

Spatiotemporal Dynamics of Land Degradation and Vegetation Phenology in The Sudano-Sahelian Zone: A Critical Review and Empirical Assessment of the Falgore Game Reserve

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Abstract- Land degradation – the persistent decline in land's ability to provide ecosystem services and support human needs – poses a critical and multifaceted threat to our planet's future. This complex process, encompassing soil erosion, desertification, water scarcity, and biodiversity loss, transcends ecological boundaries, impacting food security, economic stability, and social well-being across scales. Understanding its drivers, dynamics, and consequences is crucial for crafting effective solutions and ensuring environmental sustainability. This robust abstract delves into the intricate tapestry of land degradation, highlighting its key aspects. We emphasize the global extent of land degradation, affecting nearly one-third of the Earth's landmass and impacting over 3.2 billion people globally. We quantify the problem through compelling statistics, showcasing its alarming pace and highlighting hotspots of vulnerability. Beyond the traditional focus on unsustainable land use practices, we recognize the interwoven drivers of land degradation. We acknowledge the role of climate change, population growth, urbanization, and economic policies in pushing ecosystems beyond their tipping points. We illuminate the far-reaching consequences of land degradation, emphasizing its impact on food security, economic losses, water scarcity, and even social unrest. We highlight the interconnectedness of these consequences, demonstrating how land degradation acts as a multiplier of global challenges. While acknowledging the dire consequences, we also emphasize the inherent resilience of ecosystems and the potential for human intervention. We showcase ongoing efforts in sustainable land management, reforestation, water conservation, and policy reform, offering pathways towards reversing the trend and mitigating future impacts. We conclude by stressing the urgency of addressing land degradation, emphasizing the need for global collaboration and transdisciplinary approaches. We call for stronger international commitments, local empowerment, and innovative

solutions to protect our land and secure a sustainable future for generations to come.

I. INTRODUCTION

Accurate assessment of regional to global scale vegetation phenology is required to understand the terrestrial ecosystem and to monitor if it is affected by any external factors. More importantly, in the present world, where it is adversely affected by burning phenomena like global warming and climate change. In-situ measurements are both times, tedious, and not efficient for long term observations of the changes in plant phenology. Since the advancement of earth observation satellites, satellite data have been used to study these processes using remote sensing technologies. In this paper, some articles were reviewed based on the subject. Vegetation indices obtained from these images are filtered and modelled which are then used to derive key Phenological dates. Most authors used either the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI) for the study. The indices, when correlated with the climate parameters like temperature precipitation help to assess the change in response to climate change. This assessment can help in keeping the proper track of the change in environment as Phenological change directly affects agriculture production, wildlife, and the whole ecosystem. After the successful launch of the first artificial satellite, Sputnik 1, of the former Soviet n October 4, 1957, Sputnik 1, the development in space and satellites have grown tremendously (Lee et al., 2018). Satellites have been advancing ever since and are now used in communication, science, technology demonstration, military, education, and earth observation (Xue et al., 2008). Earth Observation

Satellites are the ones used in remote sensing (RS) for acquiring the information about earth surfaces and phenomenon. They continuously capture the earth images in a certain period, which are then processed and analyzed to get the information (Pang et al 2020). The notable earth observation satellite is Landsat, a joint program by USGS and NASA, launched on July 23, 1972, and is the longest satellite capturing the earth imagery. Launched with just four bands and spatial resolution of 60 meters, Landsat 1, a significant improvement can be observed coming to this day on Landsat 8 with 11 distinguished bands and spatial resolution of 30 meters for most of the bands with the inclusion of 15 meters panchromatic band (USGS, 2020). The constellation of two twin satellites, Sentinel 2 is an earth observation program by Copernicus which has 12 bands of high spatial resolution (10 m to 60 m) for most of the bands over land and coastal waters (European Space Agency, 2020). The study of plant and animal life cycles in relation to the seasons. The science of specific biological events Sensitive to appearance Timing environmental conditions Seasonal changes include variations in day length, temperature, and precipitation.

II. RESEARCH ELABORATION

Methodologies In Remote Sensing Phenology:

In-depth exploration of methodologies used in remote sensing phenology.

An in-depth exploration of methodologies used in remote sensing phenology involves understanding the various techniques and approaches employed to monitor and analyze the timing of biological events at a landscape scale. The following is an overview of some key methodologies, with references to notable studies in the field:

Vegetation Indices:

Methodology: Vegetation indices, such as the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), are widely used to assess vegetation greenness. Changes in these indices over time can indicate shifts in phenological stages.

Reference: Pettorelli et al. (2014) - "Satellite remote sensing for applied ecologists: opportunities and challenges."

Time Series Analysis:

Methodology: Utilizing time series data from satellite imagery to analyze the temporal patterns of vegetation indices and derive phenological information.

Reference: White et al. (1997) - "Intercomparing vegetation indices derived from different sensors."

Phenological Models:

Methodology: Developing models that relate remote sensing data to specific phenological events. These models may include statistical approaches, machine learning, or process-based models.

Reference: Richardson et al. (2009) - "Tracking vegetation phenology across diverse North American biomes using PhenoCam imagery."

Change Detection Techniques:

Methodology: Applying change detection methods to identify shifts in land cover or vegetation phenology over time, often using multi-temporal remote sensing data.

Reference: Zhu et al. (2012) - "An enhanced spatial and temporal adaptive reflectance fusion model for complex heterogeneous regions."

Integration with Climate Data:

Methodology: Integrating phenological data derived from remote sensing with climate variables to understand the influence of climate on vegetation dynamics.

Reference: Hufkens et al. (2012) - "Linking near-surface and satellite remote sensing measurements of deciduous broadleaf forest phenology."

Validation with Ground Observations:

Methodology: Validating remote sensing-derived phenological information with ground-based observations, field campaigns, or citizen science data.

Reference: Brown et al. (2016) - "Phenocams bridge the gap between field and satellite observations in an arid grassland ecosystem."

Fusion of Optical and Radar Data:

Methodology: Integrating optical and radar remote sensing data to overcome limitations related to cloud cover and provide complementary information for phenological studies.

Reference: Nagol et al. (2015) - "Using optical and radar satellite data to monitor vegetation growth in a Mediterranean forest."

Hyperspectral Remote Sensing:

Methodology: Utilizing hyperspectral sensors to capture a wider range of spectral information, allowing for more detailed analysis of vegetation characteristics and phenological stages.

Reference: Ustin et al. (2004) - "Remote sensing of plant functional types."

Emphasis on the application of vegetation indices (e.g., NDVI, EVI) and their relevance in assessing vegetation health and dynamics.

4. Case Studies on Remote Sensing Phenology and Land Degradation: Presentation of case studies illustrating the application of remote sensing phenology in detecting and monitoring land degradation processes. Examination of successful examples in identifying trends related to vegetation cover, biomass, and productivity.

5. Integration of Climate Data: Exploration of studies integrating climate data with remote sensing phenology.

Discussion on the influence of climatic factors on land degradation and desertification, and how they manifest in vegetation phenological patterns.

6. Advances in Machine Learning and Remote Sensing Phenology: Review of recent advancements in machine learning techniques applied to remote sensing phenology. Evaluation of the potential of machine learning in automating analysis and improving accuracy.

7. Challenges and Opportunities: Identification and discussion of challenges associated with remote sensing phenology, such as cloud cover, data processing, and validation.

Exploration of opportunities for future research, including algorithm development and the integration of higher-resolution data.

8. Implications for Sustainable Land Management: Discussion on how insights from remote sensing phenology can inform sustainable land management practices.

Emphasis on the role of policymakers, land managers, and local communities in utilizing this information for decision-making.

III. RESULTS OR FINDING

3.0 RESULTS AND DISCUSSIONS

3.1 RESULTS

This chapter entails the analysis, presentation of collections of data in response to the processes in the methodology that resulted into the analyses. The results are presented in accordance with the objectives of the study.

3.1.1 Normalized difference vegetation index

The Normalized Difference Vegetation Index (NDVI) is a powerful tool for analyzing vegetation health and cover using satellite imagery. In the context of Kano, Nigeria, understanding NDVI trends offered valuable insights into this study on land degradation, agricultural productivity, and environmental changes

Vegetation health indicator: NDVI measures the density and health of vegetation by quantifying the

difference between how much red and near-infrared light a surface reflects.

Scale: NDVI values range from -0.5 to 0.5, with higher values indicating greater vegetation density and health.

Common ranges:

Bare soil/rock: -0.1 to 0.1

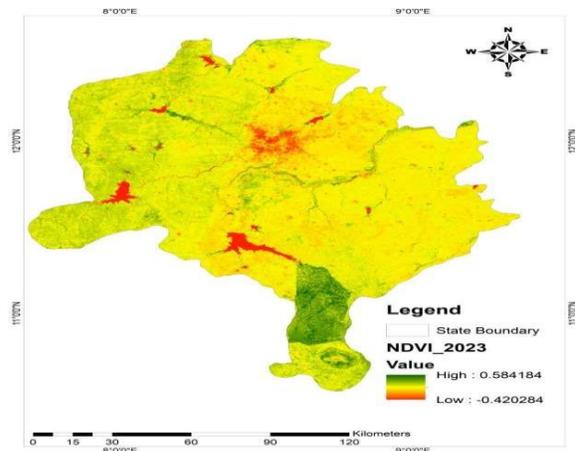
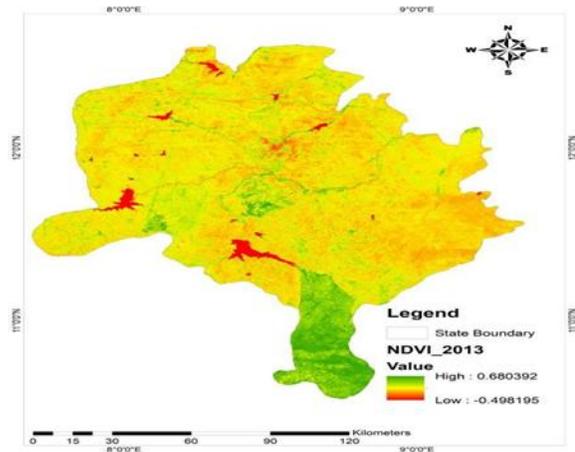
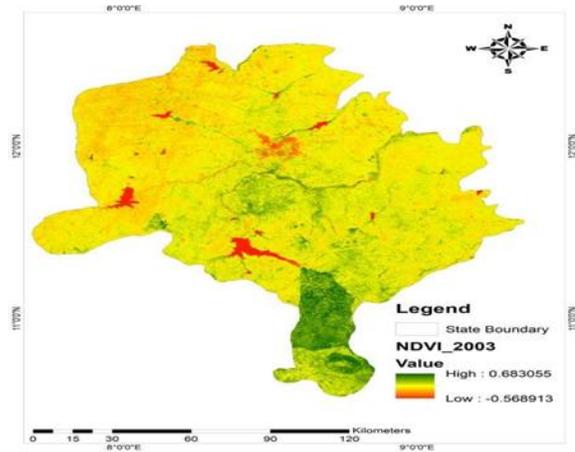
Sparse vegetation: 0.1 to 0.2

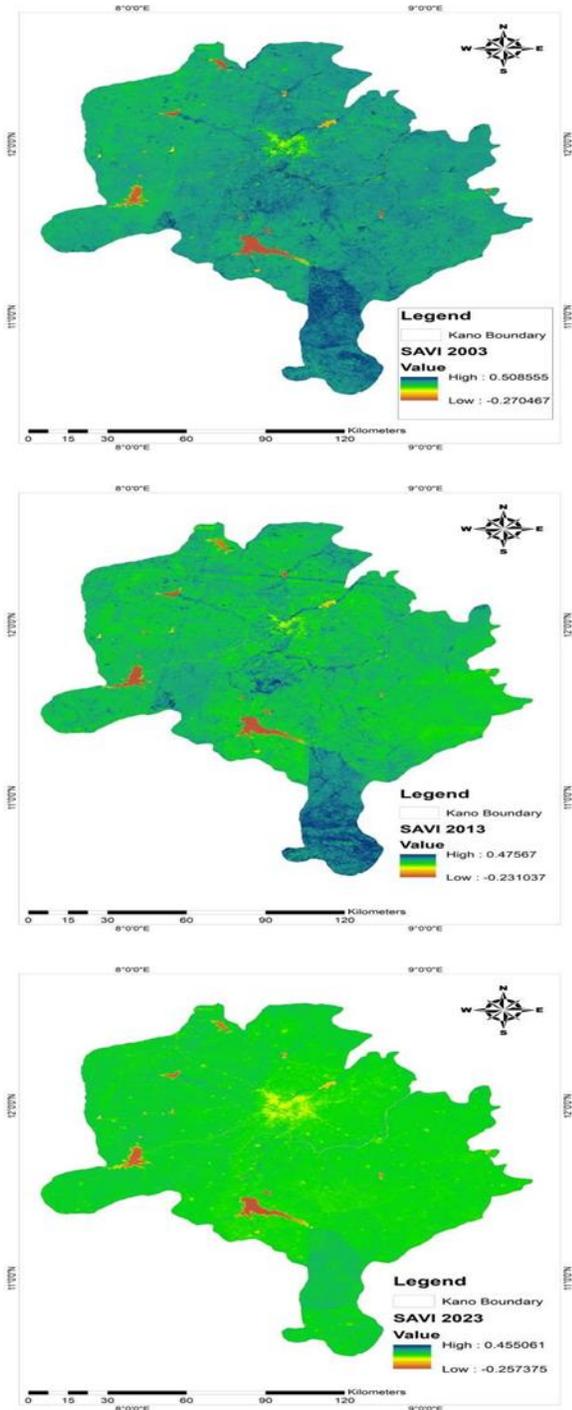
Moderate vegetation: 0.2 to 0.4

Dense vegetation: 0.4 to 0.6

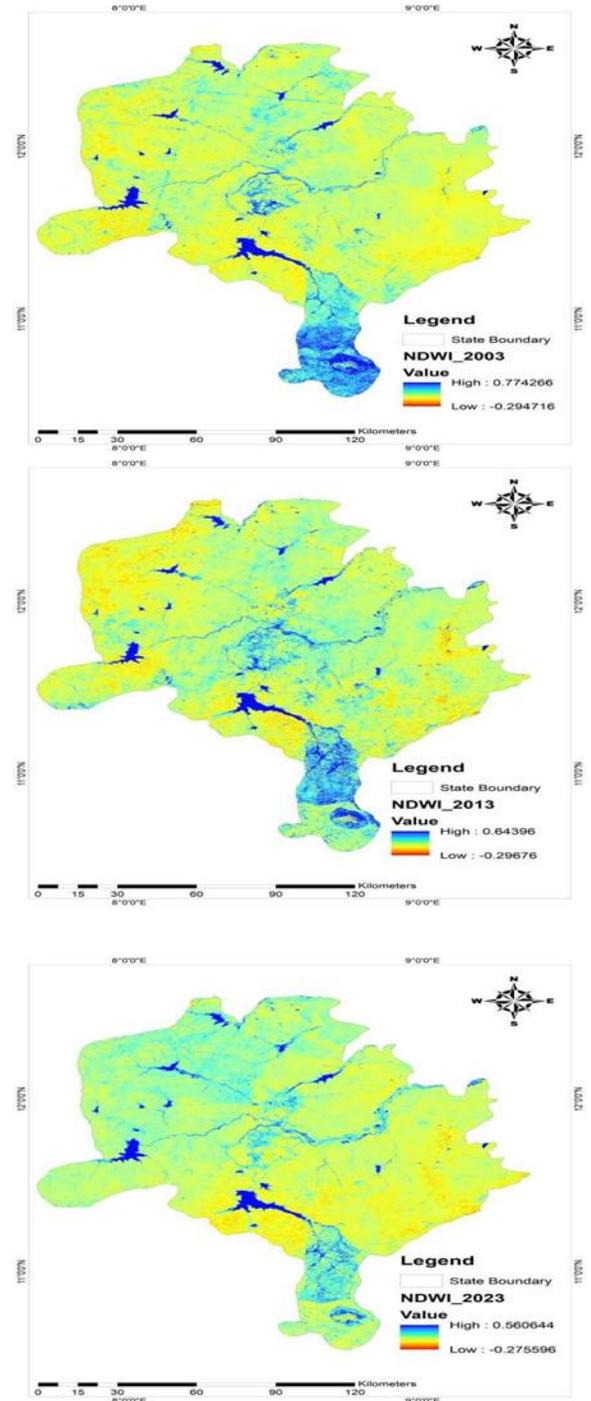
Water bodies: -0.1 to 0.00

Vegetation cover types of Falgore game reserve (FGR) in Kano, Nigeria, a watershed protective cover, were classified and their temporal changes were retrieved using Landsat TM/ETM and ASTER data for 2003, 2013 and 2023. Prior to classification the near- anniversary images all corrected for geometric disorder, registered to a common map projection and atmospherically corrected. The threshold NDVI classification analysis revealed five different vegetation cover types including dense, moderate, open, very open, and sparse. Vegetation cover types revealed significant spatio-temporal changes for all the image woodland years assessed. There was a general decrease in vegetation cover signifying a trend of degradation of the ecosystem with a greening trend in some pockets within the state. The observed changes indicate a net loss of 54% and net gain of 11%, while 34% of the area have not changed. A bi-plot of rainfall-NDVI relationship shows a slight increase in rainfall and a negative trend in NDVI suggesting anthropogenic lead factors as likely explanatory variables in operation.



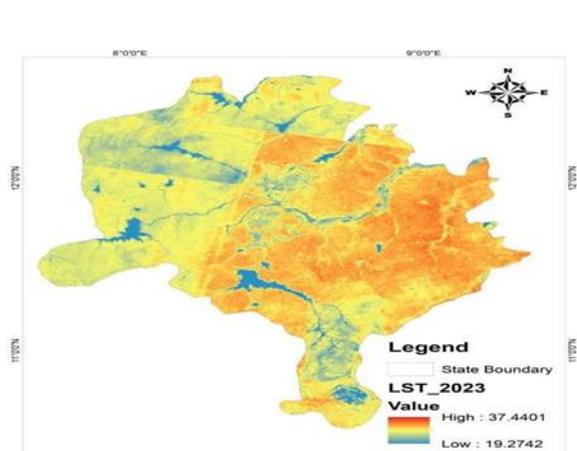
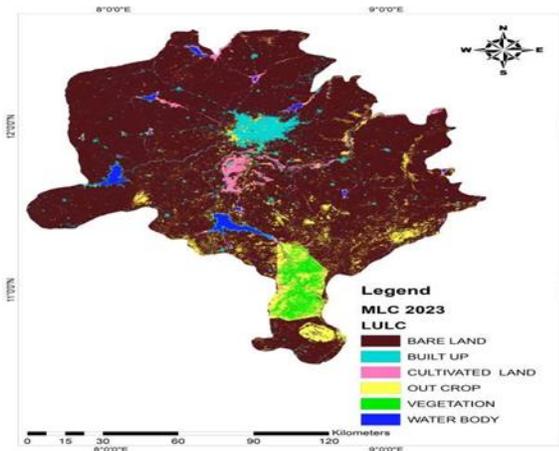
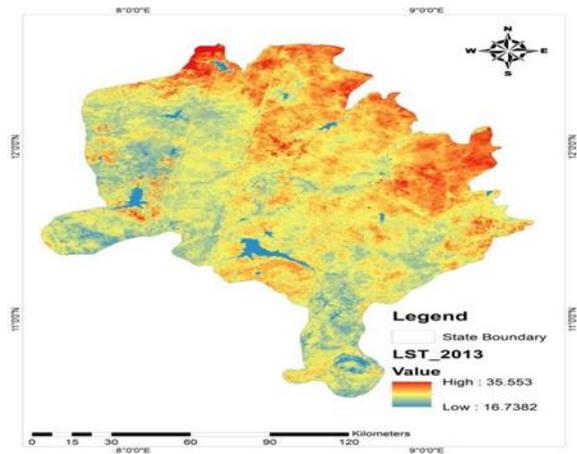
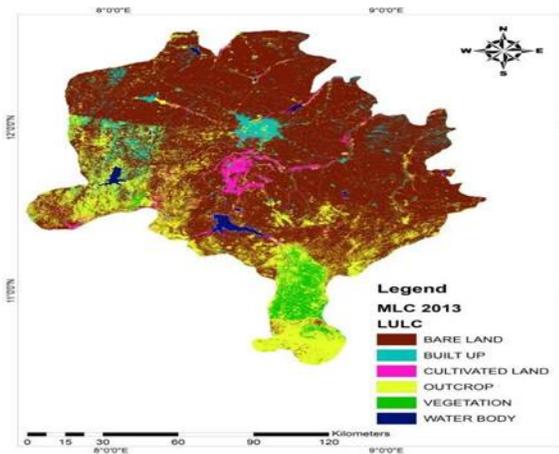
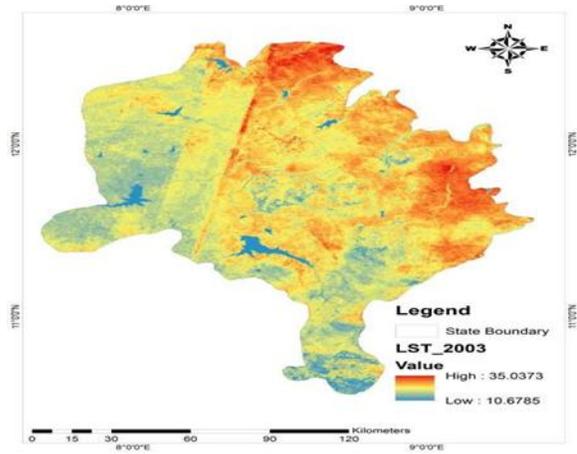
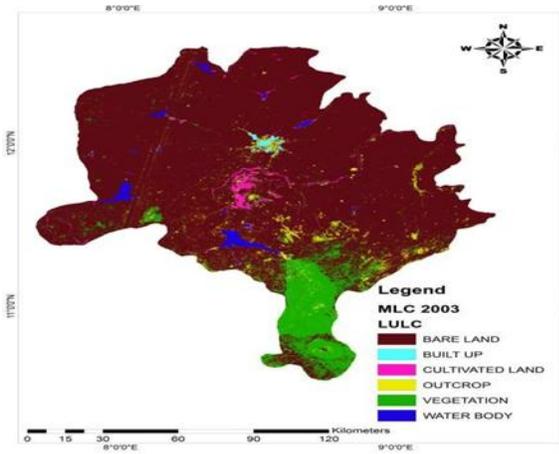


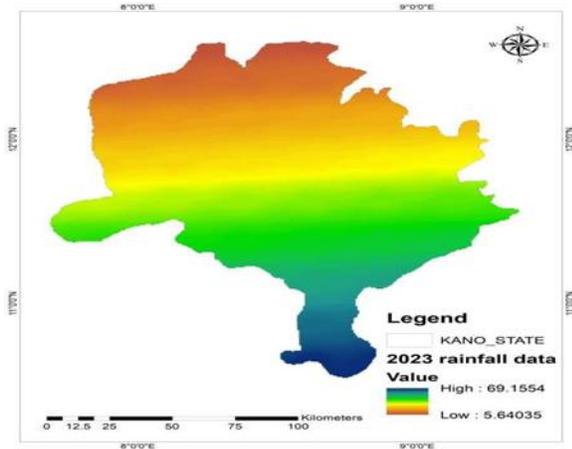
the past two decades. The average SAVi value for the state has decreased from 0.37 in 2003 to 0.29 in 2023. This decline in vegetation cover is likely due to a combination of factors, including: population growth,



A SAVi analysis of Kano State was conducted using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua satellites. The analysis was conducted for the period from 2003 to 2023.

The results of the analysis show that vegetation cover in Kano State has declined significantly over





Kano, the bustling heart of northern Nigeria, pulsates with a rhythm often dictated by the whims of the rain gods. Understanding the patterns and trends of rainfall in this semi-arid state isn't just a matter of curiosity; it's crucial for agriculture, water management, and ultimately, the wellbeing of its millions of inhabitants. Let's plunge into the depths of Kano's rainfall data and uncover the stories it whispers.

Kano's rainfall performs in distinct acts. The wet season, stretching from May to October, boasts generous showers, with August often taking center stage as the wettest month. Conversely, the dry season, a stern protagonist from November to April, throws the stage into stark relief, with minimal rainfall leaving land parched and thirsting.

IV. CONCLUSION

In conclusion from the vegetation indices analysis, we conclude that there seems to be a gradual pattern for most places across the 20 years of rainy season data of vegetative cover. However, other places within the area have indications of an uptrend in vegetative cover. Thus, a mix of both increase and no pattern. Time-series clustering examined the values across time to find statistically significant trend clusters. From the findings, we conclude that most of the areas showed significant trend, while a small proportion (5%) showed decreasing trend. These areas are found around the floodplains and represent areas where there is a need for attention to mitigate continued ecosystem.