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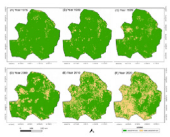

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Land degradation

Time-Series Assessment of Vegetation Structure and Compositional Changes of Wawa-Zange Forest, Gombe, Nigeria

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ABSTRACT

This study aimed to assess the vegetation changes and sustainability of the Wawa-Zange grazing reserve. The study reported the vegetation composition and changes through time (1975-2020) for the entire Wawa-Zange grazing reserve, one of the world's largest grazing reserves. Multi-temporal satellite imageries were acquired from the USGS Earth Explorer collection of Landsat data series and employed in this study. Normalized Difference Vegetation Index (NDVI) technique was used to delineate forest and non-forest areas. ArcMap was used to elucidate the transition of the reserve. The result obtained from the study showed that the reserve has changed, owing to the spread of agricultural boundaries, overgrazing, and deforestation. During the study period, the non-vegetation area expanded from 3.88 percent to 46.74 percent, while the agricultural area increased by 37 percent. This approximately 50 percent decline in vegetation cover indicates a significant decline in β-diversity at large spatial scales. It was observed that by 2030, the reserve could lose 67% of its vegetation cover. To stop land conversion and unsustainable agricultural practices, strict legislative frameworks and regulations should be implemented. Sustainable land management techniques like agroforestry and reforestation should also be encouraged.

INTRODUCTION

The United Nations (U.N.) declared 2021–2030 to be the Decade of Ecosystem Restoration in recognition of the critical need to restore natural ecosystems to stop biodiversity loss and lessen climate change's effects [1]. The U.N. set the goal of repairing a billion hectares of the environment as part of this endeavor. Ecological restoration is becoming a more critical tool for governments and conservation groups to accomplish conservation goals and lessen the effects of habitat loss on biodiversity and ecosystem services [2]. Wawa-zange grazing reserve is one of the 58 grazing reserves in Gombe State. It has about 144,000 hectares and is believed to be the largest in Africa [3]. According to [4], forests are the earth's next most important natural resources, after air and water. United Nations mandated that 25 percent of the surface area of every country should be conserved under permanent forest cover as the minimum ecological requirement for the socio-economic survival of a country. Nigeria has lost 96 percent of its forest due to deforestation [5]. The country has only four percent of our original forest cover now, and massive efforts are required to increase that coverage to at least 25 percent across the country in 30 years [5]. Governments worldwide have set aside forest reserves to enhance rainfall, lessen wind erosion, prevent desertification, and slow down desertification. Because of this, forest reserves are safeguarded by law and constitution in many countries [6].

Wawa-Zange forest reserve faces threats similar to those faced by other forest reserves in Nigeria and other developing countries, where many people are poor and rely largely on natural resources. Without baseline vegetation data, detecting and managing future changes will be impossible. Observing the vegetation allows us to understand better how habitat changes may affect the management decisions made for protected species and other wildlife [7,8]. The vegetation cover of the reserve in 1975 was 1476.878 square kilometres (km2), which is 96% of the total land area of

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1536.570 km2. Many studies [9,10] have tried to understand the vegetation condition of the reserve to distinguish anthropogenic land degradation or desertification by comparing the potential and actual status of vegetation [11,12].

However, a fundamental impediment to policy formation is the lack of extensive spatial studies at a regional size throughout Gombe, particularly in places that are preserved and gazetted for a specific purpose. Understanding the vegetation cover in a given area is necessary for regional ecological restoration. The Normalized Difference Vegetation Index (NDVI), which accurately depicts the status of surface vegetation cover, is the best indicator of vegetation coverage and the most useful indicator for tracking changes in regional vegetation and the ecological environment [13,14]. Also , predicting the magnitude of the degradation remains a challenge. The study's objective was to investigate the Wawa-Zange forest's spatiotemporal variability to ascertain the reserve's vegetation cover and evaluate vegetation changes from 1975 to 2020.

MATERIALS AND METHODS

Study area

At 579 meters above sea level, the Wawa-Zange Forest Reserve (**Fig. 1**) is located between latitudes 10˚49'22.7"N and longitudes 10˚46'23.97"E. Four local governments—Dukku, Funakaye, Kwami, and Nafada—bordered the restricted area. Shrubs, a few scattered trees, and herbs make up the vegetation. The forest reserve is an open savanna woodland home to several thorny species and both broad- and fine-leaved trees. The rainy season starts in May and continues through October, with the maximum in August and September, with the mean annual rainfall in the reserve of about 900 mm. The temperatures are high throughout the dry season, beyond 40°C during the hottest months (March – April), while during the rainy season, the average temperature is usually within 24-26°C.

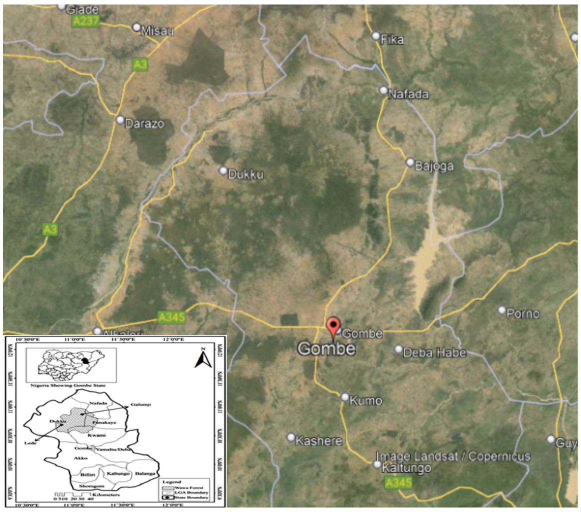

Fig. 1. Map of Wawa-Zange Grazing Reserve. Image from Google earth.

Multi-temporal satellite imageries, which are acquired from the USGS Earth Explorer collection of Landsat data series, were employed in this research. The acquired data include M.S.S. of Jun 24, 1975, M.S.S. of Jan 28, 1980, and Landsat TM of Nov 29, 1990. Others were Landsat E.T.M. of Nov 17 2000, Landsat E.T.M. of Jan 13 2010, and Landsat O.L.I. of Nov 16 2020. All the imageries have a 30m resolution except M.S.S. data, which has a 60m resolution. The normalized Difference Vegetation Index (NDVI) technique was used in delineating forest and non-forest areas, which is an indicator of the presence and condition of green vegetation. This technique used Near Infra-Red (NIR) and visible bands from each data set [15].

$$NDVI = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}$$

Where R is visible red reflectance, and NIR is near-infrared reflectance. The wavelength range of the NIR band is (750-1300 nm) and the Red band is (600-700 nm).

The images were smoothed and sharpened using filtering and stretching techniques to enhance the reflectance values of these bands for easily distinguishing forested areas and non-forest lands such as farmlands, settlements, and bare surfaces. Vegetation indices for all the images were computed using Map Algebra's "Raster Calculator" of the spatial analyst tools in ArcMap 10.7. The normalized values range between -1 and +1 and were grouped into two discrete classes of vegetation and non-vegetation with a reclassifying tool that employs the Natural Breaks (Jenks) classification model. Wawa-Zange grazing reserve boundary shapefile was then used to clip the reclassified data according to its spatial extent.

The intersect tool of the Analysis toolboxes was then used for the overlay analysis, where two classified data of different periods were compared to spatially discover which class remained undisturbed or changed to another class. Before overlay analysis, the classified data were converted to a vector data model (shapefile), as the intersect tool accepts only vector data. Finally, the area of each class for each period was computed, as well as their percentages and rate of change throughout the study period. The Hurst exponent was used to predict the future trend of vegetation [16]. The Hurst exponent approach based on rescaled interval (R/S) analysis is a fractal-theory-based time-series analysis technique with several applications in studying population movement and climate change [17].

RESULTS AND DISCUSSIONS

Spatio-temporal dynamics of vegetation cover changes

The vegetation cover statistics and land-cover classification maps of the years understudied—1975, 1980, 1990, 2000, 2010, and 2020 are shown in **Fig. 2**.

Fig. 2. Spatial trend of deforestation in Wawa-Zange forest reserve from 1975-2020.

Wawa zange vegetation's NDVI trends showed considerable variance in the spatial distribution. The reserve degradation pattern shows no direction, as encroachment was

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observed from all directions of the reserve. From 1975 to 1980, the vegetation cover had reduced in percentage by 1% (**Fig. 2**A). However, between 1980 and 2020, it had reduced significantly from 1470.14km^2 of dense vegetation to 819.06km^2 which is 46.68% (**Fig. 2**F). Non-vegetation area increased 1980–1990 from 4.31% to 7.74% and to 17.49% by 2000. This gradual decrease in vegetation and more than 100% increase in non-vegetation could be a result of an increase in the poverty rate, which was 41.7% in 1990 from 28.1% in 1980, and a significant increase in population, which was 73.42 million in 1980, 95.21 million in 1990 to 122.3 million in the year 2000 [18].

The study showed that over 71 thousand hectares of the reserve had suffered the menace of deforestation. Thus, the reserve had been destroyed to a distance of roughly 5 kilometers from the initial frontier of the woody plants, which was only a few meters away from major roadways, as shown in **Fig. 2**. This degradation affected not only the reserve vegetation cover but also directly affected the habitats of animals in the grazing reserve. The situation is made worse by the influx of pastoralists and internally displaced people (IDPs) to Gombe from the nearby Borno and Yobe States [19,20,21], which have both been devastated by Boko Haram insurgents and climate change. These economically impoverished and frustrated individuals are battling to survive and chop down the last tree in the reserve in desperate attempts to feed their families or earn a living by producing charcoal [22].

The study confirms the reports of [22] and [23] that 351,000 hectares of land are being turned into deserts each year in sub-Saharan Africa as a result of overgrazing and overcultivation [24]. Farmlands are the dominant land cover in the study area, consistently increasing throughout the 45-year study period. This is consistent with the [25], who reported that intensified agricultural activities are the major factors influencing and aggravating desertification in arid regions. According to [26], vegetation degradation is getting worse. This was also reported by [27] and [28], who noted that the land cover in Nigeria's northern states has changed dramatically over the last three decades.

Climate unpredictability and growing population density have a combined influence on the region's declining vegetation abundance, according to [26]. Growing numbers of people living in rural areas exacerbate the effects of land degradation. [29] Have emphasized the various policies and programs the Nigerian government has implemented to address environmental issues. Examples of such policies and initiatives include the Great Green Wall Project, the Federal and State Environmental Protection Agency (FEPA/SEPA), the Arid Zone Afforestation Project (AZAP) in 1977, and the River Basin Development Authorities (RBDA) in 1987. However, the issue is getting worse because the problem has been approached as a sectoral issue rather than through an integrated approach that will bridge the gap between the formation of policy and strategies to combat deforestation, drought, and desertification. [30] Reported that protected areas in north-eastern Nigeria are not well administered. The paper reported that federal government-managed protected areas are better managed than those controlled by states and local governments areas (L.G.A.s) [30].

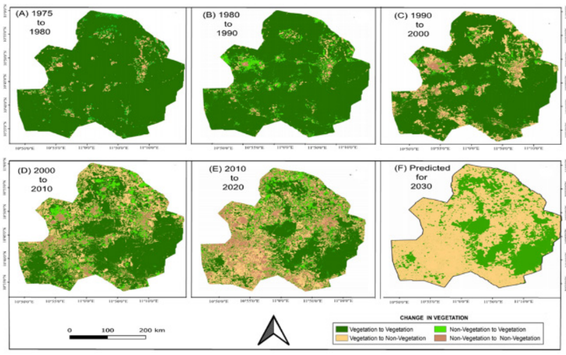

Fig. 3. Predicted vegetation dynamics of Wawa-Zange forest reserve by 2030.

By 2030, the reserve could lose 67% of its vegetation (Fig. 3). The Hurst exponent (H) was 0.7, indicating persistent behaviour. Thus, the vegetation cover in the reserve will continue to decrease in the future ($p<0.05$, $H>0.5$). This might be the result of native residents' increased demand for energy sources, with Internally Displaced Persons (IDPs) in particular placing a great deal of pressure on the woody vegetation. Furthermore, without access to any modern or governmental infrastructure, the villagers' sole energy options were firewood and charcoal.

CONCLUSION

The grazing reserve has shrunk by 47% of its original size as a result of agricultural activities, population growth, overgrazing, and overexploitation. 67% of the reserve's vegetation could disappear by 2030. Frameworks for monitoring vegetation are not being applied despite the existence of several regulations and programs. Therefore, it is recommended that strict legal structures and regulations should be put in place to stop land conversion and unsustainable farming practices and promote sustainable land management practices such as agroforestry, reforestation, and afforestation to restore degraded landscapes and increase forest cover.

REFERENCES

1. Dudley N, Gonzales E, Hallett JG, Keenleyside K, Mumba M. The U.N. Decade on Ecosystem Restoration (2021–2030): what can protected areas contribute?. Parks. 2020;26(26):111-7.
2. UNEP-FAO. The U.N. decade on ecosystem restoration 2021–2030 [Internet]. 2021 [cited 2023 Jul 18]. Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/30919/UNDecade.pdf.
3. Azubuike C. 88 forest, grazing reserves facing threat of encroachment – Gombe. Punch Newspaper. 2021 Jun 21 [cited 2023 Jul 18]. Available from: https://punchng.com/88-forest-grazing-reserves-facing-threat-of-encroachment-gombe/
4. Garg SK, Garg R, Garg R. Ecology and Environmental Studies. Khanna Publisher.
5. Ahmed YA, Aliyu I. Climate Change Induced challenges on deforestation: the needs to educe mitigation measures in Nigeria. Analele Universităţii din Oradea, Seria Geografie. 2019;29(2):64-76.
6. Ladan SI. Forests and forest reserves as security threats in northern Nigeria. Eur Sci J. 2014 Dec 1;10(35).

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https://doi.org/10.54987/bessm.v7i2.908

7. Nagendra H, Lucas R, Honrado JP, Jongman RH, Tarantino C, Adamo M, Mairota P. Remote sensing for conservation monitoring: Assessing protected areas, habitat extent, habitat condition, species diversity, and threats. Ecol Ind. 2013 Oct 1;33:45-59.
8. Cavender-Bares J, Schneider FD, Santos MJ, Armstrong A, Carnaval A, Dahlin KM, et al. Integrating remote sensing with ecology and evolution to advance biodiversity conservation. Nat Ecol Evol. 2022 May;6(5):506-19.
9. Mayomi I, Wanah B, Mbaya L. Geospatial techniques for terrain analysis of Gombe State, Nigeria. J Geogr Environ Earth Sci Int. 2016 Jan 10;6(1):1-20.
10. Abba HM, Yuguda UA, Yila CN, Zhigila AD. Woody Species Composition and Diversity of Wawa-Zange Forest, Gombe State, Nigeria. Asian J Plant Biol. 2022 Jul 31;4(1):30-5.
11. Abba HM, Timothy H. Assessment of Herbaceous Species Diversity in Lede and Galumji, Wawa-Zange Forest Reserve, Gombe State, Nigeria. Am J Plant Sci. 2021 Nov 4;12(11):1741-53.
12. Abbas AM, Jimme MA. Land Vegetation Cover Changes in and Around Some Gazeeted Forest Reserves of Gombe State, Nigeria and Implications: 1996.
13. Pettorelli N, Vik JO, Mysterud A, Gaillard JM, Tucker CJ, Stenseth NC. Using the satellite-derived NDVI to assess ecological responses to environmental change. Trends Ecol Evol. 2005 Sep 1;20(9):503-10.
14. Zhao A, Zhang A, Liu X, Cao S. Spatiotemporal changes of normalized difference vegetation index (NDVI) and response to climate extremes and ecological restoration in the Loess Plateau, China. Theor Appl Climatol. 2018 Apr;132:555-67.
15. Huang S, Tang L, Hupy JP, Wang Y, Shao G. A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. J For Res. 2021 Feb;32(1):1-6.
16. Chen J, Yan F, Lu Q. Spatiotemporal variation of vegetation on the Qinghai–Tibet Plateau and the influence of climatic factors and human activities on vegetation trend (2000–2019). Remote Sens. 2020 Sep 25;12(19):3150.
17. Tran TV, Tran DX, Nguyen H, Latorre-Carmona P, Myint SW. Characterising spatiotemporal vegetation variations using LANDSAT time-series and Hurst exponent index in the Mekong River Delta. Land Degrad Dev. 2021 Aug 15;32(13):3507-23.
18. Bello MA, Roslan AH. Has poverty reduced in Nigeria 20 years after?. Eur J Soc Sci. 2010;15(1):7-17.
19. International Organization for Migration (I.O.M.). Displacement Tracking Matrix /D.T.M.: Round II Report. Geneva: I.O.M.; 2015.
20. Raji S, Adekayaoja FA, Agaku EA, Akujobi J, Hamzat AA. North-eastern Nigeria: assessing the response capacity of National Emergency Management Agency to the plights of internally displaced persons. Heliyon. 2021 Jun 1;7(6).
21. Ekoh LA, Nnamani DO, Okafor JC. Rehabilitation of Internally Displaced Persons in North East, Nigeria: Challenges and Prospects. Socialscientia. 2022 Sep 4;7(2).
22. Tiffen M, Mortimore M. Questioning desertification in dryland sub–Saharan Africa. Nat Resour Forum. 2002 Aug;26(3):218-33.
23. Blay D, Bonkoungou E, Chamshama SA, Chikamai B, Wood P, Yapi AM. Rehabilitation of degraded lands in sub-Saharan Africa: lessons learned from selected case studies. Forestry Research Network for Sub-Saharan Africa (Fornessa), International Union of Forest Research Organizations; 2004.
24. Adewuyi TO, Ezeamaka CK. Ecological Disasters, Climate Change, and Rural Violence in Nigeria. In: Rural Violence in Contemporary Nigeria. 2023 Apr 14. p. 87-108.
25. Akbari M, Shalamzari MJ, Memarian H, Gholami A. Monitoring desertification processes using ecological indicators and providing management programs in arid regions of Iran. Ecol Indic. 2020 Apr 1;111:106011.
26. Nwilo PC, Olayinka DN, Okolie CJ, Emmanuel EI, Orji MJ, Daramola OE. Impacts of land cover changes on desertification in northern Nigeria and implications on the Lake Chad Basin. J Arid Environ. 2020 Oct 1;181:104190.
27. Naibbi A, Baily B, Healey RG, Collier P. Changing vegetation patterns in Yobe State Nigeria: An analysis of the rates of change, potential causes and the implications for sustainable resource management. Int J Geosci. 2014 Jan;5:50-62.
28. Macaulay BM. Land degradation in Northern Nigeria: The impacts and implications of human-related and climatic factors. Afr J Environ Sci Technol. 2014 Dec 2;8(5):267-73.
29. Medugu NI, Majid MR, Johar F. The Consequences of Drought and Desertification in Nigeria. I.U.P. J Environ Sci. 2009 Aug 1;3(3).
30. Umar I, Mustafa HF, Zaroug MS, Abdullahi MB, Babangida H. Evaluation of Management Approaches of Selected Protected Area Types in Dry Region of North-East Nigeria. World J Innov Res. 2018 Dec;11-22.

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