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An Empirical Assessment of Climate Change Effects on Crop Production in Kirtinagar Block, Tehri Garhwal, Uttarakhand

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Abstract: Climate change is increasingly recognized as a major factor influencing agricultural productivity worldwide. In the Himalayan region of Garhwal, this phenomenon has become particularly evident. Agriculture remains the primary source of livelihood for over 70% of the population in this region, making the community highly vulnerable to environmental changes. Key climatic variables such as temperature, radiation, rainfall, soil moisture, and carbon dioxide concentration all interact in complex ways to affect crop yields. These interactions are often non-linear, resulting in unpredictable and adverse effects on agricultural output. Recent studies indicate a decline in productivity directly linked to these climatic shifts. To understand the extent and nature of these changes, this study focuses on the Kritinagar block in Tehri Garhwal district. It employs both secondary data and primary data collected through questionnaires, schedules, and interviews. The primary objective is to evaluate the impact of climate change on crop production and to analyze associated land use changes in a dynamic environmental context.

Keyword: Agriculture • Climate Change • Crop Production • Himalaya Region • Land Use.

Introduction

Climate change poses significant challenges to agricultural systems across the globe, impacting both environmental and socio-economic aspects. It influences critical factors such as crop yield, water availability, pest and disease prevalence, and soil health. As agriculture forms the backbone of rural livelihoods, particularly in vulnerable regions, understanding the extent of these impacts has become a global research priority. Numerous studies have investigated farmers' perceptions of climate change and its consequences at international, national, and regional scales. For example, Luitel et al. conducted an assessment of climate change impacts on crop yield across ecological regions of central Nepal. Their findings revealed a general alignment between observed rainfall trends and farmers' perceptions, although respondents in temperate zones noted delayed snowfall without significant change in its quantity. Similarly, Ramesh et al. (2022) explored farmers' perceptions of changing climatic conditions in western Nepal through data from 554 households and focused group discussions. They documented local experiences of altered temperature and rainfall patterns, shifts in seasonal cycles, and perceived threats to agricultural livelihoods.

Further emphasizing regional impacts, Pandey (2022) studied the Chitwan District in Nepal, highlighting the detrimental effects of climate change on agricultural production and the economic stability of farming communities. Other researchers (Paudel & Acharya 2014; Huttunen & Alm 2003; Karki et al 2009) have shown that increasing global temperatures, greenhouse gas emissions, and erratic weather patterns—including floods, landslides, and droughts—are exacerbating environmental

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stress and undermining food security. These global and regional insights are directly relevant to the Kirtinagar Block in Tehri Garhwal district, Uttarakhand, a region where livelihoods are heavily dependent on agriculture. Here, the increasing variability of weather, including changes in rainfall patterns and rising temperatures, mirrors trends observed elsewhere. Farmers in this area face both direct and indirect impacts of climate change, which threaten crop productivity, water availability, and overall livelihood security. Thus, there is an urgent need to assess and address the local consequences of climate change to ensure agricultural sustainability and resilience in such vulnerable hill regions.

Study Area

Administrative blocks in the Himalayan region play a crucial role in shaping the socio-economic and agricultural landscape of Uttarakhand. Among these, Kirtinagar Block in Tehri Garhwal district stands out as a significant and strategically located region. Positioned in the easternmost part of the district, it forms part of the expansive Himalayan terrain and lies between 30º12´ to 30º24´ North latitude and 78º30´ to 78º54´ East longitude. Kirtinagar Block is bordered by Augustmuni Block of Rudraprayag district to the east, Jakhanidhar Block to the west, Bhilangana Block to the north, and the Alaknanda River and Pauri Garhwal district to the south. These geographic boundaries not only define its location but also influence its climate, hydrology, and land use patterns. As per the 2011 Census, the block spans an area of 362.64 square kilometers and includes 153 villages. It has a population of 45,629, consisting of 21,542 males and 24,087 females, spread across 10,580 households. Within this population, the Scheduled Tribe (ST) community accounts for 143 individuals, while the Scheduled Caste (SC) community comprises 8,494 individuals.

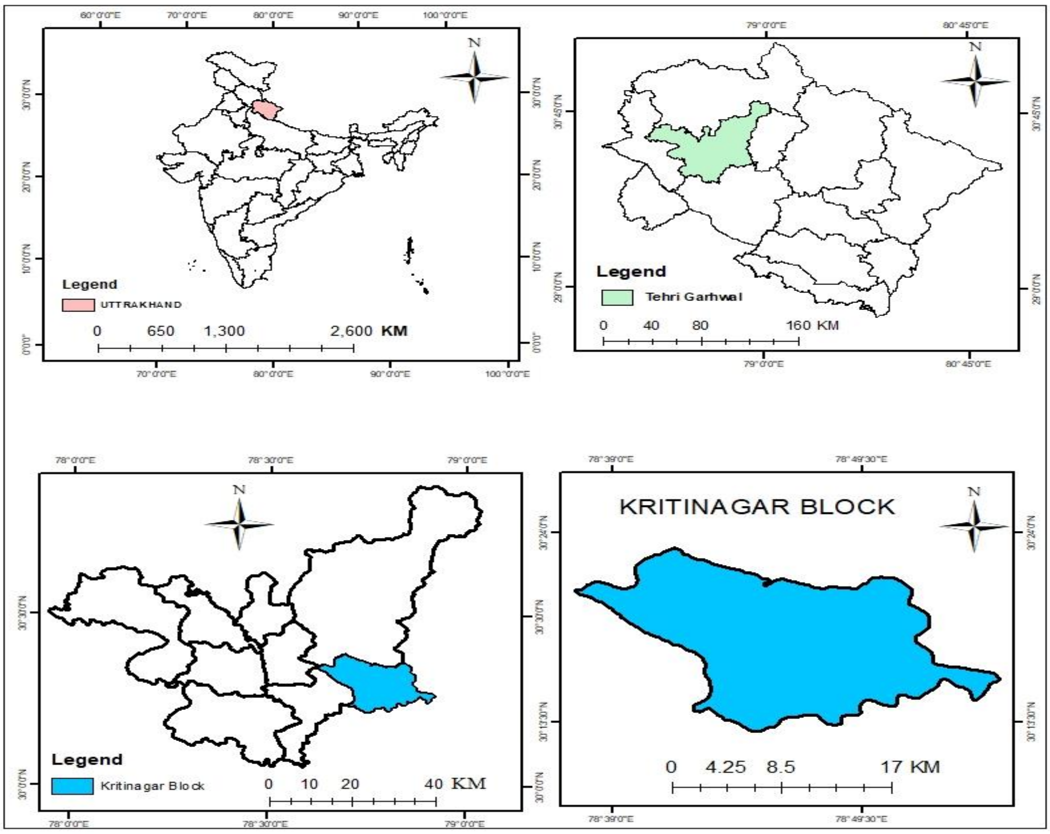

Fig 1: Map of the Study Area

The literacy rate of the block stands at 79.25%, indicating a relatively well-educated population base. The economic structure of Kirtinagar is largely agrarian. Out of a total working population of 21,257, there are 15,782 main workers and 5,475 marginal workers. Notably, 10,615 individuals are engaged full-time in agriculture, while another 1,061 pursue farming on a seasonal or part-time basis. This data highlights the centrality of agriculture to the region's livelihood and underscores the importance of understanding how climate and environmental changes might impact this sector.

Objectives

1. To examine the patterns of climate change and land use in Kirtinagar Block, Tehri Garhwal.
2. To empirically assess the impact of climate change on crop production in the study area.

Database and Methodology: This study adopts an empirical approach, relying on both primary and secondary data sources to assess the impact of climate change on crop yields in Kirtinagar Block, Tehri Garhwal, Uttarakhand.

Primary Data Collection

Primary data was collected through field surveys using interviews, structured questionnaires, schedules, and group discussions. Villages were selected using a random sampling method, ensuring coverage across different altitude zones within the block to capture geographical diversity. Respondents were selected based on their experience and involvement in agriculture—each respondent was above 25 years of age and had been continuously engaged in farming activities. Among the total respondents, 44% were male and 56% were female, providing a balanced perspective on local agricultural practices and climate-related challenges.

Secondary Data Collection

Secondary data was gathered from a variety of credible sources, including government reports, published research papers, district statistical handbooks, books, journals, and newspapers. This data provided historical insights into temperature trends, rainfall variability, land use changes, and agricultural outputs in the region.

Data Analysis Techniques

The collected data was analyzed using both graphical and statistical methods. Descriptive statistics, such as percentage change, were employed to examine trends in temperature, rainfall, and crop yields. Tables were used to present comparative data on climatic variables over time.

To support visual and spatial analysis, various software tools were utilized. MS Excel was used for data tabulation and chart generation; ArcGIS was employed for creating thematic maps; and MS Word was used for documentation and formatting of the study.

Result & Discussion

Analysis of Average Temperature Trend: In the Kritinagar block of the Tehri Garhwal district in Uttarakhand, according to NASA, **Table 01** illustrates the variability and change in average annual and monthly temperature from 2015 to 2022. Notably, in Kirtinagar block consistently experiences, the temperature in the given dataset exhibits variation, ranging from the lowest average monthly recorded temperature of -2.95° Celsius January month in 2019, while the highest average monthly temperature of 38°C in June month 2022. **Table 02** shows the average maximum annual temperature and average minimum annual temperature from 2015 to 2022. As per the given dataset, the average maximum average annual temperature was recorded at -02°C in 2019. Despite fluctuations, there is an observable increasing and decreasing trend in the data set. The increasing temperature trend was more pronounced, in 2015 and 2016, when temperature variability was also high, and the decreasing average annual temperature was recorded from 2017 to 2020, while it again increased in 2021 and 2022. These temperature trends and variations underscore the dynamic nature of climate conditions in the given dataset, with potential implications for agriculture and cropping patterns.

Table 1: Trend of Maximum Temperature

YEAR/ Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
2015	20.92	26.56	27.4	30.12	35.65	36.37	31.57	26.78	27	25.84	23.87	21.95	36.37
2016	19.69	24.47	28.72	34.05	36.76	34.66	31.56	27.54	26.33	25.88	26.98	23.11	36.76
2017	20.16	25.4	32.58	35.33	35.49	38.18	29.43	27.75	27.51	25.98	21.68	22.52	38.18
2018	22.1	24.36	29.58	32.93	36.6	35.79	30.45	26.93	27.3	24.73	20.55	17.95	36.6
2019	17.81	18.86	27.08	33.16	37.4	37.95	34.96	28.05	27.19	23.71	22.99	18.59	37.95
2020	18.13	23.97	24.73	28.66	35.01	32.62	30.67	28.62	27.75	26.5	22.9	21.84	35.01
2021	20.86	25.14	29.11	32.6	33.69	35.53	34.04	27.87	26.73	26.42	20.86	19.39	35.53
2022	17.58	18.55	30.28	34.76	36.54	37.09	29.23	28.22	26.51	25.84	22.19	20.49	37.09

Table 2: Trend of Minimum Temperature

YEAR/ Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
2015	2.48	3.73	4.78	8.78	13.79	17.88	18.4	18.05	14.53	9.08	7.84	1.59	1.59
2016	0.64	4.12	6.32	12.8	16.42	18.9	18.84	18.68	16.14	9.98	7.69	3.65	0.64
2017	-1.65	1.53	1.62	8.99	14.46	17.11	18.76	18.83	15.42	9.71	5.69	3.78	-1.65
2018	1.48	3.11	5.55	11.53	13.92	18.44	18.8	18.34	15.12	8.61	5.99	-0.96	-0.96
2019	-2.95	-0.65	02.4	9.44	13.24	16.53	18.83	18.96	15.35	10.04	6.08	-2.09	-2.95
2020	-1.82	-1.51	1.73	8.58	12.43	15.64	17.73	18.34	13.69	09.9	4.74	02	-1.82
2021	0.69	0.03	5.83	8.55	12.51	15.88	19.45	18.33	16.94	9.28	6.9	0.05	0.03
2022	-0.1	-0.84	6.47	11.3	15.57	16.71	19.32	18.8	16.1	10.4	6.39	2.08	-0.84

***(*source: NASA Power)**

Analysis of Precipitation

Precipitation Trends in Kirtinagar Block (2015–2022): Fig 2 represents the variability and trends in average monthly and annual precipitation in Kirtinagar Block, Tehri Garhwal, from 2015 to 2022, based on data sourced from NASA POWER. The data indicates a consistent precipitation pattern from 2015 to 2019, with minor fluctuations. However, a noticeable decline is observed in the years 2021 and 2022, suggesting a reduction in overall annual rainfall. The highest recorded annual mean precipitation was 15.88 mm in 2015, while the lowest was 3.42 mm in 2021. These variations reflect significant climatic shifts that may influence the region's agricultural productivity. The reduction in rainfall, especially during critical growing seasons, could negatively impact soil moisture levels and crop yields, thereby posing challenges to traditional farming practices. Moreover, the dataset indicates that July consistently recorded the highest monthly average precipitation, highlighting its importance as the peak of the monsoon period in the study area.

Table– 03 Precipitation Trend in Kritinagar block 2015 to 2022

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
2015	0	0	5.27	0	0	5.27	15.82	10.55	0	0	0	0	5.27
2016	0	0	0	0	0	5.27	10.55	10.55	0	0	0	0	5.27
2017	5.27	0	0	0	0	10.55	10.55	10.55	5.27	0	0	0	5.27
2018	0	0	0	0	0	5.27	15.82	15.82	10.55	0	0	0	5.27
2019	0	5.27	0	0	0	0	10.55	10.55	5.27	0	0	0	5.27
2020	5.27	0	5.27	0	0	5.27	10.55	10.55	0	0	0	0	5.27
2021	0.68	0.94	0.34	1.84	4.19	4.24	15.06	8.59	8.71	2.11	0.01	0.26	3.94
2022	4.88	1.82	0.02	0.07	2.26	3.86	15.04	8.7	12.36	2.23	0.12	0.03	4.31

(source: NASA Power)

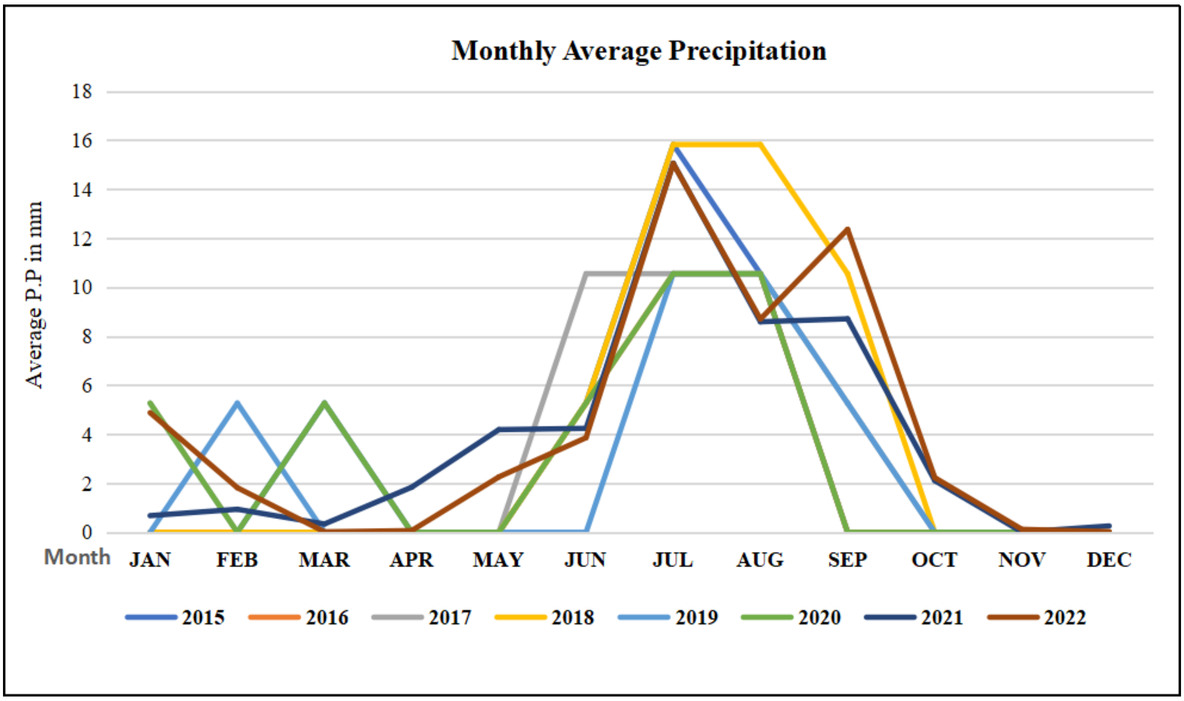

Fig 2: Monthly Average Precipitation

Land Use Change Analysis (2014–15 to 2021–22)

Table 3 highlights the changes in land use patterns in Kirtinagar Block, Tehri Garhwal district, between the years 2014–15 and 2021–22. The data reveals a notable shift in land utilization across various categories over this period. The total reported area declined from 57,326 hectares in 2014–15 to 50,833 hectares in 2021–22, registering a reduction of 11.33%.

A significant decrease in cultivated barren land is observed, shrinking by 92.67%, from 7,444.67 hectares to only 545 hectares. Similarly, current fallow land and other fallow land declined by 71.62% and 53.82%, respectively. Net shown area, which represents the actual cropped area, reduced sharply by 50.66%, dropping from 6,405.54 hectares to

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3,159 hectares. A similar downward trend is visible in the area sown more than once (−43.84%) and gross sown area (−48.45%). These reductions signal a contraction in agricultural intensity and may indicate both climatic and socio-economic challenges affecting farming practices.

In contrast, some land use categories showed an increase:

- Barren and uncultivable land rose by 26.09%, indicating land degradation or abandonment.
- Areas under gardens, trees, and bushes expanded by 10.77%, possibly reflecting agroforestry or conservation efforts.

The forest area remained unchanged, reflecting stable management or no significant encroachment or reforestation during this period. However, other usable lands except agriculture decreased by 30.39%, possibly due to urbanization or shifting land priorities. This shift in land use dynamics highlights a decline in agricultural land and intensification, raising concerns about the sustainability of crop production in the region. It also points toward the influence of climate change, socio-economic transformations, and land degradation in altering traditional land use patterns in the Kirtinagar Block.

Table 3: Land Use Change in Kirtinagar Block from 2014–15 to 2021–22

S.N.	Land use	2014-15 (in hec)	2021-22(in hec)	Change in %
1	Total Reported Area	57326	50883	-11.24%
2	Forest	40039	40039	0.00%
3	Cultivated Barren Land	7444.67	5456	-26.71%
4	Current Fallow land	1043.04	296	-71.62%
5	Other Fallow Land	964.14	441	-54.26%
6	Barren & uncultivable land	382.39	482	26.05%
7	Other usable lands except for agriculture	619.14	431	-30.39%
8	Pasture land	12.83	12.83	0.00%
9	Area of Gardens, Tress & Bushes	414.08	539	30.17%
10	Net Shown Area	6405.54	3199	-50.06%
11	Field Shown More Than once	2781.46	1562	-43.84%
12	Gross Shown Area	9235.15	4761	-48.45%

(Source: Socio-Economic Analysis & District at a Glance)

Analysis of Change in Major Crop Production

The author conducted a study across 15 villages, selected using random sampling from various altitudinal zones ranging between 500 meters and 3,500 meters. This study aimed to analyze changes in the production of major crops such as wheat, rice, barley, mandua (finger millet), sawa (jangora), black gram (urad), and red lentils (masoor) over the years 2023 and 2024. The findings, summarized in Table 4, are based on data collected through questionnaires, structured schedules, and interviews. The data clearly indicates a noticeable decline in crop production from 2023 to 2024. In 2023, the production percentages of major grains and pulses were as follows: wheat 48%, rice 50%, barley 39%, mandua 40%, sawa 37%, black gram 29%, and red lentils 25%. In 2024, these figures dropped to wheat 42%, rice 47%, barley 36%, mandua 38%, sawa 34%, black gram 25%, and red lentils 23%. According to respondents, the primary cause of this decline is the increasing impact of climate change. Variability in temperature and rainfall has introduced significant challenges for agriculture, particularly in hilly regions where over 75% of the population relies on farming for their livelihood.

Table 4: Overview of Major Crop Yields in the Studied Villages

S.N.	Production of Major Crops in % (2023-24)		
1	**Crops Name**	**2023**	**2024**
2	Wheat	48	42
3	Rice	50	47
4	Barley (Jau)	39	36
5	Mandua	40	38
6	Sawa (Jangora)	37	34
7	Black Gram (Uradh)	29	25
8	Red Lentils (Masoor)	25	23

(Data Source: Compiled by Researcher Based on Primary Data)

As presented in Fig 3, the production of crops in one crop season is between less 50kg and 5 villages come under the range of 50-100 kg production while 3 villages come under the production range is more than 100kg in a crop season. More than 65% of the respondents to questionnaire surveys and FGDs mentioned that production of major crops per hectare has decreased due to the uncertainty in the onset and withdrawal of monsoon and winter rainfall. Approx 80% of the respondents of household surveys shared that the increased incidence and severity of floods, flash floods, and landslides have led to several hectares of agricultural land and reduced availability of food, The loss of agricultural land has further deepened the economic burden and has increased the dependency on access to food from the market. Floods and landslides cause the direct loss of agricultural land, crops, livestock, and infrastructure. Like road networks, foot trails, and water supply facilities. The decline in water availability especially during summer severely undermines agriculture, causing reduced crop yields, disrupted irrigation schedules, and heightened food insecurity.

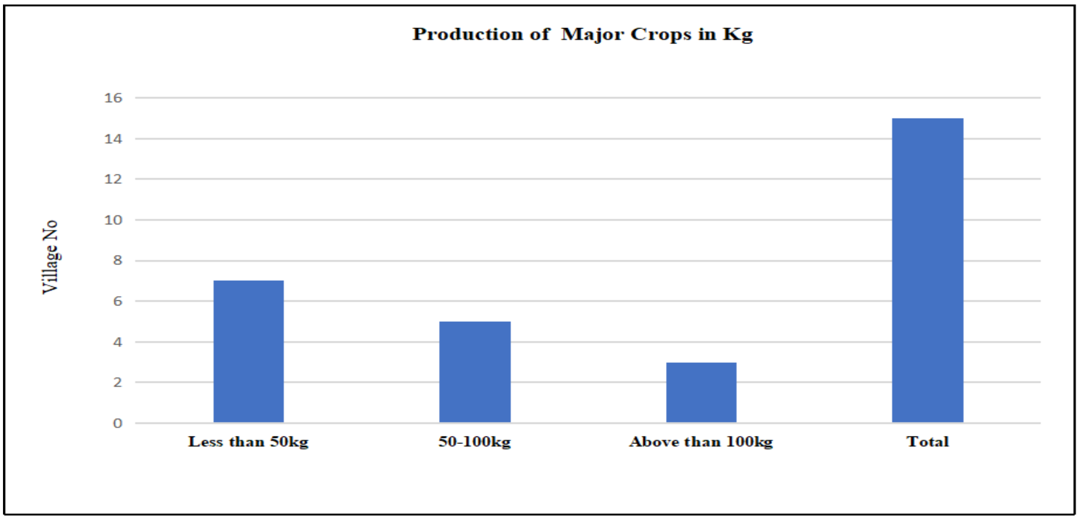

Fig 3: Production of Major crops in Kg

Conclusions

The study in Kirtinagar block highlights the adverse effects of climate change on agriculture, marked by rising temperatures and erratic rainfall patterns. A temperature increase of 1.22ºC in 2022 and altered monsoon behavior have disrupted crop cycles and land use. Cultivated barren land increased by 193.7 hectares, fallow land by 57.8 hectares, and the net sown area by 322 hectares, indicating shifts in farming practices. Data from 15 villages reveal declining yields of key crops between 2021 and 2024—rice, wheat, barley, mandua, sawa, black gram, and red lentils—all dropping by 2–4%. In several villages, production per season was below 50 kg. Over 65% of respondents cited unpredictable weather as a major cause of reduced per-hectare productivity. Around 65% reported increased instances of floods, flash floods, and landslides that degraded farmland and infrastructure, exacerbating food insecurity and economic hardship. The impacts extend beyond crops, affecting soil quality, water availability, and rural infrastructure, including roads and water systems. Winter water shortages have further strained farming and household needs. This localized study underscores the urgent need for broader regional research to develop effective climate adaptation strategies and policies aimed at sustaining agriculture and rural livelihoods in hilly, climate-vulnerable areas.

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