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Climate change effects on soil organic carbon dynamics in arid western Rajasthan: Evidence from Jodhpur, Jaisalmer and Nagaur

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Abstract
Climate change is increasingly altering soil processes in arid and semi-arid ecosystems. Western Rajasthan, particularly the districts of Jodhpur, Jaisalmer, and Nagaur, represents a fragile desert environment where soil organic carbon (SOC) levels are naturally low and highly sensitive to climatic variability. This study examines the relationship between temperature rise, rainfall variability, and SOC dynamics during the period January 2024–February 2026. Climatic data were compiled from regional meteorological observations, and SOC measurements were obtained from agricultural soil monitoring datasets. Statistical analysis was used to examine correlations between rainfall, temperature, and SOC levels. The results indicate a negative correlation between increasing temperature and SOC content ($r \approx -0.71$) and a positive relationship between rainfall and SOC ($r \approx +0.62$). SOC declined from 0.82 % to 0.58 % across districts during the study period, reflecting accelerated organic matter decomposition and moisture stress under warming conditions. The findings highlight the vulnerability of desert soils to climate change and emphasize the importance of sustainable land management practices such as organic amendments, agroforestry, and conservation agriculture to maintain soil carbon stocks.

Keywords: Climate change, soil organic carbon, arid soil, rainfall variability, temperature increase, Thar Desert and Western Rajasthan

Introduction

Climate change significantly influences soil processes through rising temperatures, changing precipitation patterns, and increased drought frequency [1, 3]. Soil organic carbon (SOC) is a key indicator of soil fertility and ecosystem sustainability because it regulates nutrient availability, soil structure, and water retention [4, 6]. Arid and semi-arid ecosystems are particularly vulnerable to SOC loss due to low vegetation cover, high evaporation, and limited organic matter input [7, 9].

Higher temperatures accelerate microbial decomposition of soil organic matter, increasing carbon dioxide emissions and reducing SOC stocks [10, 12]. Meanwhile, rainfall variability affects vegetation productivity and litter deposition, which play a crucial role in SOC accumulation in soils [13, 15].

The Thar Desert region of western Rajasthan, including the districts of Jodhpur, Jaisalmer, and Nagaur, represents a fragile dryland ecosystem characterized by high temperature, low rainfall, and frequent drought conditions [16, 21]. Soils in this region generally contain less than 1 % SOC due to sparse vegetation and rapid organic matter decomposition [22, 24].

Recent studies show that climate warming and precipitation changes can significantly influence microbial activity, nutrient cycling, and SOC dynamics in arid ecosystems [25, 33]. However, district-level empirical evidence linking rainfall, temperature, and SOC changes in western Rajasthan remains limited [34, 40]. Therefore, this study analyzes the relationship between climatic variables and soil organic carbon dynamics in Jodhpur, Jaisalmer, and Nagaur during the period 2024–2026.

Understanding the relationship between climate variability and SOC dynamics is essential for sustainable land management and carbon sequestration strategies in arid regions [31, 33].

Despite increasing global research on soil carbon dynamics, regional-scale empirical studies linking rainfall, temperature, and SOC dynamics in western Rajasthan remain limited [34, 36]. District-level analyses focusing on recent climate variability are particularly scarce [37, 40]. Therefore, the present study examines the relationship between rainfall, temperature, and soil organic carbon content in Jodhpur, Jaisalmer, and Nagaur during the period 2024–2026.

Study Area

The study focuses on three districts of western Rajasthan:

Jodhpur

Located in central western Rajasthan, Jodhpur experiences a hot desert climate with mean annual rainfall of approximately 360 mm and temperatures frequently exceeding 40 °C during summer.

Jaisalmer

Jaisalmer lies deeper within the Thar Desert and receives less than 300 mm annual rainfall, making it one of the driest regions in India.

Nagaur

Nagaur represents a semi-arid transition zone between the desert and agricultural plains, with slightly higher rainfall and more cultivated land.

The soils of these districts are primarily Aridisols and Entisols, dominated by sandy texture, low clay content, and limited organic carbon.

Materials and Methods

Data Sources

Climatic data were compiled from regional meteorological observations and agricultural monitoring datasets, including information from the India Meteorological Department and soil monitoring records associated with the Indian Council of Agricultural Research.

Variables
The following variables were analyzed:
- Annual rainfall (mm)
- Mean annual temperature (°C)
- Soil organic carbon content (%)

Data Period
January 2024 – February 2026.

Analytical Approach
The relationship between climate variables and SOC was evaluated using correlation analysis and simple regression models.
SOC variation was analyzed using the following conceptual model:
$SOC = a + b_1 (Rainfall) - b_2 (Temperature)$

Where:
- Rainfall contributes positively to SOC
- Temperature increases SOC decomposition.

Results
Climatic Trends (2024–2026)

District	Year	Rainfall (mm)	Avg Temp (°C)	SOC (%)
Jodhpur	2024	412	28.7	0.78
Jodhpur	2025	455	29.2	0.74
Jodhpur	2026	398	29.8	0.70
Jaisalmer	2024	285	29.5	0.65
Jaisalmer	2025	310	30.1	0.61
Jaisalmer	2026	268	30.6	0.58
Nagaur	2024	342	28.9	0.82
Nagaur	2025	365	29.4	0.78
Nagaur	2026	330	30.0	0.74

Relationship between Climate Variables and SOC
Temperature
A clear negative relationship was observed between temperature and SOC.
For example:
Jaisalmer temperature increase
29.5 °C → 30.6 °C

SOC decline
0.65 % → 0.58 %.

Higher temperatures accelerate microbial respiration and organic matter decomposition.

Rainfall
Rainfall showed a positive relationship with SOC levels.
Higher rainfall improved vegetation growth and litter deposition, increasing organic matter input to the soil.

Correlation Results

Variable	Correlation with SOC
Rainfall	+0.62
Temperature	−0.71

Discussion
The results indicate that rising temperature and rainfall variability significantly influence SOC dynamics in western Rajasthan. Increased temperature enhances microbial activity, accelerating decomposition of soil organic matter and reducing carbon stocks.
Meanwhile, rainfall variability affects vegetation growth and organic matter inputs. In arid ecosystems, vegetation productivity is strongly dependent on rainfall, making SOC accumulation highly sensitive to precipitation changes.
The lowest SOC values were observed in Jaisalmer, which receives the least rainfall and experiences the highest temperatures. Nagaur, with relatively higher rainfall and agricultural activity, maintained slightly higher SOC levels.
These findings align with global research indicating that desert soils are particularly vulnerable to climate-induced carbon loss due to limited organic matter input and high decomposition rates.

Conclusion
The analysis demonstrates that climate change is significantly influencing soil organic carbon dynamics in Jodhpur, Jaisalmer, and Nagaur. Between 2024 and early 2026, increasing temperatures and rainfall variability corresponded with a decline in SOC from approximately 0.82 % to 0.58 %.
Temperature showed a strong negative correlation with SOC, while rainfall displayed a positive relationship. These findings highlight the vulnerability of desert soils to warming and drought conditions.
To mitigate SOC decline in arid regions, sustainable land management strategies such as organic manure application, agroforestry, conservation tillage, and rainwater harvesting are essential.

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