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Climate change and extent of agricultural scarcity in Rajasthan

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ABSTRACT

Purpose: In this descriptive study, we have focused on the impact of climate change on agriculture in Rajasthan. The adverse impact of climate change has increased the vulnerability of agriculture due to its dependence on rainfall and temperature. The current study aims at analyzing the vulnerability of agriculture in Rajasthan to extreme climate events such as drought and flood in the kharif season and hailstorms in the rabi season. The basic aim of the current study is to chart out the relation between extreme climate events and the loss to agriculture in Rajasthan.

Design/Methodology/Approach: This study follows a descriptive pathway to evaluate the extent of value of crop damage and impact on livestock at the district level in Rajasthan using the agricultural scarcity data from the State Disaster Relief Department, Rajasthan. Based on this data, we quantify and describe the patterns of climate-related agricultural losses over past two decades. We have analyzed the long-term climate data, i.e., daily maximum temperature and rainfall data, by fitting a trend for all the districts of Rajasthan. The descriptive analysis of the value of damaged crops and affected cattle was done by making quintile plots, which distribute the data for a year for all the districts into five quintiles, indicating the severity of damaged crops. The plot for the proportion of damaged crop area to sown area for the 33 districts of Rajasthan highlights the extent of damage of sown crop area across districts. The quintile calculation and the plots were made using the pandas and matplotlib libraries in Python.

Findings: Climate change impacts all sectors in an economy. The outcomes of global warming have become more evident recently. The adverse impact of climate change has increased the vulnerability of agriculture due to its dependence on rainfall and temperature. The analysis reveals substantial economic repercussions from crop damage and significant impacts on livestock populations. These descriptive findings map the extent of climate-induced stress on Rajasthan's primary sector.

Paper Type: Theme Based Paper

KEYWORDS: Agriculture | Climate Extremes | Crop Damage Assessment | Drought and Rainfall Variability

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Introduction

The extreme climate events both directly and indirectly impact the rural households leading to income loss and involuntary migration (Cissé, 2023). Rural households in low- and middle-income countries earn 70% of their livelihood from mixed production system which includes crops, fisheries, livestock, and aquaculture (FAO,2023). The WGII AR6 report highlights the impact of extreme climate events on economic activities and thus deaccelerating economic growth and under high emission scenarios there will be a reduction of 10% in production areas. Around 43% of India's population was engaged in agriculture for their livelihood in 2019 while the share in GDP remained at 19% (Jha et al., 2023).

The decade ending 2020(2011-20) has witnessed rise in global surface temperature by 1.1 □ C compared to the 1850-1900 levels and the rise in temperatures has been more acute on land compared to the oceans directly impacting the agricultural activities (IPCC, 2023). The surface temperature globally has risen at a much faster rate in the past three decades especially after 1982 which is nearly three times (0.20°C) compared to the 1850s (0.06°C) (Rebecca Lindsey et al., 2020).The loss of agricultural productivity which includes crop yield, land productivity and labor productivity, puts an upward pressure on the prices and makes food security of a region vulnerable (Abeysekara et al., 2024). Extreme climate events have increased over the decades in 2023 and 2024, lightning and thunderstorms, floods, and heavy rainfall, as well as heatwaves, accounted for most deaths resulting from extreme weather events in Rajasthan, affecting more than 70% of the districts (IMD, 2023, 2024). The climatic factors such as CO2 emissions and increase in temperature have a negative impact on cereal yield in India while rainfall boosts the yield and other non-climatic variables such as financial development, energy consumed, and labor supply have positive impact on agricultural yield (Chandio et al., n.d.). The recent literature on climate change impact has highlighted that the long-term impact on different sectors in an economy would be much higher than the short run impacts. Maiti (2025) has clearly explained the underestimation of impact persistent temperatures on various sectors, including primary sector, due to weak methodological application and violation of assumptions of popular panel data model such as fixed effect and generalized method of moments, which fail to cater to cross-sectional dependence and heterogeneity in panel data, leading to underestimation of the impact of soaring persistent temperature.

Study Area

Rajasthan is the largest state in India, covering 10.4 percent of the geographical area, and it stretches between latitudes of 23°30' to 30°11' N and longitudes of 69°29' to 78°17' E. The state is organized into 33 districts, which are divided into 10 agro-climatic zones. The state can be broadly divided into two cropping seasons, that is kharif or monsoon season, which stretches from June to September, and the rabi season, from November to March. Rainfall is an important factor for kharif crops such as pearl millet, groundnut, etc., and rabi season crops like wheat and barley are much more dependent on irrigation in Rajasthan. Thereby, for proper crop cycle management and efficient water management, it is imperative to understand the changes and trends in rain and temperature over the period (Sharma et al., 2018).

Data

The dataset used in this research is the daily gridded rainfall data provided by the India Meteorological Department (IMD), which is available from 1901 onwards. For the analysis, we have focused on the period from 1951 to 2023. This dataset features a high spatial resolution of 0.25 x 0.25 degrees, delivering detailed daily rainfall measurements across India in millimeters (mm) (Pai et al., 2014). The data is available in binary or NetCDF format which was converted to excel format using the IMD library in Python (Nandi et al., 2024) for all the 33 district locations in Rajasthan. The data on value of crop damage, number of affected villages, affected cattle, the affected population, and the area of crop sown and damaged has been accessed from the official website of the Disaster Management, Relief & Civil Defence Department, Government of Rajasthan. This data refers to the agricultural scarcity created by drought, flood, hailstorm, pest attacks, and rain deficit for both the kharif and rabi seasons. We have aggregated the data for an annual agricultural year for analysis.

Long term changes in climate

The key indicators for analysing climate change are temperature and rainfall (World Meteorological Organization (WMO), 2024).

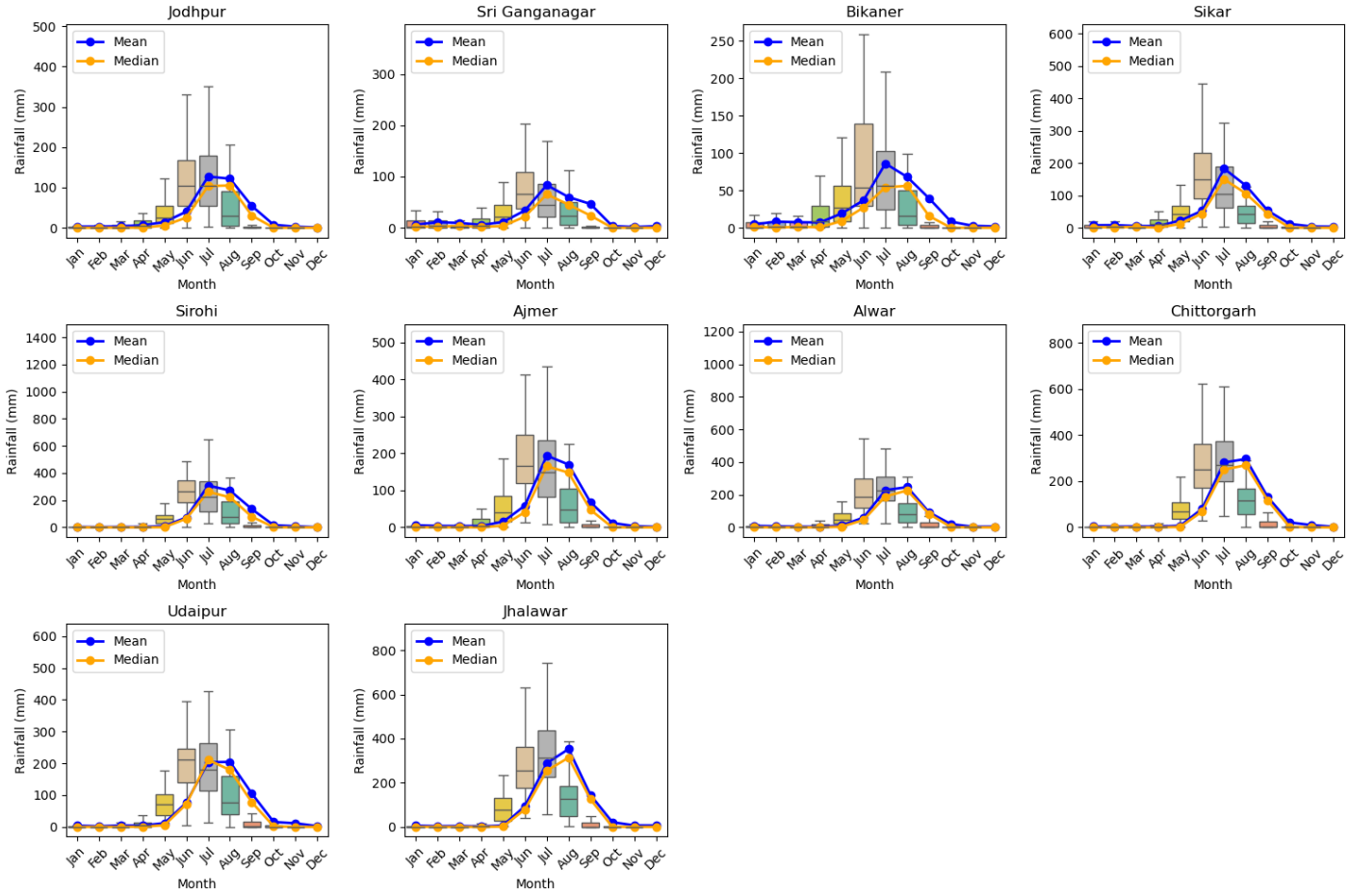

Figure 1: Monthly distribution of rainfall data from 1951-2023

Figure 1 shows that the monthly rainfall data is positively skewed and the variability of monsoon months is high, particularly for the month of June. The variability of monthly rainfall is high for districts in western Rajasthan (Bikaner & Jodhpur) compared to eastern Rajasthan (Alwar & Sikar). The trend fit for the mean of maximum daily temperature (Figure 1-4) shows an increasing trend for all the districts, while rainfall is erratic and inconsistent, showing no trend for some districts, downward for some, and upward for some. The persistent heating effect of temperature and erratic rainfall has a negative impact on crop yield (Wing et al., 2021).

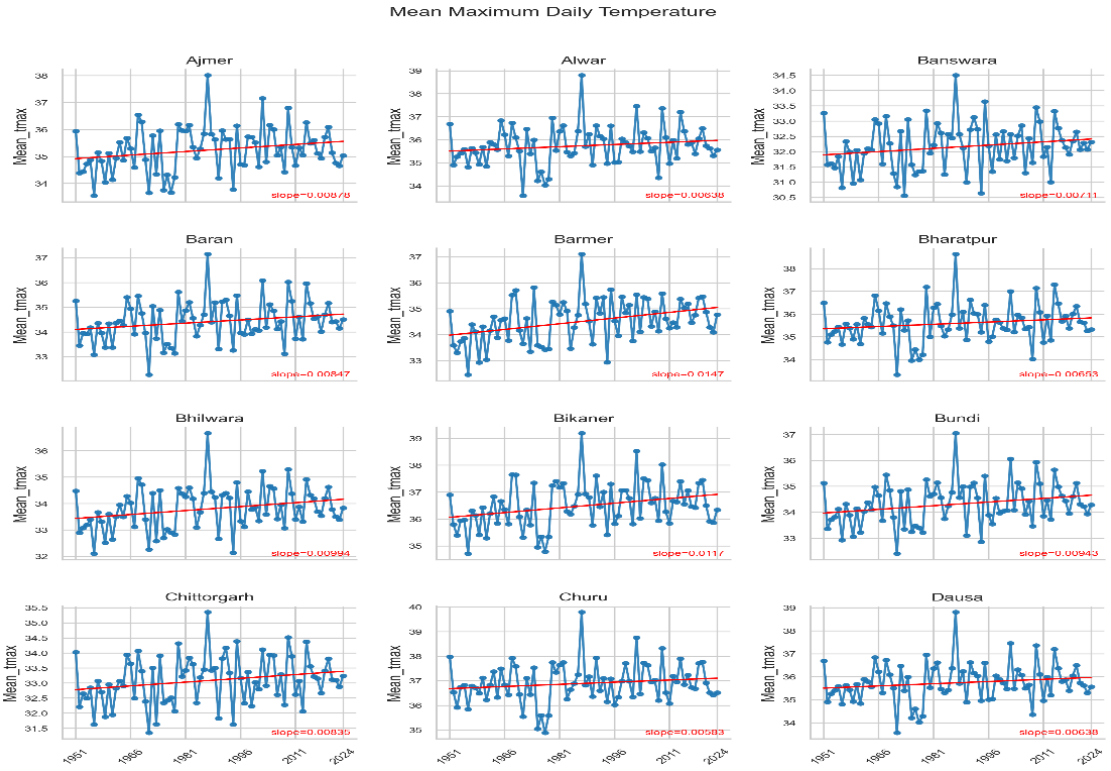

Figure 2: Annual mean of maximum daily temperature

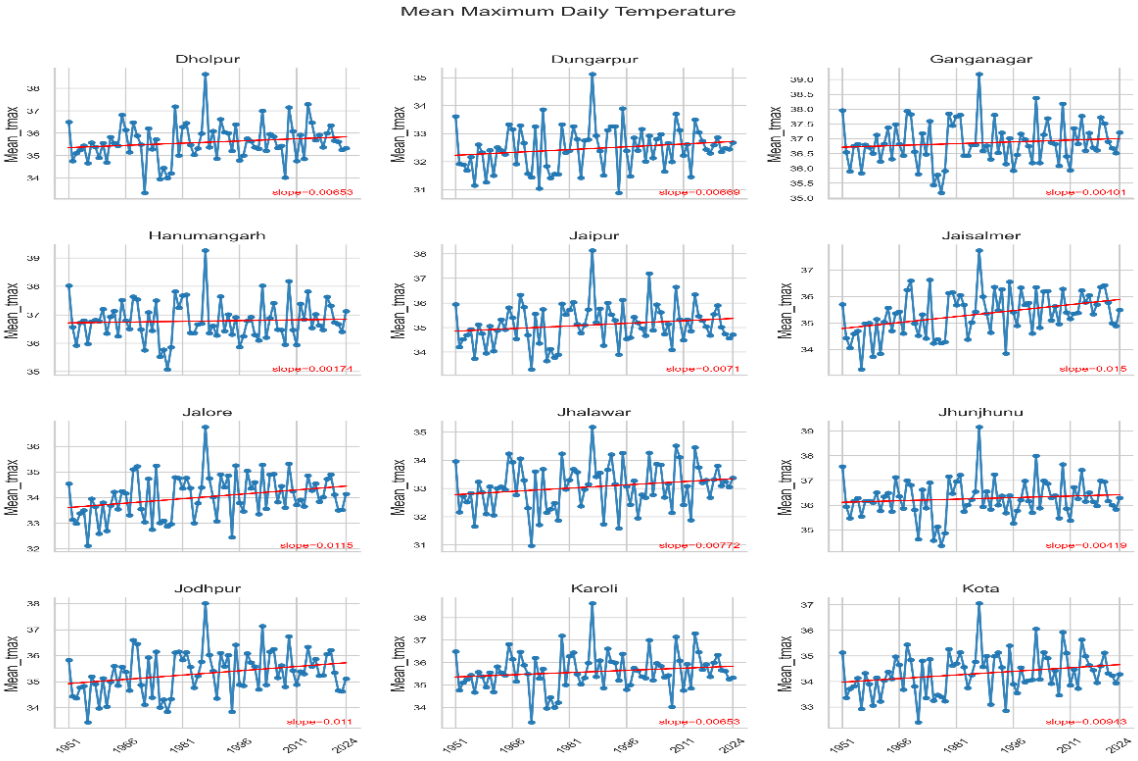

Figure 3: Annual mean of maximum daily temperature

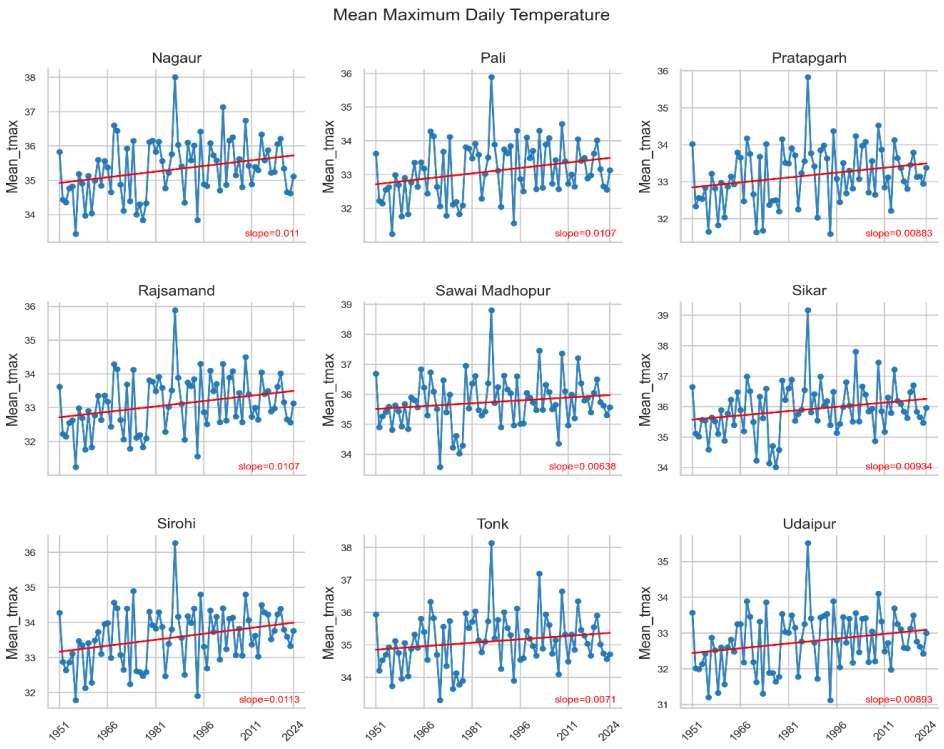

Figure 4: Annual mean of maximum daily temperature

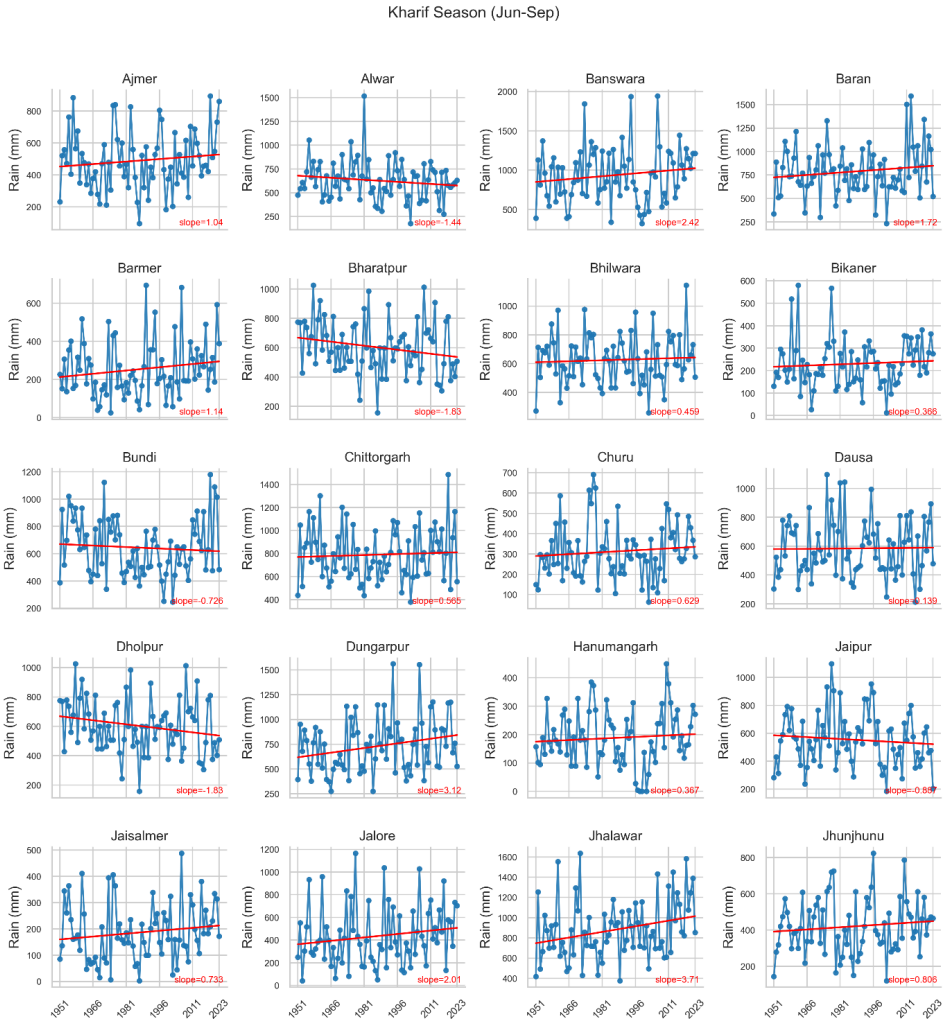

Figure 5: Annual total rainfall for kharif season

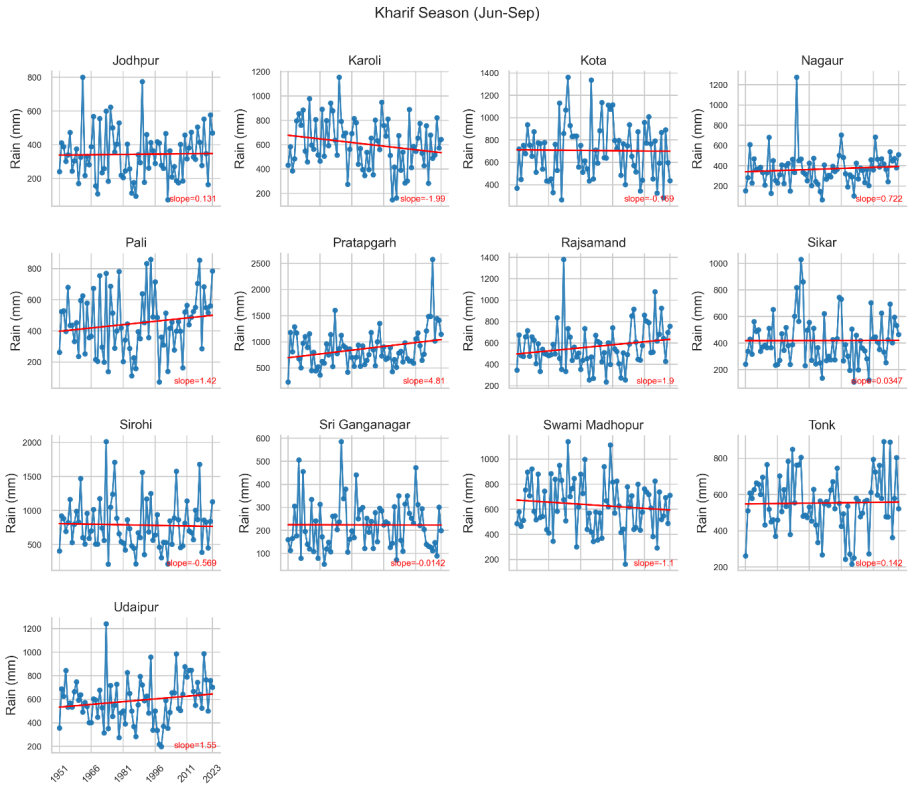

Figure 6: Annual total rainfall for kharif season

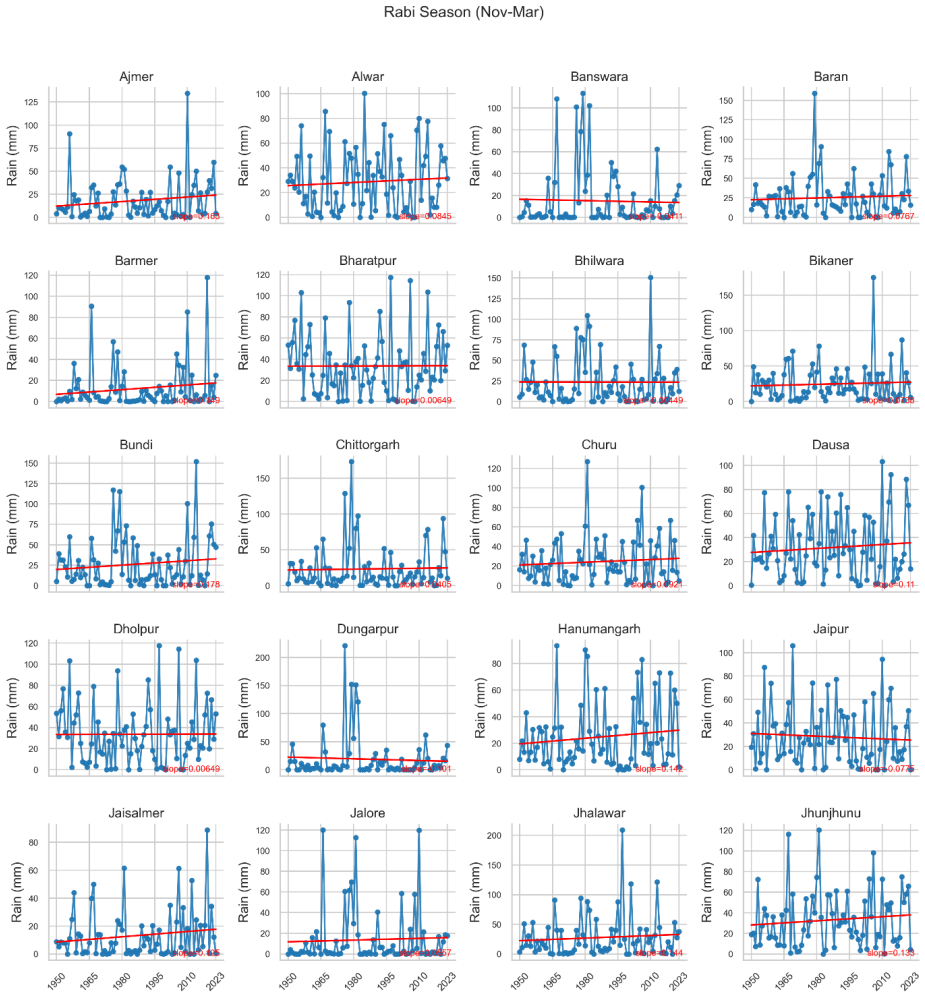

Figure 7: Annual total rainfall for rabi season

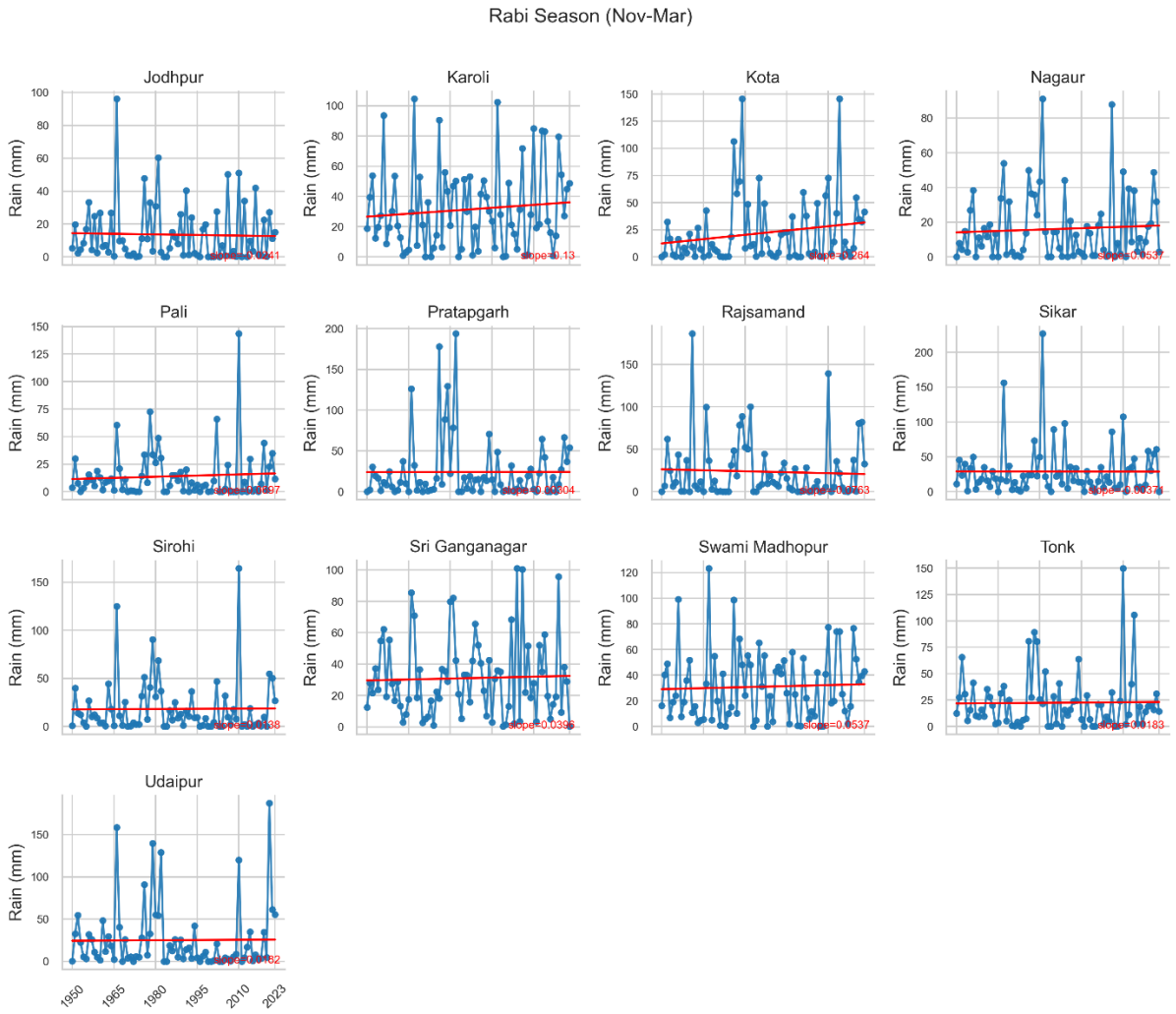

Figure 8: Annual total rainfall for rabi season

Crop Vulnerability

The proportion of damaged to sown area (lakh hectares) across districts highlights relative vulnerability of cropping area to climate shocks **(Figure 9)**. This also indicates the spatio-temporal variation of crop-damaged area across Rajasthan. If the proportion consistently falls into the higher quintiles for a district over the years indicating persistent exposure to recurring hazards (drought, floods, pests) or structural problems (irrigation shortfalls, fragile agronomy). Temporal spikes in the damage proportion for a given district and a year when aggregated and synchronized across many districts, indicate a statewide weather shock. The districts with low but highly variable proportions are different from districts with consistent damage proportions. The former needs improved early warning and resilience to shocks; the latter needs structural investments to reduce baseline vulnerability.

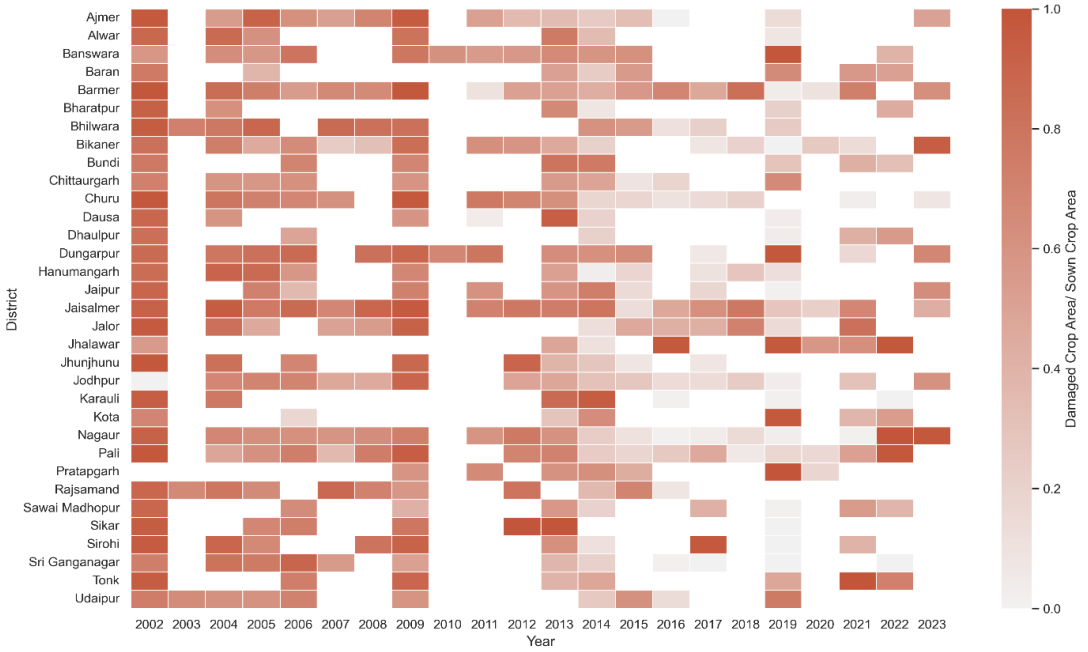

Figure 9: Proportion of damaged to sown crop area

The value of damaged crops or crop loss metric at the district level **(Figure 10)** provides an absolute economic measure that complements the proportion of damaged area. High crop loss concentrated districts or years indicated that monetary damages are concentrated, as these may correlate with areas producing high-valued crops or simply with very large sown areas. Consecutive years of crop loss across districts lead to chronic economic pressure on all the economic agents and destabilize the fiscal stability of the state. The mitigation and adaptation strategies include increased coverage of crop insurance, adoption of efficient irrigation, climate-resistant seed varieties, and diversification of farm income through an increased share of the non-farm sector to reduce crop loss in the future. Rajasthan has a mean crop loss of 6900 crores and has had an upward trend over the years.

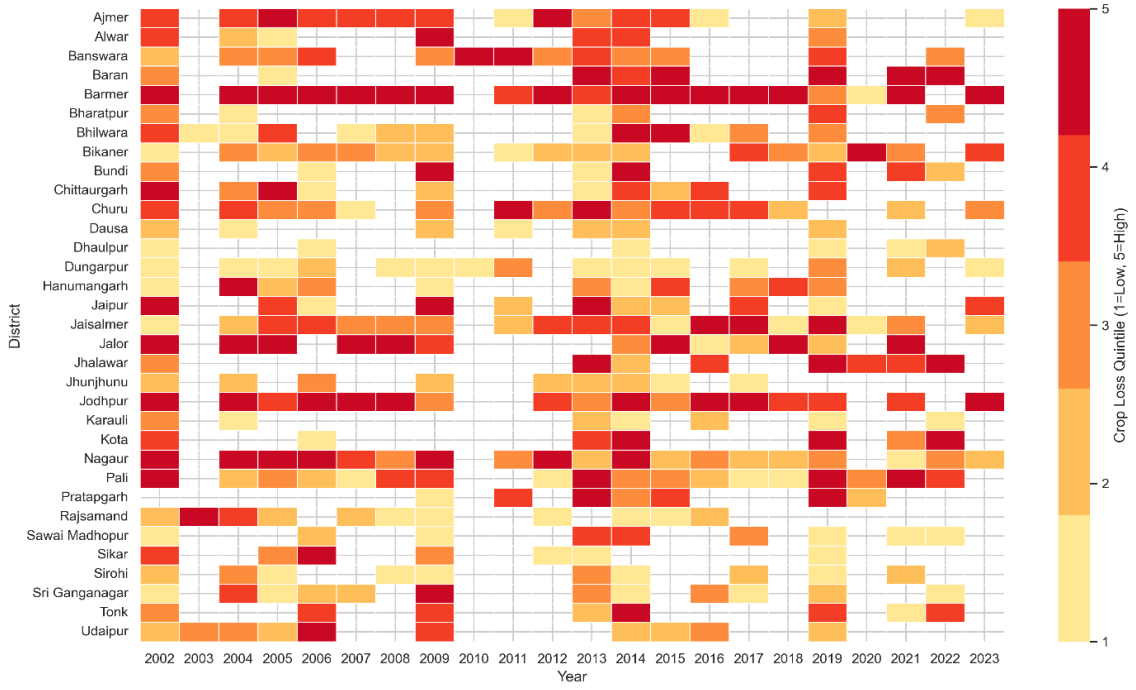

Figure 10: Value of damaged crops by quintiles

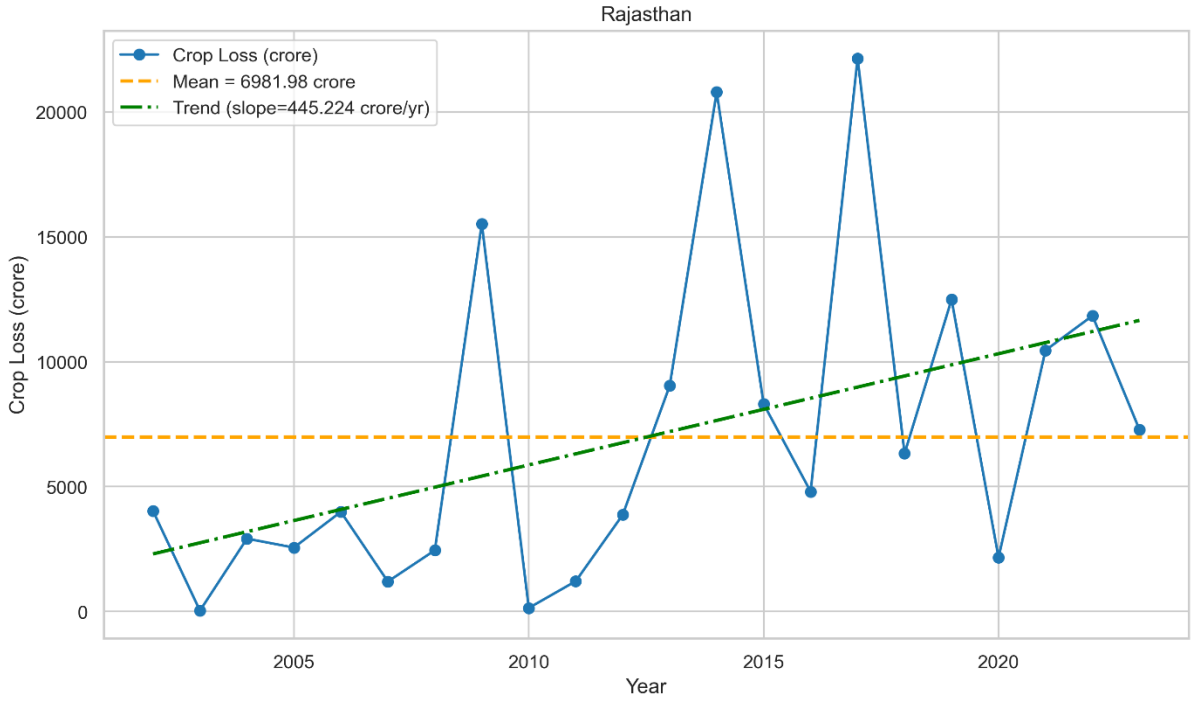

Figure 11: Value of damaged crops (2002-2023)

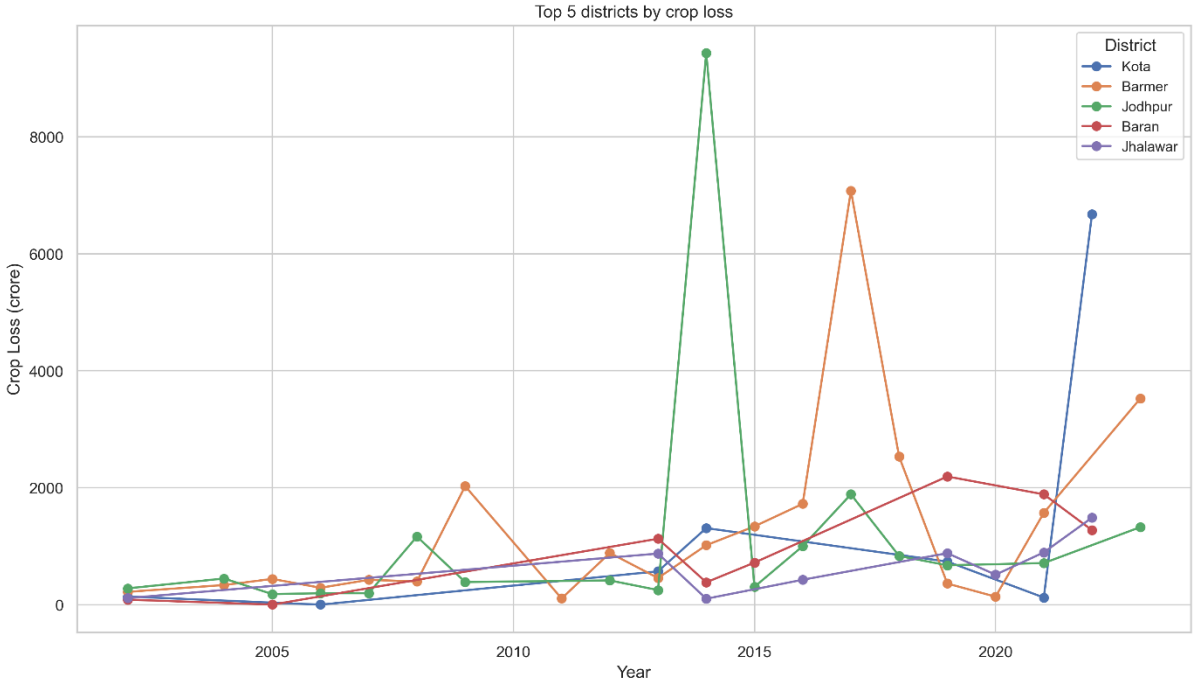

Figure 12: Top five districts experiencing crop loss (2002-2023)

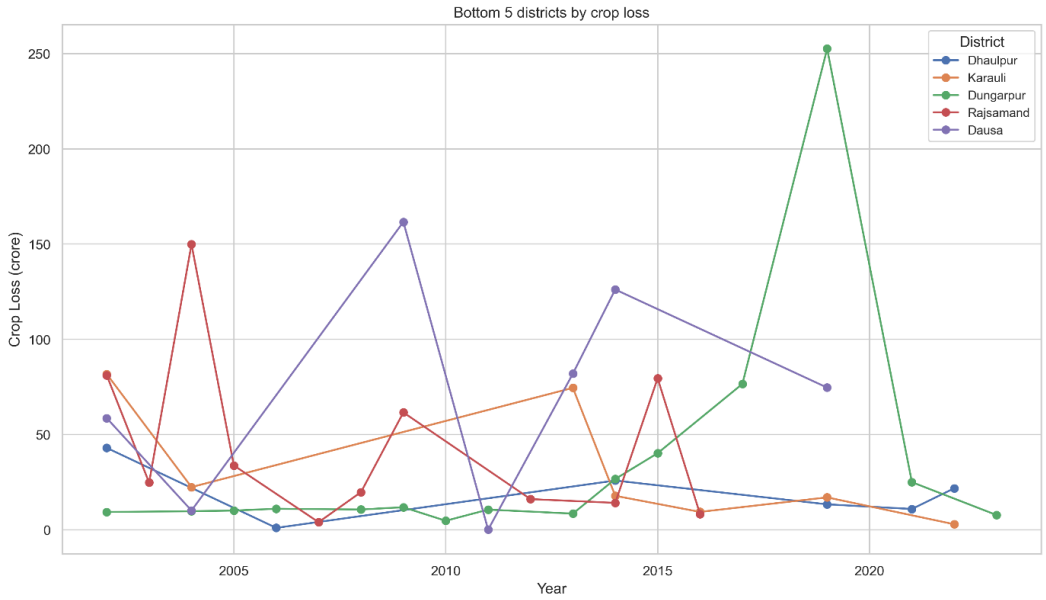

Figure 13: Bottom five districts experiencing crop loss (2002-2023)

Government intervention and drought management

The combination of low and erratic rainfall renders Rajasthan particularly vulnerable to drought, which can be generally defined as reduced soil moisture for a period leading a to shortage of food, fodder, and water. Drought occurrence is due to variation in natural climatic conditions (Disaster Management & Relief Department Jaipur, 2014; Government of Rajasthan, 2014). The frequency of drought varies according to different climatic zones. From 1949 till present, except for the years 1959-60, 1973-74, 1975-76, 1976-77, 1990-91, and 1994-95 drought has been a recurring natural hazard having a statewide impact in Rajasthan (Disaster Management & Relief Department, 2024). Among all natural disasters, drought has the potential to exert the most profound impact, affecting the largest number of people and livestock, as it has a direct impact on food production. The impact of drought is less visible instantaneously; unlike floods, it has a slow but persistent impact, i.e., impact assessment, impact mitigation, and adaptation planning in case of drought are different from other natural hazards. **Figure 14** shows the drought relief expenditure for the state of Rajasthan for the past decade, which comprises several activities. The agricultural input subsidy is a major component of drought relief, which helps the farmers to cope with losses. This subsidy is given in the areas where, after due assessment by the state government, the losses are more than 33% of the sown area. The drought-induced scarcity directly impacts the cattle population **(Figure-15),** thereby negatively impacting the farmer's income sources. The agricultural households may resort to distress sales of the cattle at prices lower than the market prices, making them economically vulnerable. The government drought relief measures help the distressed farmers by providing for fodder transport, establishing cattle camps, and supplying drinking water.

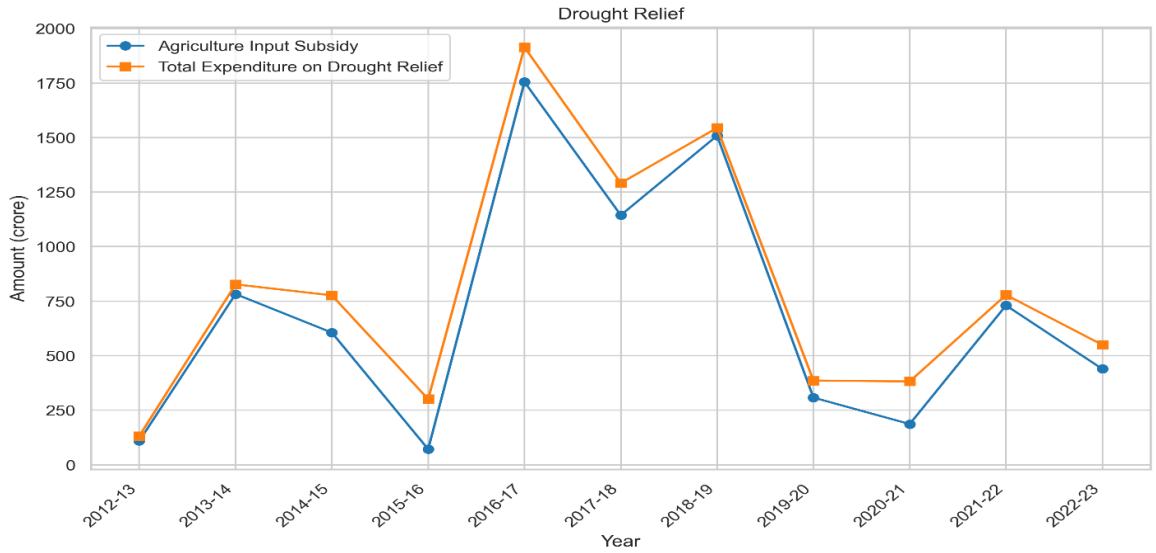

Figure 14: Drought relief expenditure (2012-2023)

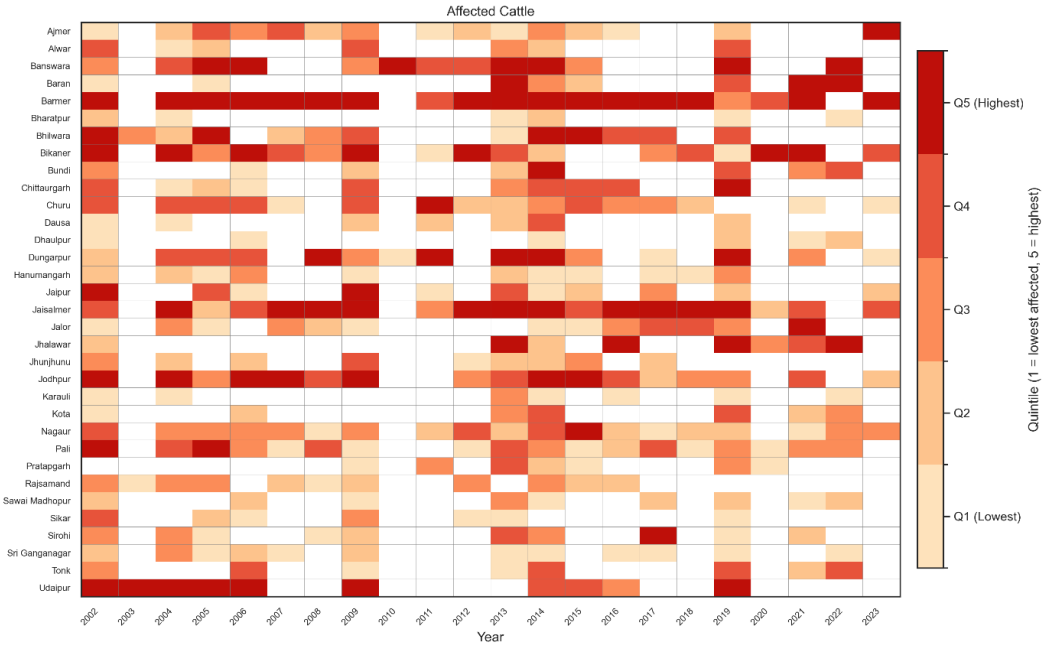

Figure 15: Affected cattle population by quintiles (2002-2023)

Conclusion

This study finds out a direct correlation between the value of damaged crops at the district level and the percentage of damaged area over sown area. The analysis of crop loss and damaged crop area during the study period, 2002 to 2023, clearly indicates the impact of major drought years, that is, 2002, 2009, 2013, 2014, 2015, and 2019. The impact of these extreme drought years is also reflected in the quintiles plot of affected livestock. The upward trend of mean temperature and erratic rainfall has negative impact on crop yield and its quality, leading to higher crop losses. The crop damage and affected cattle population have a substantial economic impact on the agriculture sector. The timely government interventions help mitigate the impact through agricultural input subsidies, fodder supply, cattle shelters, etc. The findings of this study highlight the vulnerability of Rajasthan's agriculture sector and its need for long-run adaptation strategies to cope with climate change.

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Annexure 17.3.4

Submission Date	Submission Id	Word Count	Character Count
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Reviewers Memorandum

Reviewer's Comment 1: The manuscript addresses a highly relevant issue by focusing on climate-induced vulnerability in Rajasthan's agriculture, a region particularly exposed to extreme events. The district-level analysis using disaster relief data strengthens the empirical grounding. However, the novelty of the study could be clarified by explicitly stating how it advances beyond existing vulnerability or damage assessments. Highlighting the policy relevance, would further enhance its contribution.

Reviewer Comment 2: The use of agricultural scarcity data over two decades provides a valuable longitudinal perspective on climate-related losses. The descriptive pathway is appropriate for mapping patterns of damage and livestock impacts. The study would benefit from clearer mention of the analytical techniques or indicators used to quantify vulnerability. Clarifying data limitations or assumptions would improve transparency and rigor.

Reviewer Comment 3: The findings are clearly framed around economic repercussions and livestock impacts, which underscores the severity of climate stress on agriculture. The seasonal distinction between kharif and rabi crops is a notable strength. Including indicative figures, trends, or relative magnitudes of losses strengthened the impact and clarity of the results.

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Conflict of Interest: Author of a Paper had no conflict neither financially nor academically.

Editorial Excerpt

The article has 07% plagiarism, which is within the accepted percentage as per the norms and standards of the journal for publication. As per the editorial board's observations and blind reviewers' remarks, the paper had some minor revisions, she was communicated promptly to the authors (Chander and Abhinav), and all necessary corrections were incorporated as and when directed. The comments related to this manuscript are closely aligned with the theme "**Climate change and extent of agricultural scarcity in Rajasthan**" both subject-wise and research-wise.The paper addresses an important regional manifestation of climate change impacts.The manuscripts presents a timely and regionally significant assessment of climate-induced agricultural vulnerability using official disaster relief data.After thorough reviews and the editorial board's remarks, the manuscript has been categorized and approved for publication under the "**Theme Based Paper**" category.

Acknowledgement

The acknowledgement section is an essential part of all academic research papers. It provides appropriate recognition to all contributors for their hard work and effort taken while writing a paper. The data presented and analysed in this paper by the authors (Chander and Abhinav) were collected first handily and wherever it has been taken the proper acknowledgment and endorsement depicts. The author is highly indebted to others who facilitated accomplishing the research. Last but not least, endorse all reviewers and editors of GJEIS in publishing in the present issue.

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