International Research Journal of Multidisciplinary Scope (IRJMS), 2024; 5(4):1374-1385

Original Article | ISSN (O): 2582-631X DOI: 10.47857/irjms.2024.v05i04.01374

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 pedals 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

(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 ℃ to -5 ℃. 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).

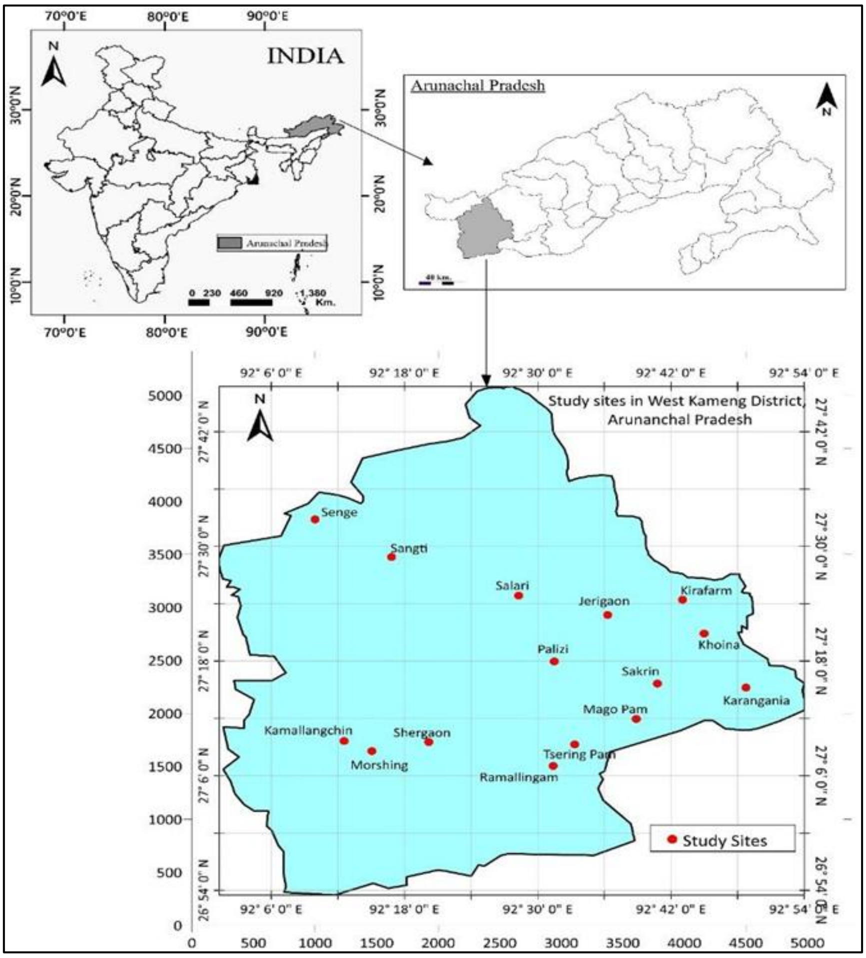

Figure 1: Map of the Study Area

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	Kalatktang-	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-vale 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 ℃, 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 ℃, 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
					∑% = 57.06	**∑%= 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 vegetables	52	8.1	30	-	189.2	106.1	2900	-	3.64	61.5	187.5	-
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
∑x̄ =	**516.8**	**152.4**	**165**	**134.8**	**1683**	**2864.5**	**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
∑x̄ =	**146.5**	**49.5**	**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
		$\sum\bar{x}$ = 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

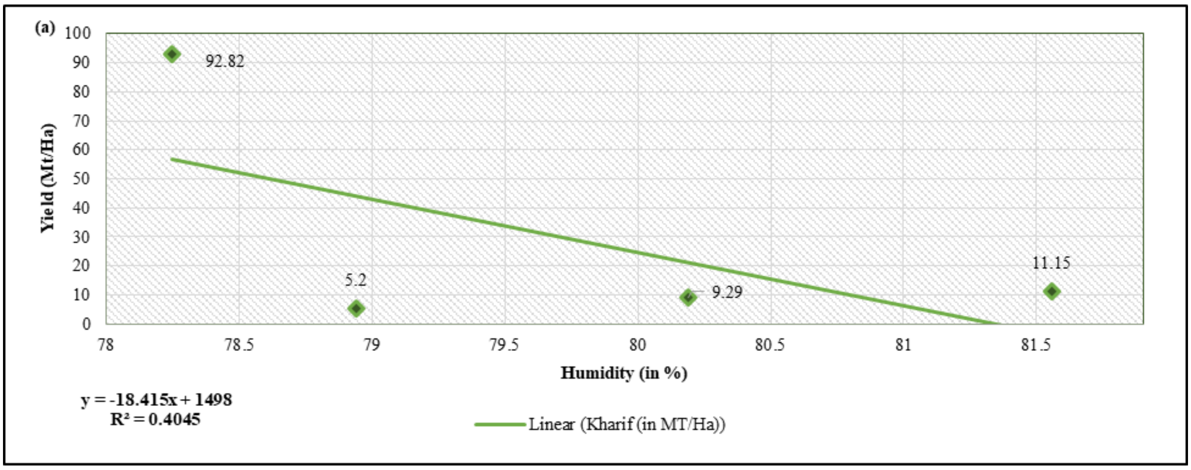

Figure 2a: Kharif v/s Humidity

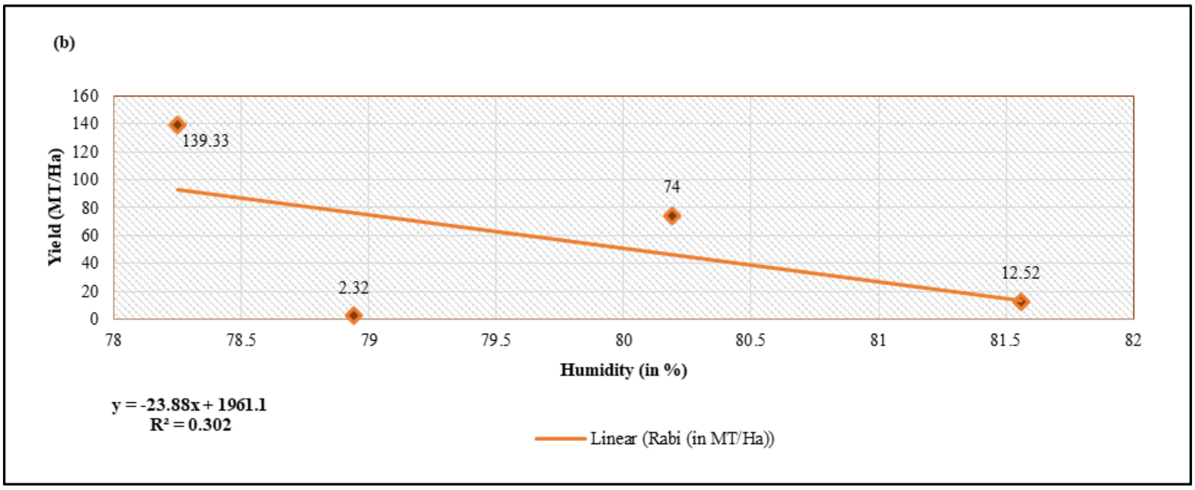

Figure 2b: Rabi v/s Humidity

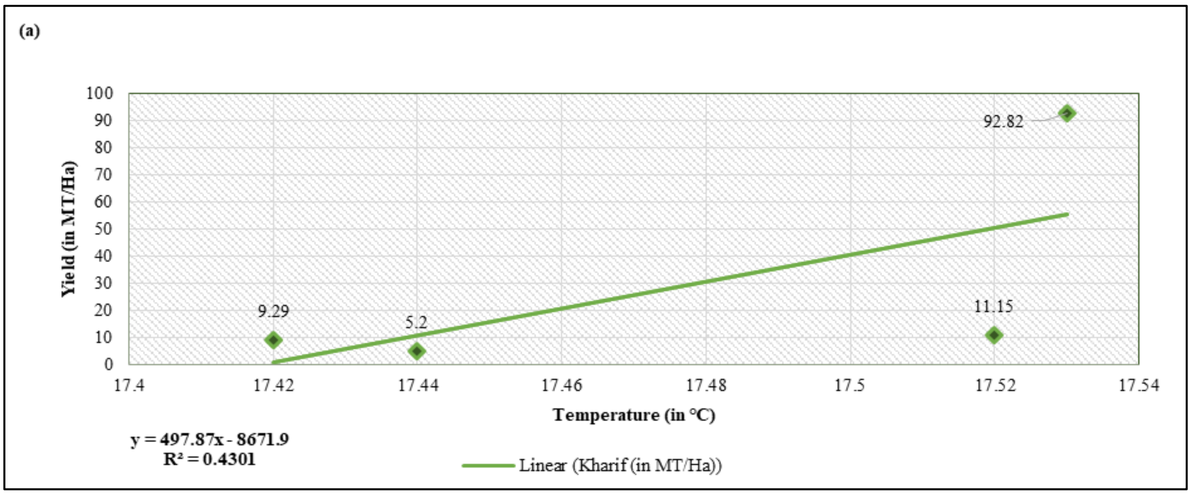

Figure 3a: Kharif v/s Temperature

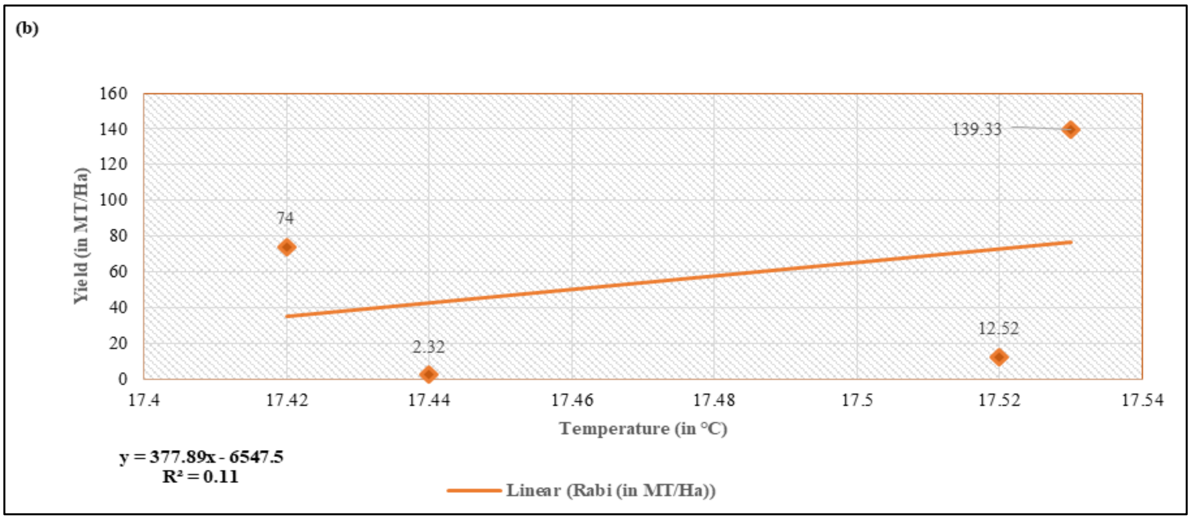

Figure 3b: Rabi v/s Temperature

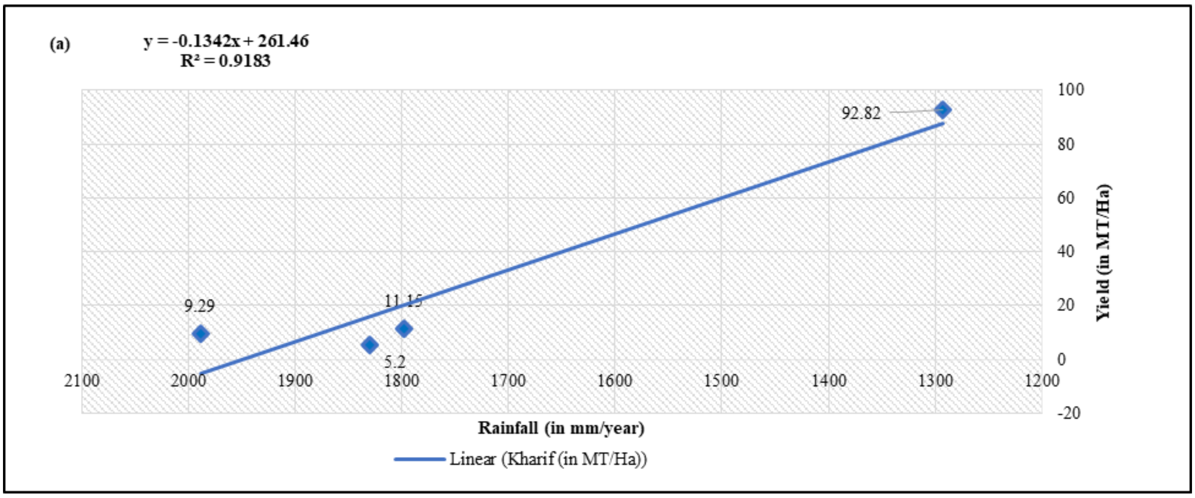

Figure 4a: Kharif v/s Rainfall

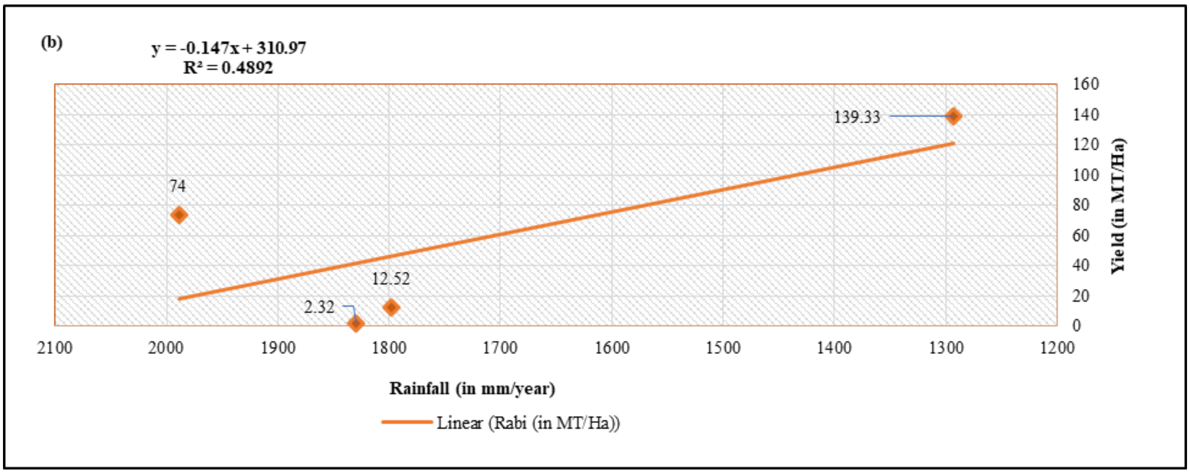

Figure 4b: Rabi v/s Rainfall

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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