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SPATIO-TEMPORAL ANALYSIS OF RAINFALL TRENDS IN SHEKHAWATI REGION OF RAJASTHAN

Wahida Khan[1] and **R.S. Vijayvergia**[2]

[1]Research Scholar, Department of Geography,
[2]Professor, Department of Geography, IIS Deemed to be University, Jaipur, India
Email: khanrijwan354@gmail.com

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Abstract: *Shekhawati region of Rajasthan lie in a semi-arid zone where livelihoods and water security hinge critically on seasonal rains and temperature regimes. This region covered three districts of the state Churu, Sikar, and Jhunjhunu. Over recent decades, farmers and water managers have reported growing unpredictability in monsoon onset, intensity, and duration, alongside rising thermal stress. Yet region-wide, quantitatively rigorous assessments of how rainfall and temperature have evolved remain limited. This study seeks to fill that gap by leveraging four decades of meteorological observations to characterize spatio-temporal trends and inform locally tailored adaptation measures. This paper presents a detailed spatio-temporal analysis of rainfall and temperature trends in Churu, Sikar, and Jhunjhunu districts from 2001 through 2020. This study analyzes two decades (2001–2020) of meteorological data from the India Meteorological Department (IMD) to detect and quantify long-term trends in annual and seasonal rainfall across the Shekhawati region.*

Keywords: Rainfall variability, Semi-arid agriculture, Climate adaptation.

Introduction

The Shekhawati region of Rajasthan encompassing the districts of Churu, Sikar, and Jhunjhunu lies within India's larger semi-arid zone, characterized by low and highly variable rainfall, extreme temperature fluctuations, and frequent droughts. Agriculture in this region remains predominantly rain-fed, making rural livelihoods, food security, and groundwater resources acutely sensitive to shifts in precipitation and thermal regimes. Over the past few decades, anecdotal evidence from farmers and water managers has pointed to increasing unpredictability of the monsoon, more intense heat during preand post-monsoon seasons, and longer dry spells. However, comprehensive, quantitative assessments of these climatic changes at district and regional scales are limited.

Understanding spatio-temporal trends in rainfall and temperature is critical for multiple reasons. First, it provides empirical evidence of climate variability and change, filling knowledge gaps for a region that supports nearly three million people. Second, it informs the design of climate-resilient agricultural practices such as choosing drought-tolerant crop varieties and adjusting sowing dates—and guides investments in water-harvesting and irrigation infrastructure. Third, insights into seasonal and geographic hotspots of change can help policymakers and local stakeholders prioritize adaptation measures, from micro-catchment development to early-warning systems for extreme events. our research aims to provide a robust, data-driven foundation for sustainable water and agricultural management strategies in one of India's most climate-vulnerable regions.

Study Area

Shekhawati region which is located in the north-eastern part of Rajasthan state and the region has geographical extension from 26°26' to 29°20' N latitude and 74°44' to 76°34' E longitude on the map of Rajasthan. The region is covered by the Topographical seat No. 44D, 44H, 44L, 44P, 45I, 45M, 53D. The region has 23 Panchayat Samitis in all. Thus, the region has 15 tehsils in total with its total 15343 sq. km. geographical area which makes 5.6 percent of the state's total. At the part of district-wise contribution by area point of view in Shekhawati region it is observed that Churu district contributes 29 percent, Jhunjhunu district contributes 31 percent and Sikar by 40 percent respectively. Shekhawati region contributes 7.02 percent of the state's total population (according to 2011 census).The region obtains high literacy rate which is about 10 percent more than Rajasthan state. Shekhawati region records high density 351 persons per sq. km area which is 75.26 percent more than that of Rajasthan state average density which is 201 persons per sq. km area (according to 2011 census). The natural climatic conditions in the region are very harsh and extreme. The temperature ranges from sub-zero Celsius in winter to more than 50°C in summer. The summer brings hot waves of air called loo. Annual rainfall is very low, around 45 to 60 cm. The ground water is as deep as 200 feet (60 m), and in places water is hard and salty. The people in the region depend on rainwater harvesting.

Actual Rainfall for Nine Stations Across Sikar District (2001-2020)

The analysis reveals high variability in rainfall across Sikar district, with some tehsils receiving significantly more rainfall than others. While years like 2010 and 2012 recorded heavy rainfall, 2002 and 2009 saw severe droughts. Neem Ka Thana experiences the most rainfall**,** whereas Laxmangarh and Sikar often receive the least. The rainfall across the district has fluctuated significantly over the years.*2010, 2012, and 2018* saw significantly higher rainfall.*2002 and 2009* had the lowest recorded rainfall, with some tehsils receiving less than 200 mm. The average annual rainfall across all tehsils is between 440 mm to 570 mm. in the duration from

2011 to 2018 Neem Ka Thana had the Highest Average Rainfall which is 628 mm per year beside this Laxmangarh tehsil had Lowest Average Rainfall which is 414 mm per year. Data shows that Each tehsil exhibits unique trends in rainfall distribution. Neem Ka Thana having Avg. 628 mm found 1209 mm actual rainfall in 2010 which was highest for any tehsil during the entire period. Beside this this tehsil also found Highly variable with some years crossing 750 mm, while others drop below 400 mm. the data also shows that Most tehsils experienced their highest rainfall in this year of 2010 and in the year of 2012 & 2018 there was Widespread heavy rainfall across multiple stations. In the year of 2002 All tehsils had low rainfall and in the year of 2009 some tehsil faced Severe drought conditions *e.g. Sikar (124 mm), Ramgarh (183 mm), and Lawmonger (162 mm).* There is a trend of low rainfall has been seen in the The western regions of the district e.g. Ramgarh, Sikar and Fatehpur because these tehsils generally receive lower rainfall. Instead, this tehsil situated in the Eastern and southern regions e.g. Neem Ka Thana and Shrimadhopur get relatively more rainfall.

Figure 01: Key Map

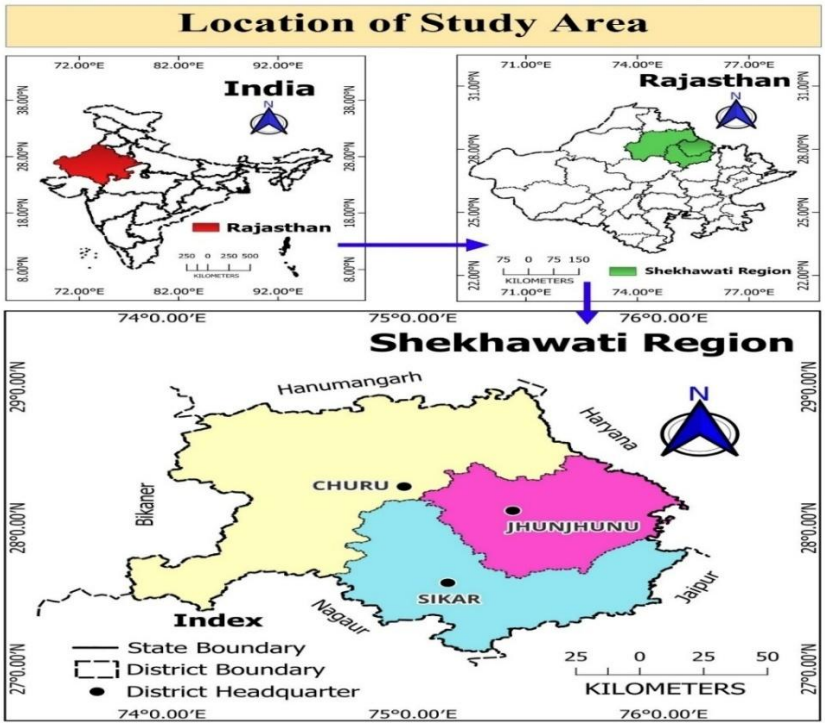


Figure 02: Actual Rainfall in Sikar District, 2001-2020

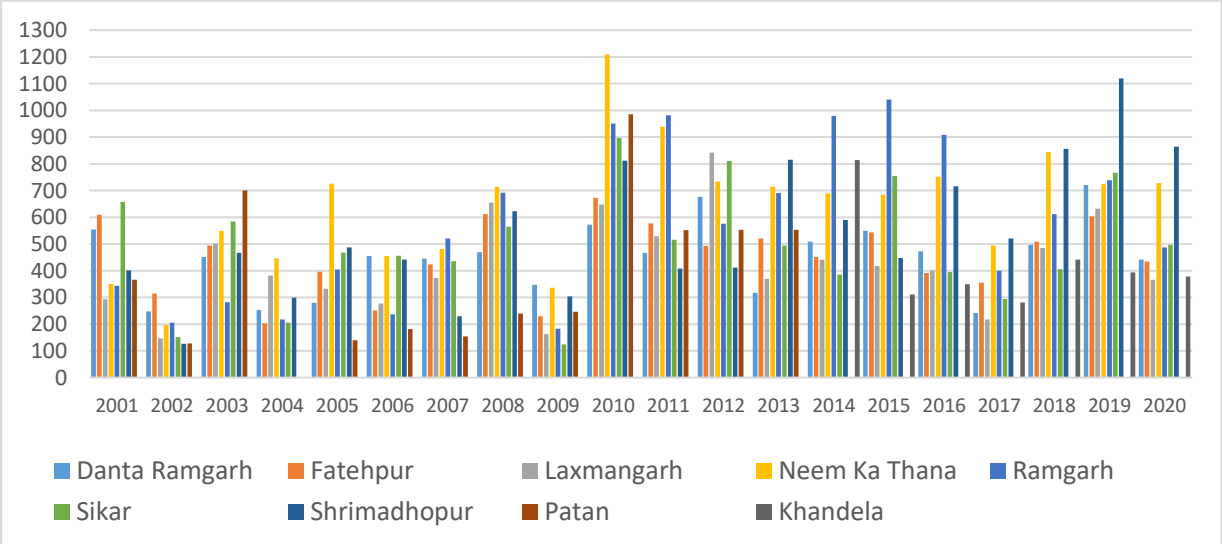


Figure 03: Rainfall Trend in Sikar District, (2001-2020)

Actual Rainfall for Six Stations Across Churu District (2001-2020)

Based on the graph02 All stations experienced above-average precipitation, with Taranagar receiving 1001 mm in 2011, the greatest total rainfall. In contrast, 2002 saw the least amount of rainfall ever recorded—just 78 mm in Ratangarh, indicating a serious drought. the Highest Rainfall in a Yearly Peaks can be seen in 2011 and 2010 in Taranagar which was 1001mm and 802 mm. the lowest rainfall was found in 2002 in Ratangarh tehsil which was 78mm**.** This suggests recurringdroughtconditionsintheearly2000s, with periodic heavy rainfall in subsequent years. These data show distinct rainfall distribution patterns over the years in the all 6 tehsils of Churu district. Eg. Churu tehsil found 165 mm in 2009 and 648 mm in 2011. This tehsil Experienced relatively stable fluctuations, with an upward trend in the 2010s. instead this the Rajgarh tehsil witnessed one of the highest annual rainfall variations, indicating sensitivity to monsoon irregularities. This tehsil had 210 mm in 2002 to 746 mm in 2016. Ratangarh consistently received lower rainfall than other stations, indicating greater susceptibility to droughts. Sardarshahar Range108 mm in 2002 to 657 mm 2015 and this tehsil also shows moderate fluctuation, with significant drought years in 2002 and 2004. Sujangarh tehsil of the district Displays a balanced rainfall pattern, with occasional peaks. The Taranagar tehsil have The most extreme variations as 157 mm in 2002 to the highest rainfall (1001 mm) in 2011. 2002, 2004, 2006, and 2009 show consistent low rainfall, highlighting periodic drought conditions and 2008, 2010, 2011, and 2013 experienced above average rainfall, benefiting groundwater recharge. The difference between the wettest and driest years in some stations (e.g., Taranagar and Rajgarh) suggests a rising unpredictability of rainfall.

Figure 03: Actual Rainfall in Churu District, 2001-2020

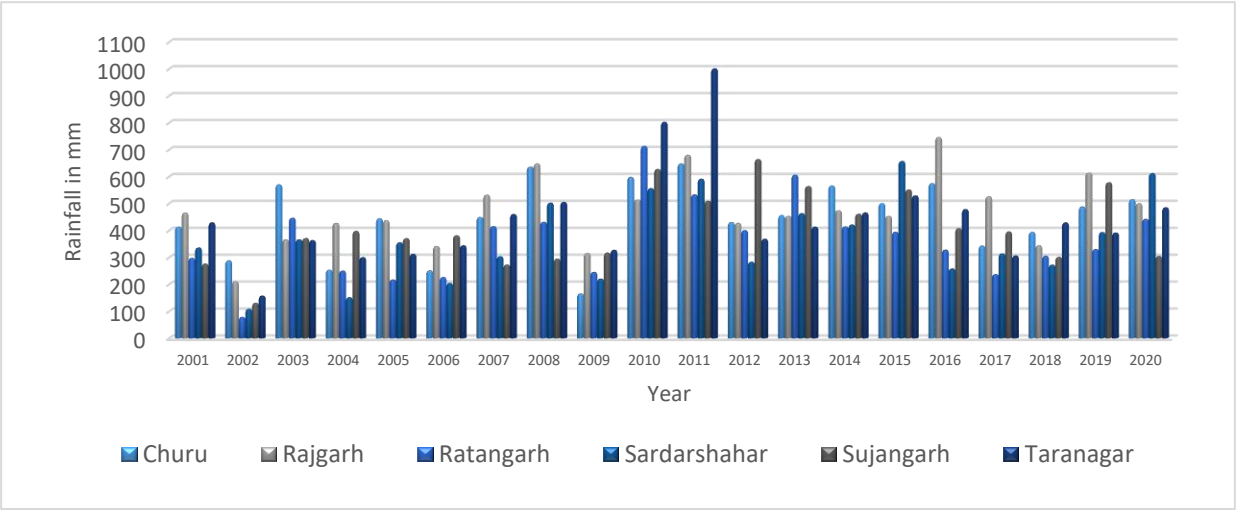
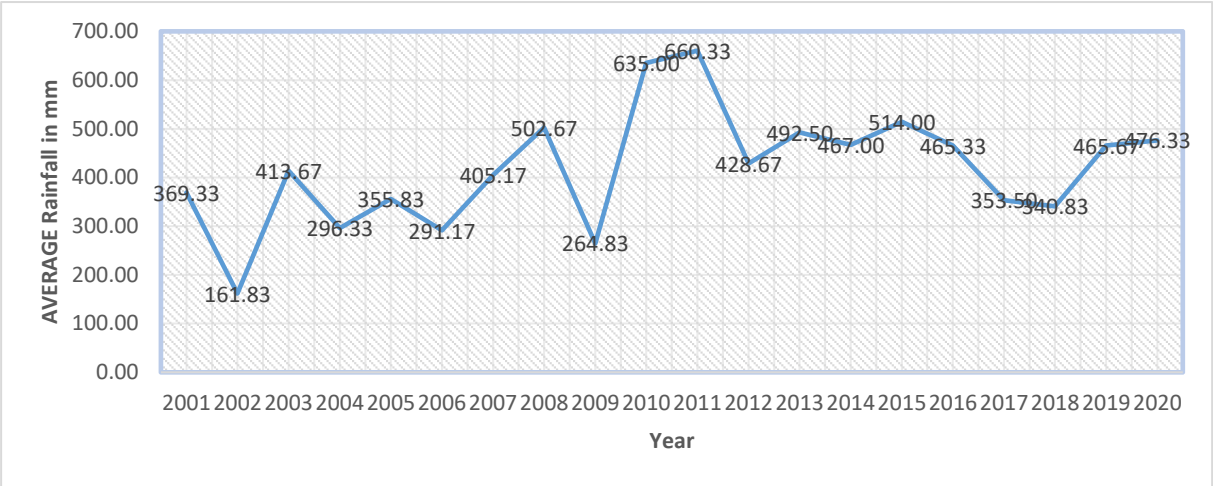


Figure 04: Rainfall Trend in Churu District, 2001-2020



Actual Rainfall in Jhunjhunu District (2001-2020)

The rainfall data for Jhunjhunu district over two decades reveals significant spatial and temporal variability across its seven tehsils. The data shows that 2002 was the driest year from 2001 to 2010. All the all tehsils recorded <250 mm except Chirawa and Khetri in this year. Whereas 2010 was recorded as Wettest Year in the district. In this year Malsisar have the rainfall of 991 mm, Jhunjhunu 828 mm and Khetri have 944 mm of rainfall. The data shows that Malsisar recorded thehighest single-year rainfall in the year 2010 which was 991 mm. instead of this Jhunjhunu tehsil had thelowest rainfall for any tehsil in a yearin 2002 which was123 mm. khetari tehsil noted as the Most volatile tehsils and Recorded 944 mm rainfall in 2010 which is highest. Udaipurwati indicates increasing of +7.5 mm/year trend line and Nawalgarh tehsil has an increase of +5.2 mm/year. Chirawa and Malsisar showed no clear directional trend. Khetri and Malsisar emerged as the wettest tehsils it may because of geographic or climatic factors. The district experienced severe droughts (e.g., 2002) where most tehsils recorded <250 mm) and intense wet years (e.g., 2010) where Malsisar received 991 mm. While some tehsils (e.g., Udaipurwati, Nawalgarh) showed gradual rainfall increases, others (e.g., Jhunjhunu, Buhana) faced declining trends. This divergence could reflect broader climatic shifts or localized environmental changes.

Figure 05: Actual Rainfall in Jhunjhunu District, 2001-2020

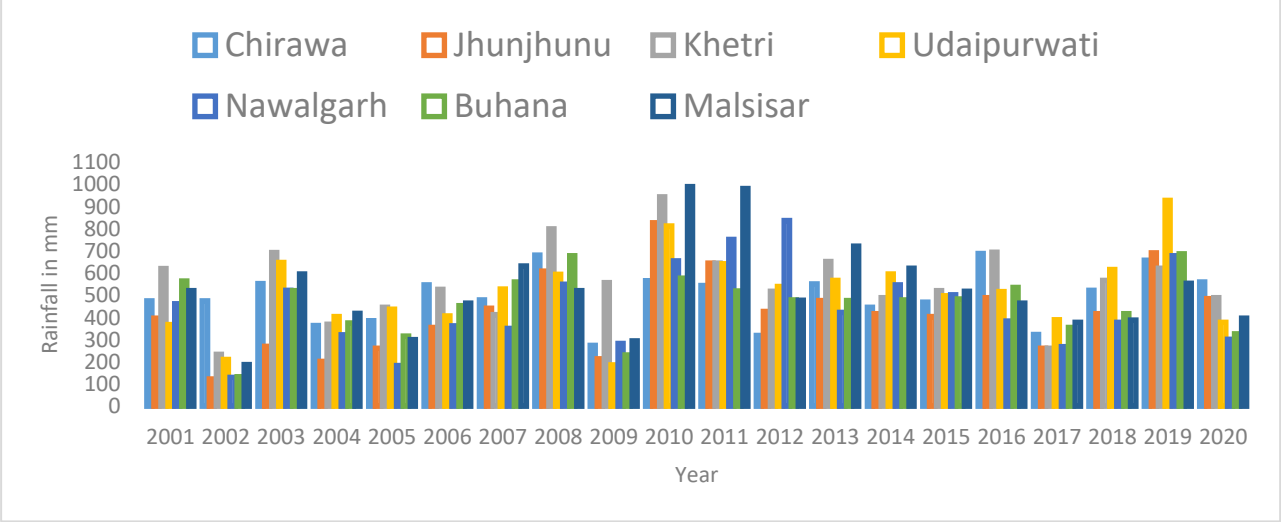
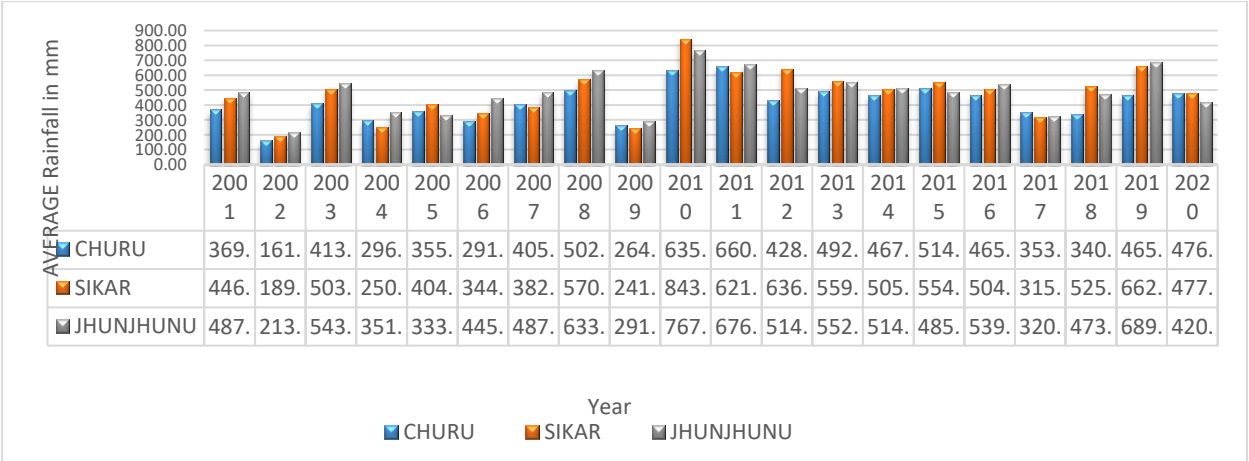


Figure 06: Rainfall Trend in Jhunjhunu District, 2001-2020

Comparative Analysis of Average Rainfall Across Churu, Sikar & Jhunjhunu Districts (2001-2020)

Comparative study of the all three district shows that all three has variability in during this period. Churu ranges 168.7 mm (2002) to 749.3 mm (2010), Jhunjhunu have 213.6 mm in 2002 and 767.9 mm in 2010 and Sikar have minimum temperature of 168.7 mm in 2002 and have maximum temperature of 749.3 mm in 2010. It is also found that Jhunjhunu (487 mm) consistently received the most rainfall, followed by Sikar (428 mm) and Churu (418 mm). Sikar exhibited the highest variability (154.8 mm), while Churu had the lowest range (498.5 mm). 2002 was the DriestYear for all districts in this year minimum rainfall in Churu was 161.8 mm, in Sikar it was 168.7 mm and in Jhunjhunu it was 213.6 mm. instead of this 2010 was recorded as Wettest year during these decades. In this year Sikar district got the highest average rainfall (749.3 mm) which was peaks for this district. Where Jhunjhunu have 767.9 mm and Churu was the second-highest district having 635.0 mm. Data shows that during this period Churu has 26 percent increase in Rainfall (369.6 mm in 2001–2010 to 466.4 mm in 2011–2020). Sikar has also Significant rise from 371.3 mm (2001–2010) to 499.6 mm (2011–2018). In it is also increased in Jhunjhunu from 455.5 mm (2001–2010) to 518.5 mm (2011–2020). All districts experienced simultaneous dry (e.g., 2002) and wet years (e.g., 2008, 2010), suggesting shared climatic influences. So that it is observed that in these districts Short-term fluctuations observed, but long-term trends indicate increasing rainfall. As a conclusion it can be said that Jhunjhunu is the wettest district, while Sikar shows the highest variability. Rainfall trends have risen notably in all districts post-2010, with 2002 and 2010 marking extreme dry and wet years, respectively.

Figure 07: Average Rainfall Across Churu, Sikar & Jhunjhunu Districts, 2001-2020



Conclusion

The study reveals that Over the 2001–2020 period, the Shekhawati region is three districts Churu, Sikar, and Jhunjhunu exhibited both pronounced inter-annual variability and clear long-term shifts in hydro-thermal conditions. Rainfall extremes synchronized region-wide 2002 marked the driest year in which Churu had 162 mm, Sikar 169 mm and Jhunjhunu had 214 mm rainfall, while 2010 brought the heaviest monsoon in which Jhunjhunu had 768 mm, Sikar-749 mm and Churu had 635 mm. Despite these swings, all three districts saw a substantial rise in average precipitation post 2010 e.g. Churu by 26 percent, Sikar by 35 percent, and Jhunjhunu by 14 percent. Jhunjhunu remained the wettest while Sikar was the most variable and Churu was the most stable albeit driest district with range 498 mm.

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