures, and relative humidity, moreover, warming is expected to accelerate throughout the region, and extreme climate events are expected to intensify (Gobiet et al., 2014). The region may face drastic changes due to human-induced warming, thus change is expected to alter the key environment and socio-economic processes (Pauli et al., 2003; Maroschek et al., 2009).

The monthly average air temperature during the warm season of the Ural Mountain region has been fluctuating in different directions, according to data from the Karpinsk weather station in Russia; May and June saw increases of 0.4–1.2°C, while August saw a decrease of 0.1°C, which resulted in a 3- to 6-day extension of the growing season and an improvement in the availability of heat during this time. Additionally, there has been an increase in yearly precipitation, primarily due to precipitation from July to September in the region. Besides, the average monthly temperature in the region over the winter and early spring (November to March) has increased by 1.5–5.1°C. As a result, the average temperature during the cold season has increased by 3.5°C in the region (Moiseev et al., 2010). The last thirty to forty years have seen the most intense global warming since the 1980s; every decade that followed an increase in temperature over the period since, 1850, with the northern regions experiencing warming more quickly than the southern ones and also experiencing an increasing trend of climate warming and the setting of new records for high temperatures, with an average annual temperature in the region rising by 3 °C since 2020 (Petrova et al., 2022; Porfiriev et al., 2022). In addition, the Arctic has also warmed faster than any other place on Earth, according to the sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) (Serreze & Barry, 2011).

The world's most remote areas are affected by the rapid changes in climate. For example, fires caused by climate change on Kilimanjaro have altered the species composition and structure of the forests, resulting in a downward shift in the amount of forest cover. Furthermore, it has also lost almost one-third of its forest cover in the last 70 years as a result of forest fires brought on by climate change; For example, Kilimanjaro's shrinking ice cap has been a well-known phenomenon for over a hundred years, and which is still preceding (Meyer, 1900; Jaeger, 1909; Klute, 1920; Thompson et al., 2002; Hemp, 2009)). For the past thirty years, the effects of climate change on mountain ecosystems have been witnessed as such changes are typically seen as a threat to the health of the ecosystems in mountain regions South Africa (Mukwada & Manatsa, 2018); where researchers also explored the effects of climate on habitat and the morphological characteristics of fruit production in West Africa and

the effects of climate change in the Mutirikwi River in Zimbabwe (Akabassi, 2023; Ziti et al., 2024)

The IPCC report from 2007 predicted that temperature will increase over central Asia, the Tibetan Plateau, and northern Asia—well above the world mean, and the Himalayan ecosystem is extremely sensitive to even small changes in temperature and precipitation conditions; therefore, the global warming by human-induced activities will result in increasing temperature and will have a cascading effect on the region's ecosystem (Whiteman, 2000). The high mountains in the northern region of India have a significant role in both creating and sustaining the climate throughout the Indian subcontinent's northern region. They also affect extreme weather occurrences, such as the wintertime western disturbances over the region; (Shekhar et al., 2010). In addition, by employing reconstructions and observations from tree rings discovered that during the late 20th century, where the pre-monsoon minimum temperature tended to drop. The rate at which the minimum temperature decreased is three times faster than the rate at which the maximum temperature decreased, suggesting that the minimum temperature is more responsible for the pre-monsoon mean temperature's cooling trend; and witnessed a shift in long-term patterns of mean, minimum, and maximum temperatures over the 20th century in the region (Bhutiyan et al., 2007; Shekhar et al., 2010).

A study by Rani et al. (2022) discussed that climate change is impacting the Himalayas, causing shrinking of the cryosphere, land use change, vegetation change, and loss of biodiversity have adversely affected the ecosystem services of the region. According to an analysis of the literature, practically all of the region's glaciers have retreated, thinned, and lost mass as a result of climate change (Mukherji et al., 2019). The Western Region, which includes the states of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand, is considered to be one of the most delicate landscapes in the world and extremely vulnerable to climate change (Shah and Malakar, 2014; Sati & Raiwani, 2016). The study carried out at several elevations in the central region—Almora, Nainital, Ranikhet, Hawal-Bagh, Mukteshwar, Mukhim, Dehradun, and Mussoorie—shows that there is an annual pattern of decreasing rainfall at all of the stations (Thakura et al., 2018).

The Himalayan region has a fragile ecosystem and climate change impact has been observed in the Eastern Himalayas, as a result, the whole Garhwal region underwent dramatic social-ecological transformation through climate change (Sati, 2015). According to data from the Indian Meteorological Department, the 2006 monsoon season saw the least quantity of rainfall in the Eastern Himalayas in 25 years, dating back to 1982 (Das et al., 2009), furthermore, a study by Sharma et al. (2000) found an increasing trend in rainfall at some stations and a decreasing trend at other stations in the Koshi basin in eastern Nepal and Southern Tibet. Similar trends in rainfall were found in the state of Himachal Pradesh and investigated changes in the rainfall pattern for thirty stations, where they found that there was an increasing trend up to 1964 after which the trend decreased during 1965–1980 for this region and changes were most explicit over the Shivaliks and the southern part and lesser part of the region (Kumar et al., 2005; Basistha et al., 2009).

Few studies provide an exclusive and comprehensive analysis of the Eastern Himalayas because the region is young and more fragile, which makes it extremely vulnerable to climate change (Sharma et al., 2009). Dash et al. (2007) observed that during the last century, the maximum temperature increased over the region by 1°C during winter and 1.1°C during the post-monsoon months, and there have been variations in rainfall during pre- and post-monsoon seasons.

Climate is changing in the Eastern Himalayas, and change will have implications for all kinds of natural ecosystems; however, the impacts will be more prominent on the already stressed ecosystems (ICIMOD, 2010). The Northeast is highly prone to the consequences of climate change because of its geo-ecological fragility; the region falls under a high rainfall zone with a subtropical type of climate, and is under the influence of global climate change, even with high rainfall areas facing drought-like situations in recent years. Region being the wettest place on the Earth, has experienced a rapid decrease in summer monsoon rainfall (about 355 mm) in the last 36 years (1979–2014), which has serious implications for the ecosystem and the livelihood of the people of this region (Das et al., 2009; Choudhury et al., 2019). The region is highly sensitive to climate change, which will have direct consequences on food-production systems and indirect impacts on food security (Ravindranath et al.,

2011). However, the region has experienced rapid drying in the last three decades, that have posed serious threats to biodiversity (Guhathakurta & Rajeevan, 2008; Konwar et al., 2012; Preethi et al., 2016; Osipova et al., 2017). Climate variability in the region is fairly perceptible in the present day, and the changes are witnessed here more than in other parts of the country (Kumar, 2011).

The impacts of climate change have already been experienced in many hill communities of Arunachal Pradesh (Bharali & Khan, 2011). The ecological systems of the region are extremely fragile due to its physiographic condition; hence climate change is posing a substantial threat to its rich diverse ecosystem and change will not only impact the bio-diversity of the region but also affect the livelihood of local communities, as they happened to be fully dependent on the natural resources (Bharali & Khan, 2011, Maiti et al., 2014). Ravindranath et al. (2011) conducted a study on the Agricultural Vulnerability Index (AVI) of the North-eastern region and reported that Arunachal Pradesh was the most vulnerable region to current climate vulnerability, and also reported that higher agricultural vulnerability was observed in the northern parts in the alpine district of the region.

4.2. Methods

4.2.1. Data collection

Monthly and annual data on Temperature, Rainfall, and Humidity were obtained from the NASA Data Access Viewer <https://power.larc.nasa.gov/data-access-viewer/>, for all fifteen villages from the year 2002 up to 2022.

4.2.2. Data analysis

Climate variables were tabulated and analyzed using various statistical tools and measures, such as mean average and trend analysis (linear regression) to examine the annual mean of the temperature, rainfall, and humidity, whereas linear trend analysis (linear regression) was used to determine the trend of climate variables.

Mean,

$$\bar{x} = \frac{\sum x_i}{n}$$

Trend (Linear) regression,

$$Y = mX + b$$

4.3. Climate variability and change

It is evident from the fact that climate change is overwhelming (Smith et al., 2009; Fussel, 2009). Climate change is almost invariably considered an issue of international interest. However, the extent to which climate change represents a problem is still a heavily debated issue; calculations on future damages associated with climate change (Koetse & Rietveld, 2009). During climate history over the last millennium, it has been noticed that the 14th to 18th centuries were a cooling period, named the Little Ice Age, after which the Earth experienced rapid global warming (Salinger, 2005). During the period, the global climate has varied by as much as 1 °C (IPCC, 2001a). Under the influence of global climate change, even high rainfall areas are facing drought-like situations in recent years, and the reverse, i.e., floods, are frequent. Similarly, winters are becoming cooler, and summers are extremely hot. For example, the two states of India, Maharashtra and Gujarat, are generally drought-prone areas, whereas these states have been experiencing flooding recently. Droughts and floods are the adverse climatic conditions arising out of deficit and excess rainfall, respectively (Das et al., 2009). By mid-century, annual average river runoff and water availability are projected to increase by 10- 40% at high latitudes and in some wet tropical areas and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water stressed areas (IPCC, 2007).

The whole Garhwal region underwent dramatic social-ecological transformation through climate change, which has resulted in the large-scale abandonment of arable land and the impact of climate change has been seen in fruits and crops (Sati, 2015). Whereas, climatic conditions have put an alarming sign in the development of horticulture in the West Kameng district due to increasing demands of the population in the form of mass deforestation, and construction of buildings, which has resulted in increased temperature, and rainfall variability (Nimasow, et al., 2014).

Moreover, the Brokpas have experienced changes in climatic conditions over the decade, where they have to cope with the adverse impact of climate change on livestock rearing and their livelihood for sustainable livestock productivity and sustainable livelihood security (Mait et al., 2014).

Similarly, in recent years, several instances of climate change and variability have been observed in the West Kameng district of Arunachal Pradesh, including drought-like situations, incessant downpours, retreating snowlines, and the drying of several streams and rivulets. Therefore, a monthly, annual, and mean analysis of humidity, temperature, and rainfall has been conducted over twenty-one years in this study to understand the trends and shifts in climate variations of the study area.

4.3.1. Temperature

Temperature is a crucial element that determines various socio-economic activities over an area. Therefore, analyzing the annual variations and temperature trends is of utmost necessity to understand their numerous implications. All the study villages show significant temperature variations over twenty-one years; the analysis has been carried out by categorizing in two different periods, i.e., 2002 to 2012 (Table 4.1) and 2013 to 2022 (Table 4.2) so that we can get a better understanding of the temperature trend of the last 21 years.

There have been tremendous fluctuations in the temperature of study villages, thus an average temperature trend of the villages was examined; Data starting from 2002 to 2012, Kamallangchin village recorded the highest temperature in the year 2006 at 17.56 °C, and the lowest in the year 2011 at 16.9 °C with a ten-year average of 17.18 °C, Shergaon village with the highest at the year 2009 at 16.99 °C and lowest in the year 2006 at 16.9 °C with a decade average of 16.82 °C, Morsing village with the highest in the year 2006 at 14.71 °C and lowest was recorded in the year of 2004 at 14.38 °C and an average of 14.59 °C. Salari is among the regions having high temperatures due to low elevation, whereas the highest ever recorded was in the year 2007 at 27.97 °C and the lowest in the year 2009 at 26.9 °C with a ten-year average of 27.52 °C, Senge village at 22.71 °C in the year 2006 and 21.8 °C in the year 2002 with a decade average of 21.74 °C, Sangti village is warmest among all the study

villages at 31.95 °C in the year 2003 and 27.61 °C in the year 2006, with a ten-year average of 29.90 °C. Jerigaon village 16.03 °C in the year 2006 and lowest in the year 2004 at 15.02 °C, Kirafarm village 16.03 °C in the year 2006 and lowest in the year 2004 at 15.02 °C, Khoina village 16.03 °C in the year 2006 and lowest in the year 2004 at 15.02 °C, all the three villages have same temperature values as all the villages fall under the radius of approximately 2 km having the same decade average of 15.37 °C. Ramallingpam recorded the highest temperature in the year 2010 at 17.07 °C and lowest in the year 2002 at 16.52 °C, with a ten-year average of 16.56 °C, Tsering-Pam recorded the highest in the year 2006 at 19.73 °C and lowest in the year 2011 at 18.9 °C with a ten-year average of 19.20, Mago-Pam village with the highest in the year 2006 at 15.93 °C and lowest in 2011 at 14.36 °C with an average of 15.14 °C. Karangania and Sakrin are adjacent villages that recorded equal temperature values with the highest in 2006 at 14.7 °C and the lowest at 14.01°C in 2004 with an average of 14.38 °C, Palizi recorded the highest in the year 2006 at 17.99 °C and the lowest in the year 2004 at 16.91 °C, with decade average of 17.46 °C. The overall mean average temperature of West Kameng (2002-2012) stood at 18.28 °C in 2003 and 2006, and the lowest mean average stands at 17.65 °C in 2004, respectively. (Table 4.1 and Fig. 4.1).

Table 4.1. Mean annual trend of temperature (in °C) of the villages (2002-2012)

Villages	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	AN
Kamallangchin	17.16	17.11	16.85	17.19	17.56	17.24	17.05	17.35	17.33	16.9	17.2	17.18
Shergaon	16.59	16.73	16.63	16.89	16.9	16.77	16.76	16.99	17.1	16.71	16.94	16.82
Morsing	14.37	14.52	14.38	14.68	14.71	14.64	14.52	14.77	14.85	14.43	14.64	14.59
Salari	26.58	28.08	26.14	28.95	26.68	28.95	28.85	26.7	26.09	27.74	27.97	27.52
Senge	21.8	22.11	20.57	21.89	22.71	22.62	21.12	22.37	21.2	21.58	21.13	21.74
Sangti	28.68	31.95	29.12	30.46	27.61	30.48	31.57	28.86	27.96	31.05	31.11	29.90
Jerigaon	15.37	15.55	15.2	15.63	16.03	16.02	15.7	15.86	15.54	15.41	15.63	15.37
Kirafrim	15.37	15.55	15.2	15.63	16.03	16.02	15.7	15.86	15.54	15.41	15.63	15.37
Khoina	15.37	15.55	15.2	15.63	16.03	16.02	15.7	15.86	15.54	15.41	15.63	15.37
Ramallingpam	16.56	16.69	16.62	16.86	16.88	16.74	16.73	16.96	17.07	16.68	16.78	16.56

Tsering-Pam	19.3 8	19.1 7	18.8 3	19.1 1	19.7 3	19.2 2	18.9 8	19.4 4	19.3	18.9	19.1 8	19.2 0
Mago-Pam	15.8	15.2 6	14.8 6	14.8 9	15.9 3	15.7 4	14.8 2	15.2 8	14.5 2	14.3 6	15.0 5	15.1 4
Karangania	14.3	14.3	14.1	14.3	14.7	14.4	14.3	14.6	14.6	14.2	14.4	14.3 8
Sakrin	14.3	14.3	14.1	14.3	14.7	14.4	14.3	14.6	14.6	14.2	14.4	14.3 8
Palizi	17.3 5	17.3 7	16.9 1	17.5	17.9 9	17.8 5	17.3	17.8 9	17.4 2	17.1 6	17.2 8	17.4 6
$\Sigma x =$	17.9 3	18.2 8	17.6 5	18.2 6	18.2 8	18.4 7	18.2 3	18.2 3	17.9 1	18.0 1	18.2 0	18.0 7

Source: NASA Data Access Viewer

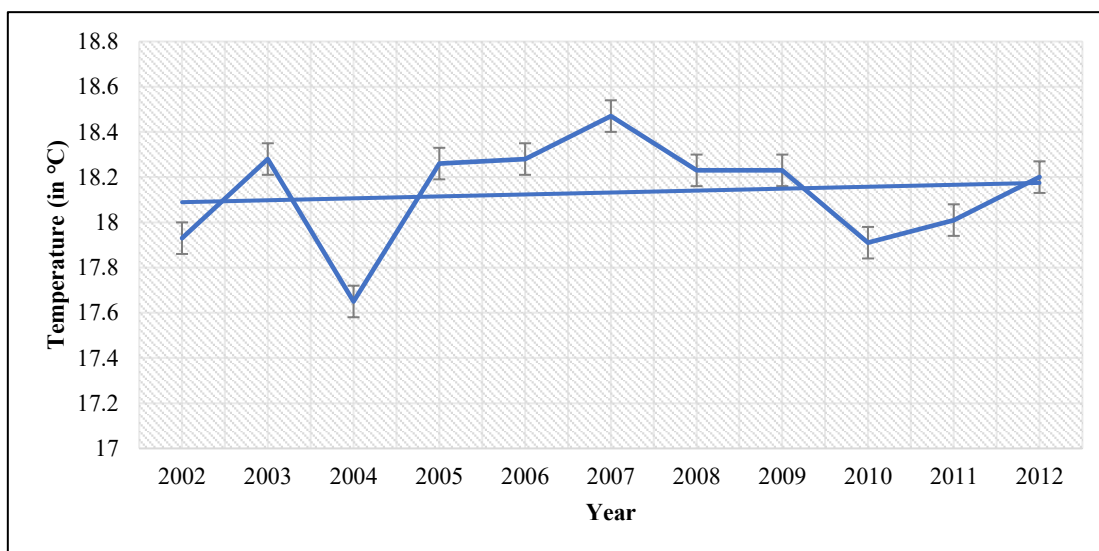


Fig. 4.1. Chart showing the annual temperature trend of West Kameng district (2002-2012).

Statistics from 2013 to 2022 show the highest temperature recorded in the year 2016 at 17.91 °C and the lowest in the year 2020 at 17.19 °C with a ten-year average of 17.53 °C, Shergaon village with the highest the year 2017 at 18.12 °C and lowest in the year 2019 at 17.44 °C with a decade average of 17.71 °C, Morsing village with the highest in the year 2017 at 15.71 °C and lowest was recorded in the year of 2022 at 15.2 °C and a decade average of 15.36 °C. Salari is among the regions with high temperatures due to its low elevation. In contrast, the highest ever recorded was in the year 2022 at 29.98 °C and the lowest in the year 2016 at 26.9 °C with a ten-year average of 28.11 °C, Senge village recorded 23.23 °C in the year 2019 and 21.28 °C in the year 2015 with a decade average of 21.98 °C, Sangti village is warmest among all the study

villages at 30.61 °C in the year 2013 and 27.63 °C in the year 2016, with a ten-year average of 29.98 °C. Jerigaon village 16.12 °C in the year 2018 and lowest in the year 2016 at 15 °C, Kirafarm village 16.12 °C in the year 2018 and lowest in the year 2016 at 15 °C, Khoina village 16.12 °C in the year 2018 and lowest in the year 2016 at 15 °C, all the three villages have same temperature values as all the villages fall under the radius of approximately 2 km having the same decade average of 15.45 °C. Ramallingpam recorded the highest temperature in the year 2016 at 18.29 °C and lowest in the years 2020 and 2021 at 17.5 °C, with a ten-year average of 17.68 °C, Tsering-Pam recorded the highest in the year 2017 at 20.22 °C and lowest in the year 2022 at 19.38 °C with a ten-year average of 19.80, Mago-Pam village with the highest in the year 2013 at 15.27 °C and lowest in 2016 at 13.53 °C with an average of 14.37 °C. Karangania and Sakrin are adjacent villages that recorded equal temperature values with the the highest in 2016 at 15.4 °C and the lowest at 14.6 in 2022 with an average of 14.96 °C, Palizi recorded the highest in the year 2017 at 18.21 °C and lowest in the year 2018 at 17.4 °C, with decade average of 17.63 °C. Overall, the highest mean average temperature of West Kameng (2013-2022) stands at 18.54 °C in the year 2017, and the lowest mean average stands at 18.19 °C in the year 2015, respectively. (Table 4.2 and Fig.4.2).

Table 4.2. Mean annual trend of temperature (in °C) of the villages (2013-2022)

Villages	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	AN N
Kamallangch in	17.6 4	17.6 5	17.6 4	17.9 1	17.8 8	17.3 3	17.3 9	17.1 9	17.4 9	17.2 6	17.5 3
Shergaon	17.4 6	17.6 5	18.0 6	18.3	18.1 2	17.5 8	17.4 4	17.5 2	17.5 3	17.4 2	17.7 1
Morsing	15.0 5	15.3 1	15.7 6	15.9	15.7 9	15.1 6	15.0 6	15.1 5	15.1 9	15.2	15.3 6
Salari	28.5 6	28.7 4	26.6 8	26.9	27.0 2	28.7 7	29.7 1	27.8 4	26.9 6	29.8 8	28.1 1
Senge	22.3	21.8 3	21.2 8	21.6 2	21.8 5	21.6 5	23.2 3	21.5 8	21.9 8	22.4 5	21.9 8
Sangti	30.6 1	29.2 6	27.8 5	27.6 3	28.2 3	29.9 5	32.4 5	32.8 4	27.3 4	32.3 4	29.8 5
Jerigaon	15.3	15.5	15.2	15	16	16.1 2	15.1 7	15.6	15.5	15.1	15.4 5
Kirafrim	15.3	15.5	15.2	15	16	16.1 2	15.1 7	15.6	15.5	15.1	15.4 5
Khoina	15.3	15.5	15.2	15	16	16.1 2	15.1 7	15.6	15.5	15.1	15.4 5

Ramallingpa m	17.4 4	17.6 2	18.0 3	18.2 9	18.0 9	17.5 6	17.4 1	17.5	17.5	17.3 7	17.6 8
Tsering-Pam	19.8 1	19.9 6	19.9 6	20.3	20.2 2	19.6 6	19.5 7	19.3 7	19.7 5	19.3 8	19.8 0
Mago-Pam	15.2 7	14.7 4	14.2 7	13.5 3	14.1 3	14.1 1	14.1 6	14.4 5	15.2 3	13.8 3	14.3 7
Karangania	15	15	15.1	15.4	15.3	14.8	14.8	14.7	14.9	14.6	14.9 6
Sakrin	15	15	15.1	15.4	15.3	14.8	14.8	14.7	14.9	14.6	14.9 6
Palizi	17.7 3	17.6 7	17.5 9	17.9 4	18.2 1	17.0 4	17.2 8	17.5 3	17.9 4	17.3 4	17.6 3
$\Sigma x =$	18.5 2	18.4 6	18.1 9	18.2 7	18.5 4	18.4 5	18.5 9	18.4 8	18.2 1	18.4 6	18.4 2

Source: NASA Data Access Viewer

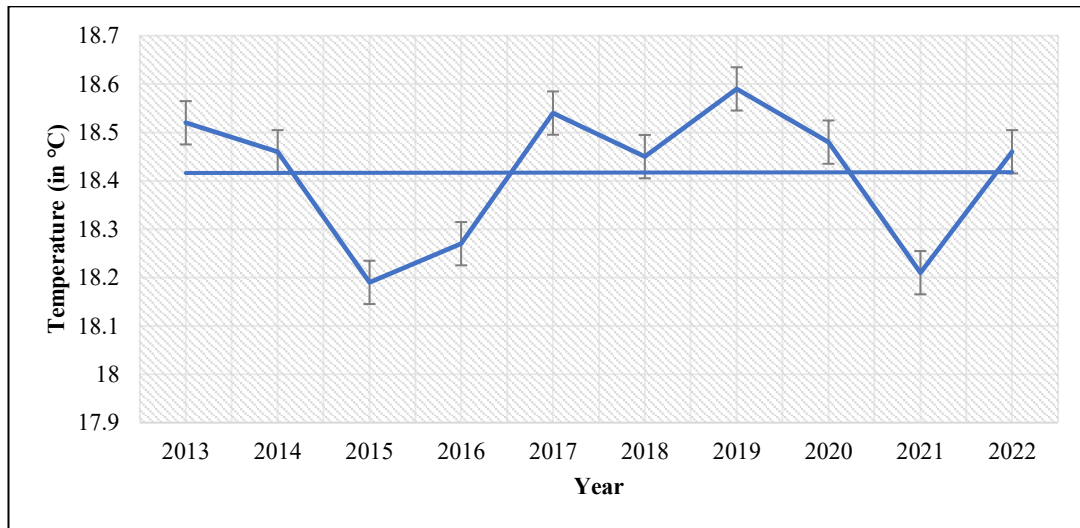


Fig. 4.2. Chart showing the annual temperature trend of West Kameng district (2013-2022)

4.3.2. Rainfall

Rainfall is a vital component that drives various farming practices over an area. A key factor in determining the different socio-economic activities that take place in a given location is rainfall. To fully comprehend their many ramifications, the annual changes and rainfall patterns must be analyzed. To gain a better understanding of the rainfall trend over the last twenty-one years, the analysis was also conducted by categorizing the study villages into two distinct periods: 2002 to 2012 (Table 4.3) and 2013 to 2022 (Table 4.4). All of the study villages exhibit significant temperature variations in the last 21 years.

Data analysis from the period 2002 to 2012 shows substantial variations over the last decade, as some areas have been receiving incessant rainfall and some areas have been facing drought-like situations, hindering agricultural practices. Kamallangchin village recorded the highest rainfall during the year 2010 with an average of 167.87 cm and the lowest in the year 2006 at 106.35 cm, with a decade average of 141.98 cm, Shergaon village with the highest in the year 2004 with 181.92 mm and the lowest in the year 2006 at 105.03 cm, with an average of 142.82 cm, Morsing village with the highest in the year 2004 at 181.92 cm, and the lowest in the year 2006 at 142.82 cm, with an average of 142.82 cm. Salari documented the highest in the year 2004 at 126.12 cm, and the lowest in the year 2008 at 82.28 cm, with a ten-year average of 92.29 cm, Senge village with the highest in the year 2004 at 97.56 cm, and the lowest in the year 2006 at 65.48 cm, with an average of 84.05 cm in the last ten-year, Sangti village with the highest in the year 2004 at 126.12 cm, and the lowest in the year 2006 at 81.74 cm, with an average of 92.29 cm over the last ten-year. Jerigaon, Kirafarm, and Khoina are the three adjacent villages within a radius of 2 km, therefore all three villages receive a uniform amount of rainfall throughout the year, recording the highest in the year 2004 with 126.12 cm, and the lowest in the year 2011 with 25.82 cm, having an average of 98.75 cm over the last decade. Ramallingpam and Tsering-Pam villages recorded the highest rainfall during the year 2004 with 173.6 cm, and the lowest in the year 105 cm in 2006, with a mean average of 141.22 cm, meanwhile Mago-pam village recorded the highest in the year 2010 with 224.06 cm, and the lowest in the year 2002 with 145 cm, with an average record of 175.47 cm over the last ten years. Karangania and Sakrin are adjacent villages recording the highest rainfall in the year 2010 with an average of 204.8 cm, the lowest in the year 2002 with 141.9 cm, having an average of 175.46 cm over the last decade, Palizi village recorded the maximum in the year 2010 with 224.56 cm, and the lowest in the year 2002 with 145.02 cm, with a mean average of 175.46 cm over the last ten years. Consequently, the overall mean rainfall of the West Kameng district over the last ten years stands at the highest in the year 2004 with 156.56 cm, and the lowest recorded in the year 2006 with 106.20 cm (Table 4.3 and Fig.4.3).

Table 4.3. Mean annual trend of rainfall (in cm) of the villages (2002-2012)

Villages	200 2	200 3	200 4	200 5	200 6	200 7	200 8	200 9	201 0	201 1	201 2	AN N
Kamallan gchin	128. 76	155. 13	158. 64	152. 49	106. 35	149. 85	138. 43	125. 68	167. 87	126. 56	152. 05	141. 98
Shergaon	126. 56	142. 82	181. 92	149. 79	105. 03	159. 52	141. 17	120. 41	167. 87	127. 44	148. 54	142. 82
Morsing	126. 56	142. 82	181. 92	149. 79	105. 03	159. 52	141. 17	120. 41	167. 87	127. 44	148. 54	142. 82
Salari	92.2 9	104. 59	126. 12	100. 64	81.7 4	112. 94	85.2 5	124. 37	95.8	108. 11	105. 57	92.2 9
Senge	74.7 1	93.1 6	97.5 6	89.2 1	65.4 8	93.1 6	87.0 1	68.9 9	94.4 8	73.3 9	87.4 5	84.0 5
Sangti	92.2 9	104. 59	126. 12	100. 64	81.7 4	112. 94	85.2 5	124. 37	95.8	108. 11	105. 57	92.2 9
Jerigaon	92.2 9	104. 59	126. 12	100. 64	81.7 4	124. 37	112. 94	85.2 5	124. 37	25.8 2	108. 11	98.7 5
Kirafrim	92.2 9	104. 59	126. 12	100. 64	81.7 4	124. 37	112. 94	85.2 5	124. 37	25.8 2	108. 11	98.7 5
Khoina	92.2 9	104. 59	126. 12	100. 64	81.8	124. 28	112. 89	84.2 5	124. 37	25.8 2	108. 11	98.7 5
Ramalling pam	126. 6	142. 8	173. 6	140. 6	105	159. 5	141. 1	120. 4	167. 9	127. 4	148. 5	141. 22
Tsering- Pam	126. 6	142. 8	173. 6	140. 6	105	159. 5	141. 1	120. 4	167. 9	127. 4	148. 5	141. 22
Mago- Pam	145	159. 1	191. 2	150. 3	151. 2	203. 5	175. 8	163. 9	224. 6	174. 9	190. 7	175. 47
Karangani a	141. 9	161. 7	184. 1	151. 2	145	197. 3	173. 6	152. 9	204. 8	159. 5	181. 5	168. 5
Sakrin	141. 9	161. 7	184. 1	151. 2	145	197. 3	173. 6	152. 9	204. 8	159. 5	181. 5	168. 5
Palizi	145. 02	159. 08	191. 16	150. 29	151. 17	203. 47	175. 78	163. 92	224. 56	174. 9	190. 72	175. 46
$\Sigma x =$	116. 34	132. 27	156. 56	128. 58	106. 20	152. 10	133. 20	120. 89	157. 16	111. 47	140. 90	130. 86

Source: NASA Data Access Viewer

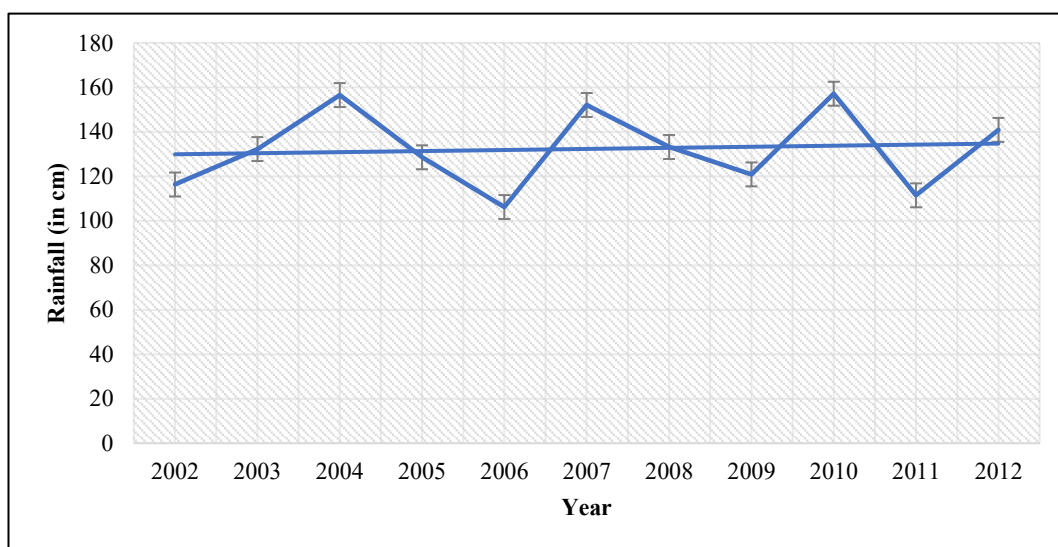


Fig. 4.3. Chart showing the annual rainfall trend of West Kameng district (2002-2012)

Figures from the period 2013 to 2022 also show a significant variation over the last decade as some areas have been receiving incessant rainfall and some areas have been facing drought-like situations, affecting various farming practices. Kamallangchin village recorded the highest rainfall during the year 2020 with an average of 179.74 cm and the lowest in the year 2021 at 109.14 cm, with a decade average of 146.23 cm, both Shergaon and Morsing villages recorded the highest rainfall in the year 2022 with 165.75 cm and the lowest in the year 2021 at 107.76 cm, with an average of 136.56 cm. Salari documented the highest in the year 2022 at 123.71 cm, and the lowest in the year 2016 at 86.13 cm, with a ten-year average of 101.67 cm, Senge village with the highest in the year 2022 at 114.22 cm, and the lowest in the year 2016 at 71.63 cm, with an average of 90.39 cm in the last ten-year, Sangti village with the highest in the year 2022 at 123.71 cm, and the lowest in the year 2016 at 86.13 cm, with an average of 101.67 cm over the last ten-year. Jerigaon, and Kirafarm villages received a uniform amount of rainfall throughout the year, recording the highest in the year 2022 with 123.71 cm, and the lowest in the year 2016 with 86.13 cm, having an average of 101.67 cm over the last decade, meanwhile, Khoina village received the highest rainfall in the year 2019 at 112.06 cm and the lowest in the year 2016 at 84.38 cm, with a decade average of 123.68 cm.

Ramallingpam and Tsering-Pam villages recorded the highest rainfall during the year 2022 with 165.58 cm, and the lowest in the year 107.8 cm in 2016 with a ten-year average of 136.56 cm, meanwhile Mago-pam village recorded the highest in the year 2017 with 222.8 cm, and the lowest in the year 2021 with 164.7 cm, with an average record of 191.38 cm over the last ten years. Karangania and Sakrin are adjacent villages recording the highest rainfall in the year 2022 with an average of 182.4 cm, the lowest in the year 2021 with 144.7 cm, having an average of 164.77 cm over the last decade, and Palizi village recorded the maximum in the year 2020 with 227.6 cm, and the lowest in the year 2021 with 164.68 cm, with mean average of 191.40 cm over the last ten years. Therefore, the overall mean rainfall of the West Kameng district over the last ten years stands at the highest in the year 2022 with 154.06 cm, and the lowest recorded in the year 2011 with 111.38 cm (Table 4.4 and Fig.4.4).

Table 4.4. Mean annual trend of rainfall (in cm) of the villages (2013-2022)

Villages	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	AN N
Kamallang chin	142. 38	120. 85	150. 73	133. 15	144. 14	134. 91	167. 87	179. 74	109. 14	179. 41	146. 23
Shergaon	139. 75	123. 49	148. 53	119. 09	134. 91	123. 93	152. 49	149. 85	107. 76	165. 75	136. 56
Morsing	139. 75	123. 49	148. 53	119. 09	134. 91	123. 93	152. 49	149. 85	107. 76	165. 75	136. 56
Salari	103. 27	90.9 7	101. 95	86.1 3	102. 83	95.8 06	112. 06	112. 5	87.5 71	123. 71	101. 67
Senge	87.4 5	71.6 3	89.2 1	82.1 8	87.0 1	87.0 1	102. 39	108. 55	74.2 3	114. 2	90.3 9
Sangti	103. 27	90.9 7	101. 95	86.1 3	102. 83	95.8 06	112. 06	112. 5	87.5 71	123. 71	101. 67
Jerigaon	103. 27	90.9 7	101. 95	86.1 3	102. 83	95.8 06	112. 06	112. 5	87.5 71	123. 71	101. 67
Kirafrim	103. 27	90.9 7	101. 95	86.1 3	102. 83	95.8 06	112. 06	112. 5	87.5 71	123. 71	101. 67
Khoina	94.8 9	90.9 2	101. 95	84.3 8	102. 83	95.8 06	112. 06	112. 5	87.5 87.2	87.2 68	123. 68
Ramallingp am	139. 7	123. 5	148. 5	119. 1	134. 9	123. 9	152. 5	149. 9	107. 8	165. 8	136. 56
Tsering- Pam	139. 7	123. 5	148. 5	119. 1	134. 9	123. 9	152. 5	149. 9	107. 8	165. 8	136. 56
Mago-Pam	166. 1	174	198. 6	185. 9	222. 8	176. 2	194. 2	227. 6	164. 7	203. 7	191. 38
Karangania	163. 9	159. 1	160	150. 3	178. 9	146. 3	169. 2	192. 9	144. 7	182. 4	164. 77
Sakrin	163. 9	159. 1	160	150. 3	178. 9	146. 3	169. 2	192. 9	144. 7	182. 4	164. 77
Palizi	166. 11	174. 02	198. 63	185. 89	222. 8	176. 22	194. 24	227. 64	164. 68	203. 72	191. 40

$\Sigma x =$	130. 45	120. 50	137. 40	119. 53	139. 22	122. 77	144. 49	152. 76	111. 38	154. 06	135. 04
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Source: NASA Data Access Viewer

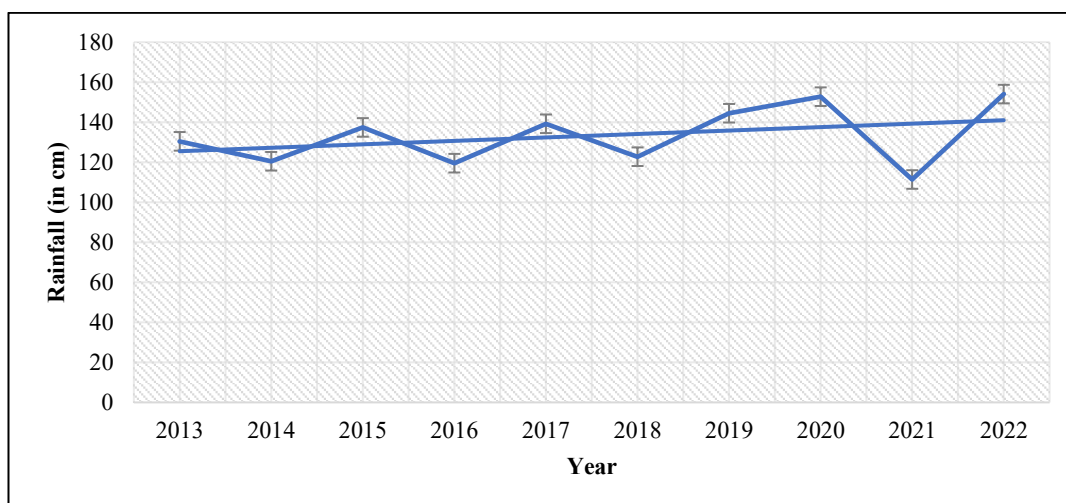


Fig. 4.4. Chart showing the mean rainfall trend of West Kameng district (2002-2012)

4.3.3. Humidity

Humidity is the amount of water vapor present in the atmosphere. Humidity plays a crucial role in the process of heating and cooling the atmosphere. Due to its ability to control a plant's water balance and other physiological processes, humidity is essential for farming, like water uptake and transpiration. Therefore, to examine the impact and trend, the humidity data of the last two decades, i.e., twenty-one years, have been analysed to understand the Humidity variations over the study area. The analysis was also conducted by categorizing the study villages into two distinct periods: 2002 to 2012 (Table 5.5) and 2013 to 2022 (Table 5.6). The study villages exhibit significant Humidity variations over the last two decades.

Figures from the period 2002 to 2012 reveal dynamic variation in humidity, where Kamallangchin village recorded the highest in 2010 with 75.19 %, and the lowest in the year 2002 with 71.19 %, having a ten-year mean average of 74.05 %, Shergaon village witnessed the highest during 2010 with 78.44 %, and the lowest in the year 2006 with 72.66 %, with an average of 76.75 % over the last decade,

meanwhile Morsing lies in the proximity to Shergaon village and recorded same average values, witnessed the highest during 2010 at 78.44 %, and the lowest in the years 2006 at 72.66 %, with an average of 76.76 %. Salari village documented the highest in the year 2012 with 81.88 %, and the lowest in the year 2002 and 2007 with 80 %, with an average of 80.58 % in the last ten years, Senge village experienced the highest during the year 2012 with 79.19 %, and lowest with 77.06 % in the year 2006, with a decade average of 78 %, and Sangti village observed the highest in the year 2012 at 81.85 %, and the lowest in the year 2006 at 79.22 %, with an average of 80.27 %. Jerigaon and Kirafarm villages experienced the highest Humidity in the year 2012 at 81.88 % and recorded the lowest in the year 2006 at 79.12 %, with an average of 80.58 % over the last ten years, meanwhile, Khoina village witnessed the highest Humidity in the year 2012 at 81.85 %, and the lowest in the year 2002 at 79.98 %, with a ten-year average of 80.48 %. Ramallingpam and Tsering-Pam villages recorded the same amount of Humidity during the last ten years, the highest during the year 2012 at 78.85 %, and the lowest Humidity in the year 2002 at 73.15 %, with an average of 76.71 % over the last decade, whereas, Mago-Pam village recorded the highest during the year 2009 at 76.97 %, and the lowest in the year 2006 at 71.02 %, with a decade average of 76 %. Karangania and Sakrin villages both witnessed the same amount of Humidity, the highest in the year 2012 at 81.85 %, and the lowest in the year 2002 at 79.98 %, with an average of 80.48 % over the last ten years, while Palizi village recorded a highest during the year 2012 at 83.29 %, and the lowest in the year 2002 at 76.67 %, with an average of 81.32 % over the last ten years. Thus, the mean average humidity of the West Kameng district during the period 2002-2012 stands highest in the year 2012 at 80.02 %, and the lowest ever recorded in the year 2006 at 76.31 % (Table 4.5 and Fig. 4.5).

Table 4.5. Mean annual trend of humidity (in %) of the villages (2002-2012)

Villages	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	AN
Kamallangchin	72.19	74	74.94	74.62	71.69	73.88	74.56	74.31	75.19	74.69	74.5	74.05
Shergaon	73.25	76.19	78.25	78	72.88	76.06	78.12	76.5	78.44	78.19	78.38	76.75
Morsing	73.39	76.19	78.25	78	72.88	76.06	78.12	76.5	78.44	78.19	78.38	76.76

Salari	80	80.5	81.1 2	80.9 4	79.1 2	80	81	80.3 1	80.3 1	81.2 5	81.8 8	80.5 8
Senge	77.9 4	78	78.5 6	78	77.0 6	77.3 1	78.1 2	77.7 5	77.6 9	78.3 8	79.1 9	78
Sangti	79.4 4	80.1 1	81.2 7	80.3 4	79.2 2	79.9 2	81.1 4	77.1 6	81.3 2	81.1 8	81.8 5	80.2 7
Jerigaon	80	80.5	81.1 2	80.9 4	79.1 2	80	81	80.3 1	80.3 1	81.2 5	81.8 8	80.5 8
Kirafrim	80	80.5	81.1 2	80.9 4	79.1 2	80	81	80.3 1	80.3 1	81.2 5	81.8 8	80.5 8
Khoina	79.9 8	80.5 3	81.1 1	80.9 1	79.1 4	80.0 6	80.9 5	80.2 4	80.2 9	80.1 8	81.8 5	80.4 8
Ramallangp am	73.1 5	76.1 3	78.2 0	77.9 5	72.8 9	76.0 3	78.0 9	76.4 6	78.4 0	78.1 4	78.3 5	76.7 1
Tsering- Pam	73.1 5	76.1 3	78.2 0	77.9 5	72.8 9	76.0 3	78.0 9	76.4 6	78.4 0	78.1 4	78.3 5	76.7 1
Mago-Pam	71.2 9	74.3 4	76.6	76	71.2	74.3	76.9 7	74.9 7	76.9 3	76.4 4	76.8 8	76
Karangania	79.9 8	80.5 3	81.1 1	80.9 1	79.1 4	80.0 6	80.9 5	80.2 4	80.2 9	80.1 8	81.8 5	80.4 8
Sakrin	79.9 8	80.5 3	81.1 1	80.9 1	79.1 4	80.0 6	80.9 5	80.2 4	80.2 9	80.1 8	81.8 5	80.4 8
Palizi	78.6 7	81.3 1	81.6 7	82.3	79.1 2	80.9 2	81.3 8	81.5 6	82.1 7	82.1 4	83.2 9	81.3 2
$\Sigma x =$	76.8 3	78.3 7	79.5 1	79.2 5	76.3 1	78.0 5	79.3 6	78.2 2	79.2 5	79.3 2	80.0 2	78.6 5

Source: NASA Data Access Viewer

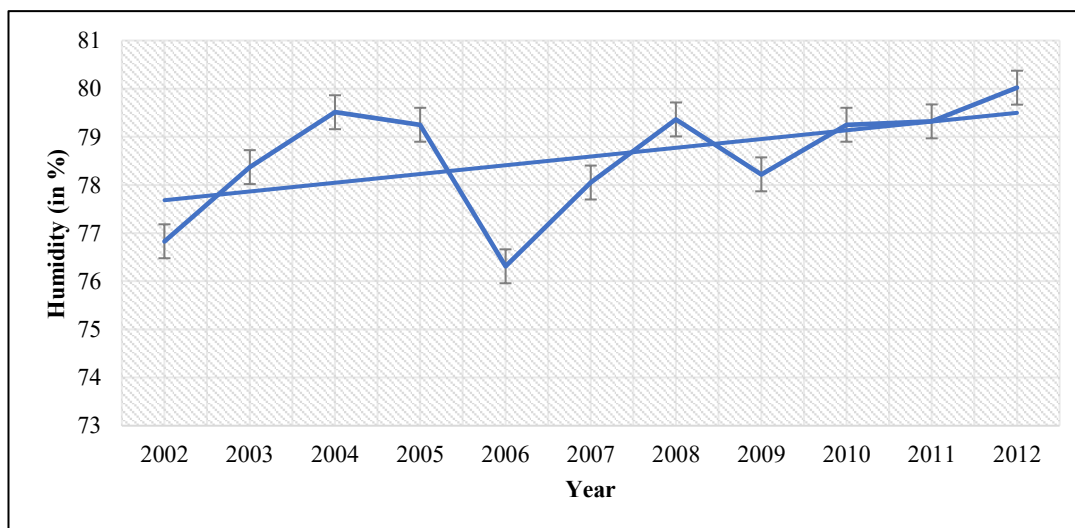


Fig. 4.5. Chart showing the annual humidity trend of West Kameng district (2002-2012)

Statistics from the period 2013 to 2022 depict significant variations, where Kamallangchin village recorded the highest in 2015 at 80.05 %, and the lowest in the

year 2013 at 74.62 %, with a ten-year mean average of 77.81 % %, Shergaon, and Morsing both the villages witnessed same percentage of Humidity, the highest during the year 2020 at 80.19 %, and the lowest in the year 2013 at 77.62 %, with an average of 79.51 % over last ten years. Salari village documented the highest in the year 2015 at 85.62 %, and the lowest in the year 2013 at 81.88 %, with an average of 83.71 % in the last ten years, Senge village experienced the highest during the year 2022 at 81.88 %, and lowest at 79.06 % in the year 2013, with a decade average of 80.97 % and Sangti village observed the highest in the year 2015 at 85.62 %, and the lowest in the year 2013 at 89.9 %, with an average of 83.58 %. Jerigaon and Kirafarm villages experienced the highest Humidity in the year 2015 at 85.62 % and recorded the lowest in the year 2013 at 81.88 %, with an average of 83.71 % over the last ten years, meanwhile, Khoina village witnessed the highest Humidity in the year 2015 at 85.61 %, and the lowest in the year 2013 at 81.81 %, with a ten-year average of 83.69 %. Ramallingpam and Tsering-Pam villages recorded the same amount of Humidity during the last ten years, the highest during the year 2020 at 81.50 %, and the lowest Humidity in the year 2013 at 77.51 %, with an average of 79.47 % over the last decade, whereas, Mago-Pam village recorded the highest during the year 2020 at 80.28 %, and the lowest in the year 2013 at 76.04 %, with a decade average of 77.95 % in the last ten years. Karangania and Sakrin villages both witnessed the same amount of Humidity, the highest in the year 2015 at 85.61 %, and the lowest in the year 2013 at 81.81 %, with an average of 80.48 % over the last ten years, while Palizi village recorded a highest during the year 2015 at 85.83 %, and the lowest in the year 2013 at 81.73 %, with an average of 84.15 % over the last ten years. Accordingly, the mean average humidity of the West Kameng district during the period 2012-2022 stands highest in the year 2015 at 83.54 %, and the lowest ever recorded in the year 2013 at 76.65 % (Table 4.6 and Fig. 4.6).

Table 4.6. Mean annual trend of humidity (in %) of the villages (2013-2022)

Villages	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	ANN
Kamallangch in	74.6 2	76.5	80.5	79.3 8	78.5 6	77.6 9	76.2 5	79.0 6	76.5 6	78.9 4	77.81
Shergaon	77.6 2	78	81.1 9	80.4 4	79.5	79.4 4	78.9 4	81.5 6	78.2 5	80.1 9	79.51
Morsing	77.6 2	78	81.1 9	80.4 4	79.5	79.4 4	78.9 4	81.5 6	78.2 5	80.1 9	79.51

Salari	81.8 8	82.8 8	85.6 2	83.8 1	83.5	83.5 6	83.3 8	84.4 4	83.6 2	84.4 4	83.71 3
Senge	79.0 6	80.3 1	83.3 8	81.3 8	80.8 1	80.3 8	80.3 8	81.1 2	81	81.8 8	80.97
Sangti	81.9	82.4 3	85.6 2	83.9 3	83.1 6	83.6 4	83.3 5	83.9 6	83.7 4	84.0 8	83.58
Jerigaon	81.8 8	82.8 8	85.6 2	83.8 1	83.5	83.5 6	83.3 8	84.4 4	83.6 2	84.4 4	83.71
Kirafrim	81.8 8	82.8 8	85.6 2	83.8 1	83.5	83.5 6	83.3 8	84.4 4	83.6 2	84.4 4	83.71
Khoina	81.8 1	82.8 4	85.6 1	83.8 4	83.4 7	83.5 5	83.3 5	84.4 4	83.5 9	84.4 3	83.69
Ramallingpa m	77.5 1	77.9 3	81.1 6	80.4 4	79.4 3	79.4 1	78.9 2	81.5 0	78.1 8	80.2 0	79.47
Tsering-Pam	77.5 1	77.9 3	81.1 6	80.4 4	79.4 3	79.4 1	78.9 2	81.5 0	78.1 8	80.2 0	79.47
Mago-Pam	76.0 4	76.5 6	79.4 5	78.6 7	77.7 8	77.1 9	77.3 6	80.2 8	76.8 7	79.3 1	77.95
Karangania	81.8 1	82.8 4	85.6 1	83.8 4	83.4 7	83.5 5	83.3 5	84.4 4	83.5 9	84.4 3	83.69
Sakrin	81.8 1	82.8 4	85.6 1	83.8 4	83.4 7	83.5 5	83.3 5	84.4 4	83.5 9	84.4 3	83.69
Palizi	81.7 3	83.6 2	85.8 3	84.6	84.2 9	84.6 6	83.5	85.3 1	83.6 4	84.2 9	84.15
$\sum x =$	79.6 5	80.5 6	83.5 4	82.1 8	81.5 6	81.5 1	81.1 2	82.8 3	81.0 9	82.3 9	81.64

Source: NASA Data Access Viewer

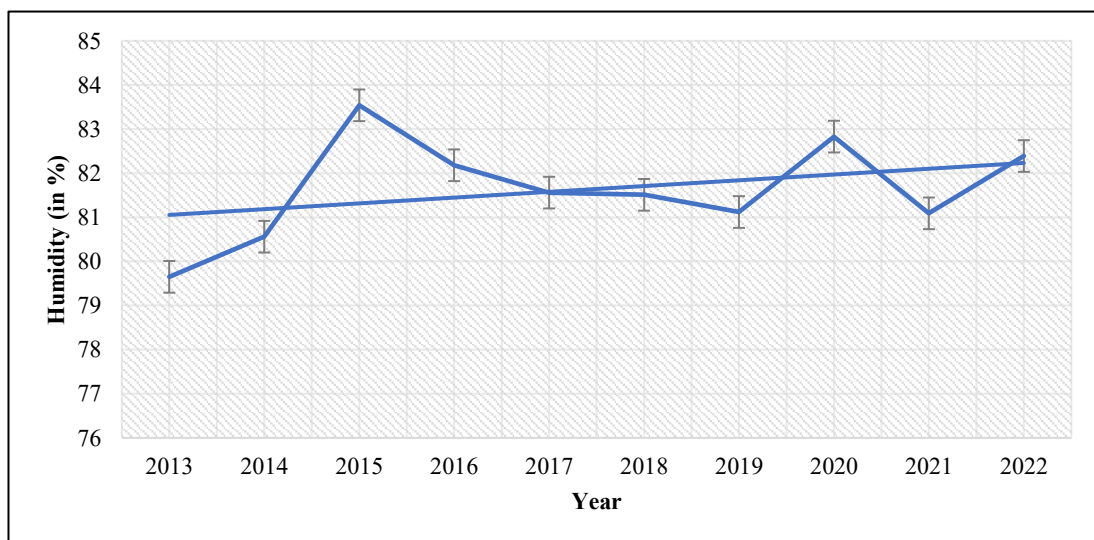


Fig. 4.6. Chart showing the mean annual humidity trend of West Kameng district (2013-2022)

4.4. Climate variability and trends

A multitude of observations indicate that the global climate is changing. Important aspects of climate study include trend identification, estimation, prediction, and the statistical and physical importance of related changes. The trend is the pace at which temperature, rainfall, and humidity change over a certain period, given a time series. Climate is changing at a global rate, and one of the most important contributors is anthropogenic or human-induced activities, which instigate the climate to vary tremendously over a given period. Several existing studies show significant climate variations in recent years, which pose a threat to the environment and socio-economic activities. Whereas trend analysis is becoming an inseparable aspect of determining the frequency and rate at which the temperature, rainfall, and humidity are changing. The present study examines and analyzes climate data (2002-2022); temperature, rainfall, and humidity of the study villages using the Linear (trend) regression (R^2), and the results represent significant variations over the last twenty-one years.

The study reveals significant variations in the humidity of the study villages of West Kameng district, which were examined using parametric trend analysis (R^2). Where the mean average humidity from Jan-Dec stands at 74.33 %, the lowest trend was recorded in the year 2010 at -10.53 %, and the highest trend in the year 2016 at 7.82 %. The average mean from Feb-Dec stands at 73.59 %, the lowest trend was recorded in the year 2002 at -7.08 %, and the highest trend in the year 2022 at 6.61 %. The lowest trend from March-Dec was recorded in the year 2009 at -6.47 %, and the highest trend in the year 2005 at 7.21 %, with an average of 70.81 % over the last twenty-one years. The lowest trend from April-Dec was witnessed in the year 2014 at -11.39 %, the highest trend in the year 2022 at 6.60 % with an average of 75.39 % in the last two decades. The mean average from May-Dec stands at 80.87 %, the lowest trend recorded in the year 2003 at -4.81 %, and the highest in the year 2022 at 4.41 %. The mean from June-Dec stands at 86.07 %, the lowest trend in the year 2005 at -3.12 %, and the highest trend in the year 2022 at 5.02 %. The average value from July-Dec stands at 88.19 %, the lowest trend in the years 2006 at -4.15 %, and the highest in the year 2020 at 2.93 %. The lowest trend from Aug-Dec was recorded in the year 2006 at -6.41 %, and the highest in the year 2015 at 2.66 % with an average of 87.47 % in the

last twenty-one years. The lowest trend from Sept-Dec was witnessed in the year 2005 at -4.08 %, and the highest in the year 2015 at 2.67 % with an average of 81.67 % over the last two decades. The mean from Oct-Dec stands at 81.76 %, the lowest trend recorded in 2006 at -6.79 %, and the highest in 2017 at 3.40 %. And lastly, the mean from Nov-Dec stands at 78.11 %, the lowest trend recorded in 2002 at -5.09 %, and the highest in 2014 at 6.55 % (Table 4.7 and Fig.4.7).

Table 4.7. Parametric trend analysis of humidity of the study villages using *Linear Regression* (R^2)

Year	Jan-Dec	Feb-Dec	March-Dec	April-Dec	May-Dec	June-Dec	July-Dec	Aug-Dec	Sept-Dec	Oct-Dec	Nov-Dec
2002	-4.19	-7.08	-5.12	-0.22	-1.91	-2.62	-0.75	-1.41	-2.33	-3.23	-5.01
2003	-8.46	0.40	0.51	-1.51	-4.81	-1.70	-0.42	-1.65	0.46	2.67	0.42
2004	-1.03	-3.32	-0.49	5.32	1.67	0.10	1.59	-0.25	-1.13	-0.71	-3.93
2005	1.59	3.11	7.21	1.04	2.31	-3.12	-2.58	1.02	-4.08	-1.25	-3.44
2006	-7.53	0.70	-6.03	-4.13	-2.73	-0.59	-4.15	-6.41	-2.62	-6.79	-1.27
2007	-6.03	4.21	-3.58	0.32	-2.38	-1.39	0.08	-1.81	-2.74	0.51	-4.16
2008	1.21	-2.84	3.14	-1.58	-1.16	0.66	-0.74	1.43	-1.11	-2.83	-7.02
2009	1.94	-3.72	-6.47	-3.85	-3.87	-2.50	-2.42	-0.04	-2.43	-2.10	1.17
2010	-10.53	-2.84	-2.50	0.44	2.02	1.96	0.86	0.75	0.70	0.11	4.91
2011	2.89	-1.89	1.43	-0.49	-0.22	-2.46	0.22	-1.64	-0.52	-1.16	-2.34
2012	2.97	-3.80	-4.53	0.45	-2.27	1.44	1.92	1.66	1.70	-0.67	-0.45
2013	-1.33	-4.84	-3.32	-3.96	-0.24	-0.35	2.88	1.96	0.38	0.48	-3.63
2014	2.78	2.33	2.55	-11.39	-3.91	0.03	0.19	2.14	0.94	1.28	6.55
2015	2.99	4.13	1.57	5.08	4.25	2.82	-0.05	2.66	2.67	2.95	6.05
2016	7.82	3.63	3.07	3.08	3.22	2.32	1.72	-1.09	2.25	-0.23	1.62
2017	-2.00	-2.03	4.19	3.66	1.54	0.27	-0.10	1.45	2.30	3.40	2.49
2018	3.87	3.48	2.60	3.28	1.43	-0.67	-0.39	0.38	2.04	-0.27	1.16
2019	-3.73	1.36	1.08	1.93	1.67	-1.15	1.12	-1.13	1.78	2.17	6.36
2020	6.84	3.72	6.64	2.24	0.92	2.21	2.93	1.20	2.58	0.61	-1.92
2021	5.93	-0.49	1.39	-5.78	0.47	0.29	-0.85	1.52	-1.13	2.81	4.53
2022	4.93	6.61	-3.94	6.60	4.41	5.02	-1.19	-0.85	1.06	2.60	-2.32
$\sum \bar{x} =$	74.33	73.59	70.81	75.39	80.87	86.07	88.19	87.47	87.24	81.76	78.11

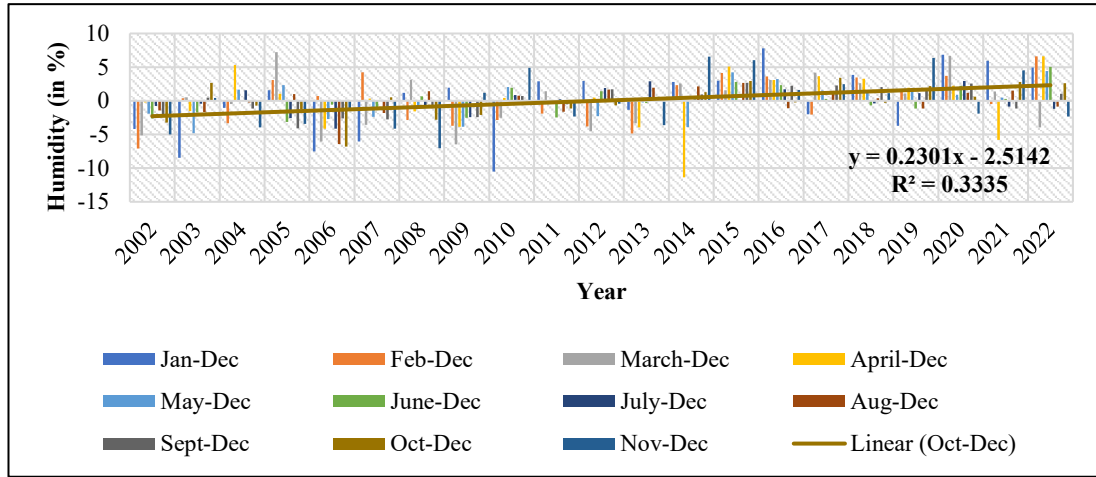


Fig.4.7. Chart showing the humidity trend of the study villages (2002-2022)

The mean average temperature over the last twenty-one years from Jan-Dec stands at 12.47 °C, the lowest trend recorded in the year 2004 at -1.54 °C, and the highest trend in the year 2009 at 1.40 °C. The average mean from Feb-Dec stands at 12.39 °C, the lowest trend recorded in the year 2022 at -2.15 °C, and the highest trend in the year 2017 at 1.01 °C. The lowest trend from March-Dec was recorded in the year 2012 at -0.88 °C, and the highest trend in the year 2022 at 1.63 °C with an average of 14.13 °C over the last twenty-one years. The lowest trend from April-Dec was witnessed in 2015 at -0.83 °C, the highest in 2007 at 0.79 °C with an average of 15.66 °C in the last two decades. The mean average from May-Dec stands at 18.12 °C, the lowest trend recorded in the year 2020 at -0.99 °C, and the highest in the year 2013 at 1.28 °C. The average mean from June-Dec stands at 19.68 °C, the lowest trend was recorded in the year 2022 at -0.84 °C, and the highest trend in the years 2019 at 0.82 °C. The average value from July-Dec stands at 19.75 °C, the lowest trend recorded in the year 2011 at -0.84 °C, and the highest in the year 2022 at 1.09 °C. The lowest trend from Aug-Dec was recorded in the year 2018 at -1.02 °C, and the highest in the year 2006 at 0.89 °C with an average of 19.48 °C in the last twenty-one years. The lowest trend from Sept-Dec was witnessed in the year 2002 at -0.79 °C, and the highest in the year 2011 at 0.77 °C with an average of 17.70 °C over the last two decades. The mean from Oct-Dec stands at 16.96 °C, the lowest trend recorded in the year 2018 at -1.30 °C, and the highest in the year 2021 at 1.40 °C. Lastly, the mean from Nov-Dec stands

at 14.65 °C, the lowest trend recorded in 2005 at -1.10 °C, and the highest in 2020 at 2.04 °C (Table 4.8 and Fig.4.8).

Table 4.8. Parametric trend analysis of the temperature of the study villages using *Linear Regression (R^2)*

Year	Jan-Dec	Feb-Dec	March-Dec	April-Dec	May-Dec	June-Dec	July-Dec	Aug-Dec	Sept-Dec	Oct-Dec	Nov-Dec
2002	-1.31	0.01	-0.03	0.24	0.76	0.00	0.25	0.28	-0.79	-0.37	-0.41
2003	0.98	-0.20	-0.30	0.02	-0.01	0.00	0.25	0.07	-0.28	-1.08	-0.41
2004	-1.54	-0.02	0.28	-0.57	0.61	0.08	-0.70	-0.66	-0.24	-0.33	-1.07
2005	0.46	0.25	0.12	0.60	-0.28	0.30	0.06	0.30	0.46	-0.63	-1.10
2006	0.60	0.93	0.21	0.61	0.10	-0.29	0.45	0.89	0.52	0.16	0.64
2007	-0.12	-0.48	0.63	0.79	0.24	0.00	0.83	0.59	0.23	0.35	0.10
2008	0.70	-0.86	-0.60	0.17	-0.55	0.24	-0.45	-0.53	-0.42	0.30	0.87
2009	1.40	0.55	-0.16	0.55	0.75	0.01	0.30	0.11	0.73	-0.34	-0.06
2010	-0.41	-1.01	0.90	0.49	-0.39	-0.71	0.05	0.15	-0.63	-0.32	-0.06
2011	-1.38	0.04	-0.72	0.15	-0.41	-0.09	-0.84	-0.02	0.77	0.00	-0.26
2012	-0.63	-0.80	-0.88	-0.72	1.14	-0.06	0.00	-0.20	-0.17	0.43	-0.05
2013	0.54	0.95	-0.28	-0.12	1.28	0.55	-0.48	-0.03	0.23	0.20	-1.02
2014	-0.10	-0.54	-0.13	0.18	-0.17	0.30	0.34	0.49	0.27	-0.41	0.67
2015	1.15	0.90	0.53	-0.83	-0.50	0.12	0.21	-0.63	-0.33	0.04	-0.44
2016	-1.14	0.77	0.24	0.10	-0.69	0.19	-0.65	-0.13	-0.39	0.65	0.48
2017	1.18	1.01	0.04	-0.11	0.23	0.21	0.10	-0.33	-0.71	1.04	-0.19
2018	0.38	0.12	-0.16	-0.71	-0.65	-0.30	-0.31	-1.02	0.06	-1.30	0.41
2019	-0.63	0.40	-0.57	-0.28	-0.94	0.82	0.13	0.13	0.24	-0.58	1.55
2020	-0.06	-0.08	-0.43	-0.85	-0.99	-0.11	-0.48	0.03	0.28	0.86	2.04
2021	0.44	-0.26	0.11	0.33	0.94	-0.67	0.09	0.41	0.59	1.40	-0.97
2022	-0.93	-2.15	1.63	0.03	-0.68	-0.84	1.09	0.11	-0.58	0.16	-0.79
$\sum \bar{x} =$	12.47	12.39	14.13	15.66	18.12	19.65	19.75	19.48	17.70	16.96	14.65

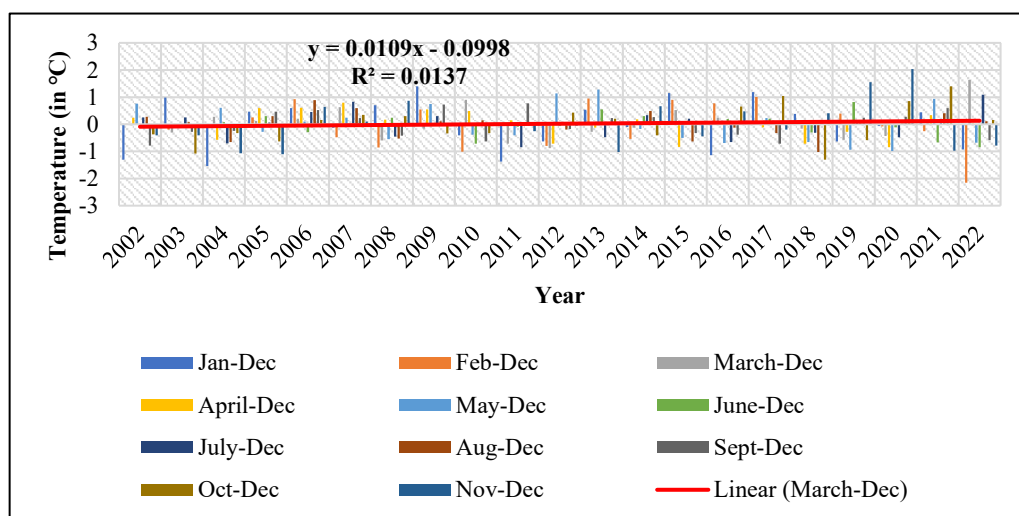


Fig. 4.8. Chart showing the temperature trend of the study villages (2002-2022)

The analysis in Table 4.9 and Fig. 4.9 shows that the mean rainfall from Jan-Dec stands at 1.93 cm, the lowest trend recorded in five consecutive years 2006, 2007, 2010, 2014, and 2018 at -6.51 cm, and the highest trend in the year 2019 at 153.32 cm. The average mean from Feb-Dec stands at 17.58 cm, the lowest trend recorded in the year 2010 at -16.77 cm, and the highest trend in the year 2007 at 48.27 cm. The lowest trend from March-Dec was recorded in the year 2006 at -38.01 cm, and the highest trend in the year 2010 at 56.91 cm with an average of 42.94 cm over the last twenty-one years. The lowest trend from April-Dec was witnessed in 2021 at -131.93 cm, the highest in 2004 at 116.63 cm with an average of 150.91 cm in the last two decades. The mean average from May-Dec stands at 197.38 cm, the lowest trend recorded in the year 2003 at -103.50 cm, and the highest in the year 2004 at 83.53 cm. The mean from June-Dec stands at 298.12 cm, the lowest trend in the year 2002 at 136.54 cm, and the highest trend in the year 2022 at 2030 cm. The average value from July-Dec stands at 327.36 cm, the lowest trend in the year 2006 at -143.40 cm, and the highest in the year 2019 at 153.32 cm. The lowest trend from Aug-Dec was recorded in the year 2016 at -128.09 cm, and the highest in the year 2005 at 175.45 cm with an average of 237.10 cm in the last twenty-one years. The lowest trend from Sept-Dec was witnessed in the year 2008 at -78.58 cm, and the highest in the year 2014 at 154.51 cm with an average of 197.76 cm over the last two decades. The mean from Oct-Dec stands at 84.18 cm, the lowest trend recorded in the year 2011 at -81.01 cm, and the

highest in the year 2004 at 108.83 cm. Lastly, the average mean from Nov-Dec stands at 12.32 cm, the lowest trend recorded in three repeated years in 2001, 2013, and 2022 at -12.32 cm, and the highest in 2007 at 49.20 cm.

Table 4.9. Parametric trend analysis of the rainfall of the study villages using *Linear Regression* (R^2)

Year	Jan-Dec	Feb-Dec	March-Dec	April-Dec	May-Dec	June-Dec	July-Dec	Aug-Dec	Sept-Dec	Oct-Dec	Nov-Dec
2002	1.93	-8.34	9.45	11.51	-38.11	-136.54	-31.95	80.04	-60.65	-52.18	23.18
2003	-4.04	-3.06	15.78	-29.98	-103.50	10.41	10.59	-40.90	69.08	65.59	3.50
2004	-1.24	-5.52	-10.59	116.63	83.53	-38.10	59.78	31.87	-46.59	108.83	-12.32
2005	6.86	-5.87	36.87	0.96	-1.20	-115.54	-73.79	171.45	-74.36	10.04	-7.40
2006	-6.51	21.20	-38.01	2.37	-14.20	9.36	-143.40	-93.63	-62.06	-9.65	9.12
2007	-6.51	48.27	-22.55	34.36	-33.89	43.81	105.16	-17.35	70.13	-31.44	49.20
2008	20.56	-15.37	41.44	-6.77	-26.16	69.83	7.78	50.15	-78.58	-12.11	-9.51
2009	-2.99	-13.96	-14.81	34.54	-47.25	-92.24	-51.99	76.52	-51.86	25.51	-5.65
2010	-6.51	-16.77	56.91	67.06	10.06	149.98	-35.47	34.33	93.33	-16.33	1.74
2011	-0.18	-11.85	18.59	-68.64	-35.65	-42.32	52.07	31.87	2.28	-81.01	19.32
2012	-4.40	-16.07	-19.03	13.27	-37.05	124.67	27.46	-34.22	56.07	4.07	-10.92
2013	-5.80	-9.04	-12.70	-40.52	62.09	-51.46	27.82	6.56	-49.75	50.47	-12.32
2014	-6.51	7.14	-35.55	-131.93	25.17	-32.13	-38.98	-28.25	154.51	-64.49	-10.92
2015	-1.59	-12.55	-32.74	-8.53	60.68	86.70	-96.99	114.14	-56.08	-42.34	7.36
2016	13.89	-5.52	6.98	83.93	-1.55	-88.37	17.97	-128.09	-24.44	-20.19	-9.51

2017	- 5.10	33.5 0	8.74	30.49	- 22.64	- 10.33	13.40	-5.75	0.52	42.74	- 4.59
2018	- 6.51	- 9.39	15.07	- 67.94	- 44.08	- 47.94	31.33	31.17	11.42	- 64.14	2.44
2019	- 5.10	6.43	4.52	-4.31	72.98	- 68.69	153.3 2	- 95.04	71.54	3.72	- 6.70
2020	6.85	3.97	-31.33	49.13	74.74	74.05	64.73	- 66.21	34.97	30.08	- 9.51
2021	- 5.21	- 16.0 7	-7.43	- 104.1 8	- 33.81	-3.23	- 22.70	- 53.03	2.23	- 22.89	- 10.0 7
2022	11.8 4	39.7 9	11.86	109.3 1	82.27	230.0 0	- 94.82	- 119.7 4	- 78.31	99.38	- 12.3 2
$\sum \bar{x} =$	1.93	17.5 8	42.94	150.9 1	197.3 8	298.1 2	327.2 6	237.1 0	197.7 6	84.18	12.3 2

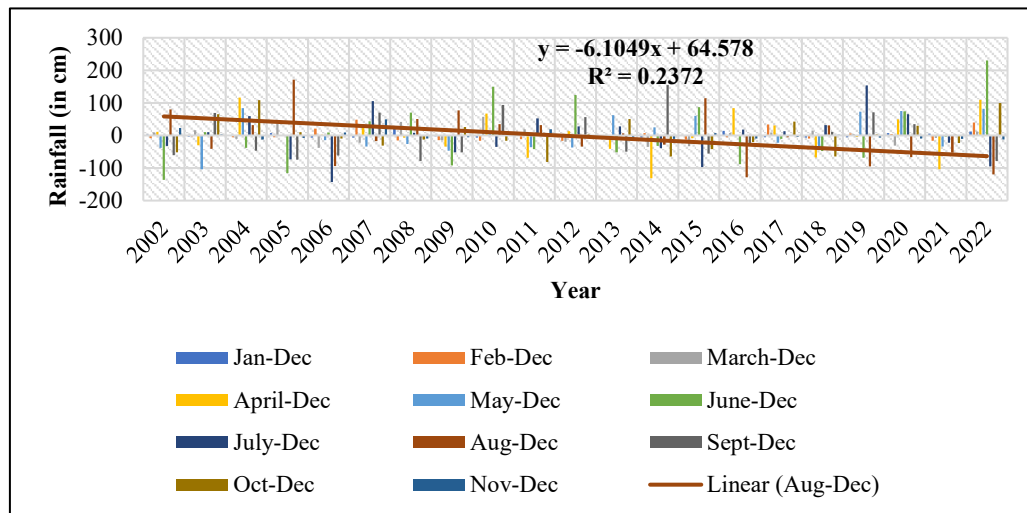


Fig. 4.9. Chart showing the rainfall trend of the study villages (2002-2022)

4.5. Seasonal trends

Changing seasons greatly determine an area's dynamic temperature, humidity, and rainfall variability, and vice versa. The crystal understanding of the climatic trend is through seasonality studies. Analysis of the climate data in seasons: winter, pre-monsoon, monsoon, and post-monsoon, helps better understand the actual climate change and trend, and how it varies in different seasons. Therefore, the study advocates the examination and analysis of the climatic data in a seasonal manner in the West Kameng district. The mean monthly average of the last twenty-one years (2002-2022) of temperature, humidity, and rainfall was analyzed, categorized, and tabulated

seasonally based on the seasons considered by the Indian Council of Agricultural Research (ICAR).

Table 4.10, and Fig. 4.10, illustrate the seasonal temperature variation of the study over the last twenty-one years, hence the statistics show a significant trend in the temperature; the lowest was recorded during the winter season with an average of 13.28°C, and the highest during the monsoon season with an average of 19.64 °C, respectively.

Table 4.10. Seasonal variability and trend of temperature (in °C) of West Kameng district (2002-2022)

Winter	Pre-monsoon	Monsoon	Post-monsoon
13.28	18.79	19.64	16.04

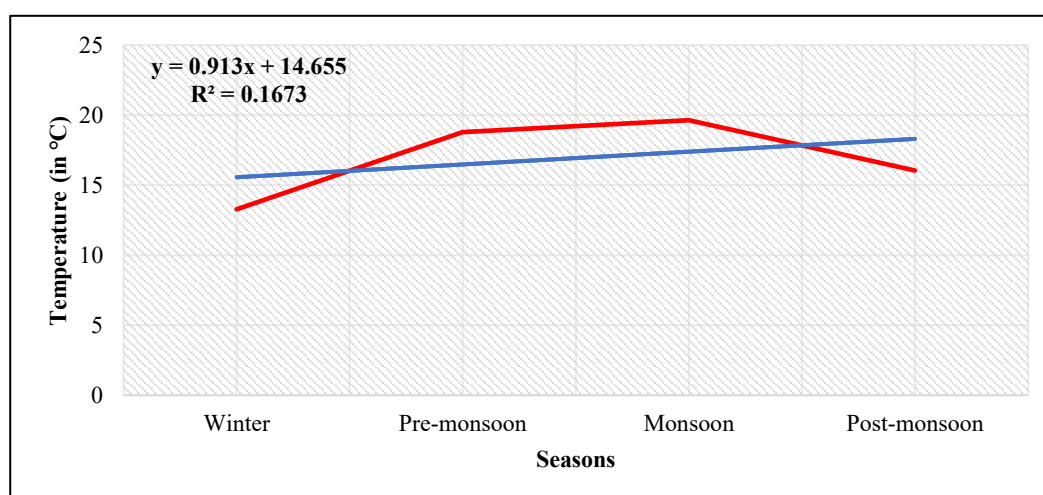


Fig. 4.10. Chart showing the seasonal trend of temperature of West Kameng district (2002-2022)

Table 4.11, and Fig. 4.11, exemplify the seasonal humidity variation of the study over the last twenty-one years; therefore, the statistics show a significant trend in the humidity; the lowest was recorded during the winter season with an average of 74.07 % and the highest during the monsoon season with an average of 87.65 %, respectively.

Table 4.11. Seasonal variability and trend of humidity (in %) of West Kameng district (2002-2022)

Winter	Pre-monsoon	Monsoon	Post-monsoon
74.07	83.47	87.65	79.7

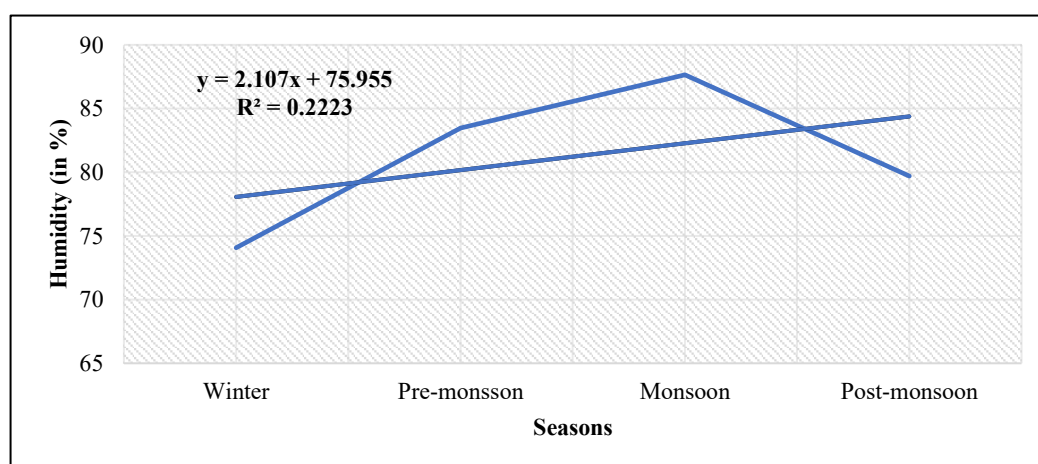


Fig. 4.11. Chart showing the seasonal trend of humidity of West Kameng district (2002-2022)

Table 4.12 and Fig. 4.12 exemplify significant rainfall intensity over the last twenty-one years. The statistics show that the West Kameng received the highest rainfall during the monsoon season with an average of 251.75 cm, and the lowest recorded during the winter season with an average of 43.28 cm, respectively.

Table 4.12. Seasonal variability and trend of rainfall (in cm) of West Kameng district (2002-2022)

Winter	Pre-monsoon	Monsoon	Post-monsoon
43.28	245	251.75	46.58

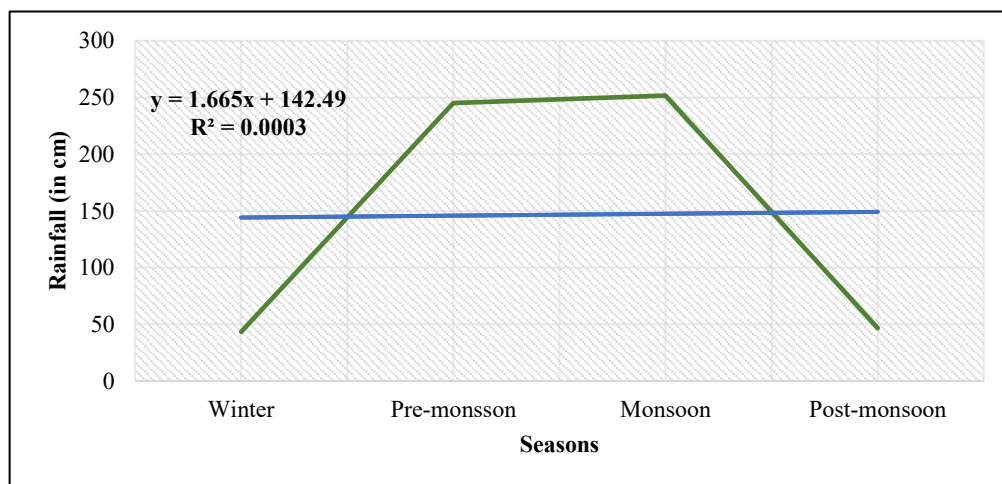


Fig. 4.12. Chart showing the seasonal trend of rainfall of West Kameng district (2002-2022)

4.6. Monthly trends

Climate is a dynamic phenomenon and change is imminent. The change follows the change in seasons in months. Some months experience extremely warm and some experience cold, whereas, generally May to August is the peak period of hot and humid, on the other hand, November up to March experience extreme cold and mild cold. Moreover, the variability in humidity is also prominent in all the months. However, the trend of rainfall varies drastically; no amount of rainfall is witnessed during dry months, i.e., October up to April. On the other hand, starting from May up to September, there is heavy to hefty rainfall in the study area. Therefore, the present study also shows prominent fluctuations in all aspects of climate variability.

Analysis of the climate data monthly helps better understand the actual climate change and trend, and how it varies in different seasons. Therefore, the study advocates the examination and analysis of the climatic data every month in the West Kameng district. The mean monthly average of the last twenty-one years (2002-2022) of temperature, humidity, and rainfall was analyzed using simple statistical techniques.

Table 4.13, and Fig. 4.13, illustrate the monthly temperature variation of the study over the last twenty-one years; hence, the statistics show a significant trend in the temperature; the lowest was recorded in February with an average of 11.63 °C, and the highest in July at 20.63 °C, respectively.

Table 4.13. Mean monthly trend of temperature (in °C) of the villages (2002-2022)

Villages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Kamallangchin	10.55	12.08	15.12	17.89	20.05	21.68	21.95	21.98	20.97	18.59	15.02	12.03
Shergaon	9.27	10.79	13.71	17.47	20.33	22.60	23.11	23.11	21.88	18.71	14.42	11.18
Morsing	7.44	8.71	11.36	14.62	17.82	20.18	20.73	20.69	19.53	16.30	12.24	9.22
Salari	17.42	11.31	11.15	17.18	15.61	12.88	19.31	18.20	12.22	15.65	15.91	16.95
Senge	11.93	13.44	15.98	18.04	20.05	21.31	21.44	21.47	20.45	18.65	15.08	12.74
Sangti	13.74	12.93	18.66	18.60	18.18	14.89	19.46	18.91	15.30	18.49	17.68	18.16
Jerigaon	17.50	13.00	11.13	11.32	15.69	18.26	19.13	17.24	12.26	15.68	16.01	17.00
Kirafrim	17.50	13.00	11.13	11.32	15.69	18.26	19.13	17.24	12.26	15.68	16.01	17.00
Khoina	17.50	13.00	11.13	11.32	15.69	18.26	19.13	17.24	12.26	15.68	16.01	17.00
Ramallingpam	9.27	10.79	13.71	17.47	20.33	22.60	23.11	23.11	21.88	18.71	14.42	11.18
Tsering-Pam	11.76	13.86	17.78	20.77	22.73	24.21	24.41	24.51	23.28	20.61	16.61	13.30
Mago-Pam	11.96	10.80	11.55	11.70	15.29	15.89	17.77	19.80	17.54	15.02	14.96	15.26
Karangania	7.22	8.75	12.02	15.06	17.48	19.56	20.13	20.24	18.85	15.81	11.81	8.77
Sakrin	7.22	8.75	12.02	15.06	17.48	19.56	20.13	20.24	18.85	15.81	11.81	8.77
Palizi	11.85	13.26	16.13	18.05	20.04	21.23	21.48	21.48	20.47	18.67	15.06	12.74
Σx =	12.14	11.63	13.51	15.72	18.16	19.42	20.69	20.36	17.87	17.2	14.87	13.42

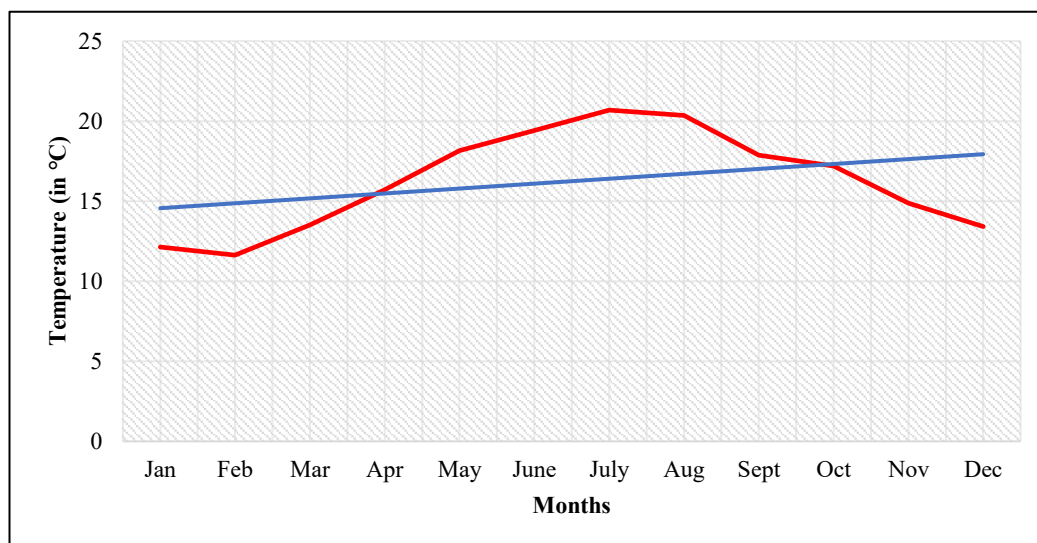


Fig. 4.13. Chart showing the monthly temperature trend of West Kameng district (2002-2022)

Table 4.14, and Fig. 4.14, illustrate the monthly humidity variation of the study over the last twenty-one years, hence the statistics show a significant trend in the humidity; the lowest was recorded in February with an average of 63.03 % and the highest in July at 89.32 %, respectively.

Table 4.14. Mean monthly trend of humidity (in %) of the villages (2002-2022)

Villages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Kamallangchin	67.68	66.02	64.01	71.47	77.76	84.58	87.23	86.51	85.03	76.82	71.72	70.74
Shergaon	74.62	69.70	63.03	70.07	77.32	84.37	87.07	86.15	86.19	81.42	77.99	78.33
Morsing	74.62	69.70	63.03	70.07	77.32	84.37	87.07	86.15	86.19	81.42	77.99	78.33
Salari	75.18	76.87	76.33	79.99	83.64	87.69	89.26	88.91	88.57	83.06	78.85	76.32
Senge	70.67	74.55	76.52	79.50	81.79	84.91	86.82	86.30	86.29	79.37	74.94	71.11
Sangti	71.56	76.84	76.46	79.99	83.88	87.69	89.26	88.87	88.57	83.06	78.85	77.08
Jerigaon	74.84	76.54	76.55	79.81	83.49	87.48	89.32	88.96	88.50	82.94	78.91	75.92
Kirafrim	74.84	76.54	76.55	79.81	83.49	87.48	89.32	88.96	88.50	82.94	78.91	75.92
Khoina	74.84	76.54	76.55	79.81	83.49	87.48	89.32	88.96	88.50	82.94	78.91	75.92
Ramallingsam	74.62	69.70	63.03	70.07	77.32	84.37	87.07	86.15	86.19	81.42	77.99	78.33

Tsering-Pam	74.6 2	69.7 0	63.0 3	70.0 7	77.3 2	84.3 7	87.0 7	86.1 5	86.1 9	81.4 2	77.9 9	78.3 3
Mago-Pam	73.1 5	69.9 1	60.9 4	68.0 7	75.5 2	82.9 0	85.7 1	84.3 7	84.6 4	79.4 0	75.8 7	76.5 5
Karangania	75.1 8	76.8 7	76.3 3	79.9 9	83.6 4	87.6 9	89.2 6	88.9 1	88.5 7	83.0 6	78.8 5	76.3 2
Sakrin	75.1 8	76.8 7	76.3 3	79.9 9	83.6 4	87.6 9	89.2 6	88.9 1	88.5 7	83.0 6	78.8 5	76.3 2
Palizi	75.1 8	76.8 7	76.3 3	79.9 9	83.6 4	87.6 9	89.2 6	88.9 1	88.5 7	83.0 6	78.8 5	76.3 2
$\Sigma x =$	73.7 9	73.5 5	71	75.9 1	80.8 8	86.0 5	88.1 5	87.5 4	87.2 7	81.6 9	77.7	76.1 2

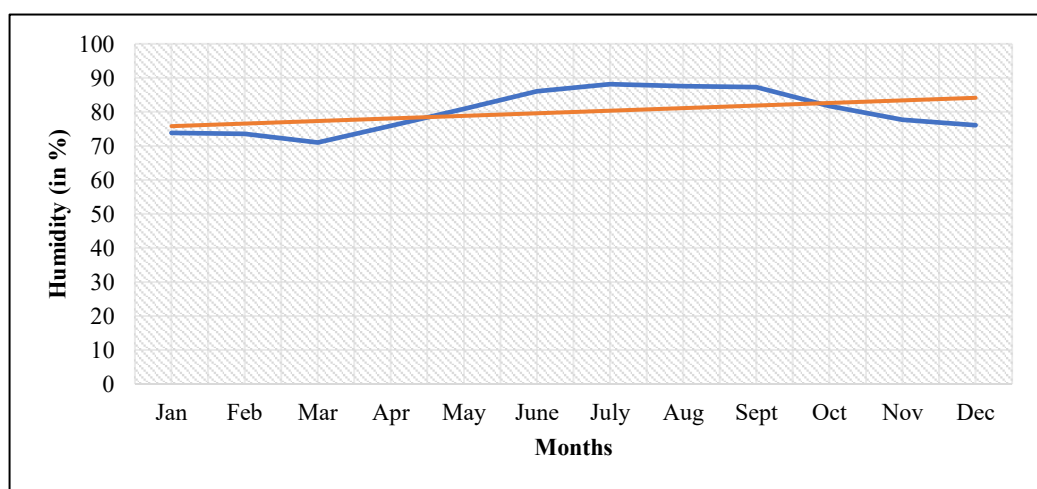


Fig. 4.14. Chart showing the monthly humidity trend of West Kameng district (2002-2022)

Table 4.15, and Fig. 4.15, illustrate the monthly rainfall variation of the study over the last twenty-one years; hence, the statistics show a significant trend in the rainfall. The lowest was recorded during December with an average of 5.23 cm, and the highest was in July at 319.29 cm, respectively.

Table 4.15. Mean monthly trend of rainfall (in cm) of the villages (2002-2022)

Villages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kamallangchin	5.36	16.53	46.65	195.60	249.93	335.12	331.34	240.34	190.82	103.00	9.80	3.58
Shergaon	6.33	15.82	45.88	166.88	227.06	300.62	326.30	249.16	206.35	86.86	14.83	5.87
Morsing	6.92	18.15	46.92	173.07	232.73	314.03	321.48	242.10	201.38	91.40	14.12	5.71
Salari	3.81	11.72	33.10	111.62	149.71	220.02	268.36	207.13	152.93	59.18	10.25	4.98

Senge	2.64	8.96	24.79	101.05	134.75	186.02	224.05	159.25	122.85	55.21	6.07	2.92
Sangti	3.81	11.72	33.10	111.62	149.71	220.02	268.36	207.13	152.93	59.18	10.25	4.98
Jerigon	4.22	11.60	31.90	108.72	151.65	223.34	269.99	200.26	154.98	59.04	9.28	4.54
Kirafrim	3.88	12.21	31.92	112.69	153.21	223.43	270.61	203.17	153.49	59.95	9.71	4.72
Khoi na	2.72	11.60	31.90	108.72	151.65	222.72	264.93	200.26	154.98	59.04	9.28	4.48
Ramalingpam	6.92	18.15	46.92	173.07	232.73	314.03	321.48	242.10	201.38	91.40	14.12	5.71
Tsering-Pam	6.92	18.15	46.92	173.07	232.73	314.03	321.48	242.10	201.38	91.40	14.12	5.71
Mago-Pam	12.36	29.72	62.63	191.49	277.84	406.76	432.82	358.78	281.62	117.32	17.43	7.83
Karanga	8.78	22.01	48.54	168.2	245.8	372.3	424.45	330.7	257.5	101.2	14.75	6.51
Sakrin	8.78	22.01	48.54	168.2	245.8	372.3	424.45	330.7	257.5	101.2	14.75	6.51
Palizi	12.36	29.72	62.63	191.49	277.84	406.76	432.82	358.78	281.62	117.32	17.43	7.83
$\Sigma x =$	5.96	16.31	41.41	147.43	202.52	287.48	319.29	243.8	192.15	81.1	12.05	5.29

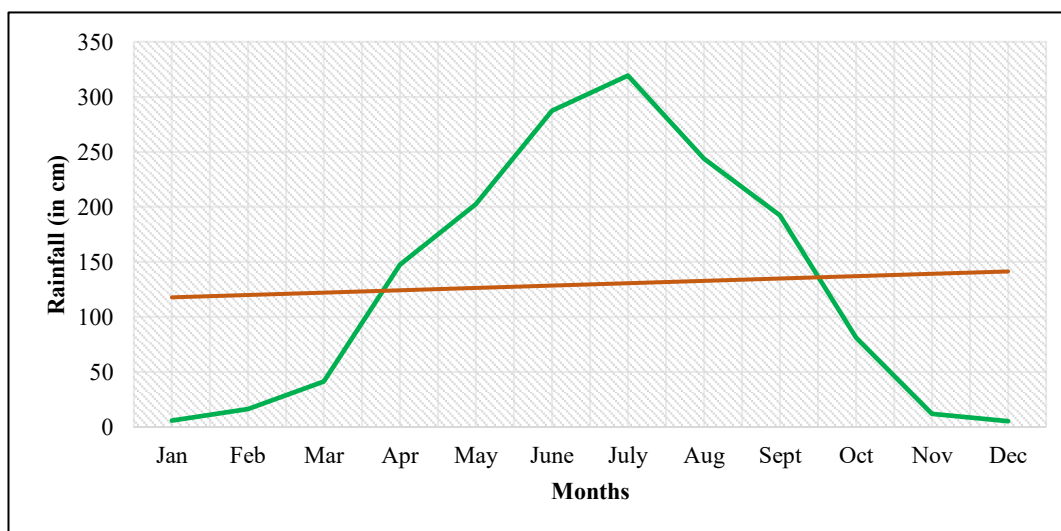


Fig. 4.15. Chart showing the monthly rainfall trend of West Kameng district (2002-2022)

4.7. Discussion

Climate is changing at a tremendous rate, and such change is affecting various entities, such as socio-economic activities and environmental settings. The West Kameng district has witnessed frequent temperature, humidity, and rainfall

fluctuations in recent years. Some of the villages are experiencing extreme climatic conditions, followed by high temperatures, humidity, and rainfall, on the other hand, some villages are undergoing extremely low temperatures, humidity, and rainfall, almost similar to drought-like circumstances. Such kind of climate change phenomenon is occurring all around the globe, and several studies have reported the implications across the various regions of the globe (Markham et al., 1993; Beniston, 1994; Sati, 2015; Diolaiuti & Smiraglia & Diolaiuti, 2016; Fugazza et al., 2021; Kotlarski et al., 2023; Cabré et al., 2024). The findings of the present day show that the data starting from 2002 to 2012, where the highest temperature ever recorded was in the year 2006 with an average of 18.28 %, a study conducted by World Wildlife Fund (WWF) in 2006 reported that the globally, 2006 was the sixth warmest year on record, after 1995. The study of the temperature data of the last ten years starting from 2002-2012, concerning temperature in all the study villages the year 2006 has been marked as the hottest year in the last two decades. The data from 2013-2022, reveals that the year 2019 recorded the highest temperature in ten years, with an average of 18.59 %, according to a study by the National Oceanic and Atmospheric Administration (NOAA) reported that overall rise of 1.8 degrees Fahrenheit (0.98 degrees Celsius) in the year 2019.

Similarly, the amount of rainfall variability has undergone over recent years. The study witnessed the year 2010 recorded the highest annual rainfall with 157.16 cm over the last ten years starting from 2002-2012. A study by the National Climate Centre, India Meteorological Department reported that the year 2010 was characterized by the high mean annual rainfall. The data from 2013-2022 illustrates the year 2022 stands as the year witnessing the highest year over the last ten years, with an annual average of 154.06 cm. A study conducted by the National Centres for Environmental Studies reported that 2022 is considered to be the wettest year over the last decade. Climatic elements such as temperature, and humidity are increasing with time, however, the data of the West Kameng district reveals a decreasing or negative trend in rainfall in the last twenty-one years which is a grave matter of concern, as the period between 2002-2012, the annual average of 157.16 cm was recorded, whereas, the period between 2013-2022, the annual average of 154.06 cm was recorded, which

means an annual average of 3.1 cm rainfall has been decreasing in the West Kameng district over the last two decades.

After thoroughly examining the data from 2002-2012, the figures show that there is a gradually increasing trend of humidity over the study areas, where the year 2012 marked the highest mean annual humidity with 80.02 %, in the last ten years, that exceeds the average humidity in India which is 73.2%, a study conducted Desai et al. (2015), reported in their work '*Effect of ambient heat on all-cause mortality in the coastal city of Surat, India*', stated that the year 2012 recorded high humidity due to extreme low air pressure and high temperature in India. The figures from 2013-2022 depict that the year 2015 witnessed the highest humidity in the last ten years, with an annual average of 83.54 %, a study by NASA Earth Observatory reported that during the year 2015, India faced a heat wave where an average of 5.5 °C rise above normal temperature. Due to this 2015 recorded high temperature and humidity at the same time. An annual average of 3.52 % increase over the last twenty-one years.

Moreover, trend (linear) regression analysis illustrates a significant trend in climate variables, concerning humidity over the last twenty-one years, where the lowest trend was recorded in Jan-Dec in the year 2014 with -11.39 % from the annual average value, and also the highest in Jan-Dec in the year 2020 with 6.84 % from the annual average value. Regarding temperature, the lowest trend ever recorded in the last twenty-one years was in 2004 during the month of Jan-Dec with -1.54 °C from the annual mean average value, and the highest ever recorded over the last two decades was in 2020 during the month of Nov-Dec with 2.04 °C. Subsequently, the lowest trend of rainfall was witnessed during the month of June-Dec in the year 2002 with -136.54 cm from the annual mean average, and the highest ever recorded in the year -136.54 cm during the month of Aug-Dec in the year 2005 with 171.45 cm from the annual mean average.

Besides, statistics from the parametric trend (linear) regression show a significant trend in all the variables; humidity, temperature, and rainfall. R^2 also known as the coefficient of determination shows the strength of a data set, therefore, the analysis of humidity of the last twenty-one years shows a significant strength of a trend

with an R^2 value of 0.3335, similarly, the R-squared value of temperature also shows strength with $R^2 = 0.0137$, furthermore, the R-squared value of rainfall also reveals significant trend with an R^2 value of 0.2372. Therefore, it is evident that climate variables have always been changing in nature with each passing year, thus, such increasing and decreasing characteristics of climatic variables have immense implications on farming systems and patterns of an area.

4.8. Conclusions

The West Kameng district is characterized by rich agriculture and horticulture practices. The climatic conditions of the region have been favorable for carrying out varied agricultural practices for many years. However, in recent years, the climate has been changing drastically in various district farming areas, resulting in a change in farming and cropping patterns. The statistics from the study reveal a gradual increase in all climate aspects, which is apparent in the temperature, rainfall, and humidity. The study shows a steady inclination in annual temperature, rainfall, and humidity over the last twenty-one years. Moreover, the parametric trend (linear) or linear regression analysis advocates a significantly increasing trend in temperature, rainfall, and humidity of the West Kameng district. Hence, the study may conclude that over the last twenty-one years, there have been imperative fluctuations concerning temperature, rainfall, and humidity of the study villages of West Kameng district.

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CHAPTER 5

CLIMATE CHANGE AND ITS IMPACT ON FARMING SYSTEMS

5.1. Introduction

Climate change is one of the biggest challenges the world faces today, posing a threat to many populations across the globe. Studies indicate that in many regions of the world, agriculture will be affected by climate change, limiting food production and threatening food security, its impact on farms can be determined by factors such as local climatic variation, physical environment, and the type of crops grown (Wheeler & Braun, 2013; Tai et al., 2014; Habtemariam et al., 2017). The impact of global climatic change on agriculture has recently become a subject of increasing importance (Glantz 1988). Agriculture is one of the most vulnerable sectors to climate change, and many farmers are currently adapting to climate change (Castellano & Moroney, 2018). Literature indicates that farmers perceived vulnerability is important to consider when understanding climate change, and its threat to livelihoods can influence whether and how farmers adapt; given that climate change impacts are expected to vary across landscapes, more importantly, farming patterns (Arbuckle et al., 2013a; IPCC, 2014; Melillo et al., 2014). Temperature and water availability remain key factors in determining crop growth and productivity; predicted changes in these factors will lead to reduced crop yields. An immense amount of literature analyzes the impacts of global warming on crop growth and production (Kurukulasuriya & Rosenthal 2003; Easterling et al. 2007; Lobell & Gourdji 2012; Altieri et al., 2015). Moreover, Sub-Saharan African countries are the most prone to climate change, having a warm climate and a lower socio-economic status that limits their capacity to adapt to the rapidly growing effects of climate change (Ringler et al., 2010). The impacts of climate change may also vary from place to place and farm to farm due to differences in the capacity of agricultural systems and farms to adapt to climate change. Another important aspect is that different crops do not respond to climate change in the same way owing to variations in their sensitivity to temperature, rainfall, and CO₂ changes (Smit & Wandel, 2006; Gornall et al., 2010). Farmers' attitudes and behaviours, as well as cultural and societal elements that may promote or impede adaptation processes, are

linked to the type and severity of climate change impacts (Vincent, 2004). As the current greenhouse gas emission rates continue, both agricultural and natural ecosystems will face enormous pressure (Singh & Reddy, 2013). Climate change affects agriculture and food production in complex ways; affects food production directly through changes in agroecological conditions and indirectly by affecting the growth and distribution of incomes (Schmidhuber & Tubiello, 2007). A study by the International Rice Research Institute (IRRI) suggests that Asian rice yields will decrease dramatically due to higher nighttime temperatures, which are declining by ten percent for each centigrade increase (IRRI, 2004). There is rising concern about the impacts of climate change and its variability on agricultural production worldwide; therefore, a consensus has emerged that developing countries are more vulnerable to climate change than developed countries, because of the predominance of agriculture in their economies, the scarcity of capital for adaptation measures, their warmer baseline climates and their heightened exposure to extreme events (Parry et al., 2001; Fischer et al., 2005).

In recent years, a noticeable change in the climatic pattern of the Eastern Himalayas has been witnessed, such as extreme events like drought, torrential/cloud burst rainfall, and the increasing rate of ice melting, which also affect agriculture practices and production. More than 80 % of precipitation occurs in the monsoon from June to September; an increase in temperature and erratic rainfall directly affects agriculture and food supply through their effects on crops, and farming systems in Nepal (Malla, 2008). The Himalayan country of Bhutan is typically an agricultural country; around 57% of the population is dependent on agriculture. However, farming has been constrained by the mountainous topography and rapid changes in environmental variabilities, such as climate change (Chhogyel & Kumar, 2018). Increasing temperature during summers, prolonged summers, delayed onset and uneven distribution of SW monsoon, delayed onset of winter, short winter periods, temperature above normal during winters, decreasing snowfall during winters, delayed snowfall and shorter winters, low-temperature spells at high altitudes during winters and unpredictable rainfalls were the main experiences of the farmers regarding climate change across the elevation zones. Climate change is described by farmers as

the temporal displacement of weather cycles, reflecting changes in crop enterprises and livelihood options (Rana et al., 2013). Global climate change and its effects are not uniform for all areas but differ with elevation. Specifically, under climate change, temperatures in mountain areas are predicted to increase more than the global mean in South Asia especially on the Tibetan Plateau and in central Asia, with the greatest warming occurring at the highest altitudes. Overall, summer precipitation is likely to increase and winter precipitation to decrease in mountain areas, with precipitation increasingly in the form of rain instead of snow, and a predicted rise in the snow line by 150 m per degree Celsius temperature increase (IPCC, 2007; Rana et al., 2013). As a result of global warming and climate change, glaciers in the Himalayas are retreating at an average rate of 15 meters per year, consistent with the rapid warming recorded at Himalayan climate stations since the 1970s. In the Himalayan region alone 67% of the glaciers have retreated in the past decade, e.g. the Gangotri glacier has been receding at a rate of 28 meters per year. Under a warming environment, the Himalayan glaciers are expected to melt faster leading to increased summer flows and flooding initially for a few decades followed by a progressive reduction in flow as the river-feeding glaciers recede and disappear from the headstreams. Climate variability and changes have rendered the role of planning and research in agriculture more crucial than ever before, and the climate factor thus needs to be included in any program aimed at maintaining and enhancing the agricultural sustainability of the northwestern Himalayan region; moreover, at present, the traditional apple farming is under stress due to climate changes in an Indian Himalayan state, Himachal Pradesh, significant effects of climate change on apple farming along the altitudinal gradient (Ives et al. 1997; Das et al., 2009; Basannagari & Kala, 2013). Climate change has been reported as one of many possible stressors on biodiversity and agriculture practices in the Eastern Himalayas. The average temperature has risen by 0.2 to 0.8 °C/decade, the maximum temperature has increased by 0.1 to 0.9 °C/decade, and the minimum temperature has increased from 0.1 to 0.6 °C/decade during the period 1965–2000 in Eastern Himalaya (ICIMOD, 2010); Jhajharia & Singh, 2011). Studies conducted in the Senapati district in Manipur and East Sikkim district in Sikkim show remarkable changes in the climatic variables over the years (Rymbai & Sheikh, 2018).

The northeastern region of India is predicted to be particularly vulnerable to the effects of climate change. Because of its geo-ecological fragility, strategic location around the eastern Himalayan landscape and international borders, transboundary river basins, and innate socio-economic instabilities. The impacts of climate change on regions like northeast India are less explored and less known till now making the future scenarios more uncertain for vulnerability assessment and risk management. However, certain indicators point to impacts already visible in the region, and most farmers perceive climate change and are aware of its agricultural and socio-economic effects. Most farmers from all eight NER states have personally experienced unusual climatic events within the last 10–15 years (Das et al., 2009; Bhalerao et al., 2022). The northeast India is equally vulnerable in terms of agriculture, eco-fragility, marginality, and inaccessibility making the future agricultural scenarios more uncertain and risk-prone due to climate variability. The erratic pattern of rainfall (spatiotemporal), higher frequency of extreme rainfall events, less rain in June-Aug, and more in Sept/Oct, and more frequent flash floods and longer dry periods in various parts of the region manifests the impact of climate change. The climate change scenario of Arunachal Pradesh and its impact on the agricultural productivity and the farming system of the state is witnessing climate change with a rise in average temperature, particularly the minimum temperature. Though the amount of rainfall remains more or less constant, the intensity has increased with the lowering of the number of rainy days by 11 percent in recent decades. Also, there are profound variations in the spatial and temporal distribution of rainfall patterns with persistent mid-season dry spells during July and August (Borthakur et al., 1989; Singh & Ngachan, 2012; Bhagawati et al., 2017).

5.2. Methods

5.2.1. Data collection

Monthly and annual data on Temperature, Rainfall, and Humidity were obtained from the NASA Data Access Viewer <https://power.larc.nasa.gov/data-access-viewer/>, for all fifteen villages from the year 2014 up to 2022. On the other hand, the data on crops and production were obtained through a primary field survey and the District Agriculture Office, Bomdila, and KVK (Krishi Vigyan Kendra) West Kameng district, Arunachal Pradesh.

5.2.2. Data analysis

Numerous statistical tools and techniques were applied to understand the impact of climate variables and change on agricultural practices. Such as Pearson (r) correlation coefficient, Two-tailed Anova, and Multiple regression analysis (R^2). Pearson (r) correlation was used to determine the relationship between the crops and different climatic variables; Two-tailed Anova was applied to understand the significance of climatic variables on crop production; Tukey's multiple comparison test and Multiple regression analysis (R^2) was applied to comprehend the relationship among multiple dependent and independent crops and climate variables.

Pearson (r) correlation,

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Two-tailed Anova,

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \epsilon_{ijk}$$

Multiple regression analysis (R^2),

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots + b_pX_p + \epsilon$$

5.3. Climate change and its impact on farming systems

Climate change navigates every sphere of the Earth's surface, wherein agriculture is the most affected entity. Such variations in temperature, humidity, and rainfall drive the nature of the soil and agricultural practices. Climate greatly affects an area's socioeconomic activities, particularly farming patterns and allied activities. Climate change is imminent and bound to occur; such a change in a certain amount of rainfall, temperature, and humidity controls the nature of the soil and greatly affects agricultural production and productivity in mountain regions. Mountain regions are highly vulnerable to climate change (Sati, 2015); climate change and its hydrological consequences may significantly modify soil conditions (Várallyay, 2010). Various studies have been conducted on climate change and crop suitability, whereas weather and climate on food production have examined the influence on crop yields. However, climate influences all components of crop production, including cropping and cropping intensity (Iizumi & Ramankutty, 2015), as altered and unpredictable weather patterns can increase crop vulnerability and the effects of extreme climate events such as high temperatures, droughts, and torrential rains. Moreover, sequential extremes, such as intense flooding rains, are catastrophic in themselves and are compounded by ecological effects that affect human populations and agricultural production (Rosenzweig et al., 2001).

It has been observed and witnessed that the climate has been rapidly changing in the West Kameng district, which has resulted in changes in farming patterns, production, and yield of different crops. The study emphasizes the West Kameng district because it is known as the 'agriculture bowl' of the state of Arunachal Pradesh, due to favorable natural elements like soil and climatic conditions, the region supports varied agriculture and horticulture practices, and various cruciferous and non-cruciferous crops are grown in the region, however, in the recent years the region has been experiencing abrupt change in the climatic conditions, cropping pattern, and farming systems. The explanations regarding these changes remain a mystery, therefore, it is of utmost necessity to interrogate and understand how, why, and what brought such changes in the region.

5.4. Correlation of climate variables with production

Correlation is a strong statistical measure to understand the relationship between different variables. Therefore, with the help of this statistical measure, the study becomes convenient in comprehending the relationship between various climate variables and crop production. Moreover, the standard *r-value* and *P-value* of the *Pearson correlation* is $r=-1$ to $+1$ and the *P-value* is 0.5, therefore, any value that comes under the stipulated value refers to having a strong correlation. The correlational analysis of humidity, temperature, and rainfall with the Kharif and Rabi production reveals a significant association among the variables. Data from 2014 to 2022 on climate, kharif, and rabi crops were examined (Table 5.1). An examination of each year was conducted between the climate variables and production.

The annual mean production of Kharif and Rabi crops is as follows; 14,235.76 MT and 3721.37 MT in 2014, 14,834.07 MT and 3772.8 MT in 2015, 15,113.76 MT and 4168.98 MT in 2016, 15,848.82 Mt and 4188.16 MT in 2017, 18,236.22 MT and 3858.23 MT in 2018, 20,196.08 MT and 3807.8 MT in 2019, 8495.81 MT and 1492.99 MT in 2020, 15,540 MT and 3490 MT in 2021, and 16,496 MT and 3565 Mt in 2022. Accordingly, humidity, temperature, and rainfall in 2014 were 80.56 %, 18.47 °C, and 120.50 mm, 83.54 %, 18.19 °C, and 137.04 mm in 2015, 82.17 %, 18.04 °C, and 119.53 mm in 2016, 81.56 %, 18.55 °C, 139.22 mm in 2017, 81.51 %, 18.43 °C, and 122.77 mm in 2018, 81.12 %, 18.69 °C, and 144.49 mm in 2019, 82.83 %, 18.53 °C, and 152.76 mm in 2020, 81.09 %, 18.22 °C, and 111.38 mm in 2021, 82.39 %, 18.53 °C, and 154.06 mm in 2020.

Table 5.1. Mean variables of production, humidity, temperature, and rainfall (2014-2022)

Sl. No	Year	Production (in MT)		Humidity (in %)	Temperature (in °C)	Rainfall (in cm)
		Kharif	Rabi			
1	2014	14235.76	3721.37	80.56	18.47	120.50
2	2015	14834.07	3772.8	83.54	18.19	137.4
3	2016	15113.76	4168.98	82.17	18.4	119.53
4	2017	15848.82	4188.16	81.56	18.55	139.22
5	2018	18236.22	3858.23	81.51	18.43	122.77
6	2019	20196.08	3807.8	81.12	18.69	144.49
7	2020	8495.81	1492.99	82.83	18.53	152.76

8	2021	15540	3490	81.09	18.22	111.38
9	2022	16496	3565	82.39	18.53	154.06

Source: Primary field survey, 2023, and Office of the Agriculture Development Officer, Bomdila, West Kameng district, Arunachal Pradesh.

Table 5.2 statistics of the year 2014 show a significant correlation between production, such as Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is 0.6181, v/s temperature is 0.9801, and v/s rainfall is 0.9954. The R^2 -value of Kharif v/s humidity is 0.7862, v/s temperature is 0.9900, and v/s rainfall is 0.9994. The *R-value* of Rabi v/s humidity is 0.6413, v/s temperature is 0.9627, and rainfall is 0.9954. The R^2 -value of Rabi v/s humidity is 0.8008, v/s temperature is 0.9812, and rainfall is 0.9977. And the *P-value* of all the variables is below 0.05. Consequently, the analysis shows a strong correlation among all the variables.

Table 5.2. Statistical value of correlation (*Pearson r*) of production and climate variables (2014)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	0.6181	0.9801	0.9988	0.6413	0.9627	0.9954
95% confidence interval	0.6942 to 0.8529	0.9851 to 0.9933	0.9991 to 0.9996	0.7140 to 0.8633	0.9719 to 0.9874	0.9966 to 0.9985
R squared	0.7862	0.9900	0.9994	0.8008	0.9812	0.9977
P value						
P (two-tailed)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
P-value summary	****	****	****	****	****	****
Significant? (alpha = 0.05)	Yes	Yes	Yes	Yes	Yes	Yes

Source: GraphPad Prism-8

Table 5.3 statistics of the year 2015 show a significant correlation between varied variables, such as Kharif and Rabi, with the climate. The *r-value* of Kharif v/s humidity is -0.1109, v/s temperature is 0.2632, and v/s rainfall is 0.5989, whereas the value of Kharif v/s humidity in the year 2015 is not significant as the value is below the standard value. The R^2 -value of Kharif v/s humidity is 0.01229, v/s temperature is

0.05579, and v/s rainfall is 0.3587. The *R-value* of Rabi v/s humidity is -0.08802, v/s temperature is 0.2069, and rainfall is 0.4928, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.007747, v/s temperature is 0.04282, and rainfall is 0.2428. The *r-value* of Kharif and Rabi v/s humidity is not significant, as the value is below standard, therefore, the *P-value* is also not significant because the *r-value* determines the *P-value*.

Table 5.3. Statistical value of correlation (*Pearson r*) of production and climate variables (2015)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1109	0.2362	0.5989	-0.08802	0.2069	0.4928
95% confidence interval	-0.3066 to 0.09387	0.03856 to 0.4160	0.4536 to 0.7132	-0.2855 to 0.1167	0.007818 to 0.3903	0.3253 to 0.6303
R squared	0.01229	0.05579	0.3587	0.007747	0.04282	0.2428
P value						
P (two-tailed)	0.2875	0.0199	<0.0001	0.3989	0.0420	<0.0001
P-value summary	NS	****	****	NS	****	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	Yes	Yes

Table 5.4 statistics of the year 2016 show a significant correlation between varied variables, such as Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is -0.1127, v/s temperature is 0.2421, and v/s rainfall is 0.4585, whereas the value of Kharif v/s humidity in the year 2016 is not significant as the value is below the standard value. The *R²-value* of Kharif v/s humidity is 0.01269, v/s temperature is 0.05860, and v/s rainfall is 0.2102. On the other hand, the *r-value* of Rabi v/s humidity is -0.08802, v/s temperature is 0.2069, and rainfall is 0.4928, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.007747, v/s temperature is 0.04282, and rainfall is 0.2428. The *P-value* of Kharif v/s humidity is 0.2796, v/s temperature is

0.0169, and v/s rainfall is <0.0001 ; meanwhile, of Rabi v/s humidity is 0.3989, v/s temperature is 0.0420, and v/s rainfall is <0.0001 . The *r-value* determines the *P-value*; therefore, as the *r-value* of Kharif and Rabi v/s humidity is below the standard value hence the *P-value* is also deemed as not-significant.

Table 5.4. Statistical value of correlation (*Pearson r*) of production and climate variables (2016)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1127	0.2421	0.4585	-0.08802	0.2069	0.4928
95% confidence interval	-0.3082 to 0.09205	0.04479 to 0.4212	0.2851 to 0.6028	-0.2855 to 0.1167	0.007818 to 0.3903	0.3253 to 0.6303
R squared	0.01269	0.05860	0.2102	0.007747	0.04282	0.2428
P value						
P (two-tailed)	0.2796	0.0169	<0.0001	0.3989	0.0420	<0.0001
P-value summary	NS	****	****	NS	****	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	Yes	Yes

Table 5.5 statistics of the year 2017 shows a significant correlation between varied variables such as; Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is -0.1138, v/s temperature is 0.2467, and v/s rainfall is 0.6101, however, the value of Kharif v/s humidity in the year 2017 is not significant as the value is below the standard value. The R^2 -value of Kharif v/s humidity is 0.01295, v/s temperature is 0.06085, and v/s rainfall is 0.3722. On the other hand, the *r-value* of Rabi v/s humidity is -0.08890, v/s temperature is 0.2112, and rainfall is 0.6405, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The R^2 -value of Rabi v/s humidity is 0.007903, v/s temperature is 0.04461, and rainfall is 0.4102. The *P-value* of Kharif v/s humidity is 0.2747, v/s temperature is 0.0149, and v/s rainfall is <0.0001 , meanwhile, of Rabi v/s humidity is 0.3942, v/s temperature is 0.0378, and v/s rainfall is <0.0001 . The *r-value* determines the *P-value*;

therefore, as the *r-value* of Kharif and Rabi v/s humidity is below the standard value, the *P-value* is also deemed as not-significant.

Table 5.5. Statistical value of correlation (*Pearson r*) of production and climate variables (2017)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1138	0.2467	0.6101	-0.08890	0.2112	0.6405
95% confidence interval	-0.3093 to 0.09089	0.04968 to 0.4252	0.4675 to 0.7217	-0.2864 to 0.1158	0.01227 to 0.3940	0.5057 to 0.7448
R squared	0.01295	0.06085	0.3722	0.007903	0.04461	0.4102
P value						
P (two-tailed)	0.2747	0.0149	<0.0001	0.3942	0.0378	<0.0001
P value summary	NS	****	****	NS	****	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	Yes	Yes

Table 5.6 Statistics of 2018 shows a significant correlation between varied variables such as; Kharif and Rabi, and climate variables. The *r-value* of Kharif v/s humidity is -0.1198, v/s temperature is 0.2452, and v/s rainfall is 0.4947, however, the value of Kharif v/s humidity in the year 2018 is not significant as the value is below the standard value. The *R²-value* of Kharif v/s humidity with 0.01435, v/s temperature with 0.06012, and v/s rainfall with 0.2447. On the other hand, the *r-value* of Rabi v/s humidity with -0.09197, v/s temperature is 0.2039, and rainfall is 0.5333, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.008459, v/s temperature is 0.04158, and rainfall is 0.2844. The *P-value* of Kharif v/s humidity is 0.2528, v/s temperature is 0.0160, and v/s rainfall is <0.0001, meanwhile, of Rabi v/s humidity is 0.3806, v/s temperature with 0.0463, and v/s rainfall is <0.0001. The *r-value* determines the *P-value*, therefore, as the *r-value* of Kharif and Rabi v/s humidity is below standard value hence the *P-value* is also deemed as not-significant.

Table 5.6. Statistical value of correlation (*Pearson r*) of production and climate variables (2018)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1198	0.2452	0.4947	-0.09197	0.2039	0.5333
95% confidence interval	-0.3158 to 0.08603	0.04702 to 0.4248	0.3266 to 0.6325	-0.2902 to 0.1139	0.003582 to 0.3885	0.3726 to 0.6629
R squared	0.01435	0.06012	0.2447	0.008459	0.04158	0.2844
P value						
P (two-tailed)	0.2528	0.0160	<0.0001	0.3806	0.0463	<0.0001
P value summary	NS	****	****	NS	****	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	Yes	Yes

Table 5.7 statistics of the year 2019 shows a significant correlation between varied variables such as; Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is -0.1210, v/s temperature is 0.2532, and v/s rainfall is 0.6509, however, the value of Kharif v/s humidity in the year 2019 is not significant as the value is below the standard value. The *R²-value* of Kharif v/s humidity was 0.01463, v/s temperature was 0.06410, and v/s rainfall was 0.4237. On the other hand, the *r-value* of Rabi v/s humidity with -0.09197, v/s temperature is 0.2102, and rainfall is 0.6853, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.008459, v/s temperature is 0.04418, and rainfall is 0.4697. The *P-value* of Kharif v/s humidity is 0.2481, v/s temperature is 0.0128, and v/s rainfall is <0.0001, meanwhile, of Rabi v/s humidity is 0.3806, v/s temperature with 0.0398, and v/s rainfall are <0.0001. The *r-value* determines the *P-value*, therefore, as the *r-value* of Kharif and Rabi v/s humidity is below the standard value, hence the *P-value* is also deemed as not-significant.

Table 5.7. Statistical value of correlation (*Pearson r*) of production and climate variables (2019)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1210	0.2532	0.6509	-0.09197	0.2102	0.6853
95% confidence interval	-0.3169 to 0.08483	0.05551 to 0.4317	0.5180 to 0.7531	-0.2902 to 0.1139	0.01014 to 0.3941	0.5620 to 0.7788
R squared	0.01463	0.06410	0.4237	0.008459	0.04418	0.4697
P value						
P (two-tailed)	0.2481	0.0128	<0.0001	0.3806	0.0398	<0.0001
P value summary	NS	****	****	NS	****	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	Yes	Yes

Table 5.8 statistics of the year 2020 show a significant correlation between varied variables, such as Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is -0.1097, v/s temperature is 0.2353, and v/s rainfall is 0.7063, however, the value of Kharif v/s humidity in the year 2020 is not significant as the value is below the standard value. The *R²-value* of Kharif v/s humidity was 0.01204, v/s temperature was 0.05539, and v/s rainfall was 0.4988. On the other hand, the *r-value* of Rabi v/s humidity is -0.03296, v/s temperature is 0.1204, and rainfall is 0.7797, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.001087, v/s temperature is 0.01450, and rainfall is 0.6079. The *P-value* of Kharif v/s humidity is 0.2951, v/s temperature is 0.0210, and v/s rainfall is <0.0001; meanwhile, of Rabi v/s humidity is 0.7538, v/s temperature with 0.2426, and v/s rainfall is <0.0001. The *r-value* determines the *P-value*, therefore, as the *r-value* of Kharif and Rabi v/s humidity is below the standard value, hence the *P-value* is also deemed as not-significant.

Table 5.8. Statistical value of correlation (*Pearson r*) of production and climate variables (2020)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1097	0.2353	0.7063	-0.03296	0.1204	0.7797
95% confidence interval	-0.3066 to 0.09614	0.03659 to 0.4162	0.5892 to 0.7943	-0.2351 to 0.1719	-0.08206 to 0.3133	0.6865 to 0.8477
R squared	0.01204	0.05539	0.4988	0.001087	0.01450	0.6079
P value						
P (two-tailed)	0.2951	0.0210	<0.0001	0.7538	0.2426	<0.0001
P value summary	NS	****	****	NS	NS	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	No	Yes

Table 5.9 statistics of the year 2021 shows a significant correlation between varied variables such as; Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is -0.1190, v/s temperature is 0.2377, and v/s rainfall is 0.3875, however, the value of Kharif v/s humidity in the year 2021 is not significant as the value is below the standard value. The *R²-value* of Kharif v/s humidity was 0.01416, v/s temperature was 0.05649, and v/s rainfall was 0.1502. On the other hand, the *r-value* of Rabi v/s humidity is -0.08870, v/s temperature is 0.1926, and rainfall is 0.4323, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.007868, v/s temperature is 0.03710, and rainfall is 0.1869. The *P-value* of Kharif v/s humidity is 0.2559, v/s temperature is 0.0197, and v/s rainfall is <0.0001, meanwhile, of Rabi v/s humidity is 0.3978, v/s temperature with 0.0601, and v/s rainfall are <0.0001. The *r-value* determines the *P-value*, therefore, as the *r-value* of Kharif and Rabi v/s humidity is below the standard value, hence the *P-value* is also deemed as not-significant.

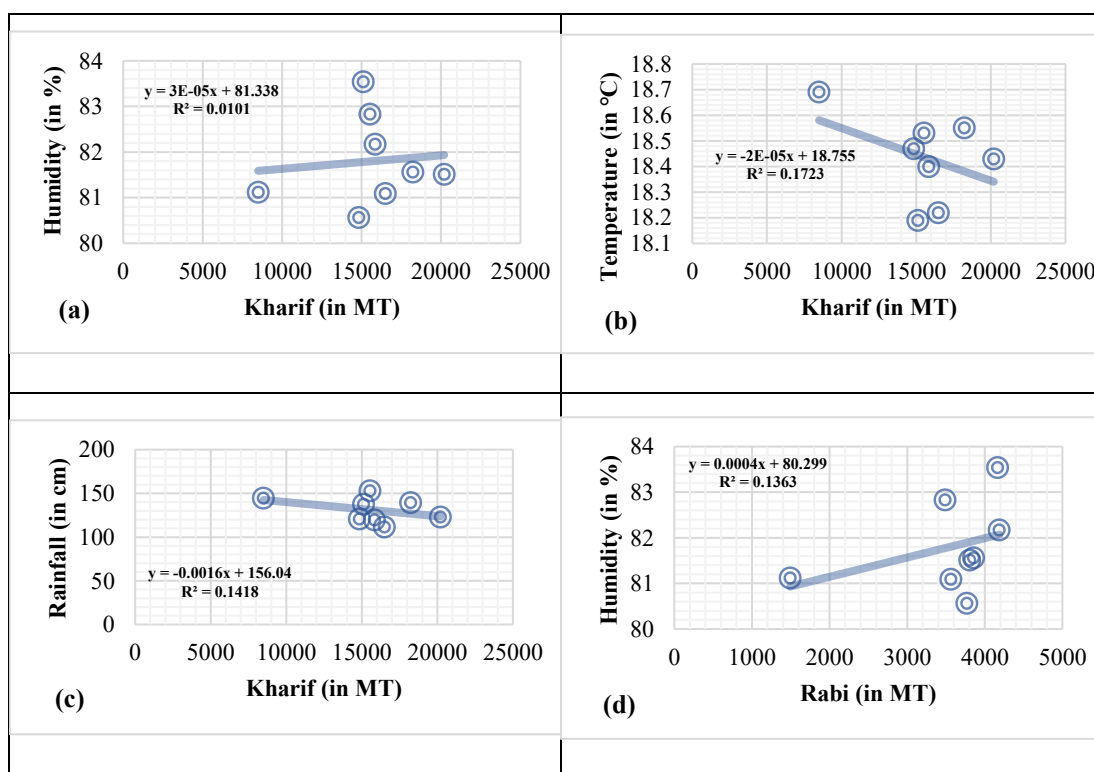
Table 5.9. Statistical value of correlation (*Pearson r*) of production and climate variables (2021)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1190	0.2377	0.3875	-0.08870	0.1926	0.4323
95% confidence interval	-0.3151 to 0.08680	0.03906 to 0.4182	0.2028 to 0.5456	-0.2872 to 0.1171	-0.008183 to 0.3785	0.2538 to 0.5823
R squared	0.01416	0.05649	0.1502	0.007868	0.03710	0.1869
P value						
P (two-tailed)	0.2559	0.0197	<0.0001	0.3978	0.0601	<0.0001
P value summary	NS	****	****	NS	NS	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	No	Yes

Table 5.10 statistics of the year 2022 shows a significant correlation between varied variables, such as Kharif and Rabi, with the climate variables. The *r-value* of Kharif v/s humidity is -0.1179, v/s temperature is 0.2467, and v/s rainfall is 0.7037, however, the value of Kharif v/s humidity in the year 2022 is not significant as the value is below the standard value. The *R²-value* of Kharif v/s humidity was 0.01391, v/s temperature was 0.06087, and v/s rainfall was 0.4952. On the other hand, the *r-value* of Rabi v/s humidity is -0.08796, v/s temperature is 0.2022, and rainfall is 0.7365, hence, the value of Rabi v/s humidity is not significant as the value is below the standard value. The *R²-value* of Rabi v/s humidity is 0.007737, v/s temperature is 0.04089, and rainfall is 0.5424. The *P-value* of Kharif v/s humidity is 0.2602, v/s temperature is 0.0154, and v/s rainfall is <0.0001, meanwhile, of Rabi v/s humidity is 0.4018, v/s temperature with 0.0482, and v/s rainfall is <0.0001. The *r-value* determines the *P-value*, therefore, as the *r-value* of Kharif and Rabi v/s humidity is below the standard value, hence the *P-value* is also deemed as not-significant.

Table 5.10. Statistical value of correlation (*Pearson r*) of production and climate variables (2022)

Correlation	Kharif			Rabi		
	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)	v/s Humidity (in %)	v/s Temperature (in °C)	v/s Rainfall (in cm)
Pearson r						
r	-0.1179	0.2467	0.7037	-0.08796	0.2022	0.7365
95% confidence interval	-0.3141 to 0.08788	0.04864 to 0.4261	0.5859 to 0.7924	-0.2865 to 0.1179	0.001811 to 0.3870	0.6289 to 0.8164
R squared	0.01391	0.06087	0.4952	0.007737	0.04089	0.5424
P value						
P (two-tailed)	0.2602	0.0154	<0.0001	0.4018	0.0482	<0.0001
P value summary	NS	****	****	NS	****	****
Significant? (alpha = 0.05)	No	Yes	Yes	No	Yes	Yes



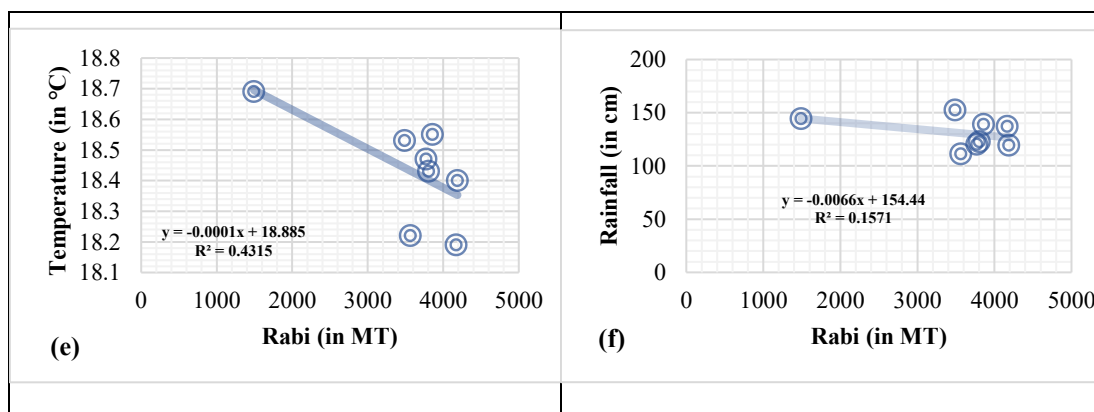


Fig. 5.1. Scatter plot of (a). Kharif v/s humidity; (b). Kharif v/s temperature; (c). Kharif v/s rainfall; (d). Rabi v/s humidity; (e). Rabi v/s temperature; (f). Rabi v/s rainfall (2014-2022)

5.5. Two-way ANOVA of production and climate variables

ANOVA, also known as *Analysis of Variance*, estimates the difference between the means of more than two groups. On the other hand, two-way ANOVA is used to calculate how the levels of two categorical variables affect the mean of a quantitative variable. To find out how two independent factors together impact a dependent variable, use a two-way ANOVA. A two-way analysis enables the researcher to determine whether there is an interaction between two independent factors and how they affect a dependent variable; therefore, applying this statistical technique is necessary for studying the correlation of different groups of independent and dependent variables. The standard value of ANOVA statistics, also known as the *F-statistic*, is normally a value that is close to 1, and if the value falls close to 1, it is considered a strong relation. On the other hand, the values that fall far from the value of 1 are considered less significant.

The study's two-way ANOVA result shows a positive and significant correlation between different variables, such as production and climate variables. As all the performed statistics result values are close to *F-value* 1, the standard *P-value* in ANOVA is $P < 0.5$; therefore, both the values of Kharif and Rabi are < 0.5 . The *P-value* of the Kharif is < 0.0001 , and the summary is significant, and the *P-value* of the Rabi is also < 0.0001 ; hence, the summary is significant. Moreover, the *F-statistics* of the Kharif is < 1 , i.e., 0.9511, and the *F-statistics* of Rabi is also < 1 , i.e., 0.9397. Therefore,

the study can be considered significant because the study result statistics are all under the standard value of significance (Table 5.11).

Table 5.11. Two-way ANOVA summary of Kharif and Rabi with climate variables ($\alpha=1$)

Kharif		Rabi	
F	207.6	F	166.2
P value	<0.0001	P value	<0.0001
P-value summary	****	P-value summary	****
Significant diff. among means ($P < 0.05$)?	Yes	Significant diff. among means ($P < 0.05$)?	Yes
F-statistic	0.9511	F-statistic	0.9397

Source: GraphPad Prism-8

5.6. Multiple regression correlation analysis

It is a type of inferential statistics that is used to estimate the significance and relationship between two or more variables. Correlation statistics are used to calculate the relationship between two variables, such as explanatory (independent) and response (dependent) variables. Whereas, multiple regression analysis is a statistical technique similar to correlation, but it is used to estimate the relationship between two or more variables, like variable v/s many variables. Multiple regression helps predict a single outcome based on multiple predictor variables, giving researchers a more thorough understanding of complex relationships. Multiple regression is used to analyze the relationship between one dependent variable and multiple independent variables, allowing them to understand how a combination of factors influences a particular outcome while controlling for the effects of other variables simultaneously. In a multiple regression analysis, a standard *P-value* is typically considered to be 0.05; meaning if the p-value for a coefficient is < 0.05 , it is considered statistically significant, indicating a meaningful correlation between the independent and the dependent variable. The *R-squared* and *P-value* in multiple regression can range from 0 to 1, where 1 indicates a perfect fit of the model to the data; also, a value between 0-1 is considered a statistically positive correlation between various explanatory and response variables.

Analysis of the present study results indicates a positive correlation between the production and climate variables. The variables of the multiple regression analysis are as follows: the *P-value* of Kharif is 0.878; similarly, between Kharif v/s humidity is 0.680; Kharif v/s temperature is 0.680; and Kharif v/s rainfall is 0.966. The overall *R-squared* value of the analysis is 0.189, meaning that the analysis is significant and that there is a strong relationship between the explanatory (climate variables) and response (production) variables (Table 5.12 & Fig. 5.2).

Table 5.12. Multiple regression analysis (R^2) of Kharif, humidity, temperature, and rainfall (2014-2022).

Variables	Coefficients	Standard Error	t-Stat	P-value	R Square
Kharif	84673.49461	520202.3749	0.162770296	0.878	0.189
Humidity (in %)	-1271.503318	2897.70904	-	0.438796063	
Temperature (in°C)	1956.375159	17902.81257	0.109277531	0.918	
Rainfall (in cm)	-9.18158203	202.5266701	0.045335175	0.966	

Source: IBM SPSS

The analysis of the Rabi production and climate variables also reveals a positive correlation. The results of the analysis are as follows: the *P-value* of Rabi is 0.909; Rabi v/s humidity is 0.975; Rabi v/s temperature is 0.806; and Rabi v/s rainfall is 0.569. The overall *R-squared* value of the analysis is 0.226, meaning that the analysis is significant and that there is a strong relationship between the explanatory (climate variables) and response (production) variables (Table 5.13 & Fig. 5.2).

Table 5.13. Multiple regression analysis (R^2) of Rabi, humidity, temperature, and rainfall (2014-2022).

Variables	Coefficients	Standard Error	t-Stat	P-value	R Square
Rabi	-	15555.32053	128867.2445	-0.120708102	0.226
Humidity (in %)	24.3474162	717.8355911	0.033917817	0.909	
Temperature (in°C)	1149.905608	4434.978068	0.259281014	0.975	
Rainfall (in cm)	-	30.58876569	50.17096262	0.259281014	

Source: IBM SPSS

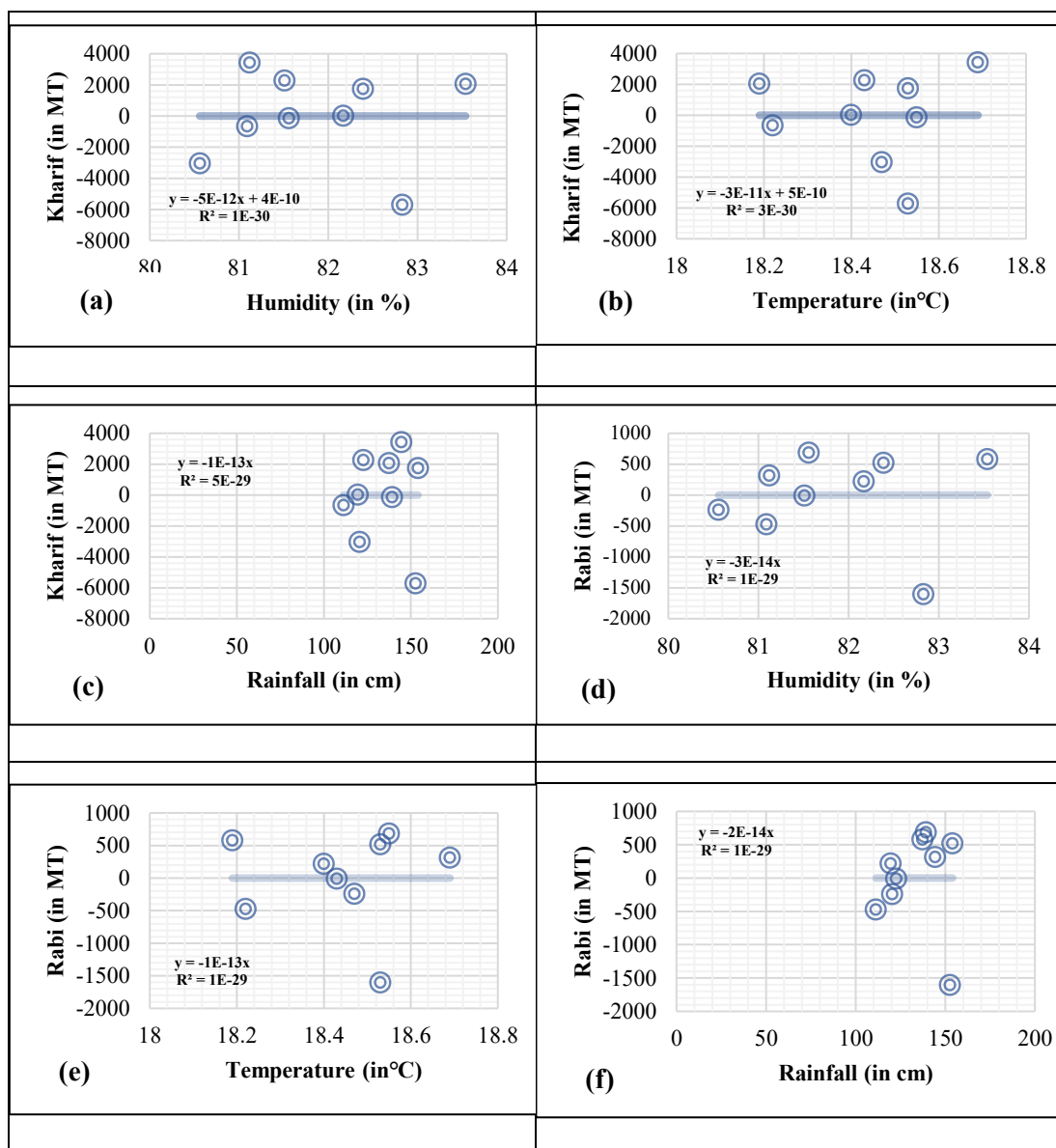


Fig. 5.2. Residual plot of Kharif, Rabi, and climate variables (2014-2022)

(a) Residual plot of Kharif v/s humidity; (b). Residual plot of Kharif v/s temperature; (c). Residual plot of Kharif v/s rainfall; (d). Residual plot of Rabi v/s humidity; (e). Residual plot of Rabi v/s temperature; (f). Residual plot of Rabi v/s rainfall

5.7. Effect of elevation on crop production

Different elevations characterize the district, and various crops are tolerant of dynamic altitudes. Certain crops tend to survive in high-altitude regions; on the other hand, some particular crops cannot sustain themselves in altitudinal zones. Various crops respond to changing elevation as some crops may produce high production and yield, and some may have lesser production and yield. The region is distinct

concerning elevation, it starts from 300 m up to 4000 m, whereas the elevation in the study villages greatly varies.

Fig. 5.3 illustrates the predominant crops in different elevations based on their maximum productivity. Tomatoes' maximum productivity can be witnessed up to 1600 m. However, tomatoes are fragile and susceptible to cold and frost, so it is difficult to grow them in high-altitude regions. Chilies and potatoes are the two highly resilient crops to even harsh weather conditions. They can survive up to an elevation of 2000 m, and their yielding ability is also high in those conditions. On the other hand, cereals can be grown up to an elevation of 1700 m; followed by green beans up to an elevation of 1500 m, and cabbage up to an elevation of 1800 m, because it is cruciferous crops that are highly vulnerable to harsh weather conditions like cold and frost.

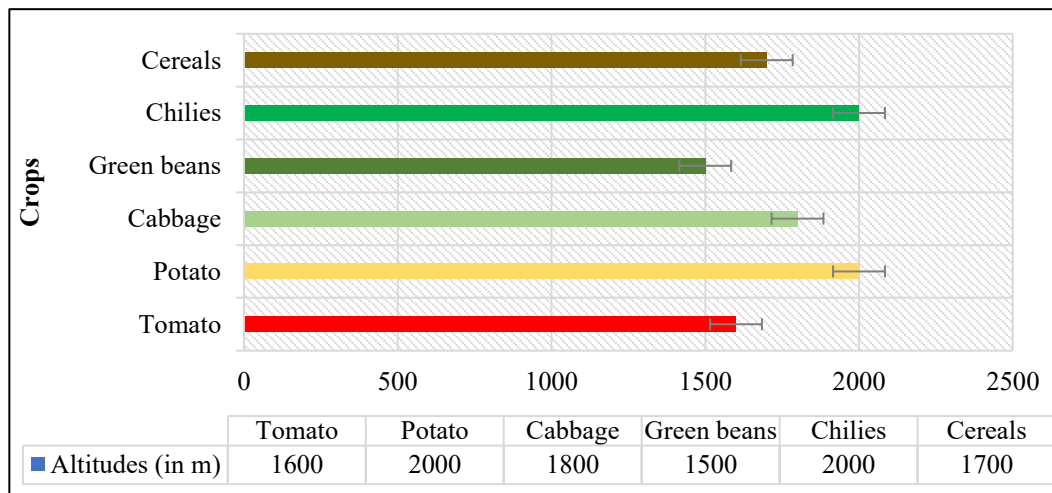


Fig. 5.3. Predominant of principal cash crops in different elevations

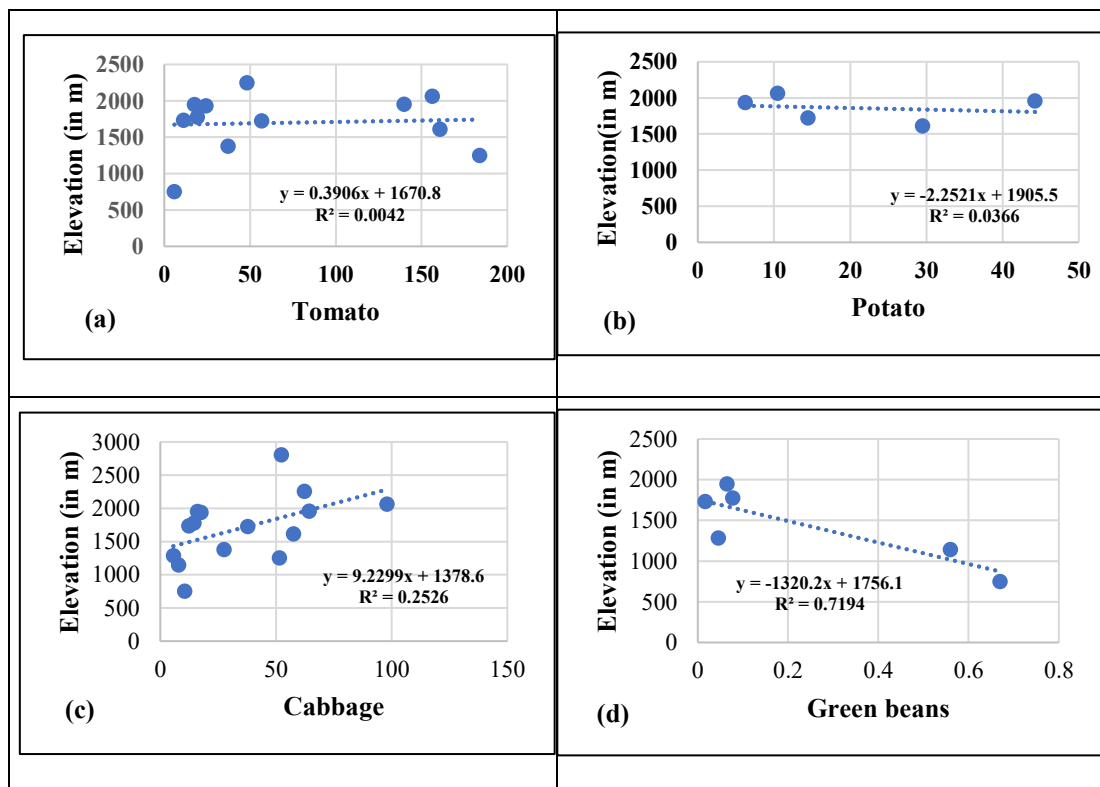
Moreover, for a clear and better understanding of the effects of elevation in commercial farming, a *multiple regression correlation* (R^2) analysis was implemented to comprehend the significance and relationship between elevation and crops. The result shows a positive outcome and significance between crops and elevation; all the crops show an increasing trendline with the rising altitude, however, crops like potato and green beans show a significantly decreasing trendline with increasing altitudes. The P-values of different crops are as follows: tomato (0.098), potato (0.501), cabbage (0.744), green beans (0.221), chilies (0.661), and cereals (0.664). All the values are well within the alpha range, i.e., between 0-1, which proves that the independent

variable (elevation) greatly affects the production and yield of the dependent variables (crops). (Table 5.14 & Fig. 5.4) show the elevation's regression statistics and scatter plot with different commercial crops.

Table 5.14. Multiple regression (R^2) of the elevation and the crops

Variables	Unstandardized Coefficients		Standardized Coefficients	t	P-value
	B	Std. Error	Beta		
Elevation	1709.959	265.422	--	6.442	0.098
Tomato	-5.353	5.362	-1.820	-0.998	0.501
Potato	4.765	11.212	0.405	0.425	0.744
Cabbage	11.350	9.437	1.853	1.203	0.442
Green beans	-725.541	412.960	-0.466	-1.757	0.221
Chilies	20.163	39.624	0.295	0.509	0.661
Cereals	20.219	40.127	0.303	0.504	0.664

*Alpha=0-1



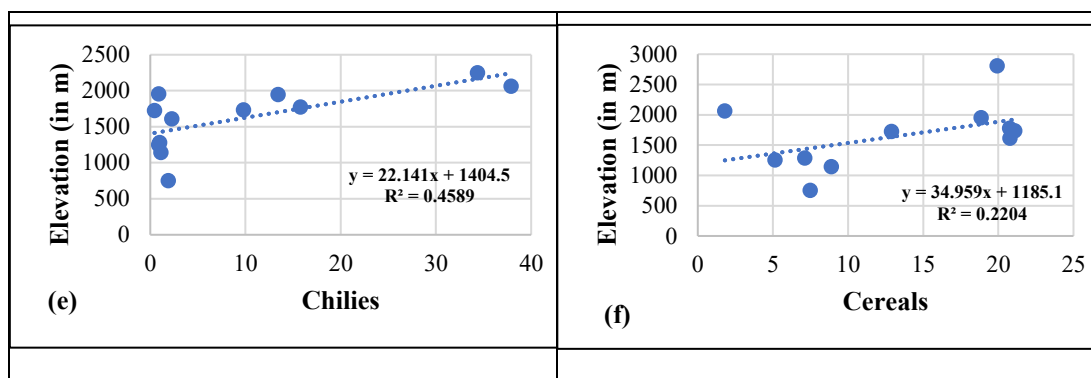


Fig. 5.4. Multiple regression (a) tomato, (b) potato, (c) cabbage, (d) green beans, (e) chilies, (f) cereals

5.8. Discussion

The climate is pivotal in determining crop production and yield capacity. Certain crop responds to different underlying climatic settings of an area; a favorable environment may result in a fruitful yield and output, and unfavorable conditions may lead to less production and productivity. Climate change not only has negative implications, but it also has certain short-term positive impacts on farming patterns. Such an increase in temperature, humidity, and rainfall tends to increase the productivity of certain selected crops. Also, a rise in carbon concentration in the atmosphere increases the yield capacity of crops like potatoes, tomatoes, wheat, barley, rice, and other vegetables. Some crops require high rainfall or water requirements, like green beans, cucumbers, and peas, therefore, an increase in rainfall may intensify the production. Moreover, some crops tend to have high productivity under high humidity conditions, especially leafy greens like lettuce, cabbage, broccoli, and mustard leaves. This means climate change in a region like firm changes in the amount of rainfall, temperature, and humidity may lead to intensification of yield and production of certain crops. Several studies have been conducted on the implications of climate change on production and yield, such as increasing temperature in highland areas is generally believed to potentially enhance crop productivity where cooler temperatures currently constrain plant productivity (Thornton et al., 2015). A study conducted by Aydinalp & Cresser (2008) suggests that variations in soil moisture may lead to an increase in insect infestation, however, an increase in carbon levels and carbon fertilization can intensify agricultural production. An increase in CO² levels may have

some positive impact on certain crops, increasing their growth and transpiration rate; crops and plants may be able to perform better photosynthesis under high carbon levels.

Climate change has dimensional implications, it does not only have a positive impact on crops, it also has negative effects like changes in agricultural production resulting from the combination of changes in yields and changes in crop acreage, also, variations in crop yields are the result of climate changes (Adamset al., 1998). Improving crop production to mitigate rising demands due to the population increase, against the background of the threats of climate change, is challenging. Whereas crop production is vulnerable to climate variability, associated with temperature and CO² increases, and changing patterns of rainfall may lead to a considerable decline in crop production and yield. Moreover, extreme weather events like droughts, heat waves, and heavy and scarce rainfall may ultimately affect crop production and yield (Mall et al., 2017). Variations in temperature, precipitation, and greenhouse gases, significantly hampered pest infestation, soil fertility, and irrigation resources, moreover, there are uncertainties regarding the future climate scenario and its probable implications on farming systems, numerous studies report that climate change will decrease agricultural productivity in the coming years (Malhi et al., 2021). The change in climate elements mainly, temperature, humidity, and rainfall has largely contributed to the initiation of crops that were only grown in warm and humid areas, so far, those crops are now cultivated and have a more successful production rate than any traditional crops in high altitudinal regions (Thongdok & Sati, 2024). Numerous studies have been conducted on various implications of climate variability and crop production across the globe (Shakoor et al., 2011; Mendelsohn, 2014; Chen et al., 2016; Arora, 2019; Yuan et al., 2024; Thongdok et al., 2024).

The underlying climatic condition of the West Kameng district has been significantly fluctuating and has affected various agricultural activities. Firm variations like an increase in temperature, rainfall, and humidity have changed the farming scenario of the region; farmers have abandoned the cultivation of traditional crops, due to lesser productivity and yield due to changes in the climate setting, and

contemporary farmers have adopted newly introduced GM seeds, such seeds, and crops are highly resistant to climate change and harsh weather conditions, and they are having the ability to produce higher productivity and yield than compared to traditional crops that are having the lesser ability to produce higher production and yield. Whereas, to understand the implication of climate on crop production and yield a *multiple regression correlation*, *two-way ANOVA*, and *Pearson correlation (r)* were performed and the statistics show a strong correlation and relationship between the climate and production variables. Production was categorized into seasonal nature, as Kharif and Rabi, and both the productions performed correlational analysis and the study revealed a strong effect of climate on crop productions. The analysis of *Pearson correlation (r)* found that the *P-value* of climate and production variables is <0.05 which means that if the values of exploratory (independent) and response (dependent) variables are <0.05 suggests a strong correlation among the variables. The results of *ANOVA* reveal that the *F-values* are under 0-1, which means that the analysis suggests a strong relationship between the independent (climate), and dependent (production) variables. Moreover, *multiple regression correlation* analysis results also depict a strong and significant correlation between the variables as all the analyzed values are below standard *P and R-values* are <1 , which means that the results reveal the strong impact of climate on crop production.

5.9. Conclusions

Climate change is imminent and it is bound to occur, in the meantime, it should not be instigated to vary at a faster rate. Several consequences of climate change can be witnessed it is undeniable that agriculture is the most affected entity. Climate determines the types, production, and yielding capacity of the various crops. It has dimensional implications such as climate change does have short-term positive impacts on agricultural production; some crops like potatoes, green beans, carrots, and peas tend to produce more outputs in higher CO₂ levels; and the introduction of new crops that require high temperature, humidity, and rainfall. On the other hand, certain crops especially cruciferous crops like tomatoes, cabbage, mustard leaves, capsicum, and other leafy vegetables, are adversely affected by climate change like extreme weather phenomena, droughts, and torrential rainfall. In contemporary farming

systems, several GM (genetically modified) crops are highly resistant to harsh climatic conditions, and varying agro-climatic zones. Climate change will occur and we have to cope with that change. Therefore, it is important to train and aware farmers of modern farming techniques and practices that involve climate-resilient farming techniques and how to grow climate-resilient crops in the region.

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CHAPTER 6

SOCIO-ECONOMIC STATUS OF THE FARMING COMMUNITIES

6.1. Introduction

Socioeconomic status is a concept that denotes an individual's or family's social and economic standing. Socioeconomic status encompasses a range of factors that define an individual or group's social and financial situation, such as income, education, occupation, housing, and sometimes family structure, age, and location. These attributes gauge one's societal position based on economic resources and social status. In other words, socioeconomic status is a combined measure of a person's or family's financial resources and social position relative to others. It considers factors like work experience, income, education, and occupation. When assessing a family's socioeconomic status, factors like household income and the education and occupations of its members are examined.

One of the most crucial variables in social science studies and research is socio-economic status, which influences a sample's psychological and behavioral characteristics, including knowledge, attitude, perception, adoption, innovativeness, aspiration level, economic motivation, etc. Socio-economic status plays an important role in significantly influencing one's access to basic resources, way of life, and other factors including food availability and nutritional status, etc. (Smith, 2005; American Psychological Association, 2007; Budry & Curtis, 2007; Raza et al., 2015; Surabhi & Mamta, 2016; Pratima & Poonam, 2019).

Socioeconomic status measures a family's position concerning others on both an economic and social level and economic and social development (Gaur, 2013). Daniel et al., 2022). According to F. Stuart Chapin, socioeconomic status assesses an individual's or family's position within society and their access to financial, cultural, social, and human resources. Socioeconomic standing refers to a family's relative position based on wealth, economic circumstances, social status, education level, occupation, and social engagement (Tiwari et al., 2005). It is defined as a measure of one's combined economic and social status; in sociological terms, socioeconomic

status is viewed as a latent construct and is measured using a composite measure of education, income, and occupation. One important aspect of socioeconomic status is income; it is linked to socioeconomic status and health through structural factors. Typically defined as pre-tax earnings from employment, income is often measured at the household or family level, encompassing the combined earnings of all members ((House 2002; Galobardes et al. 2006).

Socioeconomic status influences the accessibility to resources, and livelihood patterns (Roy et al., 2013). Sociologists and economists have investigated social inequality and societal perceptions of socioeconomic status for many years, but their methods for measuring socioeconomic status have varied concerning farmers; whereas, the assessment of the socioeconomic conditions of the farmers cannot be undermined because the socioeconomic status of farmers is an important variable in agricultural social sciences studies (Chandra et al., 2023). Farming is the economic backbone of farming communities, and farmers adopt improved farming practices only for financial gain depending upon the farmer's age, education, size of holding socioeconomic status, and progressiveness because a progressive outlook motivates the farmers to adopt new ideas or agricultural technology for economic gains.

The socioeconomic status of hill farmers is a critical area of study due to the complex, diverse, and risky nature of their livelihoods. These farmers often rely on traditional agricultural practices that require minimal input, making it difficult for them to secure their families' well-being through agriculture alone. The socioeconomic status of hill farmers is a crucial area of research given the intricate, varied, and hazardous conditions of their livelihoods. These farmers frequently employ traditional agricultural methods that demand minimal input, making it challenging for them to ensure their families' well-being solely through agriculture (Raghav & Sen, 2014). Therefore, it is essential to understand the socioeconomic status of the farmers, their societal and economic position, and their stability concerning agricultural practices.

Socioeconomic characteristics and status vary across different farming communities. It is an important measure in understanding the farmer's social standing and economic viability in society. Understanding their occupation, education, and

demographic dynamics is a prominent aspect of study in the economic characteristics of the farming community.

Moreover, the present study aims to understand the socioeconomic status of the farmers and the impact of commercial crops on the upliftment of their social status. The study deals with the change in farming patterns and their impact on the economic stability and viability of the farmers of West Kameng district, Arunachal Pradesh. The study also exerts effort on whether the social dynamics affect the social status of the farmers.

6.2. Methods

6.2.1. Data collection

The study encompasses a wide range of data sources. Both primary and secondary sources have been broadly applied. Primary sources on demographic characteristics were acquired through a field survey. Moreover, primary data on agriculture production and productivity for the year 2022 were also obtained from respective fields. In this study, the purposive sampling technique was employed, where only farmers and contractors were surveyed and questions were asked on farming systems, production, productivity, demand and supply, and average prices of the different crops. The interviewing was carried out with the help of schedules and both open and closed questionnaires. Fifteen villages were surveyed from five CD blocks (three villages from a block). Altogether, 423 households were surveyed with a sample size of 35 % of the total HHs present in a village.

Secondary sources of data, such as agriculture production from 2014 to 2021, were obtained from the records of the Office of the District Agriculture Office, Bomdila, West Kameng district, and partial demographic records from the data records of Accredited Social Health Activists (ASHA). Furthermore, an extensive literature review was conducted from published and unpublished books and articles.

6.2.2. Data analysis

Various statistical techniques and measures were applied to this study. Likewise, descriptive statistics were used to summarize and present complex data in a

way that is easier to understand, such as the mean value of crop production. The statistics were formulated using SPSS software.

Mean,

$$\bar{x} = \sum x/n$$

Moreover, to examine the revenue generated from the commercial crops of the farmers, simple per-capita formulas were used;

Per-capita production;

$$\text{Per capita production} = \text{Total Production} / \text{Population}$$

Per-capita income;

$$PCI = \text{Total Income} / \text{Population}$$

6.3. Socioeconomic status

6.3.1. Educational attainment

The total number of HHs surveyed was 423, of which 84 farmers had no minimum primary education or were illiterate; 161 had basic primary education; 124 had secondary education; 48 had higher education, and only 4 had a UG qualification. Similarly, in percentage, 19.85 % were illiterate, 38.06 % had primary education, 29.32 % had secondary education, 11.35 % had higher education, and only 0.95 % had graduated (Table 6.1 & Fig. 6.1).

Table 6.1. The educational level (n=15 villages)

Level of education	Number	%
Illiterate	84	19.85
Primary	161	38.06
Secondary	124	29.32
Higher	48	11.35
Graduate	4	0.95
Total	423	100

Source: Primary field survey 2023

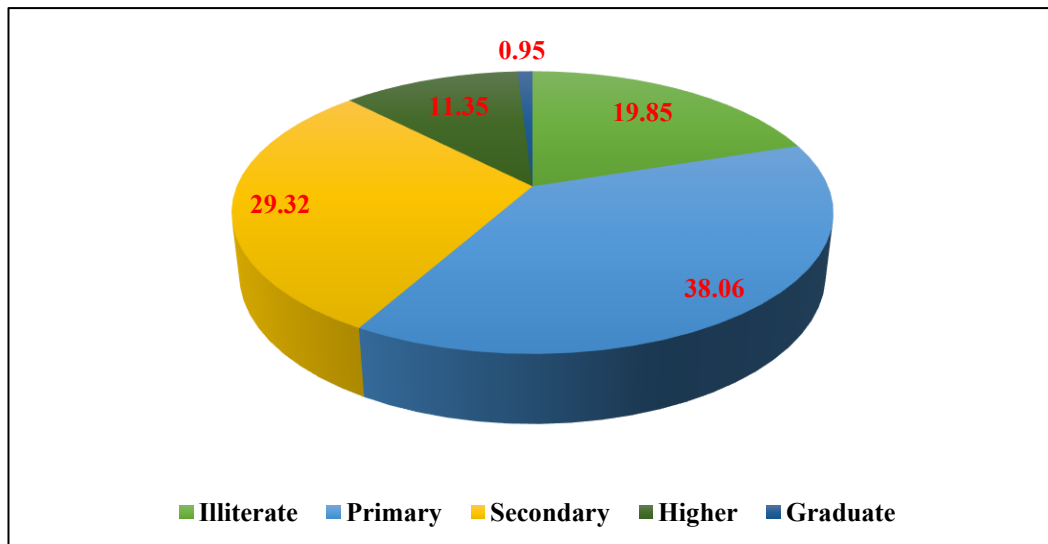


Fig. 6.1. Pie chart showing the level of education

6.3.2. Occupational structure

The study found that the occupational patterns of the villagers vary with changing seasons. During the summer and monsoon seasons, they are mainly engaged in agricultural activities, and during the dry and winter seasons, they shift their occupation to daily wages and small businesses. Both occupations are complex yet critical in terms of their livelihood and earnings. During the winter season, the temperature of the region goes below zero, which makes it difficult to grow any type of crops, and because of that, people have to shift their occupations to other non-agricultural activities. The study shows that 58.63 % of the Male population and 41.37 % of the Female population are engaged in agricultural activities, with the Male population accounting for the highest percentage of Females. During the off-farming season, 41.68 % are engaged in daily wage activities, 31.45 % are engaged in business activities, and 23.87 % are engaged in GREF works. Hence, Table 6.2 represents the occupational structure of the farmers.

Table 6.2. Seasonal occupational structure

Village	April-Oct		Oct-March		
	Agriculture practice		Non-agricultural practices		
	Male	Female	Daily wage	Businesses	GRF works
Morshing	9	4	8	3	2
Kamallangchin	14	5	10	5	4
Shergaon	27	11	4	33	1
Ramallingam	5	2	3	1	3
Tsering Pam	5	6	6	3	2
Mago Pam	7	7	6	4	4
Salari	35	18	21	10	22
Sangti	53	21	35	25	14
Senge	30	26	30	10	16
Jerigaon	20	21	20	12	9
Kirafarm	5	7	7	2	3
Khoina	7	6	7	3	3
Karangania	5	6	5	3	3
Sakrin	9	12	11	6	4
Palizi	17	23	16	13	11
$\sum x =$	248	175	189	133	101
% =	58.63	41.37	44.68	31.45	23.87

Source: Primary field survey 2023

Fig. 6.2 shows the percentage of males and females engaged in the agricultural practices, whereas males encompass 41.37 %, and females with 58.63 %. Therefore, the figures clearly show that females are more dominant than the male population concerning agricultural practices.

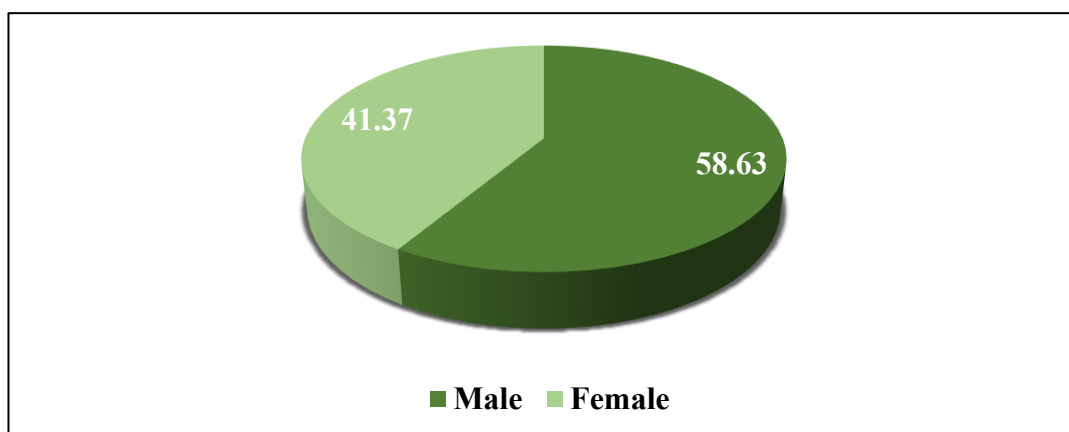


Fig. 6.2. Percentage of males and females involved in agriculture practices

Similarly, Fig. 6.3 depicts the percentage of the population involved in non-agricultural practices during the off-farming season. The daily wage accounts for 44.68 %, businesses with 31.45 %, and GREF workers with 23.87 %, respectively.

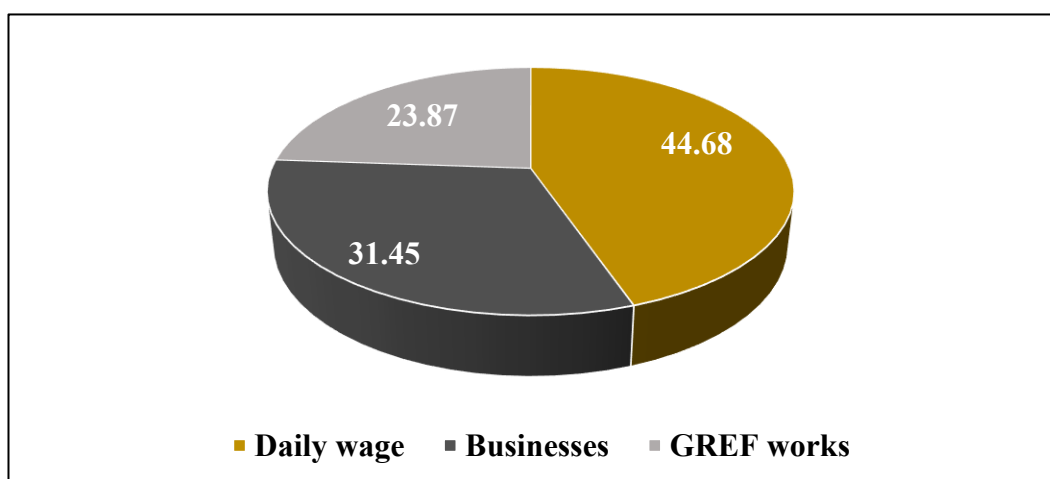


Fig. 6.3. Percentage of people involved in non-agriculture practices

6.4. Crop area, production, and productivity of principal crops

The study found that approximately 70 % of the district's population is engaged in agricultural practices. This is an agrarian society where farming and its allied activities are the primary occupations. Varied crops are grown, including subsistence (conventional) and commercial (non-conventional). Distinct crops are grown in different seasons; kharif crops are followed by paddy, maize, millet, cabbage, tomato, other vegetables, ginger, chilies, and garlic. Rabi crops like wheat, barley, mustard, potato, and green peas.

The crop production can be categorized into two growing seasons; therefore, the table 6.3 shows that kharif crops like paddy with a production of 1198.16 MT, and a productivity of 1.36 MT/ha against a total area of 881 Ha, maize with 4781.1 MT, and a productivity of 1.7 MT/ha against a total area of 2813 Ha, millet with 1015.2 MT, and a productivity of 0.94 MT/ha against a total area of 1080 Ha, cabbage with 2570.4 MT, and a productivity of 13.6 MT/ha against a total area of 189 Ha, tomato with 2835.85 MT, and a productivity of 13.19 MT/ha against a total area of 215 Ha, other vegetables with 1385.85 MT, and a productivity of 13.12 MT/ha against a total area of 106.5 Ha, ginger with 182 MT, and a productivity of 3.9 MT/ha against a total

area of 50 Ha, chilies with 226 MT, and a productivity of 3.9 MT/ha against a total area of 58 Ha, and garlic with 40 MT, and a productivity of 2.5 MT/ha against a total area of 16 Ha. Similarly, Rabi crops like wheat with 210 MT, and a productivity of 0.93 MT/ha against a total area of 226 Ha, barley with 69 MT, and a productivity of 0.75 MT/ha against an area of 92 Ha, mustard with 30.69 MT, and a productivity of 0.93 against an area of 33 Ha, potato with 3299.4 MT, and a productivity of 8.46 MT/ha against a total area of 390 Ha, and green peas with 112.1 MT, and a productivity of 1.9 MT/ha against a total area of 59 Ha in the year 2014.

Table 6.3. Crop area, production, and productivity (2014)

Season	Crops	Area (in Ha)	Production (in MT)	Productivity (MT/ha)
Kharif	Paddy	881	1198.16	1.36
	Maize	2813	4782.1	1.7
	Millet	1080	1015.2	0.94
	Cabbage	189	2570.4	13.6
	Tomato	215	2835.85	13.19
	Other vegetables	106.5	1385.85	13.12
	Ginger	50	182	3.64
	Chillies	58	226.2	3.9
	Garlic	16	40	2.5
Rabi		5408.5	14235.8	53.95
	Wheat	226	210.18	0.93
	Barley	92	69	0.75
	Mustard	33	30.69	0.93
	Potato	390	3299.4	8.46
	Green peas	59	112.1	1.9
		800	3721.37	12.97

Source: Office of the District Agriculture Office, Bomdila

Table 6.4 shows that kharif crops like paddy had a production of 1199.52 MT, and a productivity of 1.36 MT/ha against a total area of 882 Ha, maize with 4785.5 MT, and a productivity of 1.7 MT/ha against a total area of 2815 Ha, millet with 1016.14 MT, and productivity of 0.94 MT/ha against a total area of 1081 Ha, cabbage with 2584 MT, and productivity of 13.6 MT/ha against a total area of 190 Ha, tomato with 2901.8 MT, and a productivity of 13.19 MT/ha against a total area of 220 Ha, other vegetables with 1886.48 MT, and a productivity of 17.63 MT/ha against a total

area of 107 Ha, ginger with 189.28 MT, and a productivity of 3.64 MT/ha against a total area of 52 Ha, chillies with 230.1 MT, and a productivity of 3.9 MT/ha against a total area of 60 Ha, garlic with 41.25 MT, and productivity of 2.5 MT/ha against a total area of 16.5 Ha. Similarly, rabi crops like wheat with 211.11 MT, and a productivity of 0.93 MT/ha against a total area of 227 Ha, barley with 69.75 MT, and a productivity of 0.75 MT/ha against an area of 93 Ha, mustard with 31.62 MT, and a productivity of 0.93 against an area of 34 Ha, potato with 3326.32 MT, and a productivity of 8.46 MT/ha against a total area of 392 Ha, green peas with 144 MT, and a productivity of 2.4 MT/ha against a total area of 60 Ha.

Table 6.4. Crop area, production, and productivity (2015)

Season	Crops	Area (in Ha)	Production (in MT)	Productivity (MT/ha)
Kharif	Paddy	882	1199.52	1.36
	Maize	2815	4785.5	1.7
	Millet	1081	1016.14	0.94
	Cabbage	190	2584	13.6
	Tomato	220	2901.8	13.19
	Other vegetables	107	1886.48	17.63
	Ginger	52	189.28	3.64
	Chillies	59	230.1	3.9
	Garlic	16.5	41.25	2.5
		5422.5	14834.1	58.46
Rabi	Wheat	227	211.11	0.93
	Barley	93	69.75	0.75
	Mustard	34	31.62	0.93
	Potato	392	3316.32	8.46
	Green peas	60	144	2.4
		806	3772.8	13.47

Source: Office of the District Agriculture Office, Bomdila

Table 6.5 depicts the crop production based on different cropping seasons, kharif crops like paddy had an output of 1199.52 MT, and a productivity of 1.36 MT/ha against a total area of 882 Ha, maize with 4785.5 MT, and a productivity of 1.7 MT/ha against a total area of 2815 Ha, millet with 1016.14 MT, and productivity of 0.94 MT/ha against a total area of 1081 Ha, cabbage with 2584 MT, and productivity of

13.6 MT/ha against a total area of 190 Ha, tomato with 2901.8 MT, and a productivity of 13.19 MT/ha against a total area of 220 Ha, other vegetables with 1395.28 MT, and a productivity of 13.4 MT/ha against a total area of 107 Ha, ginger with 189.28 MT, and a productivity of 3.64 MT/ha against a total area of 52 Ha, chilies with 230.1 MT, and a productivity of 3.9 MT/ha against a total area of 59 Ha, and garlic with 40 MT, and productivity of 2.5 MT/ha against a total area of 16 Ha. Similarly, rabi crops like wheat with 210.18 MT, and a productivity of 0.93 MT/ha against a total area of 226 Ha, barley with 69 MT, and a productivity of 0.75 MT/ha against an area of 92 Ha, mustard with 31.62 MT, and a productivity of 0.93 against an area of 34 Ha, potato with 3299.4 MT, and a productivity of 8.46 MT/ha against a total area of 390 Ha, green peas with 144 MT, and a productivity of 2.4 MT/ha against a total area of 60 Ha.

Table 6.5. Crop area, production, and productivity (2016)

Season	Crops	Area (in Ha)	Production (in MT)	Productivity (MT/ha)
Kharif	Paddy	882	1199.52	1.36
	Maize	2815	4785.5	1.7
	Millet	1081	1016.1	0.94
	Cabbage	200	2800	14
	Tomato	223	3100	13.9
	Other vegetables	107	1395.28	13.4
	Ginger	52	189.28	3.64
	Chilies	62	245	3.10
	Garlic	16	40	2.5
		5438	14770.7	54.54
Rabi	Wheat	226	210.18	0.93
	Barley	92	69	0.75
	Mustard	34	31.62	0.93
	Potato	390	3299.4	8.46
	Green peas	63	152	2.42
		805	3762.2	13.49

Source: Office of the District Agriculture Office, Bomdila

Table 6.6 depicts the crop production based on different cropping seasons, kharif crops like paddy had a production of 1200 MT, and a productivity of 1.35 MT/ha against a total area of 883 Ha, maize with 4789 MT, and a productivity of 1.72 MT/ha against a total area of 2814 Ha, millet with 1082 MT, and productivity of 0.94 MT/ha

against a total area of 1082 Ha, cabbage with 2597 MT, and productivity of 13.59 MT/ha against a total area of 191 Ha, tomato with 3000 MT, and a productivity of 13.33 MT/ha against a total area of 225 Ha, other vegetables with 1408.32 MT, and a productivity of 13.4 MT/ha against a total area of 108 Ha, ginger with 190 MT, and a productivity of 3.45 MT/ha against a total area of 55 Ha, chillies with 231 MT, and a Productivity of 3.85 MT/ha against a total area of 60 Ha, and garlic with 42.5 MT, and Productivity of 1.36 MT/ha against a total area of 41 Ha. Similarly, rabi crops like wheat with 211.11 MT, and a productivity of 0.93 MT/ha against a total area of 227 Ha, barley with 69.75 MT, and a productivity of 0.75 MT/ha against an area of 93 Ha, mustard with 32 MT, and a productivity of 0.91 against an area of 35 Ha, potato with 3316.3 MT, and a productivity of 8.45 MT/ha against a total area of 392 Ha, green peas with 144 MT, and a productivity of 2.4 MT/ha against a total area of 60 Ha.

Table 6.6. Crop area, production, and productivity (2017)

Season	Crops	Area (in Ha)	Production (in MT)	Productivity (MT/ha)
Kharif	Paddy	883	1200	1.35
	Maize	2814	4789	1.72
	Millet	1082	1017	0.94
	Cabbage	225	2995	13.32
	Tomato	225	3000	13.33
	Other vegetables	108	1408.32	13.4
	Ginger	55	190	3.45
	Chillies	65	251	3.87
	Garlic	41	42.5	1.36
		5498	14892.8	52.74
Rabi	Wheat	227	211.11	0.93
	Barley	93	69.75	0.75
	Mustard	35	32	0.91
	Potato	395	3416	8.65
	Green peas	67	160	2.39
		817	3888.86	13.63

Source: Office of the District Agriculture Office, Bomdila

Table 6.7 depicts the crop production based on different cropping seasons, kharif crops like paddy had a production of 975 MT, and a productivity of 1.18 MT/ha against a total area of 820 Ha, maize with 3020 MT, and a productivity of 1.34 MT/ha

against a total area of 2245 Ha, millet with 560 MT, and productivity of 0.71 MT/ha against a total area of 780 Ha, cabbage with 3500 MT, and productivity of 16.67 MT/ha against a total area of 210 Ha, and tomato with 4100 MT, and a productivity of 13.66 MT/ha against a total area of 300 Ha, and other vegetables with 1134.65 MT, a productivity of 11.34 MT/ha against a total area of 100 Ha. Similarly, rabi crops like wheat with 187.89 MT, and a productivity of 0.94 MT/ha against a total area of 200 Ha, potato with 3879 MT, and a productivity of 15.29 MT/ha against a total area of 390 Ha, and green peas with 134 MT, and a productivity of 2.35 MT/ha against a total area of 57 Ha.

Table 6.7. Crop area, production, and productivity (2018)

Season	Crops	Area (in Ha)	Production (in MT)	Productivity (MT/ha)
Kharif	Paddy	820	975	1.18
	Maize	2245	3020	1.34
	Millet	780	560	0.71
	Cabbage	210	3500	16.67
	Tomato	300	4100	13.66
	Other vegetables	100	1134.65	11.34
		4455	13289.7	44.9
Rabi	Wheat	200	187.89	0.94
	Potato	398	3879	15.29
	Green peas	70	178	2.55
		668	4244.89	18.78

Source: Office of the District Agriculture Office, Bomdila

Table 6.8 shows the comparison statistics of the area, production, and productivity of the year 2019 and 2022. The kharif crop like tomato had a production of 37254.5 MT in 2019, and 8200 in 2022, productivity of 18.61 MT/ha in 2019, and 19.53 MT/ha in 2022, with an area of 390 ha in 2019, and 420 ha in 2022, therefore, the data show an increasing trend of tomato. Similarly, cabbage has a production of 3890 MT in 2019, and 4330 MT in 2022, productivity of 16.91 MT/ha in 2019, and 17.32 MT/ha in 2022, with an area of 230 ha in 2019, and 250 ha in 2022, the data also shows an increasing trend of cabbage. Cauliflower is a newly introduced crop and had a total output of 1113 MT, productivity of 42.80 MT/ha, with a total area of 26 ha in

2022. Likewise, Capsicum is also a newly introduced crop with a total output of 1320 MT, productivity of 55 MT/ha, with an area of 24 ha in 2022. Also, chillies with an output of 1280 MT, productivity of 15.43 MT/ha, with a total area of 83 ha in 2022. Maize had a total production of 2780 MT, a productivity rate of 1.41 MT/ha in 2019, however, there is no data on maize production in the year 2022. Rabi crops like potato have a total production 4000 MT, productivity rate of 9.10 MT/ha, with an area of 404 ha in 2019, similarly, 4400 MT, productivity rate of 10.61 MT/ha, with an area of 415 ha in 2022, whereas, the data shows an increasing trend of potato production. Also, green pea with a total production of 135.8 MT in 2019, and 261.11 MT in 2022, productivity rate of 2.34 MT/ha in 2019, and 0.83 MT/ha in 2022, with a total area of 58 ha in 2019, and 316 ha in 2022, thus the data also depicts an increasing trend of green pea production. In addition, green beans have a total production of 309 MT, productivity of 7.92 MT/ha, with an area of 39 ha in 2019, however, there is no production of green beans in the year 2022. The statistics of 2019 and 2022 show a significant trend in the production of both kharif and rabi crops.

Table 6.8. Crop area, production, and productivity (2019-2022)

Season	Crops	Area (in Ha)		Production (in MT)		Productivity (MT/ha)	
		2019	2022	2019	2022	2019	2022
Kharif	Tomato	390	420	7254.5	8200	18.61	19.53
	Cabbage	230	250	3890	4330	16.91	17.32
	Cauliflower	--	26	--	1113	--	42.80
	Capsicum	--	24	--	1320	--	55
	Chillies	--	83	--	1280	--	15.43
	Maize	1960	--	2780	--	1.41	--
		620	803	11144.5	16243	35.52	111.63
Rabi	Potato	404	415	4000	4400	9.10	10.61
	Green Pea	58	316	135.8	261.11	2.34	0.83
	Green beans	39	--	309	--	7.92	--
		462	731	4135.8	4661.11	11.44	11.44

Source: Office of the District Agriculture Office, Bomdila

6.5. Principal crops trend, production, and productivity

The productivity of principal crops like tomatoes, potatoes, cabbage, chilies, and green peas has increased significantly in terms of area, production, and productivity. Farmers in the region are more dedicated to practicing cash crop farming than traditional farming. In recent years, several commercial crops have been introduced and are widely practiced across the region. Change in the underlying climatic conditions have allowed crops that require high temperatures, humidity, and rainfall for their growth and production. Therefore, with every passing year, the productivity and cultivable area of those crops have been noticed to be increasing expeditiously. The assessment of the production of principal crops from 2014 to 2022 has shown an increasing trend in the crops concerning their area, production, and productivity.

Table 6.9 shows the selected principal crops, production, area, and their productivity over the last nine years. The highest tomato production was recorded in the year 2022 at 8200 MT with a total area of 420 Ha, and a total productivity of 19.53 MT/ha; the lowest was recorded during the year 2020 at 2700 MT with a total area of 280 Ha, and a total productivity of 9.4 MT/ha (Fig. 6.4). Cabbage recorded the highest production in the year 2022 at 4330 MT with a total area of 250 Ha, and a total productivity of 17.32 MT/ha; the lowest was recorded in the year 2020 at 1500 MT with a total area of 98 Ha, and a total productivity of 15.32 MT/ha (Fig. 6.5). Potato recorded the highest production during the year 2022 at 4400 MT with a total area of 415 Ha and a total productivity of 10.61 MT/ha; the lowest was recorded in the year 2020 at 1118 MT with a total area of 130 Ha and a total productivity of 8.6 MT/ha (Fig. 6.6). Chilies recorded the highest output in the year 2022 at 1280 MT with a total area of 83 Ha and a total productivity of 15.43; the lowest in the year 2020 at 75 MT with a total area of 25 Ha and a total productivity of 3 MT/ha (Fig. 6.7). Green peas recorded the highest output during the year 2019 at 271.8 MT with a total area of 309 Ha and a total productivity of 0.87 MT/ha; the lowest was recorded in the year 2020 at 31 MT with a total area of 14 Ha and a total productivity of 2.22 MT/ha, respectively (Fig. 6.8).

Table 6.9. Principal crops trend, production, and productivity (2014-2022)

Crops	Year	Area (in Ha)	Production (in MT)	Productivity (in MT/ha)
Tomato	2014	215	2835.85	13.19
	2015	220	2901.8	13.19
	2016	223	3100	13.02
	2017	225	3000	13.33
	2018	300	4100	13.66
	2019	390	7254.5	18.61
	2020	280	2700	9.4
	2021	410	7800	19.02
	2022	420	8200	19.53
Cabbage	2014	189	2570.4	13.6
	2015	190	2584	13.6
	2016	200	2800	14
	2017	225	2995	13.32
	2018	210	3500	16.67
	2019	230	3890	16.91
	2020	98	1500	15.31
	2021	243	4100	16.88
	2022	250	4330	17.32
Potato	2014	--	--	--
	2015	392	3316.32	8.46
	2016	390	3299.4	8.46
	2017	395	3416	8.65
	2018	398	3879	15.29
	2019	404	4000	9.10
	2020	130	1118	8.6
	2021	410	4150	10.13
	2022	415	4400	10.61
	2014	58	226.2	3.9
Chilies	2015	59	230.1	3.9
	2016	62	245	3.10
	2017	65	251	3.87
	2018	--	--	--
	2019	--	--	--
	2020	25	75	3
	2021	70	1050	15
	2022	83	1280	15.43
	2014	59	112.1	1.9

Green peas	2015	60	144	2.4
	2016	63	152	2.42
	2017	67	160	2.39
	2018	70	178	2.55
	2019	309	271.8	0.87
	2020	14	31	2.22
	2021	311	254	0.82
	2022	316	261.11	0.83

Source: Primary field survey, 2023 and Office of the ADO, Bomdila

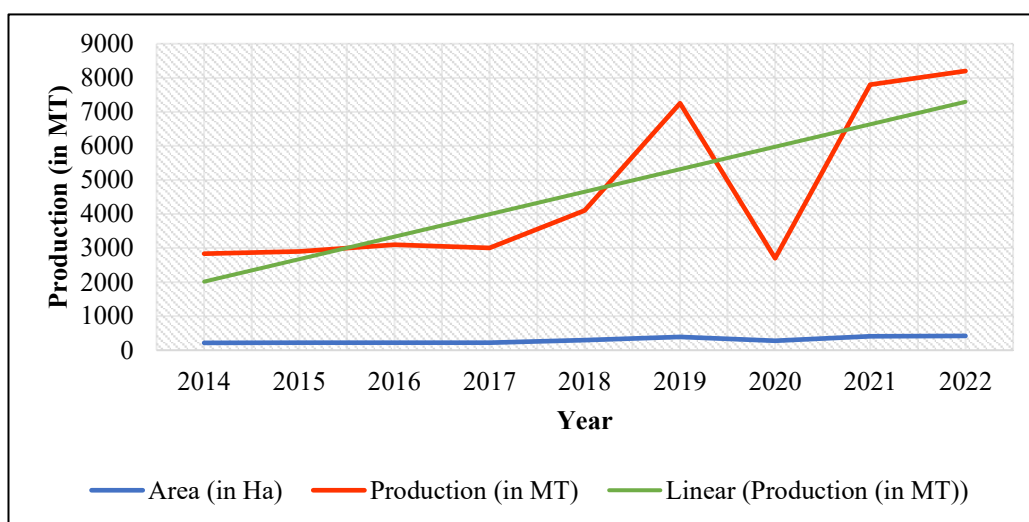


Fig. 6.4. Production trend of tomato

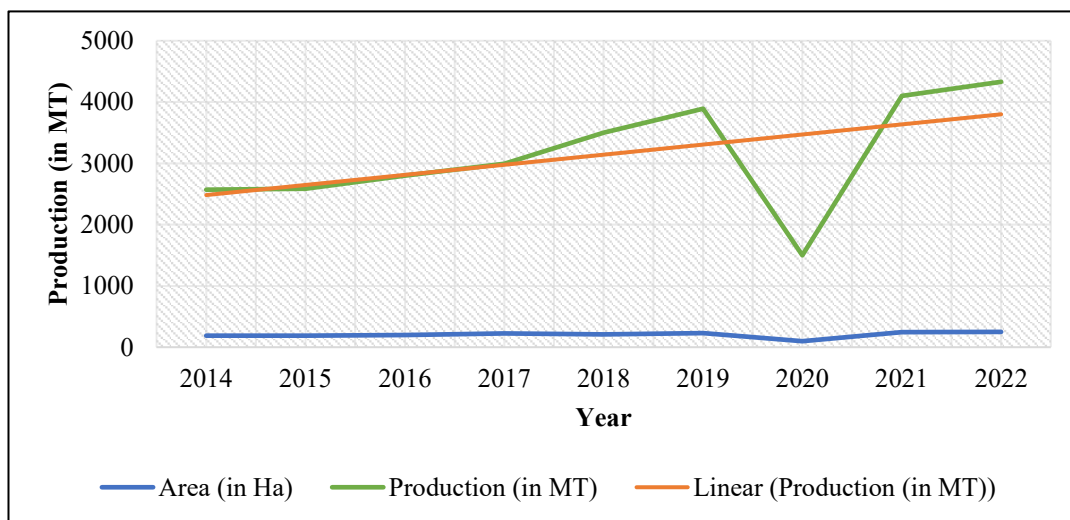


Fig. 6.5. Production trend of cabbage

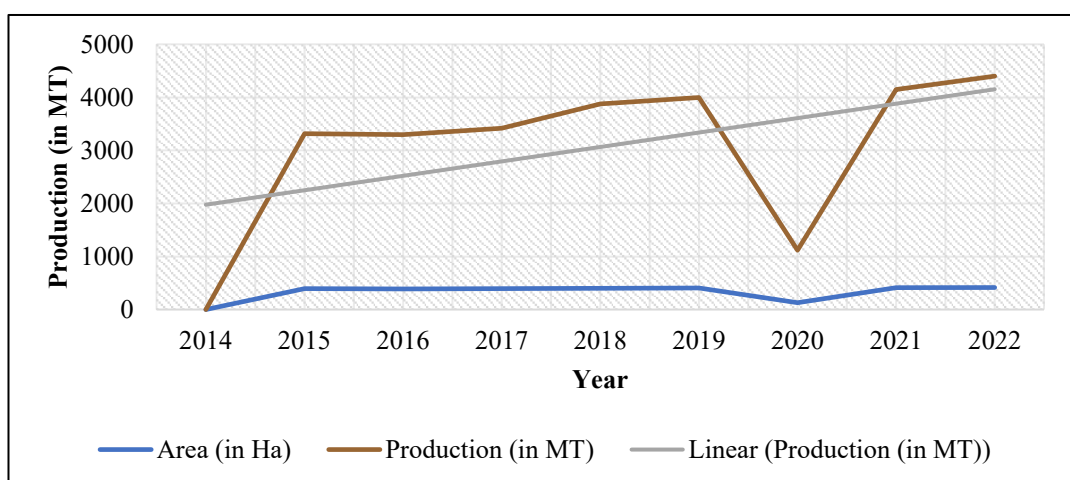


Fig. 6.6. Production trend of potato

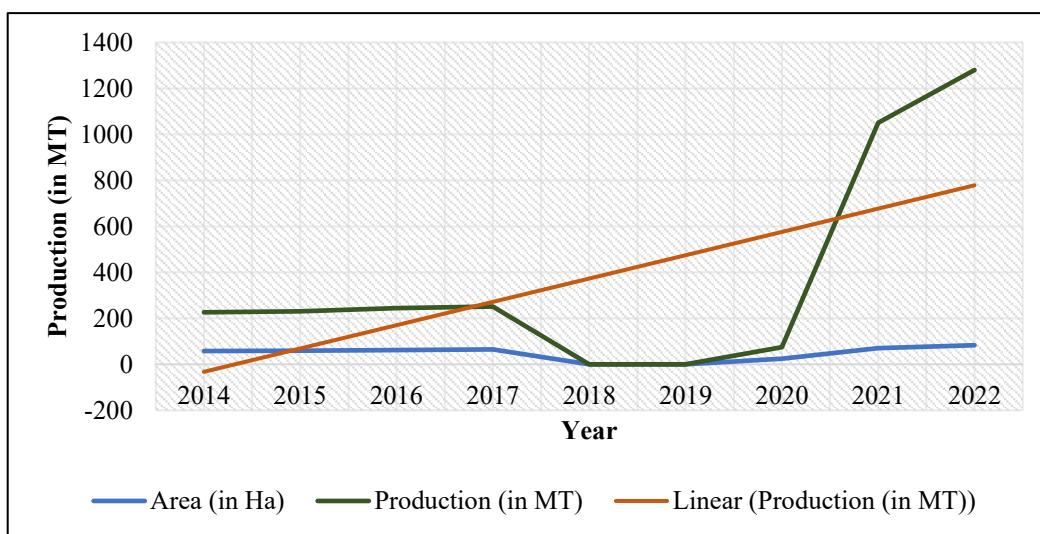


Fig. 6.7. Production trend of chilies

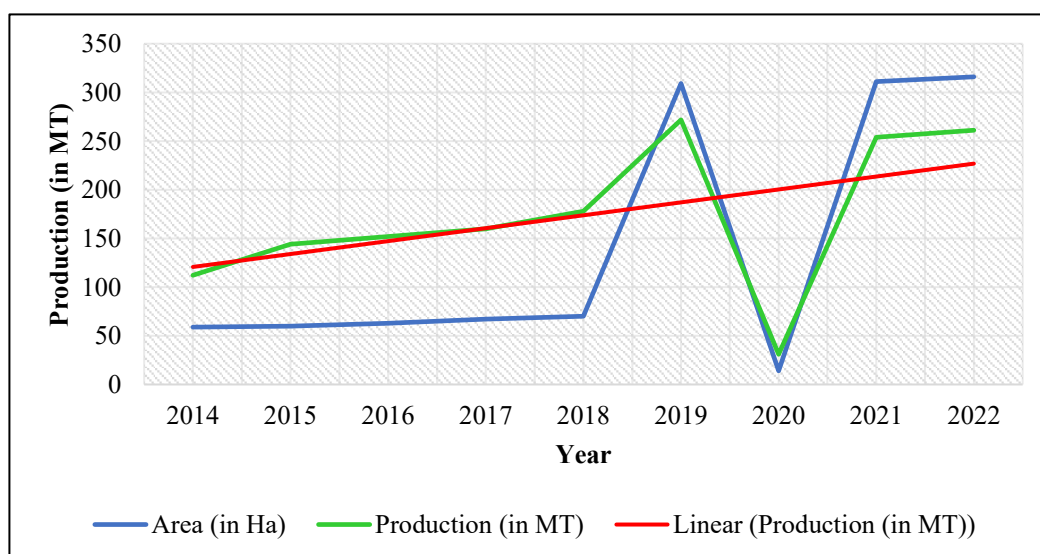


Fig. 6.8. Production trend of green peas

The region supports the cultivation of diverse crops, some of which are Indigenous crops that the farmers have been practicing for centuries. On the other hand, several crops are newly introduced, and their practices are expanding yearly. The study found that the production of traditional crops is decreasing, meanwhile, the production of freshly introduced crops is skyrocketing due to higher demand in the

local markets, leading farmers to cultivate more for higher production to meet the rising demand—such as commercial crops like tomato, potato, cabbage, and chilies, all these crops have very high demand thus, the area of cultivation and production is increasing at a tremendous rate. Therefore, the value and demand of traditional cereal crops, like millet and maize, have considerably narrowed in recent years.

Table 6.10 depicts that tomato, potato, cabbage, green beans, chilies, and cereals are the major staples commercial crops; whereas, the highest tomato production was seen in Salari village with 156.35 MT, and the lowest in Palizi village with 5.87 MT; concerning potato the highest production was seen in Shergaon village with 44.26 MT and the lowest witnessed in Ramallingpam village with 6.25 MT; the highest cabbage production was seen in Kamallangchin village with 62.25 MT and the lowest was recorded in Karangania village with 5.6 MT; concerning the green beans production the highest was recorded in Jerigaon village with 0.078 MT and the lowest was recorded in Khoina village with 0.017 MT; the highest chilies production was witnessed in Mago-Pam village with 34.34 MT and the lowest was recorded in Morsing with 0.44 MT; lastly, the highest production of cereal production was witnessed in Khoina village with 21.11 MT and the lowest was recorded in Kamallangchin village with 1.8 MT.

Table 6.10. Village-wise area, crops, and production of the principal crops (2022)

Village	Area (in ha)	Crop production (in MT)					
		Tomato	Potato	Cabbage	Green beans	Chilies	Cereals
Kamallangchin	3.092	156.35	10.49	97.9	--	37.9	1.8
Morshing	1.076	56.8	14.46	37.75	--	0.44	12.9
Shergaon	1.085	139.8	44.27	64.3	--	0.86	--
Ramallingam	0.13	24.25	6.25	17.5	--	--	--
Tsering Pam	0.091	37.25	--	27.5	--	--	--
Mago Pam	0.34	48.25	--	62.25	--	34.34	--
Salari	0.40	183.85	--	51.5	--	0.86	5.15
Sangti	0.66	160.75	29.5	57.5	--	2.26	20.78
Senge	0.51	--	--	52.3	--	--	19.93
Jerigaon	0.26	19.28	--	14.46	0.078	15.78	20.76
Kirafarm	0.15	17.53	--	15.98	0.065	13.42	18.86
Khoina	0.14	11.24	--	12.34	0.017	9.78	21.11

Karangania	0.10	--	--	5.6	0.046	0.98	7.12
Sakrin	0.06	--	--	7.8	0.56	1.12	8.9
Palizi	0.20	5.87	--	10.5	0.67	1.87	7.5
$\Sigma x =$		861.22	104.97	535.18	1.436	119.68	144.81

Source: Primary field survey 2023

Table 6.11 shows the net annual production and productivity rate of the principal crops of both kharif and rabi seasons, as well as the cultivable total area. Tomato with a total production of 861.22 MT, productivity of 103.84 MT/ha, and with an area of 8.94 ha. Potato with a total output of 104.97 MT, productivity of 17.38 MT/ha, and with an area of 6.43 ha. Cabbage with a production of 535.18 MT, productivity of 64.53 MT/ha, and an area of 8.29 ha. Green beans with a total production of 1.436 MT, productivity of 1.58 MT/ha, and an area of 0.91 ha. Similarly, chilies with a total production of 119.68 MT, productivity of 15.83 MT/ha, and with an area of 7.56 ha. Lastly, cereals with an annual production of 144.81 MT, productivity of 21.79 MT/ha, and with a total area of 6.64 ha (Fig. 6.9).

Table 6.11. Net annual production of principal crops

Sl. No	Crops	Area (ha)	Annual Production (in MT)	Productivity (MT/ha)
1.	Tomato	8.94	861.22	103.84
2.	Potato	6.43	104.97	17.38
3.	Cabbage	8.29	535.18	64.53
4.	Green beans	0.91	1.44	1.58
5.	Chilies	7.56	119.68	15.83
6.	Cereals	6.64	144.81	21.79
	$\Sigma x =$	37.76	1767.228	224.94

each individual in that area. Similarly, per-capita income is the income generated by a farmer against the total expenditure spent in a year. Per capita income is a key economic indicator that measures the average income earned per person in a specific geographical area (like a country, city, or region) within a particular period; therefore, providing a general overview of the average economic well-being of the population within that area.

Table 6.13 depicts the maximum number of farmers involved in Tomato and Cabbage cultivation, according to the findings of the study. These two crops are the highest-demand crops, which makes them more valuable, in terms of price and productivity. As the Figure shows, the annual production of Tomatoes is 861.22 MT with a per-capita production of 2.58 MT/person, and Cabbage has 535.18 MT with 1.26 MT/person. To calculate the valuation of the per-capita output of commercial crops, it is also necessary to estimate the per-capita income of the farmers.

Table 6.13. Production and per-capita production of commercial crops

Commercial crops	No. of farmers involved	Production (in MT)	Per-capita production (in MT)
Tomato	335	861.22	2.58
Potato	151	104.97	0.70
Cabbage	423	535.18	1.26
Green beans	138	1.436	0.011
Chilies	349	119.68	0.35
Cereals	353	144.81	0.42

Table 6.14 shows the total revenue generated from various commercial crops, and it is evident that Tomato and Cabbage have the highest production among all the other crops, having the highest per-capita production as well, eventually making these crops more valuable. The statistics from the table clearly express that the highest revenue generated is from the Tomato, and Cabbage; Tomato with total revenue of ₹ 24,82,17,575, and a per-capita income of ₹ 740,947.99 per farmer, and Cabbage with total revenue of ₹ 21,88,83,656, and a per-capita income of ₹ 524,558.79 per farmer of the district during the year 2022.

Table 6.14. Revenue and per-capita income of the farmers

Commercial crops	Total income (annual)	Annual per-capita income (in ₹)
Tomato	24,82,17,575	740,947.99
Potato	2,445,375	16,194.54
Cabbage	21,88,83,656	524,558.79
Green beans	39,730	287.89
Chilies	2,712,530	10,893.70
Cereals	2,881,620	8,163.23

6.7. Discussion

Farming has historically been a primary source of livelihood for rural communities. Traditionally, farming was primarily subsistence-based, with crops grown mainly for self-consumption. However, farming has shifted towards commercial crop agriculture, where crops are produced mainly for sale in the market. This shift has led to a decline in the cultivation of traditional crops, as farmers are increasingly drawn to high-demand, high-value commercial crops. These crops offer significant economic benefits to farmers due to their strong market demand and higher per-unit value.

The introduction of major commercial crops, such as tomatoes, potatoes, cabbage, green beans, chilies, and cereals, has significantly transformed the agricultural landscape of West Kameng district. These crops are well-suited to the region's climate and can produce high returns, even on small plots of land. As a result, the adoption of these crops has boosted the income and livelihood of the local farming community, which heavily relies on agriculture. The high market demand for these crops ensures their economic viability, contributing to the financial stability and improved living standards of the farmers. Compared to traditional crops, commercial crops offer higher profit margins and reliability, making them increasingly popular among farmers in the region.

The increasing demand for cash crops has driven a shift from traditional to contemporary farming practices. Farmers are now prioritizing high-productivity crops like tomatoes, potatoes, cabbage, and chilies, which have higher market value compared to indigenous crops such as beans and millet. The introduction of genetically

modified seeds has further accelerated this trend, allowing for increased production and better adaptability to various climatic conditions. As a result, commercialization has become a significant factor in shaping modern agriculture, prompting farmers to expand their cultivation areas and focus on crops that are in high demand and fetch higher prices. As a result, several traditional crops (mostly cereal grains) have now completely disappeared, and those crops are replaced by commercial crops (Thongdok and Sati, 2024).

Recent years have witnessed a significant shift from traditional to major commercial crop farming practices in the district. The introduction of such crops has transformed the agricultural landscape, leading to increased wealth and improved living standards for the local farming community. Several pieces of evidence can be found worldwide regarding the advantages of commercial crop farming and its economic incentives. A study conducted by Shoko (2022) explains the benefits of small commercial crop farming enterprises and their implications for farmers. Similarly, a study led by Peng et al. (2022) discusses how Chinese agriculture is experiencing a transition from smallholder farming to the emergence of commercial crop farms that are characterized by intensification and specialization in production, as well as commercialization. Moreira et al. (2023) also debate the importance of commercial farming to increase food production in the coming years with minimal environmental impact. In addition, Dureti et al. (2023) explain the cluster farming of crops in small land-holding and their commercialization in the economic integration of small land-holders in Ethiopia. Correspondingly, Datta and Behera (2024), deliberate on the significance of the commercialization of agriculture, forestry, and livestock in South Asia. Moreover, Sati (2024), debates the significance of mixed farming systems and their positive implication for the livelihood of the Garhwal area in the Central Himalayan region. In the same way, work carried out by (Myers et al., 2000; Nimasow et al., 2014; Sati, 2015; Babu et al., 2023; Wangchu et al., 2024; Nguyen, 2024) depicts the changing agriculture scenario and commercialization of agriculture production in the prospects of the farmers in particular and society as a whole.

Commercial crops offer immense potential to improve rural livelihoods. These crops are economically viable and generate significantly higher revenue compared to traditional crops. Their adaptability to various environments makes them a reliable source of income for farmers. As the number of farmers adopting such crops and their cultivation continues to grow, it plays a crucial role in ensuring their financial stability and sustainable livelihoods. Promoting sustainable practices in commercial crop farming can further enhance agricultural development in the region.

6.8. Conclusions

The study concludes that commercial crops have significantly contributed to improving farmers' livelihoods in the district. Introducing these high productivity crops has boosted farmers' income and economic viability. However, while commercial crop farming is thriving, it lacks modern techniques and infrastructure for sustainable agricultural development. To address this, there is a need to promote awareness of modern farming practices, revive traditional and organic farming methods, and provide farmers with access to arable land, organic manure, irrigation facilities, and market linkages. Additionally, subsidies for seeds and crop insurance can further enhance the sustainability of farming livelihoods.

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CHAPTER 7

SUSTAINABLE AND CLIMATE-RESILIENT FARMING PRACTICES

7.1. Introduction

The concept of sustainability has become a key term in our time, highlighting the need for things to endure far into the future (Morse, 2013). Sustainable rural livelihood is a multifaceted concept and refers to the maintenance or enhancement of access of rural families to food and income-generating activities on a long-term basis (Kumar, 2006). It refers to the capacity of individuals and communities to withstand and adapt to challenges and sudden changes in the natural environment that negatively affect their well-being, including their material possessions, social connections, and personal sense of satisfaction. The sustainable livelihoods framework helps to organize the factors that constrain or enhance livelihood opportunities for the rural communities (Serrat & Serrat, 2017). It is the long-term goal for poverty reduction that gives adequate importance to development from different levels, scales, and sectors (Sati, 2014). Agriculture presents a wide range of promising prospects for improving the livelihood sustainability of the rural population. Farming provides an economic platform for rural farmers for socio-economic enhancement. The impact of livelihood capital on how people make a living hasn't been thoroughly investigated. Therefore, a strategy is needed to build livelihood capital, improve livelihood strategies, integrate successes in poverty reduction, achieve long-term poverty alleviation, and promote sustainable livelihoods; moreover, earning a livelihood involves a structured process based on skills, resources, and viable activities. When considering how to make farmers' livelihoods sustainable, the safety and quality of life for those in poor areas become a central problem and a key focus of research for experts (He & Ahmed, 2022).

The concept of sustainable livelihood has become a challenging aspect for the population in the mountainous regions, due to climate variability and change. Mountain ecosystems are important, at the same time highly vulnerable to climate change; therefore, coping with climate change and balancing sustainable livelihoods has become an immense challenge for the farmers. Concerning the Himalayan region, the Himalayas are a highly vulnerable region in terms of natural disasters, and the

effects of such disasters are further compounded by other influencing co-factors such as geographical location, topography, and unique economic, political, and cultural characteristics of the region; besides, the increasing frequency of extreme climate events, widespread poverty, migration and marginalization of Himalayan people make mountain communities more vulnerable to climate variability and hindering the agriculture practices in the region (Dolan & Walker, 2006; Gerlitz et al., 2016). Moreover, the role of cash crops in livelihood enhancement in the mountainous areas of the Arunachal Himalaya is prominent due to declining production and productivity of the traditional crops, whereas, cash crops significantly contribute to improving farmers' livelihood and sustainability (Thongdok et al. 2025).

Climate plays a significant role in determining crop growth, production, and yield. Therefore, climate variability and change are substantially affecting the farming systems across the globe. It greatly affects an area's socioeconomic activities, particularly farming patterns and allied activities; Climate change navigates every sphere of the earth's surface, wherein agriculture is the most affected entity. Such variations in temperature, humidity, and rainfall drive the nature of the soil and agricultural practices (Thongdok & Sati, 2024). Climate change is imminent and bound to occur; such change in a certain amount of rainfall, temperature, and humidity controls the nature of the soil and greatly affects agricultural production and productivity in mountain regions. Mountain regions are highly vulnerable to climate change (Sati, 2015).

Therefore, climate-resilient agriculture systems and practices are essential to tackle and cope with the ongoing climate variability and change. Adoption of Environmental Smart Agriculture (ESA) is imminent. Thus, the adoption of integrated ESA practices mitigates post-harvest environmental problems and helps cope with existing climate change conditions; therefore, farm-level investment in ESA practices, i.e., the use of corrective, preventive, and local standard measures in an integrated means to promote climate-resilient farming practices (Islam et al., 2022). Temperature variations, an increase in the frequency of severe storms, heat waves, melting ice sheets, etc., are all obvious signs of global climate change. The effects of climate change, such as shifting temperatures, altered rainfall patterns, and the likelihood of

extreme events like drought and floods, overwhelm agriculture, a system that is already susceptible. Low greenhouse gas emissions and the ability to adjust to a changing environment in order to maintain the system's productivity and health are both components of an agricultural system's resilience (Goswami et al., 2023). It is high time to restructure a paradigm shift in agricultural development approaches to adapt and build climate resilience. Climate change is bound to occur; hence, adjustments and adaptations are indispensable through technological innovations, policies, and programs.

7.2. Promoting sustainable livelihood

Sustainability is important in enhancing the livelihood of the farmers and the population of the rural area in the region. The following measures may be adopted and implemented for a sustainable livelihood.

7.2.1. Improving soil health and fertility

Improvement of the soil health and fertility plays a significant role in crop growth and yield, as it reduces the external supplements for the crops, like chemical fertilizers and other substances. Most of the commercial crops grown in the district are induced with chemical fertilizers like insecticides, pesticides, potassium, and urea to enhance the growth of the crops. Whereas, Homobrassiolide 0.04 % is a chemical supplement that is used to enhance crop growth and yield (Fig. 7.1a). Moreover, Indofil M-45 is used to sustain the crop's health (Fig. 7.1b). Thus, application of this supplement is not only harmful to health, but it also deteriorates the health and organic content of the soils, which may result in the acidity of the soils, where cultivation is difficult.



Fig. 7.1. Supplements used for the crop's health and yield

7.2.2. Value chain development

The value chain is vital in the agriculture sector as it encompasses the producers (farmers), investors, buyers, markets, and producers. Regardless of the revenue earned by the farmers, there are several aspects that they have to cover, like goods and transportation costs, labour costs, and interest from the investors. Proper capital investment from the association and organizations would increase the crop security and economic viability, with zero interest from the investors, which would be helpful for the farmers. Moreover, the proper price of the crop needs to be implemented so that both farmers and investors benefit. Provisions for security and the market are essential for the trade and exchange of goods and commodities. Therefore, setting provisions for value chain development is imminent concerning the development of the agriculture sector as a whole and the enhancement of livelihood sustainability in particular.

7.2.3. Community-based resource management

Climate is changing and it is everlasting, with its change, an immense role is being played by the people through instigating climate change at a fast and alarming rate. Acres of forests are being cleared, which results in higher erosion activities, causing Earth movements like landslides, river bed swelling, leading to inundation of

the settlements and agricultural fields. Moreover, anthropogenic activities like the combustion of fuels and the emission of harmful gases, through the release from vehicles, machines, and industries. Water bodies are also being polluted by the waste from the settlements and industries.

Therefore, community-based organizations, or so-called CBOs, play an important role in enacting and implementing the policies and programs to tackle the deteriorating health of the society, economy, and environment. There are certain examples from the West Kameng district on how CBOs are playing a pivotal role in promoting sustainable livelihood and environmental conservation. The Tukpen Biodiversity Conservation (TBC) promotes coherent interaction between the environment and society, Monpa Mimang Tsokpa protects and encourages underprivileged communities and farmers, and encourages enhancing the livelihood of the rural population, and the Khellong Bomrok NGO is based in the Khellong village. The organization's primary objective is to rejuvenate the traditional practice of the Yak shepherds to promote sustainable livelihood and create awareness on the importance of traditional and organic farming practices in the district.

7.2.4. Provisions of cold storage for agricultural products

The hilly terrain of the West Kameng district poses a huge challenge, especially during the monsoon season, as most of the cultivation is carried out when the rainfall is adequate. Every year, due to its hilly terrain and heavy rainfall leads to severe consequences like road cut-offs due to landslides, and extreme flood events lead to bridges being swept away. All these factors greatly affect the agriculture harvest because most of the crops grown are cruciferous crops like cabbage, cauliflower, chilies, capsicums, tomatoes, and green beans; these crops are delicately subjected to damage. Unfortunately, the district does not have any cold storage for storing agricultural goods, although the production is abundant, and it lacks cold storage; therefore, unforeseen events lead to the deterioration of the crop production in the district. The facilitation of the cold storage will increase the food security and economic viability of the agricultural products. An assurance will be provided to the farming community to stock their farm produce when there are sudden road blockages due to heavy rainfall. The crop damage vulnerability of the production will be radically

minimized, and such a significant initiative will also eventually enhance the livelihood status of the farmers in the region.

7.2.5. Agriculture Produce Market Committee (APMC)

Proper setting up and monitoring of the public market, also known as ‘Mandi’, is essential for the farmers, as an assurance to farmers from the government. Most of the goods are being contracted by the private firms, particularly from the neighboring state of Assam. A huge amount of capital is invested in the farming practices in the district, through finance and subsidiaries. Therefore, all the crops produced are being sold to these private firms. Selling crops to private individuals has adequate economic benefits in terms of revenue, however, there is no crop security and minimum support price (MSP). Therefore, the government must intervene and buy all the crops from the farmers so that they can get the MSP for their crops. Moreover, the APMC shall make policies and programs to alleviate and compensate the farmers at the time of crop damage and loss. Besides, the authority should also eradicate the interest rate of the loans taken by the farmers and make interest-free loans to farmers.

7.2.6. Promoting Agro-tourism

The West Kameng district is gaining much popularity as the ‘Agricultural Bowl’ of the state of Arunachal Pradesh, due to its immense agricultural practice and production. The district is the highest supplier of tomatoes, chilies, cabbage, cauliflower, potatoes, and green peas. Additionally, the area of the agricultural field is also expanding, as is the production. Therefore, cooperation is imperative and essential among different organizations like CBOs, the Department of Agriculture, and the Department of Tourism to promote the agricultural richness of the region and expedite the crop cultivation and production by attracting various investors to invest, which will benefit both the farmers and the organizations. Thus, endorsing food security and economic viability, and enhancing livelihood sustainability.

7.3. Climate-resilient farming practices

Climate is changing, affecting various societal and environmental aspects, whereas agriculture is the most affected entity, as the West Kameng district is characterized by hilly and undulating topography with varied agro-climatic conditions;

hence, the region is more susceptible to climate variability, as mountain regions are imperative yet ecologically vulnerable to climate change. Climate indeed plays an important role in the overall aspect of the farming systems and practices. In contrast, abrupt changes in its setting greatly affect the patterns and nature of the farming activities of an area. Therefore, applying climate knowledge, such as short-term and long-term weather and climate predictions, is imperative to help prepare and adapt farmers for the change and its consequences. Adaptation and mitigation strategies are imminent, such as water management, afforestation, cultivation, and promoting climate-resilient, tolerant seeds and crops to tackle and endure such hasty changes.

7.3.1. Setting up of weather stations

Historical datasets are crucial for any forecasts and future predictions. Similarly, micro-level data of weather components are indispensable for resource management. However, during the study, it was found that there are no appropriate weather stations in the districts, which can be referenced for climate studies. Even though a few small weather stations are there, those are defunct and dysfunctional. Therefore, the mobilization of micro-level data of climatic components is difficult, without which any sort of climate study is unattainable.

The findings of the study suggest that there is a need to set up weather stations in various agricultural hotspot areas, so that they enable policymakers and researchers to collect, analyze, and model the data with the help of statistical measures and techniques for potential future predictions and changes, also to understand the current trend of climate change. These analyses and understanding of the trend of climate variability would help policymakers to implement measures and policies for the growth and welfare of the farmers.

7.3.2. Adaptation of mitigation technologies

Climate is changing, and adaptation to its change is imminent. Adaptation strategies need more encouragement in the present-day context than ever. Traditional crops are no longer endurable to changing weather patterns, moreover, there is a need to shift from the traditional method of farming to the modern method of farming, where technologically advanced techniques and measures are being applied in farming

practices. The following techniques would be an effective measure to overcome agriculture and its resilience to climate change.

7.3.2.1. Satellite Monitoring

Remote sensing techniques would be helpful in surveying and monitoring agricultural fields, such as monitoring of the soil types, vegetation, and extreme climate events to aware farmers. For instance, ISRO's Bhuvan platform provides hyperlocal data on soil moisture, rainfall, and crop health, which is accommodating in terms of crop choice and patterns. Moreover, farmers receive SMS alerts for drought-resistant crop choices.

7.3.2.2. Internet of Things (IoT) sensors

IoT sensors are devices that provide a usable output in response to a specified measurement. For example, the facilitation of devices and sensors like soil sensors that track nutrient levels, reducing fertilizer overuse, and GHG emissions. Because soil is the main source for plants, choosing the precise type of soil is necessary for an upright crop, its production, and yield.

7.3.3. Water management

The key impact of climate change can be witnessed in water bodies, as due to rising temperature and a decreasing trend of rainfall in the West Kameng district, several streams have been dried due to a decrease in rainfall intensity over the last two decades; therefore, the concept of water management becomes imminent. Such crops that require less water should be introduced and implemented on a large scale. Water management is crucial as it directly impacts the crop health, soil quality, and overall productivity. Its management is pivotal as it helps conserve excessive utilization of water resources, reduce costs, and mitigate the effects of droughts and water-related challenges.

Technological and digital innovations can be applied in carrying out water management strategies for climate-resilient farming practices. Therefore, the application of remote sensing techniques, like GIS Mapping, which identifies groundwater recharge zones and monitors reservoir levels (e.g., Jal Shakti Ministry's aquifer maps).

7.3.4. Afforestation practices

Sustainable farming practices are occasional so far, but it is also possible; the prospect of coherent practices of agriculture and forestry, so-called agroforestry, is one of the most sustainable modes of farming practices. Deforestation is a key drawback concerning agricultural practices, as acres of forest areas are being cleared every day for the expansion of agricultural land (Fig. 7.2). The arable land is increasing, but at great cost as natural vegetation is being cleared. Forests serve as the storehouse and filter of fresh water in hilly regions, in the form of brooks, streams, and rivers; hence, in recent years, several fresh water streams have been fully dried, resulting in difficulties with agricultural activities concerning water management. Therefore, intervention and cooperation among the various CBOs, NGOs, and government organizations are highly essential to spread awareness regarding the importance of vegetation cover and promote afforestation practices.



Fig. 7.2. Deforestation of virgin land in West Kameng district; Photo: By scholar

7.3.5. Contour farming and green belts

Contour farming or ploughing is a sustainable farming practice, especially in hilly regions, where the lands are cut into terraces, which act as a retention to soil erosion. This type of farming is mostly practiced for plantation culture or horticulture in the hilly region, and it is very effective in reducing erosional activities in elevated regions.

Whereas green belts are also known as shelter belts or wind breaks, there are rows or chains of shrubs and plants planted to protect crops from environmental hazards like extreme erosional and denudational activities. They are also helpful for other purposes like improving soil health, enhancing biodiversity, and providing shade to crops.

7.3.6. Mulching practice

The mulching process in agriculture is the process of covering the soil with organic and inorganic materials. Organic materials like straw, hay, shrubs, leaves, etc., are used to retain the moisture present in the soil. Inorganic materials like tarpaulin, plastics, MIPATEX Mulch film, or Mulching Sheet film it is a specific type of material that allows water to infiltrate and penetrate, and they shield outgoing moisture from the soil as it acts as a protective barrier. Mulching is a prominent technique used in farming practices, having numerous benefits like conserving soil moisture, suppressing weed growth, regulating soil temperature, and preventing soil erosion.

7.4. Conclusions

The study may conclude that humans are the most adaptive beings on Earth. Humans have the adaptive capability to overcome any environmental changes. Such changes as climate change and it is apparent that climate change is evident and it is bound to occur, and their occurrence is affecting various natural resources management, economic activities, and agricultural activities. Out of all the implications, agriculture is the most affected entity, as agriculture is important yet vulnerable to climate change.

Hence, promoting and adopting such measures that secure livelihood and enhance sustainability is imperative. Moreover, encouraging climate-resilient farming

practices has become a key issue in defining food security and crop productivity. The only way to tackle climate change is to enhance livelihood sustainability (SL) is to promoting climate-resilient farming techniques and sustainable farming practices.

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CHAPTER 8

CONCLUSIONS

8.1. Introduction

This era is the worst climate change event in human history. Implications of climate change events are reflected everywhere on Earth, including torrential/cloudburst rainfall in remote areas, droughts in tropical areas, decreasing snowfall intensity in polar areas, receding glaciers, rising sea level, global warming, etc. In the last sixty years, the 21st century is witnessing the hideous effects of climate change, as change is on a large scale and rapid, harming various socio-economic and environmental aspects. The most affecting entity is the agricultural activities, because they solely depend on the climate for growth and production. Particularly, farming practices in hilly and mountainous regions like the Himalayas, as mountain ecosystems are important yet vulnerable to a changing climate. Therefore, the farming activities in mountain regions are highly miser due to higher rate of erosional activities, landslides, cloudburst floods, rising temperature, and erratic rainfall patterns.

The present study has been conducted in rural villages of the West Kameng district of Arunachal Pradesh. The primary objective of this study was to examine farming systems and how they are being affected by climate variability. In recent years, the region's temperature and rainfall have been highly fluctuating; moreover, with that being said, the farming patterns have also been changed. The findings of the study suggest, after analyzing climate data of 21 years from 2002-2022, that the temperature of the region is greatly increasing, however, rainfall intensity has been decreasing ever since. Furthermore, the agricultural production data of 9 years were analyzed, and it was found that the production of traditional crops is decreasing, and the cultivation of modern crops (GM) is significantly increasing. The study also discovered that the production of modern crops is momentarily increasing, along with the production, the areas of agricultural land are also expanding.

The study also validates that these modern crops have high economic value, therefore, it was found that the culture of commercial crops is increasing the farmer's

revenue, due to its economic viability. Thus, it is apparent that the introduction of such crops has enhanced the livelihood security and sustainability of the farmers in the region.

8.2. Summary

The study can be summarized by validating the findings in the following:

8.2.1. Analysis of trends of humidity, temperature, and rainfall

The study's first objective covers two aspects: an analysis of the climate variability and trend, and parameters like humidity, temperature, and rainfall follow the first. Meteorological data on climate parameters were obtained from the NASA Data Access Viewer, also known as Power NASA, for 21 years, starting from 2002 to 2022. The data were further categorized into two groups, from 2002-2012 and 2013-2022, respectively. In addition, the data were categorized into three different aspects, i.e., annual, seasonal, and monthly, for better clarity and understanding of the variability and change. Meteorological data of fifteen villages were collected, and the average Monthly value of each village was determined. From the monthly data, the yearly average was calculated. Therefore, to understand the trend of the variables, the parametric trend analysis, or popularly known as linear (trend) regression analysis, was applied for 21 years. The analysis of humidity of the year 2002-2022 showed that the mean average humidity from January to December stands at 74.33 %, the lowest trend was recorded in the year 2010 at -10.53 %, and the highest trend was in the year 2016 at 7.82 %. And the analysis of the temperature from the year 2002-2022 showed that the mean average temperature over the last twenty-one years from January to December stands at 12.47 °C, the lowest trend recorded in the year 2004 at -1.54 °C, and the highest trend in the year 2009 at 1.40 °C. Lastly, the analysis of the rainfall from the year 2002-2022 showed that the mean rainfall from Jan-Dec stands at 142.50 cm, the lowest trend recorded in five consecutive years, 2006, 2007, 2010, 2014, and 2018 at -6.51 cm, and the highest trend in the year 2019 at 153.32 cm.

Seasonal analysis of the climate parameters was categorized based on seasons recognised by the Indian Council of Agricultural Research (ICAR), i.e., into four main seasons: winter, pre-monsoon, summer, and post-monsoon. The winter season is

considered to start from the month of December-March, pre-monsoon season from April-May, summer season from June-September, and post-monsoon season from October-November. The average temperature of the winter season of the last 21 years was recorded at 13.28 °C, similarly, the average temperature of the pre-monsoon period was recorded at 18.79 °C, followed by the summer season, that has recorded 19.64 °C, and the post-monsoon period recorded at 16.04 °C. Correspondingly, the average humidity of the winter season was recorded at 74.07 %, pre-monsoon period at 83.47 %, summer season at 87.65 %, and post-monsoon at 79.7 %, respectively. Likewise, the average rainfall of the winter season in the last twenty-one years at 43.28 cm, pre-monsoon season at 245 cm, monsoon season at 251.75 cm, and post-monsoon season at 46.58 cm, respectively.

The monthly trend analysis of the climate parameters showed a significant variation in all the months of the year. The monthly average temperature of the last twenty-one years' statistics shows a significant trend in the temperature; the lowest was recorded in February with an average of 11.63 °C, and the highest in July at 20.63 °C, respectively. Similarly, the average monthly humidity from the year 2002-2022 statistics shows a significant trend in the humidity; the lowest was recorded in February with an average of 63.03 %, and the highest in July at 89.32 %, respectively. Compatibly, the average rainfall of the year 2002-2022 statistics, shows a significant trend in the rainfall; the lowest was recorded during December with an average of 5.23 cm, and the highest in July at 319.29 cm, respectively.

8.2.2. Understanding farming systems

The study's findings validate that most farmers still practice traditional farming practices with the help of old tools and techniques. However, a change has been witnessed in crop cultivation, as farmers are growing modern crops or genetically modified (GM) crops. The farmers in the district practice agriculture in both Kharif and Rabi seasons. Various distinct crops characterize both seasons; Kharif crops like paddy, maize, millet, cabbage, tomato, chilies, millet, garlic, ginger, and other vegetables. Similarly, Rabi crops like wheat, barley, mustard, potato, and green peas. Multiple crops are practiced in both seasons, yet are adorned with major crops which are having the highest production and yield among all the other crops. Major crops in

the Kharif season are tomato, cabbage, chilies, and paddy. Likewise, major crops in the Rabi season are potato and green peas. Crop production data for nine years from 2014-2022 were tabulated and analyzed. During the analysis, the study observed that the major crops' area, production, yield, and growth rate are rapidly increasing every year. The average growth rate of tomato for the years 2014-2022 is 7.44 %, and cabbage with 3.36 % annually. Correspondingly, the potato with 1.98 % annually, chilies with 6.98 %, and green peas with 5.39 % annually, respectively (Table 8.1). Therefore, tomato is the highest producing, yield and growth rate, whereas overall, chilies have the lowest production and yield. On the other hand, cabbage has the lowest growth rate in nine years, i.e., 1.98 % annually.

Table 8.1. Production, area, yield, and growth rate of major crops

Crops	Year	Area (in Ha)	Production (in MT)	Growth rate (in %/year)
Tomato	2014	215	2835.85	1.15
	2015	220	2901.8	3.31
	2016	223	3100	-1.64
	2017	225	3000	15.49
	2018	300	4100	15.5
	2019	390	7254.5	27.75
	2020	280	2700	-45.75
	2021	410	7800	48.57
	2022	420	8200	2.5
			41892.15	7.44
Cabbage	2014	189	2570.4	0.26
	2015	190	2584	4.1
	2016	200	2800	3.37
	2017	225	2995	7.78
	2018	210	3500	5.27
	2019	230	3890	3.7
	2020	98	1500	-44.35
	2021	243	4100	46.43
	2022	250	4330	2.72
			28269.4	3.36
Potato	2014	--	--	
	2015	392	3316.32	-0.26
	2016	390	3299.4	1.73
	2017	395	3416	6.34
	2018	398	3879	1.53
	2019	404	4000	2.3
	2020	130	1118	-56.31

	2021	410	4150	57.55
	2022	415	4400	2.93
			27578.72	1.98
Chilies	2014	58	226.2	0.85
	2015	59	230.1	3.13
	2016	62	245	1.20
	2017	65	251	1.1
	2018	--	--	
	2019	--	--	
	2020	25	75	-53.98
	2021	70	1050	86.67
	2022	83	1280	9.87
			3357.3	6.98
Green peas	2014	59	112.1	12.45
	2015	60	144	2.97
	2016	63	152	2.56
	2017	67	160	5.32
	2018	70	178	20.85
	2019	309	271.8	4.3
	2020	14	31	-79.52
	2021	311	254	78.24
	2022	316	261.1	1.38
			1564	5.39

8.2.3. Climate and production

The study analyzed the agricultural production and climate parameters data of nine years. The study revealed that the climate parameters are immensely impacting the production and yield of major crops in the region. Therefore, to understand the various statistical techniques that were applied, such as *Pearson* Correlation (r), Multiple Regression Correlation Analysis (R^2), and Two-tailed ANOVA. These statistical measures are used to understand the relationship between and among different variables. Correlation analysis was performed for both the Kharif and Rabi crops, and climate variables, like temperature, humidity, and rainfall, for the nine years, starting from 2014-2022. Whereas, the correlation statistics of 2014 signify a strong correlation. The standard r -value of the correlation should be -1 to +1, and the P -value is <0.05 ; therefore, the average r -value of Kharif v/s climate parameters is 0.8656, and the r -value of Rabi v/s climate parameters is 0.8664. and P -value is all <0.05 , hence, there is a strong correlation among the climate variables and the

production of the year 2014. The statistics of the year 2015 show that the average *r-value* of Kharif v/s climate parameters is 0.7242, and Rabi is 0.6116; overall, the *P-value* also shows significant as it is <0.05 . The 2016 statistics present the average *r-value* of Kharif v/s climate variables is 0.1959, and Rabi is 0.601, *P-value* is also <0.05 . The 2017 data show the average *r-value* of Kharif v/s climate variables is 0.2543, and Rabi is 0.2543. *P-value* is also significant as it is below <0.05 . Similarly, in 2018, Kharif v/s climate variable is 0.2067, and Rabi is 0.2150. In 2019, the average *r-value* of Kharif v/s climate parameters is 0.2610, and Rabi is 0.2678. The data from the 2020 Kharif v/s climate variables is 0.2773, and Rabi is 0.2890; likewise, the statistics of 2021 show that the average *r-value* of Kharif v/s climate is 0.1687, and Rabi is 0.1787. Moreover, the *P-value* of all the years is also significant as the value is <0.05 . Finally, the data of 2022 show that the average value of Kharif v/s climate is 0.2775, and Rabi is 0.2835, besides the *P-value* is also significant as it is <0.05 .

The Two-tailed ANOVA results also depict a significant relationship among the different production and climate variables. The standard *P-value* of the two-tailed ANOVA is <0.05 , whereas the performed analysis result also shows the *P-value* <0.05 , which means that the test is significant. Moreover, the standard *F-value* of the analysis should be 1, while the performed analysis results of the Kharif v/s climate is 0.9511, and Rabi v/s Climate is 0.9397, respectively. Therefore, it can be validated that the analysis of variance is significant, and the results show a strong correlation among the variables.

Multiple Regression Correlation was also performed; the analysis shows a strong significance and correlation among the variables. A separate analysis was performed for both Kharif and Rabi, where the *P-value* of Kharif is 0.878, humidity is 0.680, temperature is 0.918, and rainfall is 0.189; hence, the overall R^2 value is 0.189, which shows that the analysis is correct and there is a strong correlation among the variables. Correspondingly, the analyzed *P-value* result of the Rabi is 0.909, humidity is 0.975, temperature is 0.975, and rainfall is 0.569; thus, the overall R^2 value of the analysis is 0.226, which depicts that the performed analysis is correct and shows a strong correlation among the variables.

8.2.4. Effect of elevation on crop production

The topography of the district is highly undulating, having distinct altitudinal variations. The elevations vary from 300 m up to 4500 m. Therefore, a study was conducted on whether elevation is affecting the agricultural production of the region. The *multiple correlation analysis* was performed between crop production and varying elevations where major crops are grown. The results of the analysis show that varying elevation, like increasing and decreasing elevations, greatly impacts crop production. The standard significance value is between 0-1. The analyzed results are as follows: the *P-values* of different crops are as follows: tomato (0.098), potato (0.501), cabbage (0.744), green beans (0.221), chilies (0.661), and cereals (0.664). Furthermore, it can be validated that the elevation is highly influencing the crop growth and production of the major crops in the region.

8.2.5. Economic benefits of the principal crops

The findings of the study suggest that there is a shift in the farming patterns in the region. Eradication of conventional crops and adoption of fresh commercial or non-conventional crops. Such crops have substantial economic latent due to their high demand in the market. Therefore, to understand the revenue generated and average production of the crops annually, the per-capita income of farmers and the per-capita production of the principal crops were determined. The total population of the West Kameng district is 83,947, whereas 58,762 are farmers, which is 69.99 % of the total population of the region. Besides, a report published by the Ministry of Agriculture and Farmers Welfare in the year 2021-2022 stated that the average per-capita income of the farmer in West Kameng district is ₹ 19,225. Moreover, a report published by NABARD, All India Rural Financial Inclusion Survey (NAFIS), is ₹ 13,661 in the year 2021-2022. Correspondingly, the present study on per-capita income and per-capita production of the farmers also indicates similar results to the mentioned published reports. The highest revenue generated is from the Tomato and Cabbage; Tomato with total revenue of ₹ 24,82,17,575, and a per-capita income of ₹ 740,947.99 per farmer, and Cabbage with total revenue of ₹ 21,88,83,656, and a per-capita income of ₹ 524,558.79 per farmer of the district during the year 2022. Whereas the average annual income of the farmer is ₹ 216,841, and the average monthly income of the farmer is ₹

18,070. Therefore, the study can validate that the introduction and adoption of the commercial crops have improved the farmers' revenue, besides the study's per-capita findings are similar to reports published by NABARD and the Ministry of Agriculture and Farmers Welfare. Such crops have enhanced the revenue and livelihood sustainability of the farmers in recent years.

8.2.6. Changing patterns of farming systems

Climate is rapidly changing, so farming systems across the globe are changing. This change requires an extensive coping and adaptation process and strategies. Adaptation concerning crops that are resistant to climate variability and change; the culture of drought-resilient crops, avoiding water-intensive crops, use of genetically modified seeds (GMs), which are highly impervious to a changing climate, and possess significant potential for high yield and survival even in harsh climatic variability.

The present study, conducted in the West Kameng district, has also witnessed a radical shift in farming systems and patterns, owing to the eradication of conventional farming, such as growing cereal crops, and the adoption of non-conventional farming systems, such as the introduction of modern crops or commercial crops. Conventional crops are highly vulnerable to climate change, moreover, such crops have less demand, resulting in low economic value in the market. Whereas, non-conventional crops are those crops that are highly resistant to climate change, as they are GMs, therefore, it is also have high demand and immense economic value in the market. Consequently, with climate change also changing the crop choices and farming systems, the majority of the farmers in the district no more practice traditional crop cultivation. On the other hand, the cultivation of commercial crops like tomato, potato, chilies, cabbage, and green peas is skyrocketing the demand and supply in the market, besides, their economic value is also on the rise.

Such a change in farming patterns has both negative and positive consequences. Concerning negative consequences, commercial crops are supplement-intensive, which means they require high resource inputs, including capital investments, the use of chemical fertilizers, and the application of harmful chemical substances such as insecticides, pesticides, and urea, all of which have a long-term

effect on the organic compounds of the soil. Excess utilization of these chemical substances alters the natural setting of the soil and makes the soil acidic, which is not suitable for any type of crop to grow. The positive impact of such farming systems is that such possess high productivity and yield rate compared to traditional crops, which makes them a convenient choice for the farmers as such crops are always in rising demand, having economic value and viability, therefore, they hold a latent potential to enhance the livelihood of the farmers. It is true to say that, by analyzing the findings of the study, the introduction and adaptation of these commercial crops have changed the farming scenario and improved the livelihood sustainability of the farmers in the region.

8.3. Conclusions

The study may conclude that the climate is changing drastically, affecting various entities, whereas agriculture and farming are the most vulnerable and affected activities. With climate change, the farmers are adopting various fresh farming methods to tackle and adjust to the climate variability. Adoption of GM crops, practising of less water-intensive crops, and promoting climate-resilient crops. The study also found that climate is greatly affecting the crop production of the region; moreover, the analysis of the effect of elevation on crops also proved that varying elevations are also affecting crop growth and production. Subsequently, the introduction of commercial crops has also enhanced the means of support to farmers, improving the standard of living and livelihood sustainability of the farmers in the region.

Appendix-I

Plate 1.1. (a) & (b) Interview with the farmers at Mago-Pam and Morsing village



Source: Photo by author

Plate 1.2. (a) A vast tomato field and (b) its product at Kamallangchin village



Source: Photo by author

Plate 1.3. (a) Spraying pesticides and chlorophylls at the tomato field at Morsing village, and (b) chemical substances ready to be sprayed



Source: Photo by author

Plate 1.4. (a) & (b) Harvested tomatoes and cabbage are ready for selling at Kamallangchin village



Source: Photo by author

Plate 1.5. (a) Scientists at Krishi Vigyan Kendra (KVK), Dirang, and (b) their experimental model crop, black soybean



Source: Photo by author

Plate 1.6. (a) Damaged and rotten cabbage due to incessant rainfall, and (b) Farmers carrying supplies to their camp at Mago-Pam village



Photo by author

Plate 1.7. (a) Seed germination process, and (b) Harvested maize for winter consumption at Morsing village



Photo by author

Appendix-II

A QUESTIONNAIRE ON

‘Climate Change and Its Impact on Farming Systems of West Kameng District, Arunachal Pradesh’

1. Village information

(i) Name of village				(ii) Name of block				(iii) No. of HH surveyed			
(iv) Latitude				(v) Longitude				(vi) Elevation			
(vii) Total no. of households											
N		S		T		TW					

N- Nalla/stream: S- Spring: T- Talab/pond: TW- Tube well/borewell

2. Household information

(i) Name of the family head				(ii) Occupation				(iii) Total no of family members			
(iv) No of livestock				(v) Area of agriculture (if any)				(vi) Types of crops grown			
(v) Source of domestic water				(vi) Source of drinking water				(vii) Source of irrigation			
(viii) Name of family members				(ix) Age				(x) Qualifications			
(a)				(a)				(a)			
(b)				(b)				(b)			
(c)				(c)				(c)			
(d)				(d)				(d)			
(e)				(e)				(e)			
(f)				(f)				(f)			
(g)				(g)				(g)			

3. Information related to farming

1. For how long have you been practicing farming

<5 years	5-10 years	>10 years
--------------------	-------------------	---------------------

2. What types of crops are grown?

--

3. Which crops are grown for commercial purpose?

--

4. Which crops are grown are grown for subsistence purpose?

--

5. What kind of farming system is practiced? Whether traditional /modern?

--

6. How many phases of crops are grown in a year?

<2	2-3	>3

7. Do you practice crop combination or diversification? If yes, mention types:

--

6. Have you been practicing the same types of crops since you started farming?

--

7. Is there any introduction of new crops?

--

8. If yes, then how many types of newly introduced crops are being practiced?

--

9. Do you use organic seeds or genetically modified/HYV seeds?

--

10. Does the use of organic or genetically modified seeds produce more yield?

--

11. Do you use organic compost or chemical fertilizers? If yes, then mention types:

Name	Composition

12. What are the steps that are involved in growing major crops in your area?

Name of crops	Steps involved

4. Information related to socio-economic attributes

1. How do you sell your crops?

--

2. Where do you sell your crops?

--

3. To whom do you sell your crops?

--

4. What is the minimum support price for your various crops?

Name of crops	Price

5. What is the maximum price for your various crops?

Name of crops	Price

6. Do you take loan or mortgage for financial assistance for farming?

--

7. Who are the financial providers or investors?

--

7.If yes, then what are the annual rate of interest at the end of the season?

--

8. What are the rates of production or yield of various crops at the end of the season?

Name of crops	Production (in quintal/kg)

9. What is the annual profit from various crops?

Name of crops	Capital invested	Profit (in rupees)

10. What is the average profit excluding the labour cost/infrastructure cost?

Total profit	Labour cost	Total profit- labour cost = Profit (in rupees)

11. Have you witnessed any economic changes in the village after introduction of these commercial crops? If yes, then explain:

--

12. Do you think that shifting from farming traditional crops to modern commercial crops have resulted in change in farming systems?

--

13. In which year did you get the least profit? If yes, state why?

--

14. In which year did you get the highest profit? If yes, state why?

--

5. Information pertinent to agro-ecological characteristics

1. What type of soil is found in your area?

Type	Composition

2. Which soil is suitable for growing various crops?

Name of crops	Soil types

3. Does the amount of rainfall effects the farming in your area?

--

4. What is the water requirements/source for farming in your area?

Spring	Stream	Pipeline supply
--------	--------	-----------------

--	--	--

5. Do you depend on Monsoon for farming?

Yes/No

6. Does the erratic nature of rainfall effects the farming in your area? If yes, please explain”

--

7. Have you ever experienced drought in your area?

Yes/No

8. If yes, then did the drought deteriorated your crops?

Yes/No

9. What could be the probable reason for drought in your area?

--

10. Do you practice shifting cultivation or permanent?

--

11. If shifting, then do you clear forest cover? Or practice in old rejuvenated land?

--

12. Have you witnessed drying of streams due to deforestation in your area?

Yes/No

13. If yes, then how many streams are dried?

1	2	>3
---	---	----

--	--	--

14. Does the drying of streams had affected the farming practices in your area?

If Yes, then explain:

15. Does your area experiences soil erosion and prompt flood due to deforestation?

--

16. Has the erosional and flooding activity devastated your crops?

If Yes, then explain:

Soil loss	Crop damage	Water inundation	Any other

17. Has deforestation caused temperature variations (rise/fall) in your village?

Yes/No

18. Is the temperature variations affects the farming practices in your area?

Yes/No (if yes, explain)

19. What could be the other factors for temperature variations in your area other than deforestation?

--

20. What is the cause of flooding in your village?

Deforestation	Land use	Unscientific agriculture	Any other

21. Do you think that due to rise in temperature tropical crops could be or are grown due to climate suitability in your area in recent years?

--

6. Information related to sustainability and climate resilient farming systems

1. How can the flooding be controlled in your village?

Afforestation	Check Dams	Any other remedies

2. What type of forest/vegetation is located in the upstream of the water sources?

No Forest	Scattered Forest	Dense Forest

3.. How do you think that the afforestation could help in sustainable farming systems?

--

4. Do you think that the stream rejuvenation could be done through afforestation?

Yes/No (if yes, explain)

5. Have you ever thought of reviving forest cover and stream in your village? If yes, what was the result?

Action taken	Action not taken	Any other measures

6. Do you think that the use of chemical fertilizers is deteriorating the organic components of endemic soil?

If yes, then explain:

7. What possible steps could be adopted to retain the soil fertility and conservation of soil?

--

8. Do think that the use of insecticides and pesticides is harmful for the environment?

--

9. Did the livestock suffer any kind of complications after consuming crops having insecticides and pesticides?

--

10. Do you think that the use of these harmful supplements may pose higher health risk?

--

11. Would you go for organic farming or modern farming?

--

12. Does your area witnessed any environmental changes due to adoption of modern farming systems?

--

13. Adaptation of appropriate mitigation technologies such as the cultivation of tolerant breeds to could overcome the climate stress?

--

14. What are your thoughts on sustainable farming?

--

15. Do you think that the climate change is a threat to agriculture practices?

16. How do you think that we can overcome/tackle climate change in relation to farming systems?

Signature of the field investigator,

Signature/Thumb
impression of the
respondent

BIO-DATA

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Sl. No	Title with page nos.	Name of the Journal/Book	ISSN/ISBN No	Year of Publication	Remark
1	Impact of Water Mills on Rural Livelihood: A Study of Arunachal Himalaya	Indian Journal of Traditional Knowledge	0975-1068	2024	Scopus Indexed
2	Tools and Techniques Involved in the Manufacturing of Traditional Watermills (Chhoskor) in West Kameng District, Arunachal Pradesh	International Journal of Intangible Heritage	1975-3586	2024	Scopus Indexed
3	Effect of Altitude, Environment, and Soil Parameters on Morphological Characteristics and Yield of Essential Oil in <i>Elsholtzia communis</i>	Environment and Ecology	0970-0420	2023	Web of Science
4	Conservation of Water				

	Resource through Traditional Ecological Knowledge: A Case Study of the Shertukpen tribe, West Kameng District, Arunachal Pradesh (India)	Unveiling the Mystique: Diversity in Geography of NE India	9798895446676	2025	Department of Geography, Rajiv Gandhi University (Book Chapter)
5	Impact of Climate and Soil on Agriculture in West Kameng District, Arunachal Himalaya	International Research Journal of Multidisciplinary Scope	2582-631X	2024	Scopus Indexed
6	The Roles of Cash Crops in Enhancing Livelihood in Arunachal Himalaya	Food & Agribusiness Management (FABM)	2716-6678	2025	Zibeline International Publication/ International peer review
7	The Role of Traditional Ecological Knowledge in Forest Conservation Practices: A Study of the Shertukpen Tribe in Arunachal Himalaya	Himalayan Bulletin, Geographical Society of Central Himalaya	UK0600332021005726	2025	--

Paper Presented:

Sl. No	Title of the Paper presented	Title of Conference/Seminar	Organised by	Whether International/ National/ State/Regional/ college
1	Agroecology: Enabling Sustainable Farming Systems: A Study of Tawang District of Arunachal Pradesh	Climate Change, Environment & Development: Indian Perspective	Department of Geography & RM, Mizoram University	National
2	A Suitability Assessment of Climate and Soil on Agricultural Production of Western Arunachal Himalaya	Climate Change and Natural Resources Management for Sustainable Development (ICNS-2024)	School of Earth Sciences & Natural Resources Management, Mizoram University	International
3	The Role of Cash Crops in Enhancing Livelihood in Arunachal Himalaya	Recent Advances in the Development of Environment and Natural Resource Management	School of Earth Sciences & Natural Resource Management, Pachhunga University College, MISTIC, and Directorate of Science and Technology, Govt of Mizoram	International

CERTIFICATE

PROUDLY PRESENTED TO :

Norbu Jamchu Thongdok

Research Scholar, Mizoram University

for Presenting at the "Two Days International Conference on Recent Advances in the Development of Environment and Natural Resource Management", on the topic 'The Role of Cash Crops in Enhancing Livelihood in Arunachal Himalaya'.

Dated: 4th & 5th February 2025

Organized by

School of Earth Sciences and Natural Resource Management
Pachhunga University College in Collaboration with MISTIC, Directorate
of Science and Technology, Govt. of Mizoram

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Mr. Naban Jambon Thangdok, Research Scholar

This is to certify that

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has presented a paper entitled

*Agriecology: Enabling Sustainable farming systems: A study of Jharkhand
administered by Ambedkar Pradesh*

at the National Seminar on 'Climate Change, Environment & Development: Indian Perspectives' held on April 25th & 26th, 2023 at Mizoram University, Mizoram

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RESEARCH ARTICLE

THE ROLE OF CASH CROPS IN ENHANCING LIVELIHOOD IN ARUNACHAL HIMALAYA

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ARTICLE DETAILS

Article History:

Received 10 January 2025
Revised 15 February 2025
Accepted 19 February 2025
Available online 18 March 2025

ABSTRACT

The role of cash crops in livelihood enhancement in the mountainous areas of the Arunachal Himalaya is prominent due to declining production and productivity of the traditional crops. This study examines the role of cash crops in the socio-economic conditions of marginal farmers and how they can enhance livelihood sustainability. A purposive random sampling method was employed and a field-level survey was conducted. The per-capita production (PCP) of crops and farmers' per-capita income (PCI) were calculated. Multiple Regression Correlation (R^2) was applied to examine the relationship between elevation and crops in varying altitudinal zones. The results show a positive correlation (P -value); elevation with P -value of 0.098; tomato at $P=0.501$; potato at $P=0.744$; cabbage at $P=0.422$; green beans at $P=0.221$; chilies at $P=0.664$; and cereals at $P=0.664$. The study reveals that the modern farming system of cultivating cash crops has enhanced the socio-economic conditions of the farmers, and improved livelihood sustainability. This study suggests that more arable land can be devoted to cash crops, using organic manure, and providing adequate markets and irrigation facilities, which will lead to high productivity of crops. Subsidies to farmers for purchasing seeds and compensating during crop failure will enhance livelihood sustainability.

KEYWORDS

Arunachal Himalaya, livelihood, cash crops, commercial farming, revenue.

1. INTRODUCTION

'Livelihood' refers to efficient food and cash to meet basic needs (Chambers, 1995). A livelihood includes the capabilities, assets (financial, physical, human, natural resource, and social), and activities required for living (Chambers and Conway, 1991). Livelihood comprises the capabilities, assets (stores, resources, claims, and access), and activities required for living. Sustainable Livelihood (SL) attempts to go beyond the conventional definitions and approaches to poverty eradication (Krantz, 2001). Livelihood is sustainable when it can cope with and recover from stresses and shock; can maintain or build on available capabilities and assets, and does not undermine the natural resource base (Sati, 2014). Furthermore, it includes access to the content's resources, materials, and services (Ellis, 2000).

The cultivation of cash crops is a farming and growing crop that intends to sell the produce for profit in the local or export market (Kumari, 2015). It can be defined as the set of agricultural practices that include cultivating vegetables, fruits, herbs, ornamental plants, tree and flower seedlings, and livestock rearing (Ulm et al., 2019). Development experts and policymakers frequently assert that encouraging the growth of cash crops to create jobs in rural areas can reduce poverty and enhance food security, such as the growing of palm oil in the northern lowlands of Guatemala has improved the economic status of the people (Hervas and Isakson, 2020). It's common knowledge that cultivating and selling commercial crops can improve "capabilities" to obtain food more effectively. Cash crops can play a large role in economic development and livelihood enhancement and can be the major source of livelihood for the majority of the population (Gc, 1978; Cosic et al., 2017).

The Himalayan region has a rich agro-climatic condition for growing

various high-yield crops, which have high economic value (Sati, 2014). A majority of people in the Himalayan region are engaged in practicing traditional agriculture. On the other hand, the agricultural lands are small and they are terraced with the domination of the cultivation of subsistence cereal crops, vegetables, and fruits. All crops are consumed domestically as their production is very nominal. The arable land is very less whereas, it is highly significant from the point of its impacts on livelihoods (Saxena et al., 2005; Sati, 2014). Meanwhile, in the recent past, the farmers have shifted their traditional croplands into the cultivation of cash crops whereas the pace is slow. In some Himalayan states, agricultural diversification towards high-value crops i.e. fruits and vegetables including off-season vegetables has increased at a fast rate and noticeably affected the status of farmers as their livelihood security increased manyfold (Sharma and Chauhan, 2008; Chaudhary and Singh, 2020).

Agricultural development in Northeast India has not yet reached its full potential. The majority of farmers, who belong to the tribal communities have long adopted the cultivation of high-yield crops so far although they practice organic farming with limited production (Kadirvel et al., 2020). In Arunachal Himalaya, over 75% of the population is engaged in agricultural practices. However, rough and rugged terrain, erratic climate, and declining soil conditions have made it difficult to achieve agricultural stability and success. These difficulties have been made worse in recent years by the effects of climate change, endangering the livelihoods of several indigenous farmers.

The West Kameng district of the Arunachal Himalaya has substantial agriculture and horticulture potential due to the favorable climate. Large-scale cultivation of apples owing to suitable agro-climatic conditions ranked it fourth in the national production. Furthermore, Kiwifruit, which is an economically important crop, is being successfully grown along the

Quick Response Code



Access this article online

Website:
www.fabm.org.my

DOI:
10.26480/fabm.01.2025.26.34

hilly terrain. The West Kameng district is rich in a variety of plant species and is regarded as a global hotspot for biodiversity. The majority of the region's soil is rich in organic carbon and other vital nutrients for plants, such as potassium and magnesium. Various crops in the West Kameng district are grown, including field crops, fodder crops, fruits, vegetables, spices, and medicinal plants (Myers et al., 2000).

Tomato production has increased and it plays a significant role in improving the socio-economic conditions of farmers in the West Kameng area of Arunachal Pradesh. It has been noted that the commercialization of tomatoes along with other cash crops will have a favourable impact on socioeconomic development. Moreover, cultivating tomatoes has contributed to employment opportunities for the residents of the study area in particular and outsiders in general (Mody and Norbu, 2015). The district has suitable climatic conditions for growing crops such as Apples, Pears, Plum, Pineapple, Orange, Grapes, and Kiwi and Vegetables like-Cabbage, Cauliflower, Beans, Tomato, Radish, Beans, Chilies, Ginger, etc. (Nimasow et al., 2014).

In recent years, the West Kameng district has witnessed noticeable changes in farming systems due to the increasing population and limited food supply. Therefore, farmers have transformed their farming patterns from subsistence to cash crops because most cash crops have high-yielding potential and high productivity. Generally, such crops are GM (genetically modified) and are resistant to harsh climatic conditions,

which can be sustained in different climatic conditions. The paper aims to examine the role of cash crops in enhancing the livelihoods of the farming communities in the West Kameng district of the Arunachal Himalaya. It also studies the factors affecting the cultivation of cash crops. This study encompasses a wide range of perspectives on transforming agriculture systems, such as the declining culture of traditional crops and the introduction of cash crops.

2. STUDY AREA

The West Kameng is located on the western fringes of Arunachal Pradesh, spanning between 27°34'28" N and 92°30'24" E (Figure 1). The physiography of the district is mostly undulated and mountainous and the elevation ranges between 213 m (840 feet) up to 4081 m (13,500 feet) above mean sea level. The district accounts for 8.86% of the state's total area and covers an area of 7422 sq. km., and total agricultural land covers an area of 1109 sq km i.e., 14.4 % of the total land area. The district is characterized by various types of climatic conditions - Alpine (>3500), Temperate sub-alpine (1500-3500), Sub-tropical hill (1000-1500), and Mid-tropical

hill (200-800). The maximum and minimum temperatures vary from 25 °C to -5 °C. The area receives an average rainfall of 1260.35 mm/year up to 1989.01 mm/year.

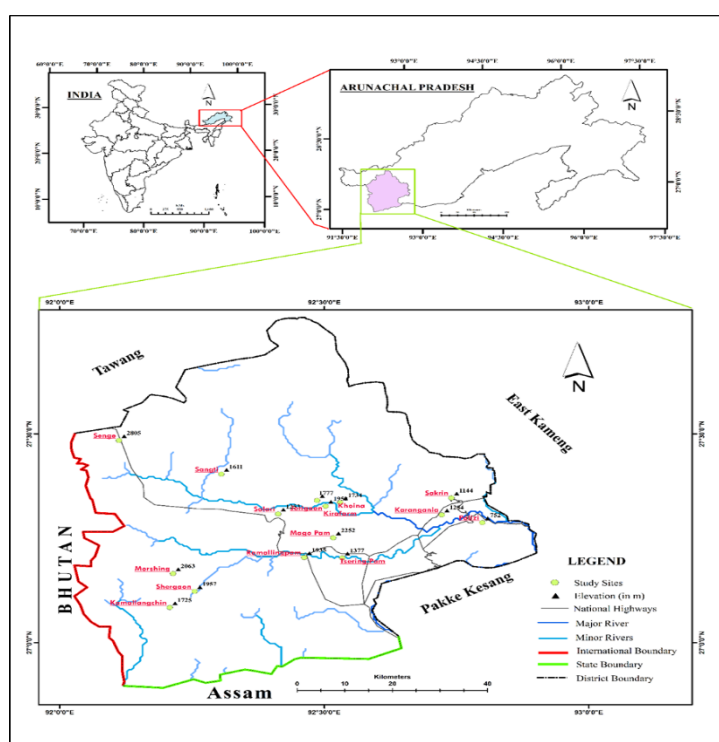


Figure 1: Map of the West Kameng district, Arunachal Pradesh

As per the 2011 Census, the district's total population was 83,947 (46155 males and 37792 females) constituting 6.0 percent of the State Population spread over 7422 sq. km. area of the district. Among the thirteen circles of the district, Dirang (18401) is the most populated circle and Kamengbari-Doimara (316) is the least populated circle. Other circles in order of their population size are Singchung, Bomdila, Nafra, Rupa, Kalaktang, Bhalukpong, Jamiri, Thrizino, Shergaon, Thembang and Balemur Circles. Out of the total population of 83,947 of the districts, 81 percent resides in the rural areas and 19 percent in the urban areas. The decadal growth rate of the district is 12.5 percent and it has a density of 11 persons per sq. km and a sex ratio of 819 females per thousand males. (Census of India, 2011).

3. MATERIAL AND METHODS

Both primary and secondary data were collected. Primary data were obtained through on-field interviews with the farmers, with the help of both open- and closed-ended questionnaires. A purposive sampling technique was adopted to carry out the survey, where agriculture hotspot villages and farmers were surveyed during the year 2023 in the West Kameng district of Arunachal Pradesh, India (Table 1). A systematic random sampling was done, and the sample size was determined at thirty-five percent of the total number of households in a village. Questions were formulated on the farming pattern of cash crops, and the declining trend of traditional crops. Relevant existing literature was reviewed for the background of this article as a secondary data source. Such as articles and books from various online sources, moreover, information was also generated from the Census of India, and the Statistical District Handbook of West Kameng district, Arunachal Pradesh.

Table 1: Salient features of the West Kameng district

Village	CD Block	No of the HHs surveyed	Total number of HH	% of HH surveyed	Elevation (in m)	Location
Morshing	Kalaktang-Rupa	13	35	35	2063	27°10'26"N;92°12'23"E
Kamallangchin	Block	19	54	35	1725	27°09'58"N;92°15'76"E

Table 1 (cont): Salient features of the West Kameng district

Shergaon		38	106	35	1957	27°14'71"N;92°27'95"E
Ramallingam	Sinchung	7	20	35	1935	27°18'38"N;92°46'51"E
Tsering Pam	Block	11	30	35	1377	27°20'24"N;92°49'47"E
Mago Pam		14	40	35	2252	27°24'96"N;92°52'34"E
Salari	Dirang	53	149	35	1253	27°32'58"N;92°43'76"E
Sangti	Block	74	210	35	1611	27°24'10"N;92°16'40"E
Senge		56	160	35	2805	27°44'75"N;92°17'95"E
Jerigaon	Nafra Block	41	117	35	1777	27°33'94"N;92°47'95"E
Kirafarm		12	35	35	1950	27°35'50"N;92°47'69"E
Khoina		13	36	35	1734	27°35'75"N;92°48'61"E
Karangania	Thrizino Block	11	29	35	1284	27°17'56"N;92°42'26"E
Sakrin		21	59	35	1144	27°21'03"N;92°43'35"E
Palizi		40	112	35	752	27°17'30"N;92°46'46"E
	Σx=	423	1192	35.48		

Source: Primary field survey 2023

4. DATA ANALYSIS

Various statistical techniques and measures were applied to this study. Likewise, descriptive statistics was used to summarize and present complex data in a way that is easier to understand, such as the mean value of crop production. The statistics were formulated using SPSS software.

Mean,

$$\bar{x} = \sum x/n$$

Multiple regression (R^2) was applied to determine the relationship between a dependent variable and multiple independent variables, such as elevation with different commercial crops.

Multiple regression,

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3$$

Moreover, to examine the revenue generated from the commercial crops of the farmers, simple per-capita formulas were used;

Per-capita production;

$$P_{\text{per capita production}} = \text{Total Production} / \text{Population}$$

Per-capita income;

$$PCI = \text{Total Income} / \text{Population}$$

5. RESULTS AND DISCUSSION

5.1 Socio-economic status

The study was formulated only for the farming communities of the district, therefore, understanding their social status, educational level, and occupation is of immense significance. During the study, four hundred twenty-three households were surveyed, out of which two hundred forty-eight were males and one hundred seventy-five were females. The percentage of males was higher than that of females. The study reveals that most of the commercial farming practices were carried out by males, and concerning traditional cereal crops such as foxtail millet, finger millet, maize, and paddy the higher percentage were found to be females. Table 2 depicts the educational level of the farmers.

5.2 Education

The below (Table 2) illustrates the educational level as follows; 19.85 % were illiterate, 38.06 % had primary education, 29.32 % had secondary education, 11.35 % had higher education, and 0.95 % had graduated.

Table 2: The educational level (n=15 villages)

Level of education	Number	%
Illiterate	84	19.85
Primary	161	38.06
Secondary	124	29.32
Higher	48	11.35
Graduate	4	0.95
Total	423	100

Source: Primary field survey 2023

5.3 Occupation

The study found that the occupational patterns of the villagers vary with changing seasons. During the summer and monsoon seasons, they are mainly engaged in agricultural activities, and during the dry and winter seasons, they shift their occupation to daily wages and small business. Both occupations are complex yet very important in terms of their livelihood and earnings. During the winter season, the temperature of the region goes negative which makes it difficult to grow any type of crops,

and because of that people have to shift their occupations to other non-agriculture activities. The study shows that 58.63 % of the Male population and 41.37 % of the Female population are engaged in agricultural activities, the Male population accounts for the highest percentage of Females. During the off-farming season, 41.68 % are engaged in daily wage activities, 31.45 % are engaged in business activities, and 23.87 % are engaged in GREF works. Hence, Table 3 represents the occupational structure of the farmers.

Table 3: Occupational structure

Village	Agriculture practice		Non-agricultural practices		
	Male	Female	Daily wage	Businesses	GREF works
Morshing	9	4	8	3	2
Kamallangchin	14	5	10	5	4
Shergaon	27	11	4	33	1

Table 3 (cont): Occupational structure

Ramallingam	5	2	3	1	3
Tsering Pam	5	6	6	3	2
Mago Pam	7	7	6	4	4
Salari	35	18	21	10	22
Sangti	53	21	35	25	14
Senge	30	26	30	10	16
Jerigaon	20	21	20	12	9
Kirafarm	5	7	7	2	3
Khoina	7	6	7	3	3
Karangania	5	6	5	3	3
Sakrin	9	12	11	6	4
Palizi	17	23	16	13	11
Σx =	248	175	189	133	101
% =	58.63	41.37	44.68	31.45	23.87

Source: Primary field survey 2023

5.4 Crop diversity and agro-climatic zones

The West Kameng district is ornamented with rich natural resources, such as fertile soil, favorable climatic conditions, vegetation, and convenient agro-climatic zones, which support various agriculture and horticulture crops. The district is also known as the 'agriculture bowl' of the state due to its rich and distinct agriculture practices. Practices of both traditional and modern or newly introduced cash crops; conventional crops like foxtail millet, finger millet, maize, and paddy are the least dominant crops

compared to non-conventional or cash crops like Tomato, Potato, Cabbage, and Chilies, which are predominantly practiced in the region. The district is endowed with diverse climatic conditions and zones concerning increasing altitudes that support various agriculture and horticulture crops. Certain type of crops requires specific altitudes and underlying climatic conditions; sub-tropical, sub-temperate, temperate, and cold are the four major climatic zones found in the district. Table 4 shows the farming practices of different crops.

Table 4: Crops in different altitudes and agro-climate zones

Altitude (in m)	Agro-climatic zone	Crops	Local name	Botanical name
< 1000	Sub-tropical	Tomato	<i>Blati</i>	<i>Solanum lycopersicum</i>
		Green beans	<i>Fam-fla</i>	<i>Phaseolus vulgaris</i>
		Cabbage	<i>Gobi</i>	<i>Brassica oleracea</i>
		Chilies	<i>Mong-oho</i>	<i>Capsicum annuum</i>
		Foxtail millet	<i>Daa-chhak</i>	<i>Setaria italica</i>
		Finger millet	<i>Gaa-chham</i>	<i>Eleusine coracana</i>
		Maize	<i>Pheng-tong</i>	<i>Zea mays</i>
1000-1500	Sub-temperate	Tomato	<i>Blati</i>	<i>Solanum lycopersicum</i>
		Potato	<i>Juu</i>	<i>Solanum tuberosum</i>
		Cabbage	<i>Gobi</i>	<i>Brassica oleracea</i>
		Chilies	<i>Mong-oho</i>	<i>Capsicum annuum</i>
		Green beans	<i>Fam-fla</i>	<i>Phaseolus vulgaris</i>
		Foxtail millet	<i>Daa-chhak</i>	<i>Setaria italica</i>
		Finger millet	<i>Gaa-chham</i>	<i>Eleusine coracana</i>
		Maize	<i>Pheng-tong</i>	<i>Zea mays</i>
		Paddy	<i>Ge-shey</i>	<i>Oryza sativa</i>
1500-2000	Temperate	Tomato	<i>Blati</i>	<i>Solanum lycopersicum</i>
		Potato	<i>Juu</i>	<i>Solanum tuberosum</i>
		Cabbage	<i>Gobi</i>	<i>Brassica oleracea</i>
		Chilies	<i>Mong-oho</i>	<i>Capsicum annuum</i>
		Green beans	<i>Fam-fla</i>	<i>Phaseolus vulgaris</i>
		Foxtail millet	<i>Daa-chhak</i>	<i>Setaria italica</i>
		Finger millet	<i>Gaa-chham</i>	<i>Eleusine coracana</i>
		Maize	<i>Pheng-tong</i>	<i>Zea mays</i>
>2000	Cold	Potato	<i>Juu</i>	<i>Solanum tuberosum</i>
		Cabbage	<i>Gobi</i>	<i>Brassica oleracea</i>
		Chilies	<i>Mong-oho</i>	<i>Capsicum annuum</i>
		Maize	<i>Pheng-tong</i>	<i>Zea mays</i>
		Paddy	<i>Ge-shey</i>	<i>Oryza sativa</i>
		Foxtail millet	<i>Daa-chhak</i>	<i>Setaria italica</i>
		Finger millet	<i>Gaa-chham</i>	<i>Eleusine coracana</i>

5.5 Principal crops-area, and production

The region supports the cultivation of diverse crops, some of the crops are Indigenous which the farmers have been practicing for centuries, on the other hand, several crops are newly introduced and their practices are expanding yearly. The study found that the production of traditional crops is decreasing, meanwhile, the production of freshly introduced crops is skyrocketing due to higher demand in the local markets, leading farmers

to cultivate more for higher production to meet the rising demand—such as cash crops like tomato, potato, cabbage, and chilies, all these crops have very high demand thus, the area of cultivation and production is increasing at a tremendous rate. Therefore, the value and demand of traditional cereal crops, like millet and maize have considerably narrowed in recent years. Table 5, 6, and Figure 2 show the principal crops and their production in different villages.

Table 5: Village-wise area, crops, and production of principal crops

Village	Area (in ha)	Crop production (in tons)					
		Tomato	Potato	Cabbage	Green beans	Chilies	Cereals
Kamallangchin	3.092	156.35	10.49	97.9	--	37.9	1.8
Morshing	1.076	56.8	14.46	37.75	--	0.435	12.9
Shergaon	1.085	139.8	44.265	64.3	--	0.86	--
Ramallingam	0.13	24.25	6.25	17.5	--	--	--
Tsering Pam	0.091	37.25	--	27.5	--	--	--
Mago Pam	0.34	48.25	--	62.25	--	34.34	--
Salari	0.40	183.85	--	51.5	--	0.863	5.15
Sangti	0.66	160.75	29.5	57.5	--	2.269	20.78
Senge	0.51	--	--	52.3	--	--	19.93
Jerigaon	0.26	19.28	--	14.46	0.078	15.78	20.76
Kirafarm	0.15	17.53	--	15.98	0.065	13.42	18.86
Khoina	0.14	11.24	--	12.34	0.017	9.78	21.11
Karangania	0.10	--	--	5.6	0.046	0.98	7.12
Sakrin	0.06	--	--	7.8	0.56	1.12	8.9
Palizi	0.20	5.87	--	10.5	0.67	1.87	7.5
Σx =		861.22	104.97	535.18	1.436	119.68	144.81

Source: Primary field survey 2023.

Table 6: Net annual production of cash crops

Sl. No	Crops	Area (ha)	Annual Production (in tons)	Productivity (tons/ha)
1.	Tomato	8.294	861.22	103.84
2.	Potato	6.043	104.97	17.38
3.	Cabbage	8.294	535.18	64.53
4.	Green beans	0.91	1.436	1.57
5.	Chilies	7.563	119.68	15.83
6.	Cereals	6.648	144.81	21.79
	Σx =	37.76	1767.228	224.94

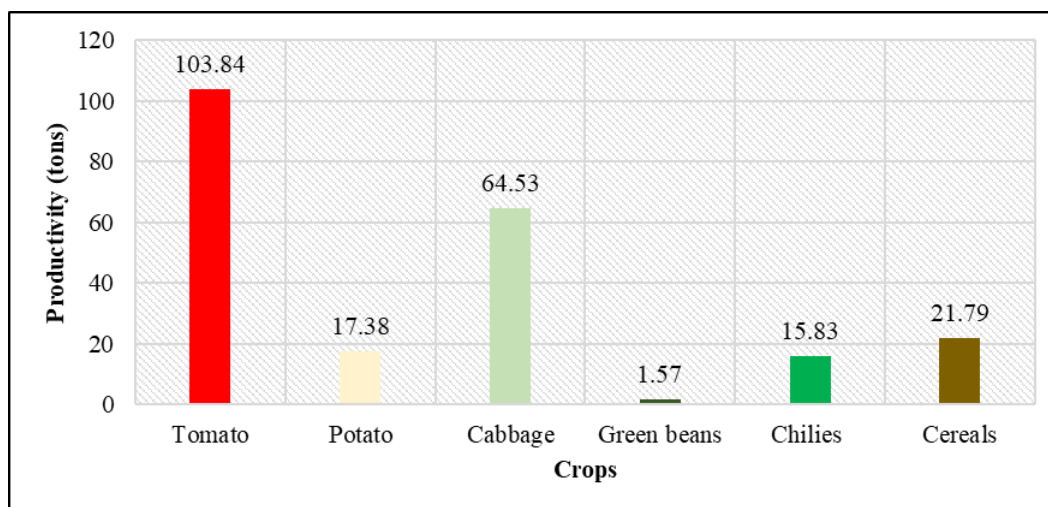


Figure 2: Productivity of principal crops

Different crops have different growing and yielding seasons, and therefore the major crops found in the study area may be categorized as follows; the growing season of tomatoes starts in March and lasts till the end of October; potatoes are sown during the initial days of December, and

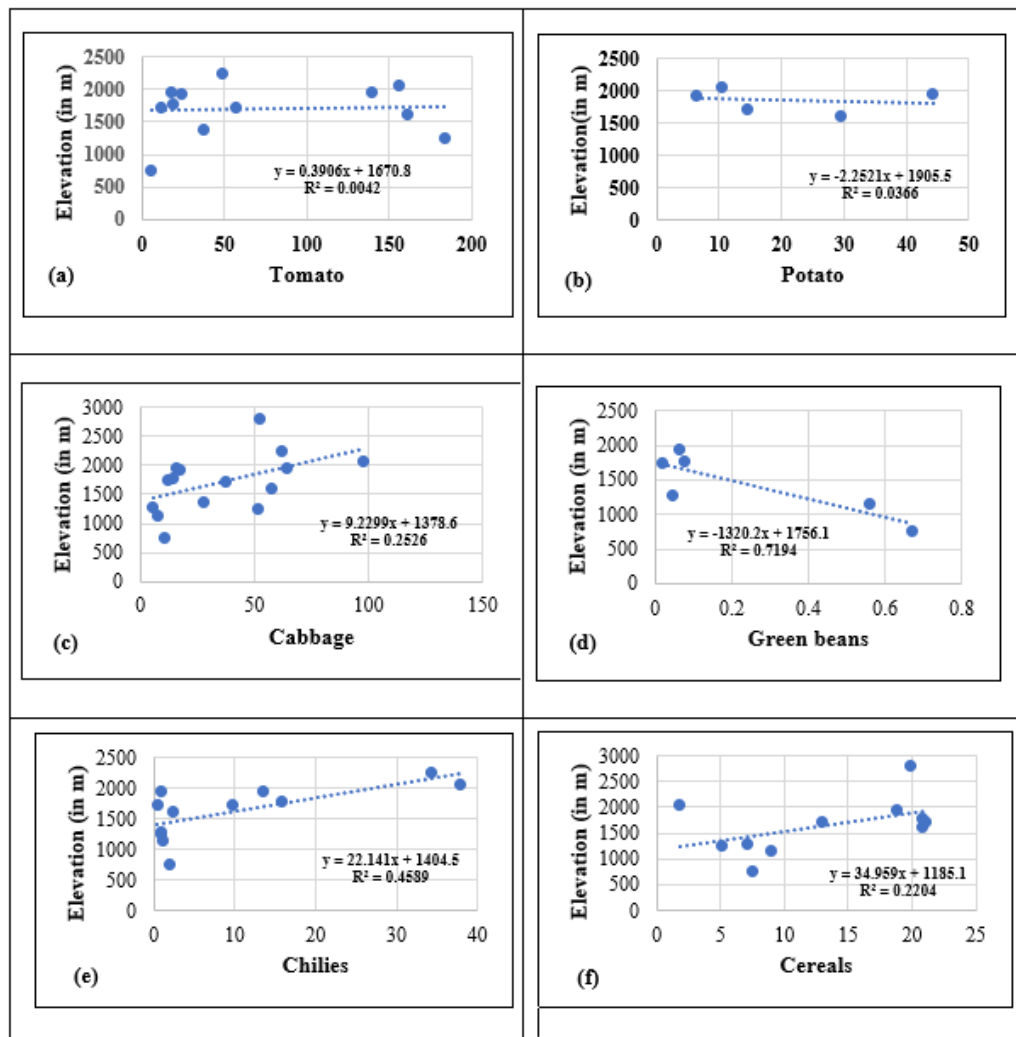
harvested in May; growing season of cabbage starts from the end of April and lasts till October; green beans begin from May and harvested in late September; similarly, the growing season of chilies begins from May and lasts till the end of October, and lastly, cereals growing season starts from

(0.664). All the values are well within the alpha range i.e., between 0-1, which proves that the independent variable (elevation) greatly affects the production and yield of dependent variables (crops). (Table 10 and Figure

3) show the elevation's regression statistics and scatter plot with different cash crops.

Table 10: Multiple regression (R^2) of the Elevation, and crops

Variables	Unstandardized Coefficients	Standardized Coefficients	t	P-value
	B	Std. Error	Beta	
Elevation	1709.959	265.422	--	6.442
Tomato	-5.353	5.362	-1.820	-0.998
Potato	4.765	11.212	0.405	0.425
Cabbage	11.350	9.437	1.853	1.203
Green beans	-725.541	412.960	-0.466	-1.757
Chilies	20.163	39.624	0.295	0.509
Cereals	20.219	40.127	0.303	0.504



*Alpha=0-1

Figure 4: Multiple regression (a) tomato (b) potato (c) cabbage (d) green beans (e) chilies (f) cereals.

Farming has historically been a primary source of livelihood for rural communities. Traditionally, farming was primarily subsistence-based, with crops grown mainly for self-consumption. However, modern farming has shifted towards cash crop agriculture, where crops are produced mainly for sale in the market. This shift has led to a decline in the cultivation of traditional crops, as farmers are increasingly drawn to high-demand, high-value cash crops. These crops offer significant economic benefits to farmers due to their strong market demand and higher per-unit value.

The introduction of cash crops, such as tomatoes, potatoes, cabbage, green beans, chilies, and cereals, has significantly transformed the agricultural landscape of West Kameng district. These crops are well-suited to the region's climate and can yield high returns, even on small plots of land. As a result, the adoption of these crops has boosted the income and livelihood

of the local farming community, which heavily relies on agriculture. The high market demand for these crops ensures their economic viability, contributing to the financial stability and improved living standards of the farmers. Compared to traditional crops, cash crops offer higher profit margins and reliability, making them increasingly popular among farmers in the region.

The increasing demand for modern crops has driven a shift from traditional to contemporary farming practices. Farmers are now prioritizing high-yielding crops like tomatoes, potatoes, cabbage, and chilies, which have higher market value compared to indigenous crops such as beans and millet. The introduction of genetically modified seeds has further accelerated this trend, allowing for increased production and better adaptability to various climatic conditions. As a result, commercialization has become a significant factor in shaping modern

agriculture, prompting farmers to expand their cultivation areas and focus on crops that are in high demand and fetch higher prices. As a result, several traditional crops (mostly cereal grains) have now completely disappeared and those crops are replaced by modern commercial cash crops (Thongdok and Sati, 2024).

Recent years have witnessed a significant shift from traditional to cash crop farming practices in the district. The introduction of cash crops has transformed the agricultural landscape, leading to increased wealth and improved living standards for the local farming community. Several pieces of evidence can be found worldwide regarding the advantages of cash crop farming and their economic incentives. A study conducted by a research explains the benefits of small cash crop farming enterprises and their implications for farmers (Shoko, 2022). Similarly, a study led by discusses how Chinese agriculture is experiencing a transition from smallholder farming to the emergence of cash crop farms that are characterized by intensification and specialization in production, as well as commercialization (Peng et al., 2022). A group researchers also debate the importance of commercial farming to increase food production in the coming years with minimal environmental impact (Moreira et al., 2023).

In addition, a group researcher explain the cluster farming of crops in small land-holding and their commercialization in the economic integration of small land-holders in Ethiopia (Dureti et al., 2023). Correspondingly, deliberate the significance of the commercialization of agriculture, forestry, and livestock in South Asia (Datta and Behera, 2024). Moreover, some researchers debates the significance of mixed farming systems and their positive implication for the livelihood of the Garhwal area in the Central Himalayan region (Sati, 2024). In the same way, work carried out by most of researcher depicts the changing agriculture scenario and commercialization of agriculture production in the prospects of the farmers in particular and society as a whole (Myers et al., 2000; Nimasow et al., 2014; Sati, 2015; Babu et al., 2023; Wangchu et al., 2024; Nguyen, 2024).

Cash crops offer immense potential to improve rural livelihoods. These crops are economically viable and generate significantly higher revenue compared to traditional crops. Their adaptability to various environments makes them a reliable source of income for farmers. As the number of farmers adopting cash crop cultivation continues to grow, it plays a crucial role in ensuring their financial stability and sustainable livelihoods. Promoting sustainable practices in cash crop farming can further enhance agricultural development in the region.

6. CONCLUSIONS

The study concludes that cash crops have significantly contributed to improving farmers' livelihoods in the district. Introducing these high-yielding crops has boosted farmers' income and economic viability. However, while cash crop farming is thriving, it lacks modern techniques and infrastructure for sustainable agricultural development. To address this, there is a need to promote awareness of modern farming practices, revive traditional and organic farming methods, and provide farmers with access to arable land, organic manure, irrigation facilities, and market linkages. Additionally, subsidies for seeds and crop insurance can further enhance the sustainability of farming livelihoods.

ACKNOWLEDGMENTS

The authors thank the Department of Geography and Resource Management of Mizoram University (Central), Mizoram for encouraging and providing infrastructural facilities for conducting research. The authors also acknowledge the people and farmers of West Kameng district, Arunachal Pradesh, Northeast India for their kind cooperation. Also, the authors appreciate the District Agriculture Office, Bomdila, Arunachal Pradesh, and Accredited Social Health Activists (ASHA) for providing the necessary information.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest with the publication of this article.

DATA AVAILABILITY

Data is available and may be provided if necessary.

AUTHOR CONTRIBUTION

Norbu Jamchu Thongdok contributed substantially to the conception or design of the work, acquisition, analysis, and interpretation of data. Vikrant Kumar initiated the map. Whereas, Vishwambhar Prasad Sati revised the work and finalized the manuscript. The authors declare that both authors made significant contributions to the work.

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Article in International Research Journal of Multidisciplinary Scope · November 2024

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Impact of Climate and Soil on Agriculture in West Kameng District, Arunachal Himalaya

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Abstract

Climate change navigates every sphere of the earth's surface, wherein, agriculture is the most affected entity. Such variations in temperature, humidity, and rainfall drive the nature of the soil and agricultural practices. The West Kameng district is located in the westernmost part of Arunachal Pradesh, Northeast India. The present study attempts to understand and assess whether climate and soil affect the agricultural production and yield of the study area. A field survey was carried out in fifteen villages comprised of five CD blocks. A systematic purposive sampling was applied, and agriculture hotspot villages were selected for the study. Soil samples were collected from the villages, and were laboratory assessed using the 'Oven Dry Method' (suggested by Cope and Trickett, 1965) and the 'Hydrometer Method' (suggested by Piper, 1942). Besides, climate data from 2019-2022 were tabulated and analyzed using Linear regression (R^2). The data and results show a positive correlation or relationship among the temperature, humidity, rainfall, and production, similarly, the examined soil properties also show favorable conditions for growing crops. The study paves the way for a comprehensive understanding of how certain crops respond to particular soil types and underlying climatic conditions for their growth and yield. Besides, the study also envisages sustainable and eco-friendly farming systems in the region.

Keywords: Agriculture, Climate, Resilient Agriculture, Soil, Suitability.

Introduction

Climate greatly affects an area's socioeconomic activities, particularly farming patterns and allied activities. Climate change is imminent and bound to occur, such change in a certain amount of rainfall, temperature, and humidity controls the nature of the soil and greatly peddles agriculture production and productivity in mountain regions. Mountain regions are highly vulnerable to climate change (1); climate change and its hydrological consequences may significantly modify soil conditions (2). Various studies have been conducted on climate change and crop suitability, whereas weather and climate's impact on food production have examined the influence on crop yields. However, climate influences all components of crop production, including cropping and cropping intensity (3), as such altered and unpredictable weather patterns can increase crop vulnerability and the effects of extreme climate events such as high temperatures, droughts, and torrential rains. Moreover, sequential extremes, such as intense flooding rains, are catastrophic in themselves and are

compounded by ecological effects that affect human populations and agricultural production (4).

In particular, under rain-fed conditions, the production potential of a crop depends on the climatic conditions of an area (5); therefore, each crop will thrive within a specific climatic envelope that can be enhanced by management—yet climate change will alter satisfaction of these requirements and subsequently, the geography of crop suitability (6). Climate change impacts crop production and yields directly and indirectly; thus, land capability is expected to decrease under climate change, and summer crops are expected to be more sensitive to climate change than winter crops (7). Crop suitability assessment models can indicate the best locations to grow different crops and, in doing so, support efficient use of land to leave space for or share space with, nature (8). Thus, assessing agricultural suitability and yield under climate change is crucial for sustainable agricultural production (9). Agricultural production is under threat due to climate change in food-insecure

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(Received 20th June 2024; Accepted 25th October 2024; Published 30th October 2024)

regions, especially in Asian countries. Various climate-driven extremes, i.e., drought, heat waves, erratic and intense rainfall patterns, storms, floods, and emerging insect pests have adversely affected the livelihood of the farmers (10). Moreover, anthropogenic activities are contributing to current environmental problems such as climate change, natural resource degradation, including soil degradation and biodiversity loss, and environmental pollution (11). Climate change has been reported as one of many possible stressors on biodiversity and agriculture practices in the Eastern Himalayas. The average temperature has risen by 0.2 to 0.8 °C/decade, the maximum temperature has increased by 0.1 to 0.9 °C/decade, and the minimum temperature has increased from 0.1 to 0.6 °C/decade during the period 1965–2000 in Eastern Himalaya (12, 13). Studies conducted in the Senapati district in Manipur and East Sikkim district in Sikkim show remarkable changes in the climatic variables over the years (14).

The study emphasizes the West Kameng district because it is known as the 'agriculture bowl' of the state of Arunachal Pradesh, due to favorable natural elements like soil and climatic conditions, the region supports varied agriculture and horticulture practices, and various cruciferous and non-cruciferous crops are grown in the region, however, in the recent years the region has been experiencing abrupt change in the climatic conditions, cropping pattern, and farming systems. The explanations regarding these changes remain a mystery, therefore it is of utmost necessity to interrogate and understand, how, why, and what brought such changes in the region.

Furthermore, through this study the pivotal role of assessment of the soil would help us in precise and comprehensive understanding of the crops that are grown there are suitable for cultivation. Moreover, analyzing the climate data such as temperature, rainfall, and humidity would enlighten the trend of climate change and its implication on agriculture practices. Overall, the study would help our interpretation of the in-depth relationship between the underlying physical setting and agriculture, it would also envisage the vision of sustainable farming practices and management of natural resources.

The study aims to examine how agriculture is determined by the underlying soil and climate. In addition, the study also advocates how certain crops respond to certain soil attributes and climatic conditions. The study would analyze soil samples and examine whether the underlying soil condition is determining the agricultural production and yield, and even if the soil characteristics are suitable for growing various types of crops. Also, how farmers have shifted their farming system from traditional to modern farming systems, the study seeks to understand the factors responsible for the abandonment of the subsistence farming systems. Besides, the study attempts to analyze the trend in climate and production chain and to examine whether underlying soil conditions are suitable for the crops. Moreover, two hypotheses were assumed for the study: the climate of the study does not affect production and yield, and the underlying soil condition is not favorable for crops.

Methodology

Study Area

The West Kameng is the Southwestern district located on the western fringes of Arunachal Pradesh. It is located between 27°34'28" N and 92°30'24" E (Figure 1). The physiography of the district is mostly undulated and mountainous and the elevation ranges between 213 m (840 feet) up to 4081 m (13,500 feet) above mean sea level. The district accounts for 8.86% of the state's total area and covers an area of 7422 sq. km. And total agricultural land covers an area of 1109 sq km i.e., 14.4 % of the total land area. The district is characterized by various types of climatic conditions followed by Alpine (>3500), Temperate sub-alpine (1500-3500), Sub-tropical hill (1000-1500), and Mid-tropical hill (200-800). The maximum and minimum vary from 25 °C to -5 °C. The area receives an average rainfall of 1260.35 mm/year up to 1989.01 mm/year. As per the findings of the 2011 Census, the total population of the district is 83,947 (46155 males and 37792 females) constituting 6.0 percent of the State Population spread over 7422 sq. km. area of the district (15).

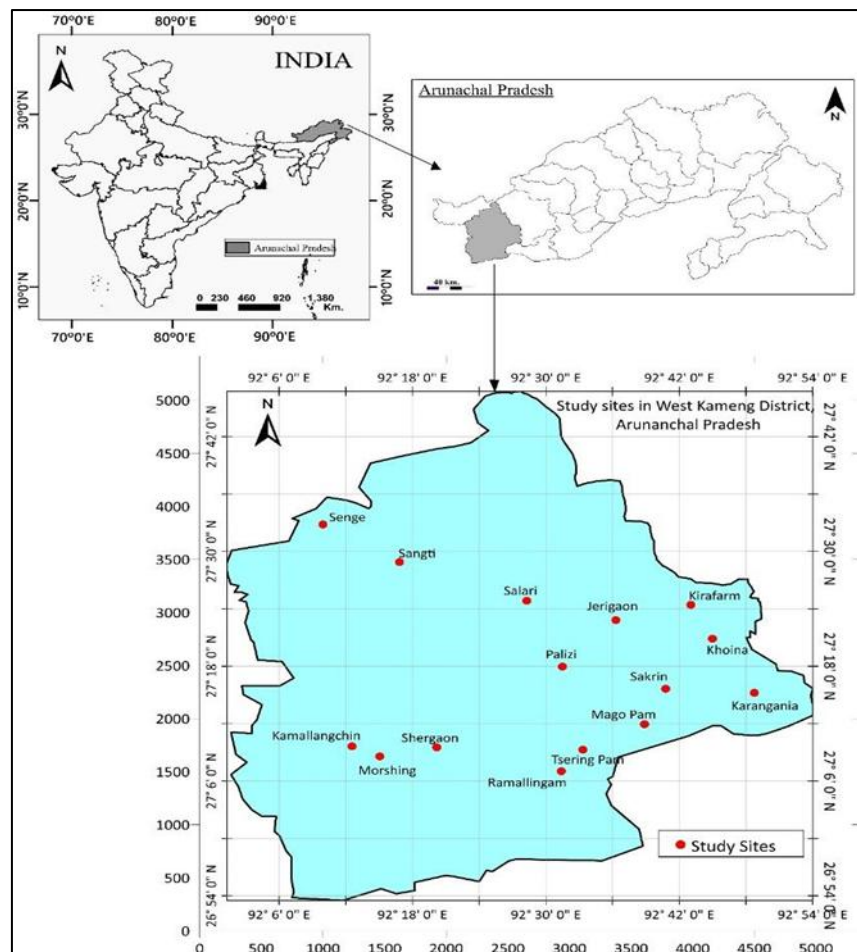


Figure 1: Map of the Study Area

Data Collection

A study on farming systems requires sophisticated data sets. For the present study, both primary and secondary data sources have been extensively applied to attain the primary objectives of this study. Five community development blocks (CD Blocks) were considered for the study, and three villages were selected from each block based on their location and agricultural practices, with a total of fifteen villages surveyed (Table 1). A purposive sampling technique was implemented where agriculture hotspot locations were targeted. A survey was carried out according to the designed schedules and objectives to achieve household and farming systems data. Moreover, soil samples were collected from all fifteen villages for moisture and

texture analysis to examine whether the soil textures suit the crops.

Secondary data related to agriculture production from 2019-2022 were obtained from the District Agriculture Office, Bomdila, West Kameng district, Arunachal Pradesh. In addition, monthly data on temperature, humidity, and rainfall from 2019-2022 were obtained from Meteorological Centre, Itanagar, Arunachal Pradesh, *NASA Data Access Viewer (16)*, Rural Works Department, West Kameng district, Arunachal Pradesh, Office of the Agriculture and Horticulture officer, and Krishi Vigyan Kendra, Dirang, Arunachal Pradesh. The climate data were collected in both hard and soft records from various departments. Moreover, the Statistical Handbook of West Kameng district, Census of India, and several published research papers were considered for reference purposes.

Table 1: Salient Features of the Surveyed Villages

Sl.No	Village	CD Blocks	Location	Elevation
1.	Morshing	Kalatkang-	27°10'29" N - 92°12'58" E	2063
2.	Kamallangchin	Rupa Block	27°05'26" N - 92°12'21" E	1725
3.	Shergaon		27°07'28" N - 92°15'41" E	1957
4.	Ramallingpam	Sinchung	27°11'07" N - 92°27'34" E	1935
5.	Tsering Pam	Block	27°12'01" N - 92°29'36" E	1377
6.	Mago Pam		27°14'54" N - 92°30'55" E	2252
7.	Salari	Dirang Block	27°19'46" N - 92°26'17" E	1253
8.	Sangti		27°24'20" N - 92°16'42" E	1611
9.	Senge		27°28'53" N - 92°06'46" E	2805
10.	Jerigaon	Nafra Block	27°20'14" N - 92°28'14" E	1777
11.	Kirafarm		27°21'21" N - 92°28'33" E	1950
12.	Khoina		27°21'21" N - 92°29'22" E	1734
13.	Karangania	Thrizino	27°18'20" N - 92°43'20" E	1284
14.	Sakrin	Block	27°20'45" N - 92°44'25" E	1144
15.	Palizi		27°17'44" N - 92°46'28" E	752

Data Analysis

Data analysis is a process for obtaining raw data, and subsequently converting it into statistics for understanding the significance of the data and the study itself. Descriptive statistics, particularly Mean was used to comprehend the typical arrangement of the data set. The temperature, humidity, rainfall, and production data were analyzed using inferential statistics such as; the Multiple Regression Correlation (R^2) method used to understand the significance and correlation between the climate and crop production variables. The universal value correlation coefficient (R^2) is between -1 to +1, whereas, the analysis validated the study results in which all the values are well within the universal R-value; humidity v/s kharif with R-value of 0.4045, rainfall v/s kharif with 0.9183, temperature v/s kharif with 0.4301, temperature v/s rabi with 0.11, humidity v/s rabi with 0.302, and rainfall v/s rabi with 0.4812. Hence, the data analysis results show a strong correlation and significance among different climate and production variables, which can be validated that the climate variables strongly determine the production of the region.

Mean, $\bar{x} = \sum x/n$

Multiple regression, $Y = a + b_1X_1 + b_2X_2 + b_3X_3$

The soil samples were analyzed using the 'Oven-dry method' (17), and 'Hydro-meter method' (18). Whereas, oven dry method was used to determine the actual moisture content of the soil;

Soil moisture = Original weight (OW) – Dry weight (OD)

- The original weight of the soil is weighed on a weighing scale.
- After weighing the soil was sieved using a 2 mm sieve.
- After, sieving the soil was kept in an incubator for 24 hours at 110 °C.
- After that the soil is again weighed to determine the actual moisture content of the soil;

Soil moisture = Original weight (OW) – Dry weight (OD)

In the same way, the Hydro-meter method was used to determine soil texture primarily using a hydro-meter. The following are the steps involved in texture determination;

- Weigh out 50 grams of oven-dried soil sieved through a 2 mm sieve.
- Put the soil sample in the grinding jar and 10 ml of Sodium Hexametaphosphate along with about 400 ml of deionized water.
- Grind the sample using an electronic grinder
- Empty the mixed solution into a graduated cylinder or beaker.
- A- more de-ionized water till it reaches the 1000 ml mark on the graduated cylinder
- Cover the cylinder with a rubber bung and mix the solution by inverting it 10 times carefully.
- Let it rest undisturbed for 20 seconds.
- At 20 seconds take temperature and hydrometer readings by placing the thermometer and hydrometer into the solution for another 20 seconds.
- After taking the readings cover up the cylinder and mix it well again by inverting it 10 times.

- Let it rest for the next 2 hours undisturbed.
- On completion of 2 hours take temperature and hydrometer readings once again.

After the first 20 seconds, the sand particles settle down as the heaviest particles in the solution. The hydrometer reading at 20 seconds reflects the weight of silt and clay in the solution which are still suspended. We find the sand content by subtracting this value (weight of silt + clay) from the original weight of the soil sample (50 grams). For the calculation of sand percentage, we divide sand content from the original sample weight and multiply it by 100. Once we get the percentages of sand, silt, and clay, the values are put on a soil texture triangle to determine the textural class of the respective soil sample.

Results and Discussion

Soil and Crop Suitability

Soil analysis is an essential process to determine the physical and biological properties of soil. Also, knowing the precise soil texture and moisture requirements for growing crops is momentous and beneficial because it provides a tool to acknowledge whether the soil is suitable or not. Therefore, for the current study soil moisture, like original weight (OW) was measured from each respective village with the help of a soil testing tool

(three-way soil testing meter), and soil samples were obtained by digging 10 inches below the surface, and collected samples were subjected for laboratory analysis, where the samples were kept in the incubator for 24 hours at 110 °C, then to examine the actual soil moisture the OW was subtracted by DW and the actual soil moisture was calculated. For the texture analysis, the samples kept in the incubator for 24 hours at 110 °C, were analyzed following the hydrometer method. The soil samples collected during the study were analyzed using rigorous methods, and the results showed a positive indication because most of the textures found were loamy and clayey loam, similarly, the analyzed soil moisture was also found suitable ranging between 22.2% and 57.06%. According to the USDA (United States Department of Agriculture), the basic soil texture requirement for agriculture is loamy, and textured soil which is considered the most suitable. Whereas, the basic soil moisture requirement is between 20-60 %, which is overall considered ideal for all kinds of crops. Consequently, analyzed soil data is compatible with the characteristics cited by the USDA, according to them the most suitable soil for agriculture is loamy and clayey loam, and the moisture required for crops was also found suitable with the analysis results (Table 2).

Table 2: Soil Texture and Moisture Analysis (Primary Field Survey)

Sl.No	Village	Elevation	Hydrometer reading of specific gravity or bulk density		Soil Moisture (in %)		Texture
			Before 2 hours	After 2 hours	Original weight (OW)	Dry weight (DW)	
1.	Mago-Pam	2063	1.040	1.030	45	17	Clay
2.	Salari	1725	1.052	1.020	50	22	Silty clay
3.	Kamallangchin	1957	1.096	1.003	61	29	Loamy sand
4.	Morsing	1935	1.002	1.099	70	30	Clay
5.	Shergaon	1377	1.003	1.099	35	20	Clay
6.	Jerigaon	2252	1.002	1.004	60	28	Silty clay
7.	Ramallingam	1253	1.004	1.099	30	18	Clay
8.	Khoina	1611	1.035	1.002	65	20	Silt loam
9.	Sangti	2805	1.015	1.003	67	22	Sandy loam
10.	Senge	1777	1.006	1.004	68	20	Silt loam
11.	Tsering-Pam	1950	1.040	1.099	60	21	Silt loam
12.	Kirafarm	1734	1.045	1.098	65	21	Silt loam
13.	Karangania	1284	1.003	1.002	52	18	Clay
14.	Sakrin	1144	1.004	1.002	60	23	Clay
15.	Palizi	752	1.007	1.099	68	24	Clay
					$\Sigma\% = 57.06$	$\Sigma\% = 22.2$	

*Before 2 hours is considered for sand and after two hours is considered for clay calculation

The study depicts that the underlying soil condition is highly suitable for growing various kinds of cruciferous and non-cruciferous crops during both kharif and rabi cropping seasons. Since most of the crops grown are mostly vegetables (cruciferous) which require loamy and textured soil that supplements the growth and yielding capacity of crops; in the same way, the

vegetables that are grown there are medium moisture intensive or moderate water-holding capacity crops, therefore, the presence of the precise moisture of the soil is encouraging the crop production and yielding capacity. Table 3 shows the total cultivated area, production, and yielding capacity underlying soil condition.

Table 3: Salient Information on Cultivated Area, Production, and Yielding Capacity of Crops (Primary Survey and Office of District Agriculture Officer, West Kameng District, Arunachal Pradesh)

Crops	Area (in Hectare) (2019-2022)				Production (in MT) (2019-2022)				Yield (MT/ha) (2019-2022)			
	19	20	21	22	19	20	21	22	19	20	21	22
Kharif												
Paddy	2815	DD	DD	60	4785.5	DD	DD	72	1.7	DD	DD	1.2
Maize	785	-	-	210	737.9	-	-	336	0.94	-	-	1.6
Millet	225	-	-	10	3060	-	-	120	13.6	-	-	12
Cabbage	550	180	195	200	7254.5	2800	3900	4100	13.1	20	20	20.5
Tomato	225	388	390	400	2939	8342	7800	8200	13.6	21.5	20	20.5
Other		8.1	30	-		106.1	2900	-		61.5	187.	-
vegetables	52				189.2				3.64		5	
Ginger	59	-	-	-	230.1	-	-	-	3.9	-	-	-
Chilies	16	35	45	35	40	210	1350	115	2.5	12	110	-
Garlic	250	-	-	-	280	-	-	-	1.12	-	-	-
Rajma	36	-	-	-	258.4	-	-	-	7.17	-	-	-
Soyabean	309	-	-	-	271.8	-	-	-	0.87	-	-	-
Other												
beans	880	151	-	29	149.6	135.9	-		0.17	0.9	-	5.9
Σx =	516.8	152	165	134.8	1683	2864.	3987	2157	5.19	23.1	84.3	10.2
Rabi												
Wheat	40	DD	DD	DD	37.2	DD	DD	DD	0.93	DD	DD	DD
Barley	100	-	-	-	75	-	-	-	0.75	-	-	-
Buck												
Wheat	245	-	-	-	228.7	-	-	-	0.94	-	-	-
Mustard	34	4.5	-	-	31.62	0.99	-	-	0.93	0.66	-	-
Potato	390	130	150	150	3299.4	1118	1200	1200	8.46	8.6	8	8
Pea	70	14	14	15	135.8	224	2240	2100	1.94	16	60	140
Σx =	146.5	49.	82	82.5	634.6	447.6	1720	1650	2.32	8.42	34	74

*Abbreviation: DD – Data Deficient

Data demonstrates trends of both kharif and rabi seasonal crops. The data shows the shift in farming patterns from growing traditional crops such as maize, wheat, paddy, and other cereal crops to modern crops including tomato, potato, and chilies. The facts on traditional crops could only be observed in the year 2019; however, after that, no data has been documented leading to data deficient on various crops, particularly cereal crops, condiments, and vegetables. The information on agricultural land is lacking with the passing year and the data shows a declining trend

under the kharif cropping season; 516.8 (Ha) in 2019 to 152.4 (Ha) in 2020 and 165 (Ha) in 2021 to 134.8 (Ha) in 2022. Despite decreasing agricultural land area production is increasing steadily; 1683 (MT) in 2019, 2864.5 (MT) in 2020, 3987 (MT) in 2021, and 2157 (MT) in 2022 respectively. Similarly, cumulative trends in yielding capacity have been observed; 51.9 (MT/ha) in 2019, 23.1 (MT/ha) in 2020, 84.3 (MT/ha) in 2021, and 10.2 (MT/ha) in 2022. Changes in climatic components have immensely affected cropping seasons, the study revealed that

the production and yielding capacity of rabi crops have been seemingly uplifted in recent years. The data shows a positive tendency of agricultural land; 146.5 (Ha) in 2019 to 49.5 (Ha) in 2020, and 82 (Ha) in 2021 to 82.5 (Ha) in 2022. Likewise, the production has also improved; 634.6 (MT) in 2019, 447.6 (MT) in 2020, 1720 (MT) in 2021, and 1650 (MT) in 2022. The data also shows a steady increase in the yielding capacity of rabi crops; 2.32 (MT/ha) in 2019, 8.42 (MT/ha) in 2020, 34 (MT/ha) in 2021, and 74 (MT/ha) in 2022 respectively.

A majority of the farmers have shifted their farming patterns from conventional farming (traditional) to non-conventional farming (modern). Various factors affect the change in farming systems such as increasing population and rising food demands, in the olden days, most farming practices were subjected to own consumption, as most of the farming practices were subsistence in nature, whereas, in the present-day context population explosion led to an abnormal upsurge in food crop demand. In addition, the commercialization of traditional crops and the introduction of HYV crops have become predominant, as most of the HYV crops are genetically modified (GM) which has the potential for high production and yielding capability, even in small farming lands, furthermore, such crops are also adaptive to changing climates, which makes them suitable for practices.

Most crops newly introduced in the region are proving to be highly resistant to harsh weather conditions like drought, high temperatures, incessant rainfall, and frost. Traditional crops are very susceptible to climate variability, which

makes them prone crops, whereas, GM crops like tomatoes, potatoes, cabbage, green beans, and chilies are adaptive to various climatic conditions, and can be grown in multiple areas having different climatic conditions, similarly, these crops are highly resistant to climate change, which makes them less susceptible to climate variability, unlike traditional crops which are much vulnerable to even slight change in climatic variables. And because of that the culture of practicing and commercialization of GM crops has become the highly preferred crop to the farmers of the region.

Climate and Crop Yield

The climate is an inseparable component of agriculture that largely determines the nature of farming practices. Climate elements such as temperature, humidity, and rainfall initially drive overall aspects of agriculture, including seed germination, growth, production, and yield (Table 4).

The current study reveals a significant impression of climatic elements on the production and crop yield. The data analysis result through linear regression (R^2) shows a strong relationship among the climate and crop variables. The standard value of R^2 or coefficient of determination is 0-1; meanwhile, the data (Table 5) represents 0.4045 of humidity v/s kharif (Figure 2a), 0.302 of humidity v/s rabi (Figure 2b) and 0.4301 of temperature v/s kharif (Figure 3a), 0.11 of temperature v/s rabi (Figure 3b), similarly 0.9183 of rainfall v/s kharif (Figure 4a) and 0.4812 of rainfall v/s rabi (Figure 4b).

Table 4: Mean value of Humidity, Temperature, Rainfall, and crop yield (2019-2022, NASA Data Access Viewer and Office of District Agriculture Officer, Arunachal Pradesh)

Sl. No	Year	Humidity (in %)	Temperature (in °C)	Rainfall (in mm/year)	Yield (in MT/Ha)	
					Kharif	Rabi
1	2019	78.94	17.44	1829.88	5.2	2.32
2	2020	81.56	17.52	1798.24	11.15	12.52
3	2021	78.25	17.53	1293.15	92.82	139.33
4	2022	80.19	17.42	1989.01	9.29	74
		$\Sigma \bar{x} = 79.73$	17.48	1727.5	37.75	57.04

Table 5: R^2 Values of Multiple Correlation Regression (2019-2022)

Variable	Humidity v/s Kharif	Rainfall v/s Kharif	Temp v/s Kharif	Temp v/s Rabi	Humidity v/s Rabi	Rainfall v/s Rabi
R^2 -value	0.4045	0.9183	0.4301	0.11	0.302	0.4812

* R^2 values or the coefficient of determination of climate variables and yield

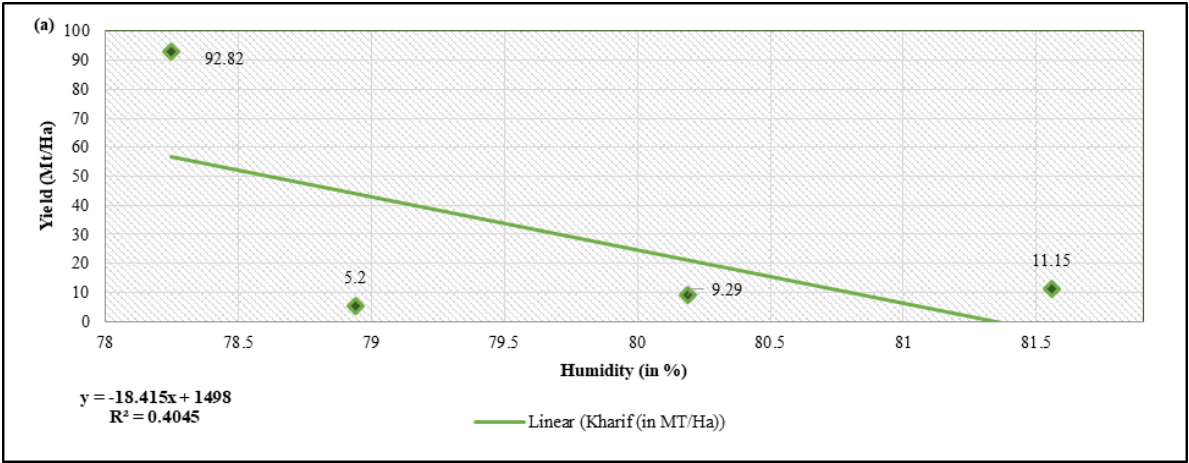


Figure 2a: Kharif v/s Humidity

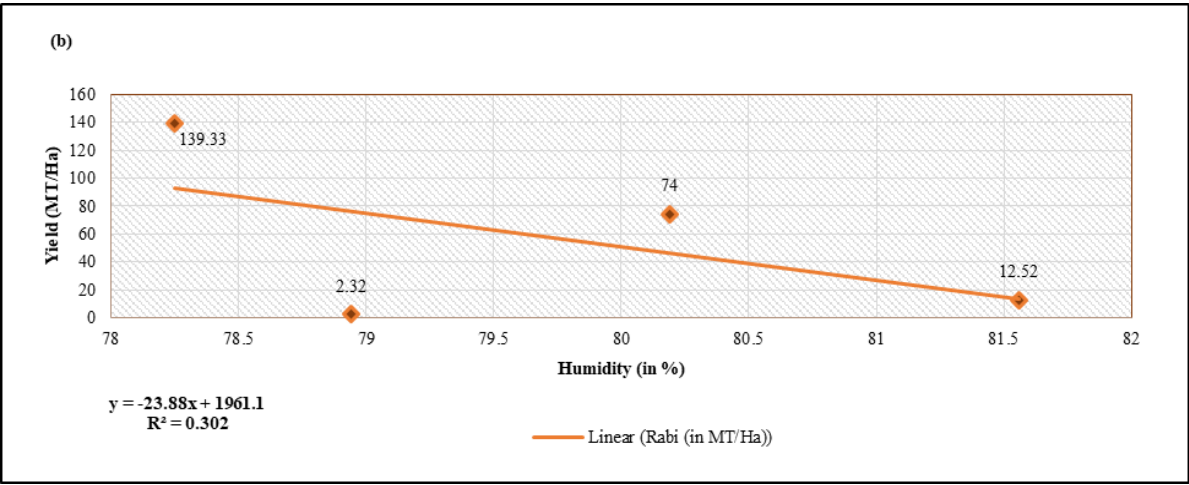


Figure 2b: Rabi v/s Humidity

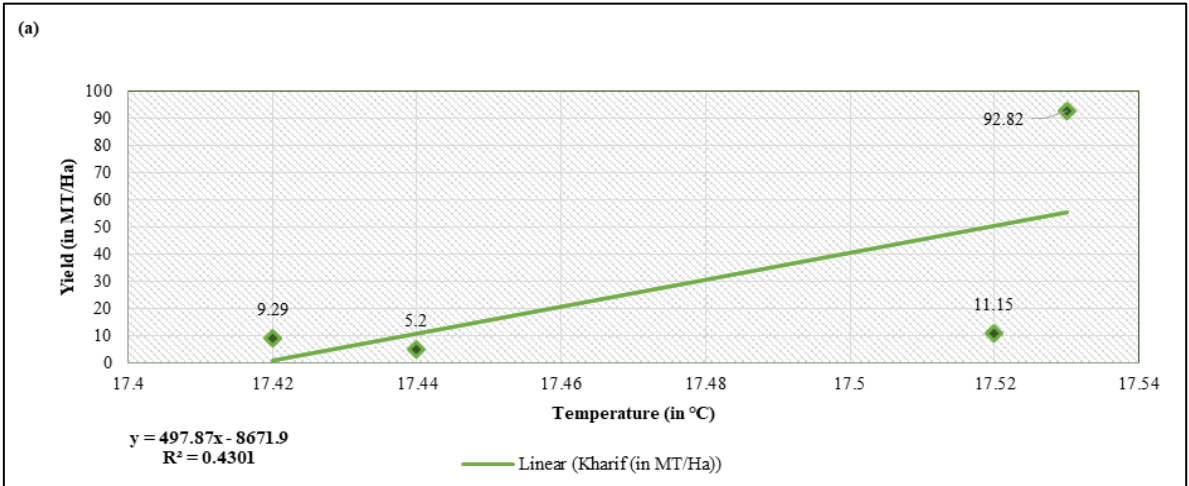


Figure 3a: Kharif v/s Temperature

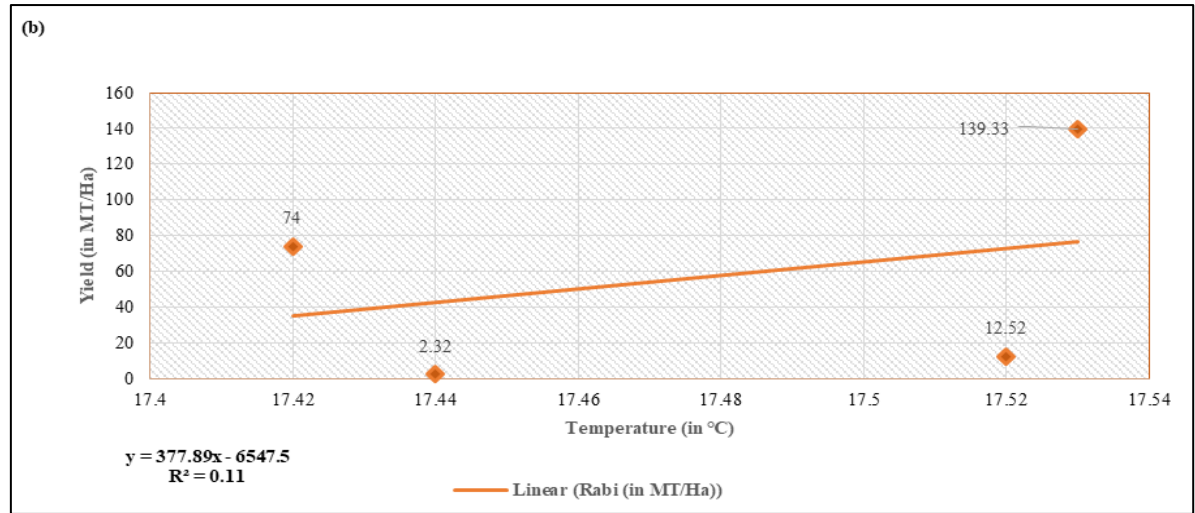


Figure 3b: Rabi v/s Temperature

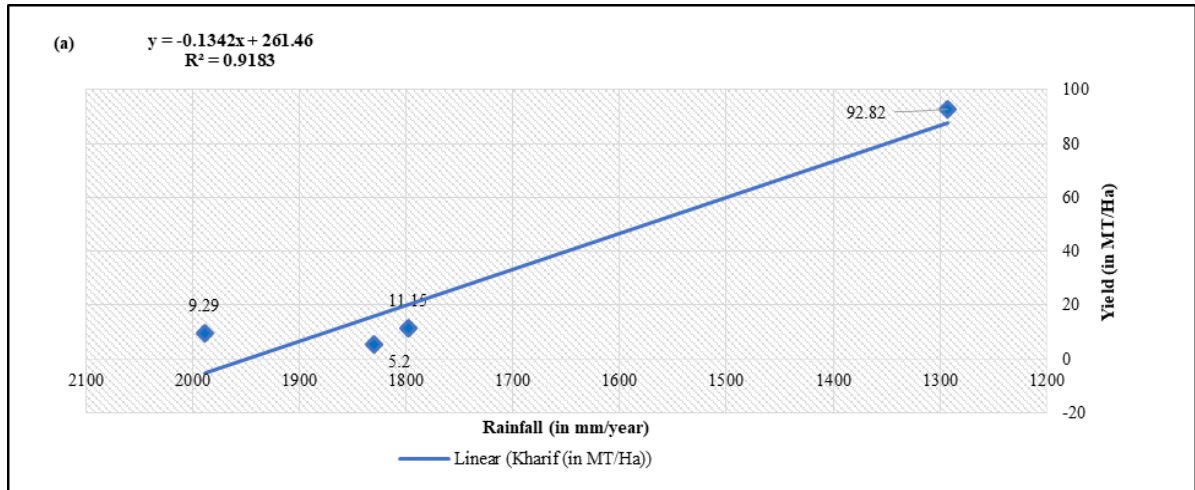


Figure 4a: Kharif v/s Rainfall

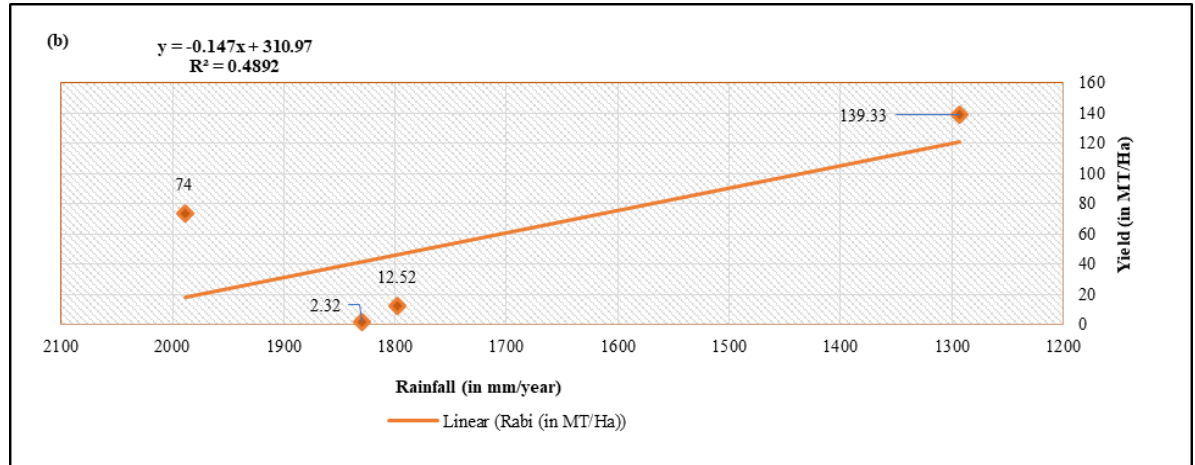


Figure 4b: Rabi v/s Rainfall

Climate change is imminent and bound to occur at one point in time, with the change in certain climatic elements bringing changes in farming patterns across the globe. The West Kameng district is a rich pool of agriculture production due to favorable climatic conditions and soil for healthy

growth and sufficient yield of various cruciferous and non-cruciferous crops. Several studies have been conducted on climate change and crop suitability such as (1, 2, 5, 8, 9). A recent study (19), suggests that studying the impact of climate change on the efficiency of agricultural production

has become crucial in helping major agricultural regions around the world adopt novel technologies to improve the adaptability of agricultural production. Similarly, a study on 'Climate change-induced aridity is affecting agriculture in Northeast Italy' deliberates regarding how climate change is affecting agriculture activities through drought-like situations in several areas of Northeast Italy (20). Numerous studies have been conducted worldwide on the adversities of climate change impacts on agriculture, a major study in India (21) on 'Impact, adaptation, and mitigation of climate change in Indian agriculture', the work demonstrates how crops respond to changing climates and what mitigation measures have to adopted for the climate resilient farming systems. Through this study, an attempt has been made to examine whether and to what degree the

underlying physical setting is affecting agricultural practices, thus the study found significant suitability among the distinct variables. Concerning soil types, the standard soil requirements for vegetable crops are textured soils, as such the soil experiment result found most of the soil types falling under the loamy and clayey loam, due to the presence of these kinds of soil a healthy growth and yield of crops were observed during the study (Figure 5). Moreover, the statistics from linear trend analysis reveals significant trend among the climate variables and crop yield, which ultimately proves that the climatic condition of an area greatly determines the cropping pattern and yield, in addition through this study it is apparent that the particularly cropping pattern and production tend to vary with the variations in climatic elements over time.



Figure 5: Cabbage field and harvested tomatoes

Conclusion

The study concludes that the population is rising every minute putting more and more pressure on land and agricultural areas. The increasing population eventually put immense pressure on the demand and supply of food commodities. Thus,

challenges supplementary agriculture production to meet the rising food demands, which also destabilizes the optimum capacity of the land to produce a certain amount of production and yielding capacity. The study also found that the farmers have transformed their farming system

from extensive agriculture to an intensive farming system, where they grow commercial GM crops in confined agricultural land, that has high demand and production volume. The change in climate elements mainly, temperature, humidity, and rainfall have largely contributed to the initiation of crops that were only grown in warm and humid areas, so far, those crops are now cultivated and have a more successful production rate than any traditional crops. Due to commercialization the demand for crops has enlarged and instigated the farmers to grow commercial crops. Because of that several traditional crops (mostly cereal grains) have now completely disappeared and those crops are replaced by modern commercial crops. These modern crops have certain drawbacks as such these crops require chemical fertilizers and various pesticides are being induced thus deteriorating crop health, on the other hand applying chemical fertilizers depreciates organic components of the soil. The majority population of the district is dependent on agriculture as a source of livelihood, particularly the farming community of the region. Therefore, farmers practice those crops which are having higher demand and economic value. In the olden days, people were engaged in the culture of subsistence farming practices of traditional crops, which had high traditional value but not the demand and economic value, crops grown were fully subsistence and were subjected to self-consumption, and lacking commercial worth. Therefore, factors such as population and climate change have immensely affected the agriculture scenario of the region, rising food crop demand led farmers to adopt those crops that have higher demand and price in the market, for the economic incentives and viability of the marginal farmers, on the other hand, climate variability; fluctuation of temperature, humidity, and rainfall have significantly affected the cropping yield and farming system; not every crops are climate resistant whereas, with changing climate farmers have implemented those crops which are having higher tensional resistant to extreme climates, HYV crops are genetically modified (GM) and are having high production and yielding capacity. Consequently, farmers had to shift their cropping pattern and farming system to cope with the climate change in the region. Such crops require enormous amounts of chemical fertilizers and various chemical supplements for

their growth and yield, which harm human and environmental health. Therefore, encouraging indigenous crops is safe and fully sustainable for agricultural practices.

Abbreviations

DD: Data Deficient, OW: Original Weight, DW: Dry Weight, MT: Metric Ton, Ha: Hectare.

Acknowledgments

The authors are thankful to the Department of Geography and Resource Management of Mizoram University (Central), Mizoram for encouraging and providing infrastructural facilities for conducting research. The authors also acknowledge the people and farmers of West Kameng district, Arunachal Pradesh, Northeast India. Also, the authors are appreciative to the District Agriculture Office, Bomdila, Arunachal Pradesh, and Accredited Social Health Activists (ASHA) for providing the necessary pieces of information.

Author Contributions

Norbu Jamchu Thongdok contributed substantially to the conception or design of the work, acquisition, analysis, and interpretation of data. Whereas, Vishwambhar Prasad Sati revised the work and finalized the manuscript. The authors declare that both authors made significant contributions to the work.

Conflicts of Interest

The authors declare that they have no conflict of interest with the publication of this article.

Ethics Approval

The authors of this article approve all the ethical standards of the journal.

Funding

Nil.

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DEPARTMENT : Geography & Resource Management

TITLE OF THE THESIS : Climate Change and Its Impact on Farming
Systems of West Kameng District, Arunachal
Pradesh

DATE OF ADMISSION : 31.08.2022

APPROVAL OF RESEARCH PROPOSAL:

1. DEPARTMENTAL RESEARCH COMMITTEE : 16th March, 2023
2. BOARD OF STUDIES : 24th April, 2023
3. SCHOOL BOARD : 26th May, 2023

MZU REGISTRATION NO. : 2200629

Ph.D. REGISTRATION NO. & DATE : MZU/Ph.D./2071 of 31.08.2022

Extension (if any) : NIL

Head

Department of Geography & Resource Management

ABSTRACT

**CLIMATE CHANGE AND ITS IMPACT ON FARMING
SYSTEMS OF WEST KAMENG DISTRICT,
ARUNACHAL PRADESH**

**A N ABSTRACT SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF
PHILOSOPHY**

NORBU JAMCHU THONGDOK

MZU REGISTRATION NO.: 2200629

Ph.D. REGISTRATION NO.: MZU/Ph.D./2071 of 31.08.2022



**DEPARTMENT OF GEOGRAPHY & RESOURCE
MANAGEMENT
SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCES
MANAGEMENT
SEPTEMBER, 2025**

**CLIMATE CHANGE AND ITS IMPACT ON FARMING SYSTEMS OF WEST
KAMENG DISTRICT, ARUNACHAL PRADESH**

BY

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Submitted

**In partial fulfillment of the requirement of the Degree of Doctor of Philosophy
in Geography & Resource Management of Mizoram University, Aizawl.**

CHAPTER 1

INTRODUCTION

Climate change is a comprehensive term and a burning issue at present. It is a crucial driver that greatly affects agricultural practices. It affects agriculture in many ways, such as variations in rainfall, temperatures, and extreme events, with an important impact on soil erosion, resulting in a variation in the growing season agricultural sector and climate change are closely intertwined. Various prominent authors have distinctively defined climate change. climatic variation as an immense threat to the 21st century. Climate change is the most adverse phenomenon; it is larger, more complex, and unpredictable than any other environmental issue.

Climate change greatly affects the socioeconomic activities of an area, most importantly, farming patterns and other agricultural activities. Owing to the drastic change in climate, the agriculture sector and farming practices are under threat, as a consequence of an increase in anthropogenic activities such as industrialization, urbanization, deforestation, change in land use patterns, etc. Agriculture is an economic activity that is largely dependent upon weather and climate to produce the food, fibre, and other necessary things to sustain human. The crop yield shows a strong relationship with climate change. Climate change is much faster and poses a higher potential threat to agricultural practices. Agricultural activity is expected to be vulnerable to climate variability.

Climate affects numerous socioeconomic activities, particularly farming patterns and allied activities. Change is imminent, and it is bound to occur; such change in a certain amount of rainfall, temperature, and humidity controls the nature of the soil and greatly affects agricultural output in mountain regions; besides, its change and its hydrological consequences may result in the significant modification of soil conditions. Numerous studies have been conducted with regard to climate change and crop suitability; its impact on food production has been examined, particularly with crop yields. Nevertheless, climate affects all elements of crop production and productivity, as such fluctuations in weather patterns can elevate the crop susceptibility and the consequences of extreme climate events like high temperatures, droughts, and

incessant rainfall. Moreover, consecutive climate events, such as abnormal flooding and rains, are disastrous and are intensified by environmental effects that also distress human and agricultural activities.

In particular, under rain-fed conditions, the potential of crop to produce solely determine by the climatic setting of an area; consequently, respective crop will flourish within a specific climatic condition that can be improved by management—however, climate change will modify the satisfaction of these requirements of the components of crop suitability. Directly or indirectly, climate change affects crop production; thus, land capability is expected to decrease under climate change, and crops grown in summer are anticipated to be more sensitive to its change than winter season crops. Crop suitability assessment models can indicate the best locations to grow different crops and, in doing so, support efficient use of land to leave space for or share space with nature. Thus, assessing agricultural suitability and yield under climate change is essential for eco-friendly agricultural production. Due to climate change, several traditional crops (mostly cereal grains) have now completely disappeared, and those crops are being replaced by commercial cash crops that are resilient to climate variability.

Climate controls agriculture in numerous aspects, such that the plant mechanisms, and therefore yields, are influenced by several ecological factors, such as humidity and temperature, which affect either directly or indirectly with other factors, in defining the agricultural production. It is the primary factor of agricultural practices. Despite the crucial role of agriculture, concern has been raised about the latent effects of its change on agricultural production and productivity. Climate change is projected to determine crop and livestock practices, water bodies, and other elements of agricultural patterns. Moreover, variations in temperature and rainfall will affect the dispersal of agroecological zones. Changes in soil moisture and the content will vary during the period and the length of growing seasons of different crops.

India is highly vulnerable to climate change, mainly in the agriculture sector. In India, many studies have provided experimental evidence that climate change has resulted in a deterioration in agricultural productivity. Farming is the main occupation

and a major source of livelihood in the West Kameng district of Arunachal Pradesh. The agro-climatic conditions are rich for the cultivation of various crops. Some crops, such as potatoes, are largely grown. Meanwhile, there is a large change observed in climatic conditions in the recent past, which is affecting farming systems in the region.

Furthermore, through this study, the pivotal role of assessment of the soil would help us in a precise and comprehensive understanding of the crop pattern and suitability for cultivation. Moreover, analyzing climate data, such as temperature, rainfall, and humidity, would help illuminate the trend of climate variability and its implications for agricultural practices. Overall, the study would help our interpretation of the in-depth relationship between the underlying physical setting and agriculture, it would also envisage the vision of sustainable farming practices and management of natural resources.

This study will explore the current situation of the farming system and climate variability and change in the West Kameng district of Arunachal Pradesh. The major research queries stressed for this study are: What are the climatic conditions and farming systems that prevail in the region? And what are the implications of its change on farming systems? The study will also focus on understanding the agroecological conditions: climate, vegetation, soil, water availability, and their relationship with agriculture.

In recent years, the West Kameng district has attained the name ‘agriculture bowl’ of the state of Arunachal Pradesh due to its high agricultural productivity. However, over the years, the region has been experiencing a drastic climate variability; changes in rainfall patterns and increasing temperature. It is proven that climate change poses a huge threat to agriculture and allied activities, whereas, often, climate change tends to have short-term positive impacts on agricultural productivity. Crops require certain climate conditions for their growth and yield; therefore, the increasing trend of temperature may lead to the introduction of new crops, and such a case has been witnessed across the region. The district is experiencing an increasing trend of temperature and a decreasing trend of rainfall over the last 21 years.

The farming patterns and systems of the region are changing; the farmers have superseded the traditional crops like maize and cereals with cash or non-conventional crops like tomato, potato, chilies, cabbage, etc. These crops are commercial. The change in climate conditions, like an increase in temperature, has resulted in the abandonment of traditional crops and the adoption of such crops, which are climate resilient and have the potential for high productivity. Moreover, the farmers have ceased practicing the water-intensive crops due to decreasing rainfall patterns in the region.

The problems of the study arise from the fact that the climate in the region is changing at a fast pace, resulting in both positive and negative impacts on the environmental and societal aspects. It was also found that the introduction of these cash crops holds high potential to enhance the standard of living or livelihood of the farmers due to their economic viability. Therefore, the primary objectives of the study are to examine the changing climate pattern and its implications on the farming systems in the district. Besides, such changes in farming systems and patterns have resulted in livelihood enhancement over the region.

Climate is inevitable and dynamic; thus, climate is bound to change and occur. Variability in climate conditions in day-to-day life is becoming more evident. It directly influences various socio-economic activities, most importantly, agricultural practices and productivity. Whereas, mountain ecosystems are important yet very fragile to climate change. The rural population dwelling in mountainous regions is more vulnerable to climate change, with changes in agricultural practices and patterns due to climate change and variability.

Over the recent years, the Himalayan state of Arunachal Pradesh has been witnessing a drastic change in conditions like fluctuating rainfall, increasing temperature, and drought-like situations across various regions in the state. The maximum percentage of the population in the state is still dependent upon agriculture and its allied activities as a primary source of income and occupation. The West Kameng district in the state is most vulnerable to climate change, as it has been evident in recent years with changes in farming patterns in the region.

This study focuses on climate change and its impact on the farming systems of the West Kameng district of Arunachal Pradesh. Agriculture is the main occupation of the people of West Kameng, also the region is known as the agricultural bowl of the state. It has a suitable climatic condition that favors the growth and practices of varied agricultural and horticultural crops. However, in recent years, the region has been witnessing a shift in agricultural production and practices, perhaps due to variations in climatic conditions. This study endeavors to chalk out a meaningful strategy to comprehend the impact of climate change on the farming system and endorse sustainable and climate-resilient farming practices in Arunachal Pradesh in general and the West Kameng district in particular.

CHAPTER 2

LITERATURE REVIEW

A literature review is an integral part of research, providing a better vision and insight into the researcher's topic. It is essential in any research and study, as a thorough review of the literature would pave the way for a better understanding of the problems and prospects in the field of research.

Numerous studies concerning climate and its implications for various social systems and activities have been conducted at the international, national, regional, and local levels. It is essential to construct the knowledge base of distinct studies on climate variability and its implications on social activities, primarily on agricultural practices. The review of the literature highlights the overall framework of the implications of climate change on societal impacts, particularly in agricultural practices and systems.

The literature review has been carried out at various levels, such as International, National, and Local levels. A total of twenty-four reviews for the International level, twenty for the National level, twelve for the Regional level, and five for the Local level, respectively.

CHAPTER 3

GEO-ENVIRONMENTAL SETTING

Geographical or geo-environmental background is an important aspect of the geographical study of any domain. Comprehending and highlighting the background, such as soil moisture, soil texture, annual rainfall, annual humidity, annual temperature, drainage, and people, is essential for overall research studies. It provides a significant base for executing any research tasks; determining research designs, and the degree of research. Understanding the extant climate and people is prominent in agricultural research, as cropping patterns and the regional underlying climatic conditions strongly determine productivity. Moreover, the investigation of the socioeconomic characteristics of farmers, such as occupation, literacy rate, and income, is crucial in Geographical studies.

Physical background is natural features like rivers, plains, mountains, plateaus, drainage, etc., which is essentially the geographical landscape of a region. It is important to understand the characteristics of these features; such features involve entities without involving any human activities, the physical background can also be described as the study of physical Geography, which focuses on Earth's physical features rather than human aspects. In the meantime, background factors such as temperature, humidity, rainfall, soil moisture, soil texture, and drainage are crucial for the study.

Geology, in layman's terms, refers to rock science or the study of rock formation, which deals with the physical structure and substance of the earth. The geological composition of the study area is found to be of Subansiri Formation, Dirang Formation, Bomdila gneiss formation, Tenga Formation, Chillipam Formation, Bichom Formation, Bhareli Formation, Dafla Formation, and Kimin Formation.

Elevation measures the vertical distance of a point or object from the mean sea level. The vertical distance or elevation of the study areas or villages surveyed ranges from 752 m up to 2805 m from the MSL.

In simple terms, the flora and fauna refer to the diversity of the plants and animals over an area or ecosystem. The district is adorned with rich floral and faunal diversity. There are two national parks: the Namdapha National Park and the Mouling National Park. Besides, there are eight wildlife sanctuaries, followed by the Eaglenest Wildlife Sanctuary, the Dibang Wildlife Sanctuary, the Mehao Wildlife Sanctuary, the Kamlang Wildlife Sanctuary, the Pakhui Wildlife Sanctuary, the Daying-Earing Wildlife Sanctuary, the Talley valley Wildlife Sanctuary, and the Itanagar Wildlife Sanctuary.

The district is home to over 500 species of birds and more than 200 species of mammals, moreover, Arunachal Pradesh is also known as '*Orchid Paradise of India*', there are around six hundred twenty-two species of orchids in the state, additionally, it is also home to many species of reptiles, butterflies, and insects.

Valleys are the flat, elongated plains or an area between the two elevated hilly areas. Valleys are characterized by flat areas which can be found in high altitudes as well as low-lying areas. The following are the valleys of the district: the Bichom River Valley; the Tammaphu River Basin; the Tenga Valley; the Bhairabkund River Valley, and the hills of the district.

This chapter also deals with the socio-cultural characteristics of the study area.

CHAPTER 4

CLIMATE VARIABILITY AND CHANGE

Climate variability refers to short-term changes in weather patterns, whereas climate change refers to long-term changes in weather patterns. Climate change is a significant threat to humanity, and its impacts on natural and human systems have already been observed. Mountain regions are highly vulnerable to climate change, as they are ecologically fragile, tectonically and seismically active, and geologically sensitive. With other global challenges, climate action demands global and local collaboration and must be addressed in a revolutionary, systemic, and comprehensive manner that prioritizes short-term targeted action and long-term ecological and human well-being. In fact, many environmental systems, especially those that extend well beyond the mountain limits, depend heavily on meteorological and climatic phenomena in mountainous locations. Whereas mountain climates are primarily influenced by four factors: terrain, altitude, latitude, and continentality. However, it is generally accepted that high mountain ecosystems are especially susceptible to changes in the climate.

Climate is changing at a tremendous rate, and such change is affecting various entities, such as socio-economic activities and environmental settings. The West Kameng district has witnessed frequent temperature, humidity, and rainfall fluctuations in recent years. Some of the villages are experiencing extreme climatic conditions, followed by high temperatures, humidity, and rainfall; on the other hand, some villages are undergoing extremely low temperatures, humidity, and rainfall, almost similar to drought-like circumstances. Such of climate change phenomenon is occurring all around the globe, and several studies have reported the implications across the various regions of the globe. The study of the temperature data of the last ten years starting from 2002-2012, concerning temperature in all the study villages the year 2006 has been marked as the hottest year in the last two decades. Similarly, the amount of rainfall variability has undergone over recent years. Climatic elements such as temperature, and humidity are increasing with time, however, the data of the West Kameng district reveals a decreasing or negative trend in rainfall in the last twenty-

one years which is a grave matter of concern, as the period between 2002-2012, the annual average of 157.16 mm was recorded, whereas, the period between 2013-2022, the annual average of 154.06 mm was recorded, which means an annual average of 3.1 mm rainfall has been decreasing in the West Kameng district over the last two decades.

Moreover, trend (linear) regression analysis illustrates a significant trend in climate variables, concerning humidity over the last twenty-one years, where the lowest trend was recorded in Jan-Dec in the year 2014 with -11.39 % from the annual average value, and also the highest in Jan-Dec in the year 2020 with 6.84 % from the annual average value. Regarding temperature, the lowest trend ever recorded in the last twenty-one years was in 2004 during the month of Jan-Dec with -1.54 °C from the annual mean average value, and the highest ever recorded over the last two decades was in 2020 during the month of Nov-Dec with 2.04 °C. Subsequently, the lowest trend of rainfall was witnessed during the month of June-Dec in the year 2002 with -136.54 mm from the annual mean average, and the highest ever recorded in the year -136.54 mm during the month of Aug-Dec in the year 2005 with 171.45 from the annual mean average.

Besides, statistics from the parametric trend (linear) regression show a significant trend in all the variables; humidity, temperature, and rainfall. R^2 also known as the coefficient of determination shows the strength of a data set, therefore, the analysis of humidity of the last twenty-one years shows a significant strength of a trend with an R^2 value of 0.3335, similarly, the R-squared value of temperature also shows strength with $R^2 = 0.0137$, furthermore, the R-squared value of rainfall also reveals significant trend with an R^2 value of 0.2372. Therefore, it is evident that climate variables have always been changing in nature with each passing year, thus, such increasing and decreasing characteristics of climatic variables have immense implications on farming systems and patterns of an area.

The West Kameng district is characterized by rich agriculture and horticulture practices. The climatic conditions of the region have been favorable for carrying out varied agricultural practices for many years. However, in recent years, the climate has been changing drastically in various district farming areas, resulting in a change in

farming and cropping patterns. The statistics from the study reveal a gradual increase in all climate aspects, which is apparent in the temperature, rainfall, and humidity. The study shows a steady inclination in annual temperature, rainfall, and humidity over the last twenty-one years. Moreover, the parametric trend (linear) or linear regression analysis advocates a significantly increasing trend in temperature, rainfall, and humidity of the West Kameng district. Hence, the study may conclude that over the last twenty-one years, there have been imperative fluctuations concerning temperature, rainfall, and humidity of the study villages of West Kameng district.

CHAPTER 5

CLIMATE CHANGE AND ITS IMPACT ON FARMING SYSTEMS

Climate change is one of the biggest challenges the world faces today, posing a threat to many populations across the globe. Studies indicate that in many regions of the world, agriculture will be affected by climate change, limiting food production and threatening food security, its impact on farms can be determined by factors such as local climatic variation, physical environment, and the type of crops grown. The climate is pivotal in determining crop production and yield capacity. Certain crop responds to different underlying climatic settings of an area; a favorable environment may result in a fruitful yield and output, and unfavorable conditions may lead to less production and productivity.

Climate change not only has negative implications, but it also has certain short-term positive impacts on farming patterns. Such an increase in temperature, humidity, and rainfall tends to increase the productivity of certain selected crops. Also, a rise in carbon concentration in the atmosphere increases the yield capacity of crops like potatoes, tomatoes, wheat, barley, rice, and other vegetables. Some crops require high rainfall or water requirements, like green beans, cucumbers, and peas, therefore, an increase in rainfall may intensify the production. Moreover, some crops tend to have high productivity under high humidity conditions, especially leafy greens like lettuce, cabbage, broccoli, and mustard leaves. This means climate change in a region like firm changes in the amount of rainfall, temperature, and humidity may lead to intensification of yield and production of certain crops. Several studies have been conducted on the implications of climate change on production and yield, such as increasing temperature in highland areas is generally believed to potentially enhance crop productivity where cooler temperatures currently constrain plant productivity. Variations in soil moisture may lead to an increase in insect infestation; however, an increase in carbon levels and carbon fertilization can intensify agricultural production. An increase in CO² levels may have some positive impact on certain crops, increasing their growth and transpiration rate; crops and plants may be able to perform better photosynthesis under high carbon levels.

Climate change has dimensional implications, it does not only have a positive impact on crops, it also has negative effects like changes in agricultural production resulting from the combination of changes in yields and changes in crop acreage, also, variations in crop yields are the result of climate changes. Improving crop production to mitigate rising demands due to the population increase, against the background of the threats of climate change, is challenging. Whereas crop production is vulnerable to climate variability, associated with temperature and CO² increases, and changing patterns of rainfall may lead to a considerable decline in crop production and yield. Moreover, extreme weather events like droughts, heat waves, and heavy and scarce rainfall may ultimately affect crop production and yield. Variations in temperature, precipitation, and greenhouse gases, significantly hampered pest infestation, soil fertility, and irrigation resources, moreover, there are uncertainties regarding the future climate scenario and its probable implications on farming systems, numerous studies report that climate change will decrease agricultural productivity in the coming years. The change in climate elements mainly, temperature, humidity, and rainfall has largely contributed to the initiation of crops that were only grown in warm and humid areas, so far, those crops are now cultivated and have a more successful production rate than any traditional crops in high altitudinal regions. Numerous studies have been conducted on various implications of climate variability and crop production across the globe.

The underlying climatic condition of the West Kameng district has been significantly fluctuating and has affected various agricultural activities. Firm variations like an increase in temperature, rainfall, and humidity have changed the farming scenario of the region; farmers have abandoned the cultivation of traditional crops, due to lesser productivity and yield due to changes in the climate setting, and contemporary farmers have adopted newly introduced GM seeds, such seeds, and crops are highly resistant to climate change and harsh weather conditions, and they are having the ability to produce higher productivity and yield than compared to traditional crops that are having the lesser ability to produce higher production and yield. Whereas, to understand the implication of climate on crop production and yield a *multiple regression correlation, two-way ANOVA, and Pearson correlation (r)* were

performed and the statistics show a strong correlation and relationship between the climate and production variables. Production was categorized into seasonal nature, as Kharif and Rabi, and both the productions performed correlational analysis and the study revealed a strong effect of climate on crop productions. The analysis of *Pearson correlation (r)* found that the *P-value* of climate and production variables is <0.05 which means that if the values of exploratory (independent) and response (dependent) variables are <0.05 suggests a strong correlation among the variables. The results of *ANOVA* reveal that the *F-values* are under 0-1, which means that the analysis suggests a strong relationship between the independent (climate), and dependent (production) variables. Moreover, multiple *regression correlation* analysis results also depict a strong and significant correlation between the variables as all the analyzed values are below standard *P and R-values* are <1 , which means that the results reveal the strong impact of climate on crop production.

Climate change is imminent and it is bound to occur, in the meantime, it should not be instigated to vary at a faster rate. Several consequences of climate change can be witnessed it is undeniable that agriculture is the most affected entity. Climate determines the types, production, and yielding capacity of the various crops. It has dimensional implications such as climate change does have short-term positive impacts on agricultural production; some crops like potatoes, green beans, carrots, and peas tend to produce more outputs in higher CO₂ levels; and the introduction of new crops that require high temperature, humidity, and rainfall. On the other hand, certain crops especially cruciferous crops like tomatoes, cabbage, mustard leaves, capsicum, and other leafy vegetables, are adversely affected by climate change like extreme weather phenomena, droughts, and torrential rainfall. In contemporary farming systems, several GM (genetically modified) crops are highly resistant to harsh climatic conditions, and varying agro-climatic zones. Climate change will occur and we have to cope with that change. Therefore, it is important to train and aware farmers of modern farming techniques and practices that involve climate-resilient farming techniques and how to grow climate-resilient crops in the region.

CHAPTER 6

SOCIO-ECONOMIC STATUS OF THE FARMING COMMUNITIES

Socioeconomic status is a concept that denotes an individual's or family's social and economic standing. Socioeconomic status encompasses a range of factors that define an individual or group's social and financial situation, such as income, education, occupation, housing, and sometimes family structure, age, and location. These attributes gauge one's societal position based on economic resources and social status. In other words, socioeconomic status is a combined measure of a person's or family's financial resources and social position relative to others. It considers factors like work experience, income, education, and occupation. When assessing a family's socioeconomic status, factors like household income and the education and occupations of its members are examined.

Farming has historically been a primary source of livelihood for rural communities. Traditionally, farming was primarily subsistence-based, with crops grown mainly for self-consumption. However, farming has shifted towards commercial crop agriculture, where crops are produced mainly for sale in the market. This shift has led to a decline in the cultivation of traditional crops, as farmers are increasingly drawn to high-demand, high-value commercial crops. These crops offer significant economic benefits to farmers due to their strong market demand and higher per-unit value.

The introduction of major commercial crops, such as tomatoes, potatoes, cabbage, green beans, chilies, and cereals, has significantly transformed the agricultural landscape of West Kameng district. These crops are well-suited to the region's climate and can produce high returns, even on small plots of land. As a result, the adoption of these crops has boosted the income and livelihood of the local farming community, which heavily relies on agriculture. The high market demand for these crops ensures their economic viability, contributing to the financial stability and improved living standards of the farmers. Compared to traditional crops, commercial crops offer higher profit margins and reliability, making them increasingly popular among farmers in the region.

The increasing demand for cash crops has driven a shift from traditional to contemporary farming practices. Farmers are now prioritizing high-productivity crops like tomatoes, potatoes, cabbage, and chilies, which have higher market value compared to indigenous crops such as beans and millet. The introduction of genetically modified seeds has further accelerated this trend, allowing for increased production and better adaptability to various climatic conditions. As a result, commercialization has become a significant factor in shaping modern agriculture, prompting farmers to expand their cultivation areas and focus on crops that are in high demand and fetch higher prices. As a result, several traditional crops (mostly cereal grains) have now completely disappeared, and those crops have been replaced by commercial crops.

Recent years have witnessed a significant shift from traditional to major commercial crop farming practices in the district. The introduction of such crops has transformed the agricultural landscape, leading to increased wealth and improved living standards for the local farming community. Several pieces of evidence can be found worldwide regarding the advantages of commercial crop farming and its economic incentives. The benefits of small commercial crop farming enterprises and their implications for farmers. Similarly, Chinese agriculture is experiencing a transition from smallholder farming to the emergence of commercial crop farms that are characterized by intensification and specialization in production, as well as commercialization. The importance of commercial farming is to increase food production in the coming years with minimal environmental impact. In addition, the cluster farming of crops in small land-holding and their commercialization in the economic integration of small land-holders in Ethiopia. Correspondingly, the significance of the commercialization of agriculture, forestry, and livestock in South Asia.

Commercial crops offer immense potential to improve rural livelihoods. These crops are economically viable and generate significantly higher revenue compared to traditional crops. Their adaptability to various environments makes them a reliable source of income for farmers. As the number of farmers adopting such crops and their cultivation continues to grow, it plays a crucial role in ensuring their financial stability

and sustainable livelihoods. Promoting sustainable practices in commercial crop farming can further enhance agricultural development in the region.

The study concludes that commercial crops have significantly contributed to improving farmers' livelihoods in the district. Introducing these high-productivity crops has boosted farmers' income and economic viability. However, while commercial crop farming is thriving, it lacks modern techniques and infrastructure for sustainable agricultural development. To address this, there is a need to promote awareness of modern farming practices, revive traditional and organic farming methods, and provide farmers with access to arable land, organic manure, irrigation facilities, and market linkages. Additionally, subsidies for seeds and crop insurance can further enhance the sustainability of farming livelihoods.

CHAPTER 7

SUSTAINABLE AND CLIMATE-RESILIENT FARMING PRACTICES

The concept of sustainability has become a key term in our time, highlighting the need for things to endure far into the future. Sustainable rural livelihood is a multifaceted concept and refers to the maintenance or enhancement of access of rural families to food and income-generating activities on a long-term basis. It refers to the capacity of individuals and communities to withstand and adapt to challenges and sudden changes in the natural environment that negatively affect their well-being, including their material possessions, social connections, and personal sense of satisfaction. The sustainable livelihoods framework helps to organize the factors that constrain or enhance livelihood opportunities for the rural communities. It is the long-term goal for poverty reduction that gives adequate importance to development from different levels, scales, and sectors. Agriculture presents a wide range of promising prospects for improving the livelihood sustainability of the rural population. Farming provides an economic platform for rural farmers for socio-economic enhancement. The impact of livelihood capital on how people make a living hasn't been thoroughly investigated. Therefore, a strategy is needed to build livelihood capital, improve livelihood strategies, integrate successes in poverty reduction, achieve long-term poverty alleviation, and promote sustainable livelihoods; moreover, earning a livelihood involves a structured process based on skills, resources, and viable activities. When considering how to make farmers' livelihoods sustainable, the safety and quality of life for those in poor areas become a central problem and a key focus of research for experts.

The concept of sustainable livelihood has become a challenging aspect for the population in the mountainous regions, due to climate variability and change. Mountain ecosystems are important, at the same time highly vulnerable to climate change; therefore, coping with climate change and balancing sustainable livelihoods has become an immense challenge for the farmers. Concerning the Himalayan region, the Himalayas are a highly vulnerable region in terms of natural disasters, and the effects of such disasters are further compounded by other influencing co-factors such

as geographical location, topography, and unique economic, political, and cultural characteristics of the region; besides, the increasing frequency of extreme climate events, widespread poverty, migration and marginalization of Himalayan people make mountain communities more vulnerable to climate variability and hindering the agriculture practices in the region. Moreover, the role of cash crops in livelihood enhancement in the mountainous areas of the Arunachal Himalaya is prominent due to declining production and productivity of the traditional crops, whereas cash crops significantly contribute to improving farmers' livelihood and sustainability.

Climate plays a significant role in determining crop growth, production, and yield. Therefore, climate variability and change are substantially affecting the farming systems across the globe. It greatly affects an area's socioeconomic activities, particularly farming patterns and allied activities; Climate change navigates every sphere of the earth's surface, wherein agriculture is the most affected entity. Such variations in temperature, humidity, and rainfall drive the nature of the soil and agricultural practices. Climate change is imminent and bound to occur; such a change in a certain amount of rainfall, temperature, and humidity controls the nature of the soil and greatly affects agricultural production and productivity in mountain regions. Mountain regions are highly vulnerable to climate change.

CHAPTER 8

CONCLUSIONS

This era is the worst climate change event in human history. Implications of climate change events are reflected everywhere on Earth, including torrential/cloudburst rainfall in remote areas, droughts in tropical areas, decreasing snowfall intensity in polar areas, receding glaciers, rising sea level, global warming, etc. In the last sixty years, the 21st century has witnessed the hideous effects of climate change, as change is on a large scale and rapid, harming various socio-economic and environmental aspects. The most affecting entity is the agricultural activities, because they solely depend on the climate for growth and production. Particularly, farming practices in hilly and mountainous regions like the Himalayas, as mountain ecosystems are important yet vulnerable to a changing climate. Therefore, the farming activities in mountain regions are highly miser due to higher rate of erosional activities, landslides, cloudburst floods, rising temperature, and erratic rainfall patterns.

The present study has been conducted in rural villages of the West Kameng district of Arunachal Pradesh. The primary objective of this study was to examine farming systems and how they are being affected by climate variability. In recent years, the region's temperature and rainfall have been highly fluctuating; moreover, with that being said, the farming patterns have also been changed. The findings of the study suggest, after analyzing climate data of 21 years from 2002-2022, that the temperature of the region is greatly increasing, however, rainfall intensity has been decreasing ever since. Furthermore, the agricultural production data of 9 years were analyzed, and it was found that the production of traditional crops is decreasing, and the cultivation of modern crops (GM) is significantly increasing. The study also discovered that the production of modern crops is momentarily increasing, along with the production, the areas of agricultural land are also expanding.

The study also validates that these modern crops have high economic value, therefore, it was found that the culture of commercial crops is increasing the farmer's revenue, due to its economic viability. Thus, it is apparent that the introduction of such

crops has enhanced the livelihood security and sustainability of the farmers in the region.

The study may conclude that the climate is changing drastically, affecting various entities, whereas agriculture and farming are the most vulnerable and affected activities. With climate change, the farmers are adopting various fresh farming methods to tackle and adjust to the climate variability. Adoption of GM crops, practising of less water-intensive crops, and promoting climate-resilient crops. The study also found that climate is greatly affecting the crop production of the region; moreover, the analysis of the effect of elevation on crops also proved that varying elevations are also affecting crop growth and production. Subsequently, the introduction of commercial crops has also enhanced the means of support to farmers, improving the standard of living and livelihood sustainability of the farmers in the region.