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Adapting Agriculture to Climate Variability: A Path to Increased Yields

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Abstract : *Climate variability-marked by fluctuations in temperature, precipitation, and extreme weather events-poses significant challenges to global agriculture. Essentially, the ecosystem's functions and services are significantly impacted by global climate change, primarily due to anthropogenic causes. The vulnerability of agriculture will also increase locally due to climate change and variability, as the biosphere's carrying capacity to produce enough food and goods will be determined by various climatic parameters. The cultivators do experience this climatic variability and change as they depend on the natural environment. The people who live in the Koch Bihar district are socially and economically disadvantaged and mainly depend on subsistence farming for their livelihood. The perception of climate change and its induced adaptation practices is very important in agricultural activity. The objective was to find out the cultivators' perceptions about climate change and their adaptation practices in the study area. Both primary and secondary data were collected using qualitative and quantitative methods. The adaptation policy regarding agricultural practices is a widely recognized vital component to cope with climate change. Koch Bihar is a vital district situated in the foothill zone of the Himalayas, where new alluviums are found. The nature of the climate is just like a tropical monsoon. However, proactive adaptation strategies can not only mitigate risks but also unlock opportunities to enhance yields and promote food security.*

Key words: *Agriculture, Climate, Cultivators and Food security*

Introduction

Agricultural development denotes the quality of the agricultural system in a region. Agriculture plays a dual role in the abolition of hunger; it produces the food, and it can also create opportunities for several jobs needed by the households to buy food. Raising production and productivity in this sector can immediately place additional purchasing power in the hands of the rural poor, who will, in turn, utilize the extra income for purchasing more food, clothing, and other basic consumer goods that will create more jobs and higher incomes for countless others (Jagdish Singh, 2004). The Cooch Behar Sadar subdivision is an agro-climatic region in the Eastern Himalayas in West Bengal, India. The working site location as measured by GPS was 26°00′14″N to 26°30′15″N latitude and 89°15′30″E to 89°30′30″E longitude. The mean altitude of the area was 49 meters above sea level. The region is subtropical and receives an average annual

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rainfall of 250-300 mm from the southwest monsoon, with most of it occurring from June to August. The summer and winter temperatures are around 33°C during May, with the highest temperature reaching 33°C and the lowest temperature being 7°C in January. In this research, an attempt was made to assess the cultivators' perception about climate change and the strategies related to agricultural practices that they adopt in response to such variability and such changes in the study area.

Objectives

The present study was designed to execute the following objectives:

i. To study the cultivators' perception about climate change and variability in the study area.

ii. To analyze cultivators' perception of agricultural practices

iii. To understand the cropping pattern and spatial distribution of different crops in the years 2012 & 2022.

Study Area

The study was conducted at Cooch Behar Sadar sub-division (Eastern Himalayan agro-climatic region) of West Bengal, India (Figure 1). The working site location as measured by GPS was 26°00′14″N to 26°30′15″N latitude and 89°15′30″E to 89°30′30″E longitude. The mean altitude of the area was 49 m above MSL. The region is subtropical, receiving average annual rainfall of 250-300 mm from the southwest monsoon, of which 80% is received from June to August. The summer and winter temperatures are around 33°C, with the highest temperature in May, while the lowest temperature is 7°C in January.

In the study area, the majority of the respondents were male (85%). Females without their male folk did not respond to our schedule, and so, only 15% of the females responded. Approximately all of the respondents were literate, and a majority of them (90%) had attended school up to the primary level, and the rest of them had attended more than the primary level. The livelihood of the respondents depends on cultivation, and around 84% of them had landholdings of small size. In the Koch Bihar district, out of a total geographical area of 3.387 lakh hectares, 2.46 lakh hectares is the net cropped area, and irrigated land accounts for 106.00 thousand hectares.

Methods of Data Collection

Both primary and secondary data were used in this study. Primary data was gathered from the household surveys in the study area. The household scheduled survey, participant interviews, focus group discussions, and field observation methods were applied to collect primary data from the field. Additionally, these methods were also helped to collect more insight into the socio-economic issues in this study area. These secondary data, such as different documents related

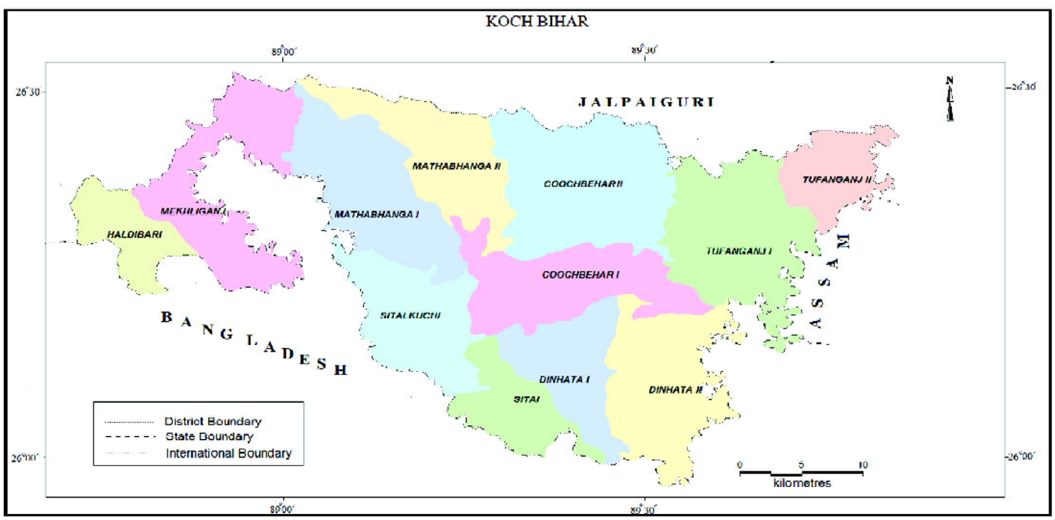

Fig. 1: Study Area, 2021

to the study, were necessary for an in-depth understanding of how far the problem had been studied and what areas had not been covered in the research. These secondary data were obtained from different websites and literature.

Methods of data analysis

The data was based on a survey of 150 rural farm households through a primary survey complemented with secondary data of temperature, rainfall, and humidity from 1969 to 2022, and decadal rainfall and temperature for 35 years. Differential statistical tools like frequency, CV, SD, mean, skewness, and kurtosis are used to analyze the data. The statements about climate change perception were presented to respondents aged 35 and older, as they have observed climate changes over time. Each statement offered three response options: “Agree” (AG), “Undecided” (UD), and “Disagree” (DG). The mean score for each statement was calculated using the following formula:

Mean score: $n1 - n2/N$

Where: $n1$ = Number of respondents who agreed,

$n2$ = Number of respondents who disagreed,

We aimed to assess the knowledge and adoption levels of various adaptive strategies among respondents by calculating a community-level Knowledge-Adoption Index (KAI) for each strategy. This index reflects the rates of knowledge and adoption among respondents.

$KAI = fk + 2fa/2N$

Where, fk = respondents aware of the strategy but not adopted, fa = respondents who have adopted the strategy, and N = total number of respondents. This study analyzes indicators of agricultural development by evaluating key variables. Using the composite Z-score statistical technique, it identifies relatively developed and less developed regions within the Koch Bihar district based on agricultural input and output indicators.

Sl. No.	Selected Indicator	
1	Total Agricultural Area/ Gross Cropped Area	X_1
2	Net Area under Cultivation/ Net Sown Area (Area in Ha)	X_2
3	Cropping Intensity (%)	X_3
4	Cropping Yield (Kg / Hectare)	X_4
5	Total Irrigated Area in Hectares	X_5
6	Population Served Per Bank office (Commercial & Gramin '000)	X_6
7	Number of agricultural laborers per thousand area of net sown.	X_7
8	Number of Fertilizer Depots	X_8

Regional Disparities and Spatial Distribution of Agricultural Development

The area, production, and yields of cereals, food grains, and pulses have been analyzed to understand the regional disparities and spatial distribution of agricultural development within the study area. These studies have been conducted at the block level using secondary data. Food grains include cereals such as rice, wheat, and maize, as well as pulses like musur, khesari, til, and mustard seeds.

Between 2012 and 2022, the area under food grains decreased, reflecting a growth rate of -8.23%. The Sitai block showed the highest growth (87.38%), while Cooch Behar II experienced the largest decline (-67.81%). The decrease in area is attributed to rapid urbanization and cash crop cultivation. Food grain production increased by 36.58% during the same period, with Sitai showing a remarkable rise of 288.51%. Conversely, Cooch Behar II saw a decline of -54.33%, dropping from 55570 metric tons to 25380 metric tons. High production growth in Sitai, Tufanganj II, and Sitalkuchi is linked to modern technology and increased awareness, while Cooch Behar II remains in the low-grade category. The yield of food grains in Cooch Behar rose by 48.99% from 2012 to 2022. Sitai recorded the highest yield growth (107.29%), whereas Dinhata had the lowest (9.57%). Overall, the growth in yields is attributed to modern agricultural practices and awareness among farmers. (Fig. 2)

Block-wise analysis of the Regional Pattern of Area, Production, and Yield of Cereal Crops

Cereals are a vital food source in the study area, comprising over 99 percent of total food

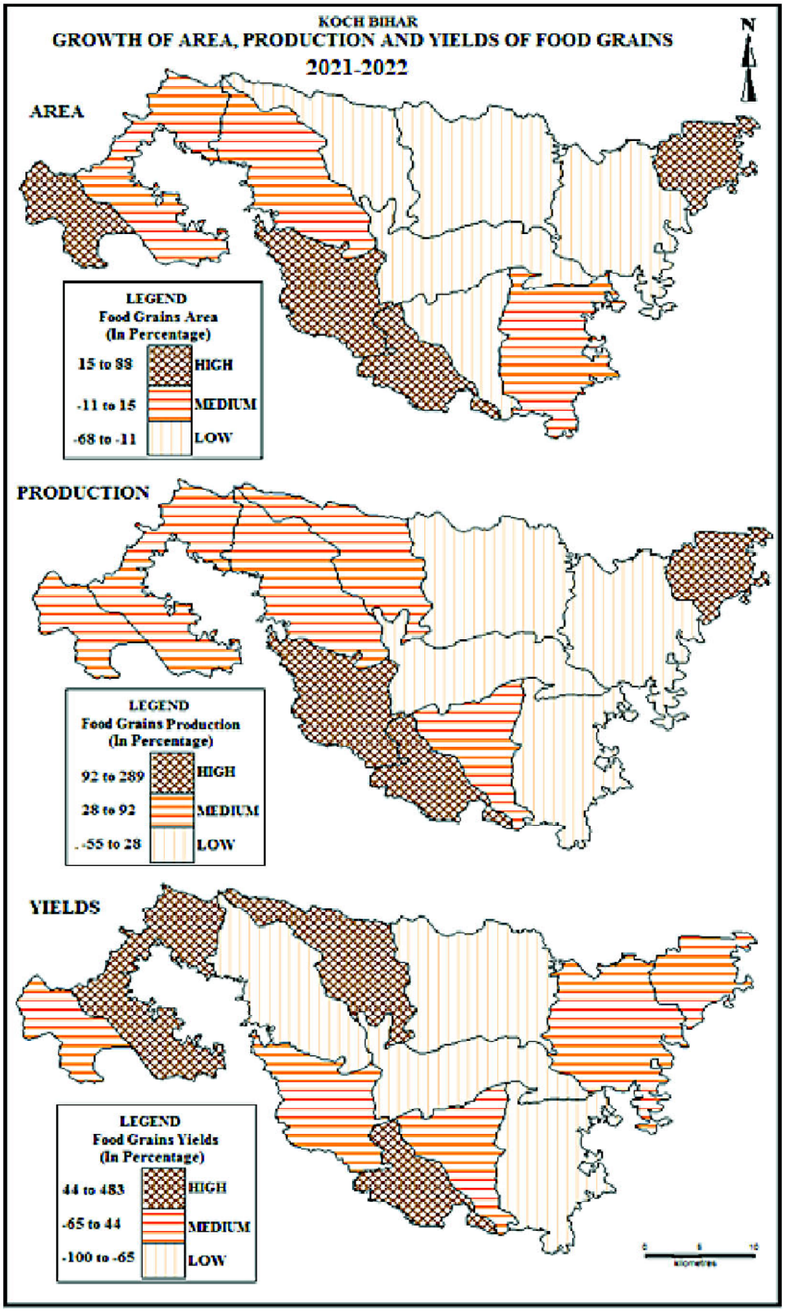

Fig. 2: Growth of Area, Production,, and Yield of Food Grains

grain production. In 2012, cereals occupied 93 percent of the food grains area, increasing to 99 percent by 2022. (Fig.: 3)

The area planted with cereals fell, showing a -6.64 percent growth rate from 2012 to 2022. The highest growth in area occurred in one block at 87.96 percent, followed by Tufanganj II at 52.63 percent and Sitalkuchi at 29.11 percent. The largest decline was in Cooch Behar II, which decreased from 35,180 hectares in 2012 to 11,452 hectares in 2022 (-67.45 percent), attributed to urbanization and a shift to cash crops.

Cereal production rose from 2012 to 2022, with a growth rate of 37.29 percent. Sitai recorded the highest production increase, soaring from 17,200 metric tons to 66,930 metric tons, with a growth of 289.13 percent. Cooch Behar II saw a decline of -54.2 percent. Cereal yields increased from 1,617 kg to 2,382 kg, reflecting a growth rate of 47.06 percent. The highest yield growth was in Sitai (106.99 percent), followed by Mathabhanga II (82.1 percent) and Mekhliganj (80.05 percent). The lowest growths were in Dinhata II (7.75 percent) and Cooch Behar I (16.98 percent). The increase in yields is largely due to modern techniques such as high-yielding variety (HYV) seeds, better irrigation, fertilizers, and farmers' increased agricultural awareness.

Block-wise Analysis of the Regional Pattern of Area, Production, and Yield of Pulses

Pulses represent only 1% of the total food grains in the study area, a decline from nearly 5% in 2022. Major pulses produced include Musur, Maskalai, and Khesri. In the Koch Bihar district, the area dedicated to pulse cultivation has decreased by 75.46% from 2012 to 2022. This decline is attributed to low productivity, poor market prices, and the labor-intensive nature of pulse farming. Farmers are increasingly shifting to more profitable crops like tobacco, potatoes, and boro paddy. The most significant production growth was seen in Sitalkuchi, which increased from 60 to 207 metric tons, a 245% rise. In contrast, Cooch Behar I, Cooch Behar II, and Tufanganj I reported a growth rate of -100%. Sitalkuchi recorded the highest yield growth at 1,048.52%, from 66 kg/ha in 2012 to 781 kg/ha in 2022. Similar declines were reported in Cooch Behar I, Cooch Behar II, and Tufanganj I, all with a -100% growth rate.

Block-wise analysis of the Regional Pattern of Area, Production, and Yield of Cash Crops

Cash crops are primarily grown for sale, either in raw or semi-processed forms, with examples including jute, tobacco, potatoes, and oilseeds.

Between 2012 and 2022, the area dedicated to cash crop cultivation decreased, reflecting a -62.00 percent change. Sitai saw the highest growth, increasing by 448.31 percent from 2,670 hectares to 14640 hectares. In contrast, Haldibari experienced a sharp decline of 96.33 percent, dropping from 76,970 hectares to 2,828 hectares. Other blocks like Mekhliganj and Tufanganj II also faced significant reductions. The highest area growth was noted in Sitai, Mathabhanga I, and Mathabhanga II, while lower growth occurred in Dinhata I, Dinhata II, Tufanganj I, Sitalkuchi, and Cooch Behar II. This shift towards market-oriented farming practices has driven the increase in cash crop area.

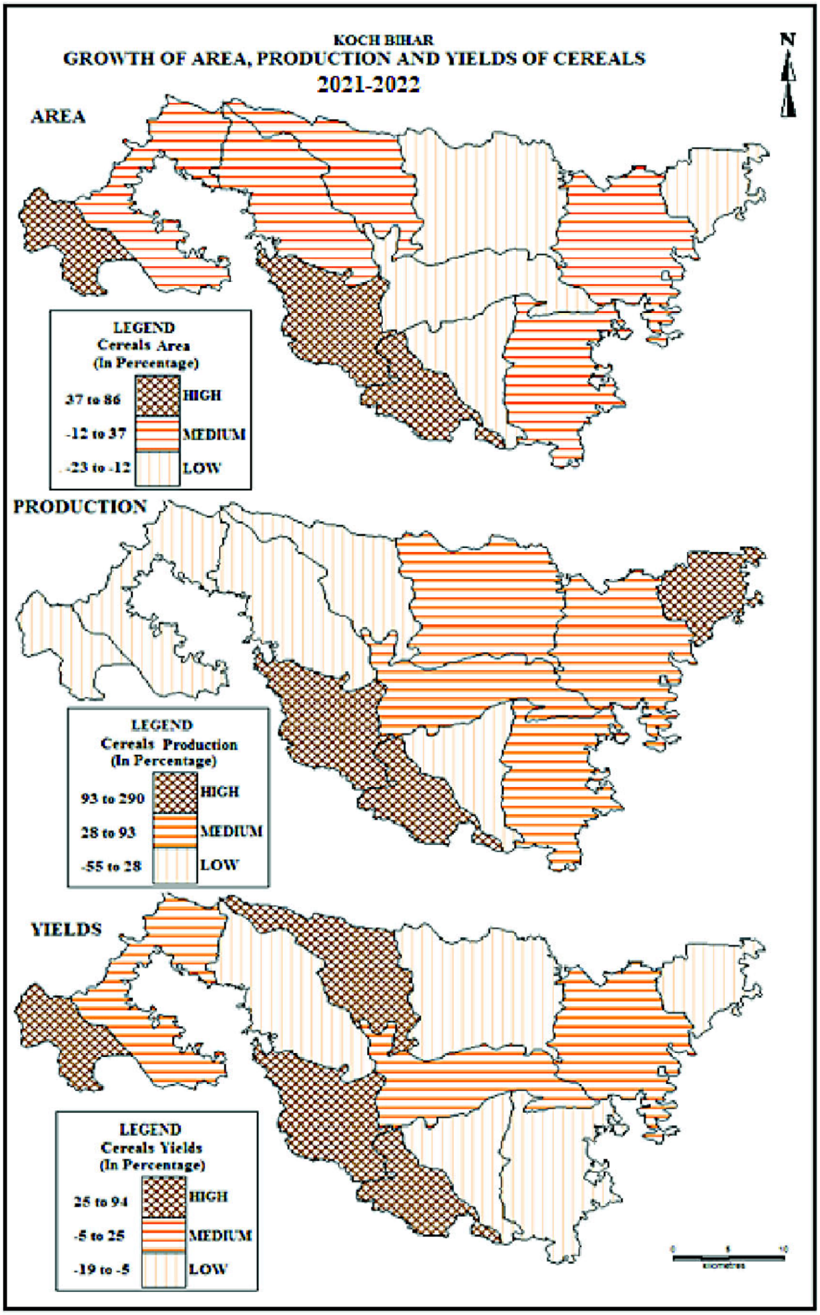

Fig. 3: Growth of Area, Production, and Yield of Cereal Crops

The most significant increase in production was in Sitalkuchi (555.67 percent), while Haldibari faced an 80.73 percent decline. The highest production growth was in Sitai, Mathabhanga I, and Mathabhanga II, while five blocks, including Haldibari, recorded the lowest growth. Increased production is attributed to the use of high-yielding variety seeds, improved irrigation, and better access to agricultural credits. The greatest yield increases were seen in Mekhliganj (479.29 percent) and Haldibari (426.6 percent), whereas Mathabhanga II and Tufanganj I experienced declines.

Agro-climatic Zone & Major Agro-ecological Situations (Based on Soil and Topography)

The district is predominantly a level plain that gently slopes towards the southeast. The soils here are formed by alluvial deposits from various river systems, including the Torsa, Kaljani, Mansai, Teesta, Raidak, Gadadhar, and Sankosh rivers. Throughout the district, the soil primarily has a sandy loam texture. There are small pockets of heavier soil found between the Mora Torsa and Ghargharia rivers. The depth of the soil ranges from 0.15 to 1 meter.

Based on major river basins' soil characteristics and meteorological parameters, three major agro-ecological situations prevail in the district.

1. Torsa-Kaljani Basin (AES-I)—Consists of the basin of the rivers Torsa, Ghargharia, Gadhadhar, Raidak, Kaljani, etc. The basin comprises six blocks: Cooch Behar I & II, Tufanganj I & II, and Dinhata I & II.
2. Mansai Basin (AES-II)—All blocks (Mathabhanga I & II, Sitalkuchi, and Sitai) of this AES fall under the basin of the river Mansai.

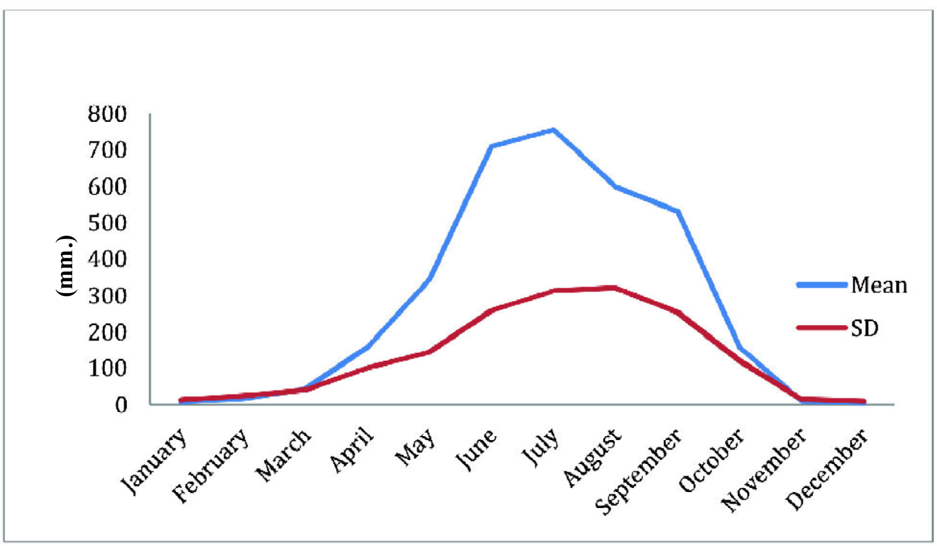

Fig. 4: Relation Between mean and SD of rainfall (mm.), 1969-2022.

3. Teesta Basin (AES-III) – Blocks viz. Mekhliganj and Haldibari fall under the basin of the river Teesta.

Impact of Climatic Variability on Regional Development of Agriculture of Koch Bihar District

There are regional variations in rainfall within this district. The western and southwestern areas receive less than 3000 mm of rainfall annually. The central part of the district receives between 3000 mm and 3500 mm of rainfall. In contrast, the extreme northeastern portion experiences an average annual rainfall of more than 3500 mm. (Table 1)

The coefficient of variation (CV) of rainfall in this study ranged from 36.34% to 183.64%, indicating significant variability over time. Skewness values ranged from 0.10 to 2.62, with the highest skewness and kurtosis (2.62 and 7.96, respectively) observed in January, suggesting a right skew and leptokurtic distribution. (Fig. 4)

Table 1: Descriptive statistics of monthly rainfall (mm) of Koch Bihar District, West Bengal (1969-2022)

Months	Mean	SD	CV	Skewness	Kurtosis
January	7.34	13.08	178.37	2.62	7.94
February	16.31	23.43	143.71	2.60	7.96
March	43.30	39.61	91.49	0.71	-0.74
April	156.49	101.46	64.84	1.59	4.06
May	342.94	143.61	41.88	1.58	2.76
June	708.67	257.54	36.34	0.10	-0.66
July	756.13	312.09	41.27	0.44	-0.03
August	597.42	320.33	53.62	1.28	2.43
September	530.54	253.36	47.75	1.53	3.24
October	156.50	119.53	76.38	1.18	1.58
November	9.85	14.36	145.74	1.68	2.21
December	4.86	8.93	183.64	2.15	3.82

The highest skewness and kurtosis (3.01 and 13.60, respectively) were observed in the winter season. The CV was 23.49% during the monsoon season and peaked at 107.33% in winter. (Table 2). This analysis of seasonal rainfall trends between 1969 and 2022 showcased that rainfall variability was greater over the entire area during these winter seasons. The winter season indicated the lowest rainfall received, while the highest rainfall was received in the monsoon season. It indicates that agriculture completely depends on monsoon rainfall. The yearly precipitation CV

Table 2: Descriptive statistics of seasonal and annual rainfall (mm) of Koch Bihar District, West Bengal (1969-2022)

Seasons	Mean	SD	CV	Skewness	Kurtosis
Pre-monsoon	542.73	193.10	35.58	1.07	2.42
Monsoon	2592.76	609.04	23.49	0.59	0.72
Post-monsoon	166.35	124.98	75.13	1.22	1.74
Winter	28.50	30.59	107.33	3.01	13.60
Annual	3330.34	723.10	21.71	0.10	-0.13

was 21.71 %, with a standard deviation of 723.10, skewness of 0.10 (right skew), and kurtosis of -0.13 (platykurtic). In recent decades, the potential yields of crops in Koch Bihar have significantly increased due to the development of improved cultivars and better pest management programs. However, local farmers understand that even when they plant the highest-yielding cultivars in fertile soils and apply optimal cultural practices, actual yields are still affected by weather conditions, particularly the amount and distribution of rainfall and temperature. It clearly shows from Table 3 and Figure 5 that temperature is rising in each decay and rainfall is decreasing. As a result, crops in the region often fail to reach their maximum potential yields due to physiological constraints imposed by unfavorable weather conditions. The differences in average temperature are almost the same throughout every season.

Table 3: Decadal change of rainfall (mm) and temperature of Koch Bihar District, West Bengal (1901-2019)

Year	1901-1929	1930-1959	1960-1989	1990-2019
Average Maximum temperature in °C	29.75	30.05	30.12	30.88
Average Minimum temperature in °C	19.39	19.76	19.69	20.23
Average Rainfall in mm	176.24	180.28	177.94	171.70

Perception study of cultivators about climate change and variability

Cultivators believe that the climate is changing compared to previous years, with a notable perception of unpredictable rainfall and temperature day by day, averaging a score of 0.91 (Table 4). Most report a rise in average daytime temperatures during the pre-monsoon (0.75), followed by an increase in the range of day and night temperatures day by day (0.94) and a change in the duration and intensity of rainfall (0.96). Other observed changes include late onset of monsoon rains (0.79), changing duration and intensity of rainfall (0.96), early withdrawal of rain in monsoon (0.97), increased number of incidents of floods and droughts, climate-related extremes and hazards

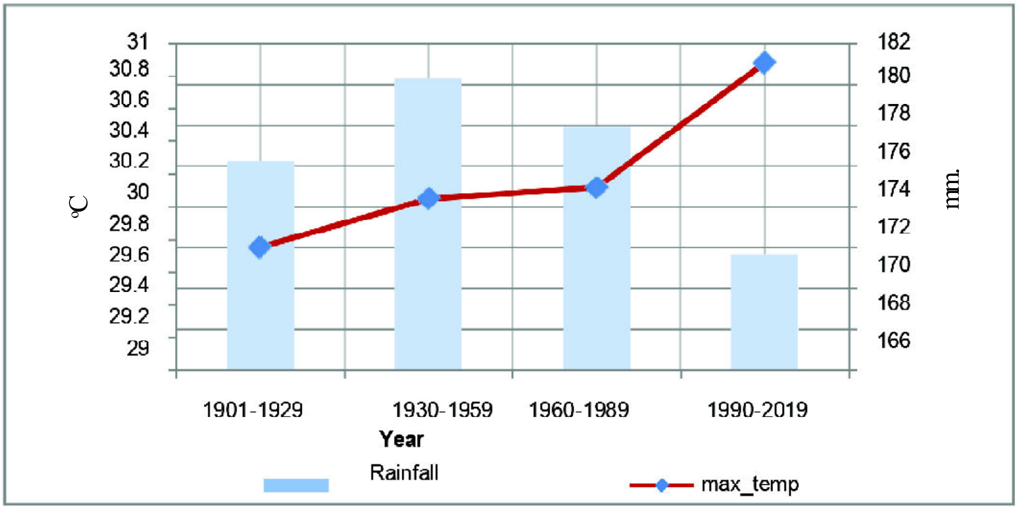

Fig. 5. Decadal change of rainfall (mm) and temperature of Koch Bihar District, West Bengal (1901-2019)

Table 4: Perception study of cultivators about climate change and variability

Statement	A	U	D	MS
Occurrence of unpredictable rainfall day by day	143	1	6	0.91
Uneven distribution of rainfall	38	41	71	-0.22
Late onset of monsoon rains	147	1	2	0.96
Early onset of monsoon rains	39	53	58	-0.34
Late withdrawal of monsoon rains	32	62	56	-0.16
Early withdrawal of rain in monsoon	148	0	2	0.97
Average diurnal range of temperature increased in pre-monsoon	122	21	9	0.75
Changing Duration and intensity of rainfall	147	0	3	0.96
Incidents of number of floods droughts, climate related extremes and hazard are increasing	133	2	15	0.78
Average day temperature increased in pre-monsoon	131	14	5	0.84
Duration of cloudy days	121	6	23	0.65
Increasing the range of day and night temperature day by day	143	5	2	0.94

Source: *Computed by the Author. Where A=Agree, U=Undecided, D=Disagree, and MS=Mean Score.*

(0.78), and fewer cloudy days (0.65). The overall farmer community perception of climate event regularity in rainfall is moderate. Most cultivators believe that monsoon rainfall trends show a late onset and early withdrawal, followed closely by changing season durations and increasingly unpredictable rainfall.

Table 5: Block-wise distribution of composite Z-score value of agricultural development (2012-2022)

Sl. No.	Name of the blocks	composite Z Score Value	
		2012	2022
1	Haldibari	-0.478	-1.182
2	Mekhliganj	-0.214	-0.392
3	Mathabhanga-I	0.151	0.408
4	Mathabhanga-II	0.102	-0.032
5	Sitalkuchi	0.473	0.205
6	Cooch Behar—I	0.282	0.476
7	Cooch Behar- II	0.647	0.696
8	Tufanganj—I	-0.052	0.743
9	Tufanganj – II	-0.047	-0.341
10	Dinhata—I	0.204	0.399
11	Dinhata- II	-0.302	-0.130
12	Sitai	-0.766	-0.851

The blocks of Koch Bihar district have been classified based on the composite Z score to highlight the regional disparities in agricultural development (Table 5). Maps illustrate these patterns for 2012 and 2022 (Fig. 6). In 2012, over 50 percent of the blocks had a negative composite score, reflecting low agricultural development, which improved slightly to over 40 percent in 2022. Central blocks, such as Cooch Behar-I and Tufanganj-I, showed better development due to improved infrastructure and knowledge of agricultural practices. In contrast, the eastern blocks are categorized as having low and very low agricultural development due to their lower elevation (35-40 meters) and vulnerability to flooding. The Western blocks face challenges from limited irrigation and low fertilizer usage, further hindering agricultural productivity. These areas often contain Antisols—newly formed soils that are weakly developed and prone to erosion, contributing to low fertility. Additionally, rising agricultural input costs present significant challenges for small and marginal farmers, who are a major segment of Indian agriculture (Shah, 2006).

Adaptation Strategies Adopted by Cultivators of Koch Bihar District

To boost productivity, immediate improvements in infrastructure are needed, including power supply, rural roads, and marketing. Quality seeds, balanced fertilizers, adequate machinery, changes in land policy, a farmer-friendly extension service, and an effective credit system should also be provided.

Table 6: Adaptation strategies adopted by cultivators of Koch Bihar District

Sl No	Indicators	AD	NAD	DK	KAI
1	Practice of crop rotation	111	39	0	.87
2	Practice of crop diversification	95	55	0	.81
3	Access to climate change information	19	86	45	.41
4	Useof drought/flood-tolerant varieties	14	94	42	.40
5	Use of rainwater harvesting	32	79	39	.47
6	The practice of soil testing	52	85	13	.63
7	Access to market information	40	74	36	.51
8	Use of crop insurance	82	36	32	.67
9	Use of HYV seed	142	8	0	.97
10	Mulching	127	20	3	.91
11	Zero tillage	54	72	20	.60
12	Practice of pulses cultivation in wasteland	48	86	16	.61
13	Owned livestock and poultry	32	91	27	.52
14	More infestations, pests, and diseases	121	24	5	.88
15	Alteration of sowing time	127	23	4	.92

Source: Primary Survey computed by authors, AD- Adopted, NAD- Not adopted, DK- Don't know, KAI-Knowledge Adaptation Index.

The study area has identified a total of 15 adaptation strategies adopted by cultivators. These strategies include practices such as crop rotation, crop diversification, access to climate change information, the use of drought- and flood-tolerant varieties, rainwater harvesting, soil testing, market information access, crop insurance, the use of high-yielding varieties (HYV), and mulching. The knowledge-adoption index indicates a high level of awareness among cultivators, with scores ranging from 0.81 to 0.91 for practices like the use of HYV seeds, crop rotation, crop diversification, and mulching, as well as regarding pest and disease infestation. The majority of cultivators have adopted these strategies. In contrast, practices that received a low to medium knowledge-adoption index score of 0.51 to 0.61 include the cultivation of pulses in wastelands, the use of crop insurance, zero tillage, and access to market information. Techniques such as using drought- and flood-tolerant varieties, accessing climate change information, and rainwater harvesting are not widely adopted among cultivators. (Table No:6)

Farmers often shy away from growing vegetables or other risky crops due to low profits and inadequate storage. To address this, we must enhance their confidence through crop insurance and support for agricultural loans, improving their economic conditions and lifestyles.

Conclusion

Adaptation of agricultural practices in Koch Bihar district to climate variability is essential for maintaining food security, enhancing farmer resilience, and promoting sustainable development. Changing weather patterns increasingly challenge conventional farming methods. Innovative approaches by farmers in the agricultural sector like climate-smart agriculture, advanced irrigation systems, resilient crop varieties, and data-driven decision-making, provide effective solutions to protect livelihoods and improve yields under uncertain climatic conditions and for supporting the growing food demand of Koch Bihar district.

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