ISSN: 3065-0380

Columbia Journal of Agricultural and Environmental Sciences

Research Article

SPATIO-TEMPORAL PATTERNS OF DESERTIFICATION IN KANO STATE VIA GIS AND REMOTE SENSING

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DOI: 10.5281/zenodo.19628591

Abstract

Soil degradation and desertification are pressing environmental challenges in semi-arid regions, where fragile ecosystems are highly vulnerable to human activities and climatic stress. Kano State, located in Nigeria's semi-arid Sudan savanna, experiences intensive agricultural demands, high population pressure, and seasonal rainfall variability, which exacerbate soil nutrient depletion, erosion, and land degradation. Anthropogenic factors such as overgrazing, deforestation, and unsustainable farming practices accelerate desertification, reducing soil fertility and threatening ecosystem functionality. This study highlights the extent, causes, and implications of soil degradation and desertification in Kano State, emphasizing the need for integrated land management strategies. Employing geospatial analysis through GIS and remote sensing, the research provides insights into spatial patterns of land degradation, informing sustainable agricultural planning and environmental conservation in dry land regions.

Keywords: Soil degradation, Desertification, GIS, Remote sensing, Kano State

1. INTRODUCTION

1.1 Background

Soil degradation and desertification are critical global environmental challenges, particularly in dryland regions where fragile ecosystems are susceptible to human pressures and climate stressors. Desertification refers to the process by which fertile land becomes increasingly arid and degrades, resulting in the loss of biological productivity and ecosystem functionality (UNCCD, 1994). In West Africa, anthropogenic activities, such as overgrazing, deforestation, and unsustainable cultivation, intensify soil degradation (Obalum et al., 2012).

Kano State, positioned within Nigeria's semi-arid savanna ecology in Sudan, is characterized by seasonal rainfall, high population density, and intensive agricultural demands. The state is central to Nigeria's cereal production, yet it faces persistent threats from soil nutrient depletion, erosion, and advancing desertification. Understanding the extent and drivers of these processes is critical for sustainable land management and food security.

1.2 Problem Statement

Despite the agricultural significance of Kano State, the integrated assessment of soil degradation and desertification processes using both spatial analysis and ground-based data is limited. Existing studies tend to focus on separate indicators without synthesizing landscape change, soil health parameters, and socioeconomic factors. This knowledge gap hampers effective policy formulation and land rehabilitation strategies.

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1.3 Objectives

The primary aim of this study is to assess the processes of soil degradation and desertification in Kano State by the following:

1. Mapping land cover change and degradation hotspots using RS and GIS
2. Quantification of key soil health indicators (organic matter, texture, and nutrient status)
3. Identifying anthropogenic and climatic degradation drivers
4. Recommending sustainable rehabilitation and management strategies.

2. METHODOLOGY

2.1 Study Area

Kano State lies between latitudes 10°00′ and 12°00′N and longitudes 7°45′ and 9°30′E, covering approximately 20,131 km². The climate is characterized by distinct wet (May–September) and dry (October–April) seasons. Agriculture dominates the economy, with a mix of cereals, legumes, and livestock.

Table 1: Climatic characteristics of the Kano state

Parameter	Mean Value	Range	Implications for soil degradation
Annual rainfall (mm)	800	600–1000	Low and variable rainfall increases the risk of erosion and desertification
Mean annual temperature (°C)	26.5	20–40	High temperatures accelerate evapotranspiration
Length of the dry season (months)	7	6–8	Prolonged dryness reduces vegetation cover
Relative humidity (%)	45	30–65	Low humidity contributes to wind erosion

2.2 Data sources

- **Satellite Imagery:** Landsat TM and Sentinel-2 data for 2000, 2010, and 2020.
- **Soil sampling: stratified** random sampling across 40 locations representing cultivated, grazing, and degraded lands.
- **Climate Data:** Rainfall and temperature records were obtained from the Nigerian Meteorological Agency (NiMET).
- **Socioeconomic Surveys:** Structured questionnaires were administered to 200 farmers/herders.

2.3 Remote Sensing and Geographic Information System Analysis

- **Land Cover Classification:** Supervised classification using the maximum likelihood algorithm to detect changes in vegetation, bare land, and water bodies.
- **Normalized Difference Vegetation Index (NDVI):** quantifying vegetation dynamics over time.

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- **Soil erosion modeling:** Revised universal soil loss equation (RUSLE) is used to estimate erosion risk zones.

2.4 Soil Analysis

The collected soil samples were analyzed in the laboratory for the following:

- **Texture** (hydrometer method)
- **Organic matter** (Walkley-Black method)
- **pH** (soil-to-water ratio)
- **Nutrients:** Nitrogen (Kjeldahl method), phosphorus (Bray-P1), potassium (flume photometry)
- **Salinity** (electrical conductivity)

2.5 Statistical analysis of the data

Data were processed using the following:

- **SPSS v25:** Descriptive statistics and correlation analyses.
- **ArcGIS Pro:** spatial analysis and mapping.
- **Trend Analysis:** Temporal comparisons of NDVI and susceptibility to erosion.

3. RESULTS

Change in land cover (2000–2020)

- The vegetative cover decreased by approximately 22%, particularly in the northern and eastern areas of the local government.
- Bare and degraded land areas expanded by 18%.
- Urban and settlement expansions accounted for a 6% increase.
- NDVI trends indicate declining vegetation health, especially during dry seasons.

Table 2: Land Use/Land Cover Changes in Kano State (2000–2020)

Land Use Category	2000 (%)	2010 (%)	2020 (%)	Change (%)
Vegetation Cover	48.6	39.2	26.4	−22.2
Cultivated Land	31.8	38.4	45.1	+13.3
Bare/Degraded Land	12.4	15.8	30.5	+18.1
Built-up Areas	7.2	6.6	8.0	+0.8

Soil health indicators

- **Organic matter: Depleted** in cultivated and overgrazed sites (average <1.2%).

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- **Soil pH:** This ranged from slightly acidic to moderately alkaline (pH 6.8–8.2), with higher alkalinity in the degraded zones.
- **Nutrients:** Nitrogen and phosphorus levels were low in 65% of the sampled sites.
- **Salinity:** Elevated electrical conductivity in lower elevation basins indicates salt accumulation.

Erosion risk assessment

- The RUSLE outputs identified high-erodition-risk zones along seasonal river courses and slopes, correlating with sparse vegetation cover.
- Wind erosion was significant across flat, exposed landscapes.

Community Perceptions

- 83% of farmers reported worsening soil fertility over the last decade.
- 72% acknowledged rainfall inconsistency as a major concern.
- Overgrazing and continuous cropping without fallow were cited as key degradation drivers.

DISCUSSION

The results confirm substantial soil degradation and advancing desertification processes within Kano State. Declining vegetation cover and NDVI trends indicate persistent stress on natural ecosystems, likely driven by unsustainable land use, increased cultivation intensity, and climatic variability. Soil nutrient depletion, especially organic matter loss and low nitrogen content, reflects poor soil management, burning of crop residue, and lack of nutrient replenishment.

Table 3: Soil physicochemical properties across land use types

Parameter	Cultivated Land	Grazing Land	Degraded Land	FAO Standard
pH	7.4	7.8	8.1	6.0–7.5
Organic matter content (%)	1.3	1.0	0.6	≥2.0
Total nitrogen content (%)	0.07	0.05	0.03	≥0.15
Available phosphorus concentration (mg/kg)	6.8	5.2	3.1	≥10
Electrical conductivity (dS/m)	1.2	1.6	2.4	≤2.0

The spatial distribution of degradation indicates that the state's northern and peripheral zones are more vulnerable, aligning with broader Sahelian climatic gradients. Elevated salinity and alkaline conditions in some areas may result from evapotranspiration exceeding rainfall, promoting salt buildup.

Community perceptions align with biophysical evidence, reinforcing that anthropogenic pressures—overgrazing, deforestation, and indiscriminate cultivation—are primary determinants of land degradation. These findings underscore that desertification is both a human-induced and climate-amplified phenomenon, necessitating integrated approaches to land restoration.

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Table 4: Estimated soil erosion risk using the RUSLE model

Risk Class	Area (km²)	Percentage (%)	Dominant Land Use
Low	5,420	26.9	Dense vegetation
Moderate	6,315	31.4	Cultivated land
High	4,987	24.8	Sparse vegetation
Very High	3,409	16.9	Bare/degraded land

Table 5: Causes of Soil Degradation Perceived by Respondents

Cause	Frequency	Percentage (%)
Overgrazing	78	39
Continuous cropping	54	27
Deforestation	41	20.5
Climate variability	27	13.5
Total	200	100

CONCLUSION

This assessment reveals that soil degradation and desertification processes are intensifying in Kano State, with significant implications for agricultural productivity, food security, and rural livelihoods. The combined use of remote sensing, soil analyses, and community insights demonstrates clear patterns of vegetative decline, soil nutrient depletion, erosion susceptibility, and land cover change over the past two decades.

Without timely intervention, continued degradation threatens to render productive lands unviable, worsening poverty and ecological vulnerability.

RECOMMENDATIONS

To address soil degradation and desertification in Kano State, the following actions are recommended:

Sustainable Land Management (SLM)

- Conservation agriculture: minimum tillage, crop rotation, and cover crops.
- Agroforestry practices to enhance soil structure and biodiversity
- Contour farming and terracing on sloped landscapes
- Improve soil fertilityt
- Promote organic amendments such as compost and manure.
- Regular soil testing to tailor fertilizer application.

Controlling erosion and salinity

- Establishment of windbreaks and vegetative buffers
- Implement water harvesting structures to reduce runoff and retain soil moisture.

Policy and Institutional Strengthening

- Develop land use planning frameworks that limit overgrazing and deforestation.
- Soil rehabilitation programs are encouraged through subsidies or community-based initiatives.

Capacity Building and Awareness

- Train farmers **on soil conservation techniques**.
- Educate communities on the impacts of desertification and sustainable practices.

Monitoring and research

- Establish long-term soil health monitoring networks.
- Encourage collaboration between government, academic, and international partners for ongoing research and knowledge exchange.

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