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Assessment of land cover changes and endangered tree species in Rurum ward of Rano Local Government Area of Kano State

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ABSTRACT

The study assessed land cover changes and endangered tree species in Rurum Ward of Rano Local Government Area, Kano State, using Landsat imageries from 1992, 2002, 2012, and 2022. A geospatial approach, complemented by semi-structured questionnaire and key informant interviews, identified the main drivers of land cover change and endangered tree species. Two wards, Rurum Sabon Gari and Rurum Tsohon Gari, were purposively sampled, with 80 respondents randomly selected. The GIS-based analysis categorized land cover changes into Built-up Areas, Vegetation/Forest Cover, Agricultural Land, Water Body, and Bare Surface. Over 30 years (1992-2022), Forest Cover decreased by 22.82%, while Agricultural Land, Settlement, Water Body, and Bare Surface increased by 12.33%, 5.58%, 2.94%, and 1.97%, respectively. Results from the interview showed that 66.2% of respondents were aware of land cover change dynamics, confirming the geospatial findings. The primary drivers of these changes were fuel wood exploitation (48.11%) and agricultural land expansion (26%), with poverty (67.5%) and population growth/settlement expansion (16.9%) as underlying causes. Key informant interviews identified the most endangered tree species *as Khaya senegalensis*, *Afzelia africana*, *Vitellaria paradoxa*, *Faidherbia albida*, *Ficus polita*, *Syzygium guineensis*, and *Vitex doniana*. The study concluded that fuel wood exploitation is the main contributor (48.1%) to land cover changes, driven primarily by poverty (67.5%). It recommends restoring threatened and endangered tree species, enhancing poverty-eradication programs, and promoting renewable energy sources in rural areas to reduce reliance on wood fuel.

Keywords: Fuelwood exploitation; endangered trees; poverty; geospatial analysis

INTRODUCTION

Forests cover around 20% of our planet, and their presence is intricately connected to nearly every aspect of human life. They are crucial for maintaining the earth's energy balance

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and are a fundamental part of our ecosystem (FAO, 1997). Trees are essential land resources that require careful management and sustainable use for the benefit of present and future generations, making vegetation protection a critical global issue. Vegetation provides basic needs such as food, fuel, wood, herbs, land conservation, and soil fertility, playing a vital role in human development (Oboho, 2014). Forests maintain environmental and ecological balance by preventing unwanted climate change and maintaining equilibrium among humans, animals, and other abiotic components (De Frenne *et al*., 2021).

Tropical forests are declining at alarming rates, losing 1-4% of their area annually (Pearce and Brown, 2023). This decline is largely due to increased human activities such as agricultural expansion, firewood demand, overgrazing, and illegal logging, driven by growing populations near forests. The loss of forests threatens the livelihoods of people who depend on them for socio-cultural, ecological, and economic services and affects forest composition, structure, regeneration capacity, and biodiversity (Kacholi, 2019).

The economic activities of many rural people are closely linked to deforestation and forest degradation. Population growth near forest areas increases pressure on forest resources due to higher land demands for agriculture. Poverty drives local communities near forest reserves to engage in unsustainable farming practices, including uncontrolled burning, forest clearance, and shifting cultivation, all contributing to deforestation and degradation of forest resources (Kacholi, 2019).

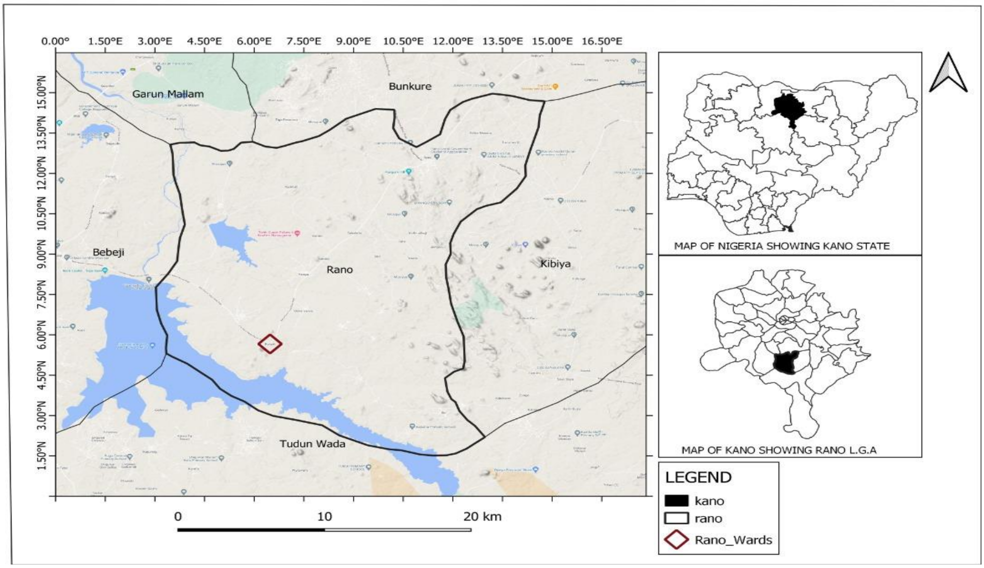
In Nigeria, approximately 400,000 hectares of vegetation are lost annually, with much of the forest cover being deliberately cleared for mineral exploitation, infrastructure development, and reliance on fuelwood for domestic energy, especially among low-income households (Wada *et al.*, 2019). Between 2002 and 2020, Nigeria lost 141,000 hectares of humid primary forest, accounting for 14% of the country's total tree cover loss during this period, resulting in a 7.4% reduction in the total area of humid primary forest (Ojeh, Yusha'u, and Usman, 2022; Ibrahim *et al.*, 2022; Shamaki, 2022). From 2001 to 2019, 14% of tree cover loss occurred in areas where deforestation was the primary driver. Edo state experienced the most significant loss, with 268,000 hectares, followed by Ondo (107,000 hectares), Cross River (102,000 hectares), Taraba (91,100 hectares), and Ogun (82,000 hectares), collectively responsible for 54% of all tree cover loss between 2001 and 2020 (Global Forest Watch, 2020). From 2001 to 2012, Nigeria gained 60,300 hectares of tree cover, less than 0.1% of the global total. In 2010, Taraba had 1.64 million hectares of tree cover, covering 27% of its land area, but by 2020, it had lost 7,820 hectares, resulting in 2.39 million tonnes of CO2 emissions. In 2021, 4.0 million hectares of land were burned in Nigeria (Global Forest Watch, 2020).

Despite ongoing research on land cover patterns, there is a pressing need for comprehensive datasets with quantitative and spatial land cover information. Natural vegetation is increasingly scarce, with forest loss accelerating due to subsistence agriculture and shifting cultivation. Both natural forests and forest reserves are threatened by land-use changes (Tudunwada, 2012). This highlights the global need for studies on land cover change to aid planners and resource managers (Olokeogun, *et al*., 2014). A substantial lack of information affects national decision-making and planning. This research seeks to map, identify, and measure land cover changes and endangered tree species in Rurum, Rano LGA, Kano State, Nigeria, employing remote sensing, GIS technologies, and research questionnaires. It seeks to determine the major causes of these changes, assess the impacts of land cover dynamics, and explore effective strategies for sustainable forest management.

MATERIALS AND METHODS

Study Area

Rurum town is located within the Rano Local Government Area of Kano State. It lies between latitudes 11° 26' N and longitudes 8° 30' E, situated in the southern part of Kano State, approximately 73 km by road from Kano city. According to the 2006 National Census, Rurum has a population of 40,574. The inhabitants are primarily Hausa-Fulani, speaking Hausa and predominantly practicing Islam. The soil in the area is deep, well-drained, and lacks coarse material layers, with subsoil textures typically being clay loam. The vegetation falls under the northern Guinea savanna, consisting mostly of trees and shrubs with remnants of savanna woodland (Adenle and Ifejika, 2020). The trees usually have broad canopies and are generally less than 20 meters tall, *with Parkia biglobosa*, *Adansonia digitata*, and *Hyphaene thebaica* being exceptions. Common tree species include different Acacia species (*Albida*, *Molotica, and Seyal), Ficus polita*, *Vitellaria paradoxa*, *Eucalyptus camaldulensis, Azadirachta indica*, *Khaya senegalensis*, *and Ceiba pentandra*. These trees are mostly drought and fire-resistant, providing shade and nesting sites for animals. Grasses grow during the wet season, rarely exceeding 1.5 meters in height, and dry off during the dry season. The mean annual rainfall ranges from over 1000mm in the extreme south to just under 800mm in the extreme north, lasting for three to five months. The mean annual temperature ranges from 26°C to 33°C, with Rano's mean annual temperature ranging from 24.4°C to 28.7°C (KNARDA, 2019). The area experiences four seasons: a dry and cool season (Kaka) from mid-November to February, a dry and hot season (Bazara) between the Harmattan and wet seasons, a wet and warm season (Damina) from mid-May to September, and a dry and warm season from October to mid-November.



Source: GIS lab, Centre for Dryland Agriculture (BUK)

Fig 1: Map of Rano Local Government showing the study area

The main economic activities of Rurum settlers are farming, fishing, and trading. They exploit much of fuelwood during the dry season and also cultivate crops like millet, sorghum, and rice. Some of the wood exploited is being processed in a local sawmill while others are used as a source of fuel. A significant amount of the fuelwood and crops are sold to the neighboring settlements, where from the wood exploited and the crops cultivated, they make their living. Farm ownership is usually through inheritance given to some members of a family. Some family members sell out farms to people due to their large size, need for capital, or their inability to entirely cultivate the land (Reconnaissance survey, 2022).

Data Collection Processes and Sources

Data were collected through primary sources (through administration of questionnaire, interviews, field observations, and pictures) and secondary sources including remotely sensed data from Landsat imageries, reputable journals, articles, books, and the internet). It involves both formal and informal interactions with locals who are knowledgeable about the research study; both quantitative and qualitative data were collected. Four Landsat imageries (path 188, row 52) acquired in 1992 ETM+ (Enhanced Thematic Mapper Plus), 2002 ETM+, 2012 ETM+, and 2022 Landsat 8 were used in the study to obtain land cover over the study area over 30 years (Table 1).

Table 1: Characteristics of the Landsat imageries and the date of acquisition

Imageries for the study	Path/Row	Resolution	Date of acquisition
Landsat 7 ETM+	188/052	30m	1992-01-07
Landsat 7 ETM+	188/052	30m	2002-02-22
Landsat 7 ETM+	188/052	30m	2012-01-16
Landsat 8	188/052	30m	20022-01-12

Image Sub-Setting

The Satellite imageries were imported into ArcGIS 10 environment. A subset covering the area of interest was extracted from the larger scene of Landsat OLI and Landsat ETM+. The image bands were layer-stacked to produce a color composite. Since the remotely sensed data used for this study is ortho-rectified, there was no need for geometric and radiometric corrections to be performed on them. However, the data sets were geo-coded (geo-referencing) and GIS software (Arc GIS 10.1) was used for analyzing images as well as other geographic data acquired for this research.

Image Geo-Referencing

The Landsat ETM+ with a 30-meter spatial resolution and Landsat 8 (OLI) with a 30-meter spatial resolution were imported into the ArcGIS 10 environment. There, they were rectified to a common projection, the Universal Transverse Mercator (UTM). This process translates the images to real-world coordinates. Geo-referencing involves registering data to a geographic coordinate system by assigning geographic information, such as location and position, to the datasets (images). This allows the researcher to define the existence of these datasets in physical space and establish their location in the real world.

Image Classification

A supervised classification technique was performed using a maximum likelihood algorithm to classify the images into various classes (themes). This method is preferable due to its high level of accuracy and reliability in handling spatial data. This technique gives room to the researcher to generate training classes based on the land use/land cover themes present in the area. This helps in curtailing ambiguity that is associated with the unsupervised techniques in image classification (Richards, and Richards, 2022; Asokan *et al.*, 2020). With these techniques, sample sites (training pixels) were selected based on spectral signatures of the features on the images. The known land cover types (training sites) were coded with the names of the corresponding thematic features. Based on Jensen's (2005), land use/cover classification scheme, the various land use land cover types within the area will be classified into five (5) viz: vegetation, bare surface, settlement, agricultural/farmland, and water bodies.

Questionnaire Sampling Technique, Data Collection and Analysis

For the questionnaire survey, 80 copies were distributed to assess land cover change, its impacts, and the driving forces. A simple random sampling technique was used for administering the questionnaire. The two wards in the study area, Rurum Sabon Gari and Rurum Tsohon Gari, were purposively sampled, with 45 questionnaires distributed in Rurum Sabon Gari and 35 in Rurum Tsohon Gari.

The collected data were both qualitative and quantitative, including interviews to gather information on the respondents' demographic and socio-economic aspects, their views on the extent of land cover changes, the factors driving these changes, the impacts of land cover change dynamics, and effective strategies for sustainable forest management in the study area. Descriptive statistics were used to analyze the data, employing simple percentages, maps, tables, and bar charts

RESULTS AND DISCUSSION

Extent of Land Cover Changes in Rurum, Rano LGA.

The land-use/land-cover classes of Rurum in 1992, 2002, 2012, and 2022 were characterized into five prominent classes which include: settlement, agricultural land, vegetation, bare land, and water bodies. The area and percentage coverage are depicted in Table 2.

Table 2 presents the various land cover types and their respective proportions of the total area. The analysis of 1992 Landsat ETM+ imagery (Fig 2) shows that vegetation occupied the largest portion, covering 60.64% of the area, followed by agricultural land at 22.89%, while water bodies, bare surfaces, and settlements accounted for 11.47%, 3.11%, and 1.88%, respectively.

Table 2: Extent and proportion of land cover

Land cover type	1992 Area (Ha)	Area (%)	2002 Area (Ha)	Area (%)	2012 Area (Ha)	Area (%)	2022 Area (Ha)	Area (%)	Change (Ha)	Change (%)
Agric land	1819.63	22.89	2037.33	25.63	2616.51	32.92	2799.41	35.22	979.78	12.33
Settlement	149.37	1.88	249.16	3.13	398.73	5.02	592.86	7.46	443.48	5.58
Vegetation /Forest Cover	4819.38	60.64	3992.52	50.23	3537.91	44.51	3005.57	37.81	-1813.81	-22.82
Bare surface	247.54	3.11	506.23	6.37	489.84	6.16	404.17	5.09	156.63	1.97
Waterbody	911.97	11.47	1162.65	14.63	904.9	11.39	1145.88	14.42	233.91	2.94
Total	7947.89	100	7947.89	100	7947.89	100	7947.89	100		

Source: Author's Analysis, 2023.

In the 2002 Landsat ETM+ image classification (Fig 2), vegetation remained the predominant land cover but decreased to 50.23%. Agricultural land, water bodies, bare surfaces, and settlements increased to 25.63%, 14.63%, 6.37%, and 3.13%, respectively.

The 2012 Landsat ETM+ results (Fig 3) showed a further decline in vegetation to 44.51%, while agricultural land rose to 32.92%. Bare surfaces and settlements increased to 6.16% and 5.02%, and water bodies decreased slightly to 11.39%.

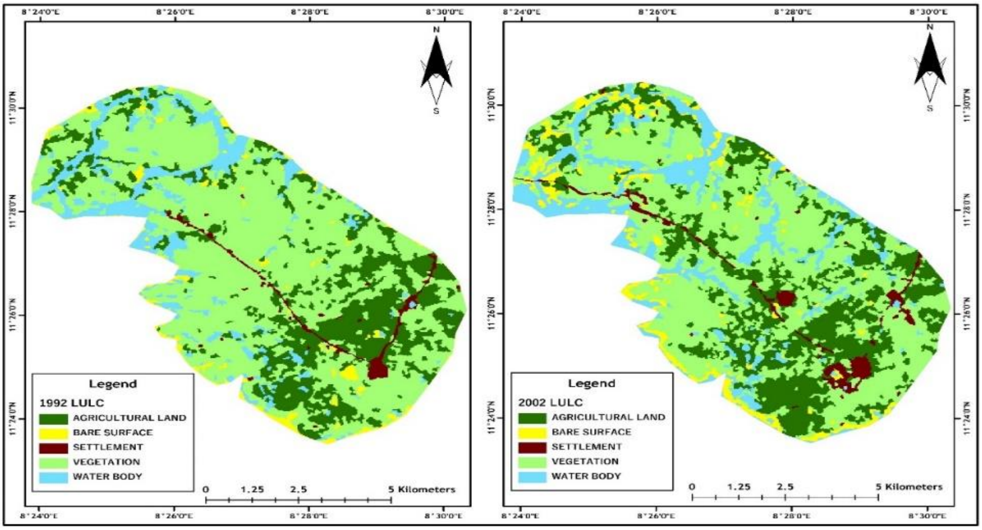


Figure 2: Land cover of the Study Area 1992 and 2002 respectively

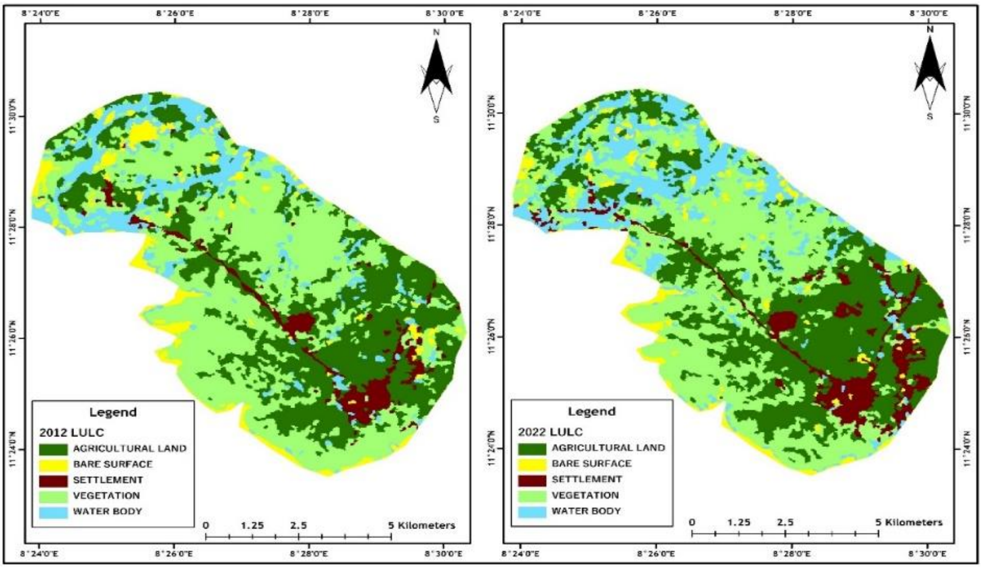


Figure 3: Land cover of the Study Area 2012 and 2022 respectively.

The 2022 Landsat OLI analysis (Fig 3) indicated a continued decrease in vegetation to 37.81% and agricultural land slightly decreased to 32.22%. Water bodies and settlements increased to 14.42% and 7.46%, respectively, while bare surfaces declined to 5.09%.

These results demonstrate the effectiveness of remote sensing and geographical information systems (GIS) in measuring and analyzing landscape changes over time, consistent with previous studies (Quan *et al*., 2013; Ayele *et al*., 2018; Chen, 2002; Amna *et al*., 2015; Sekela and Manfred, 2019; Erasu, 2017). The land-cover maps for the four study years, showing the five land-cover classes, are depicted in Figures 2 and 3.

This result correlates with the view of Lieberman and Amaya-Jackson (2005) that deforestation is largely due to clearance of Forest land for Agriculture and other human activities (Aderele, Bola, and Oke, 2020). The clearance of the forest each year is due to the quest of the rural dwellers for more agricultural lands (Kirkpatrick, 2024). The common farming practice, which is a fallow system, entails that farmers abandon a piece of land for some years to recover. While they allow the land to fallow, they seek new fertile land and the alternative place to go is the forest. Other reasons could be attributed to the high rise in poverty level and population size. All these leave the people with no alternative but to seek more forest land to satisfy their need for more farmland.

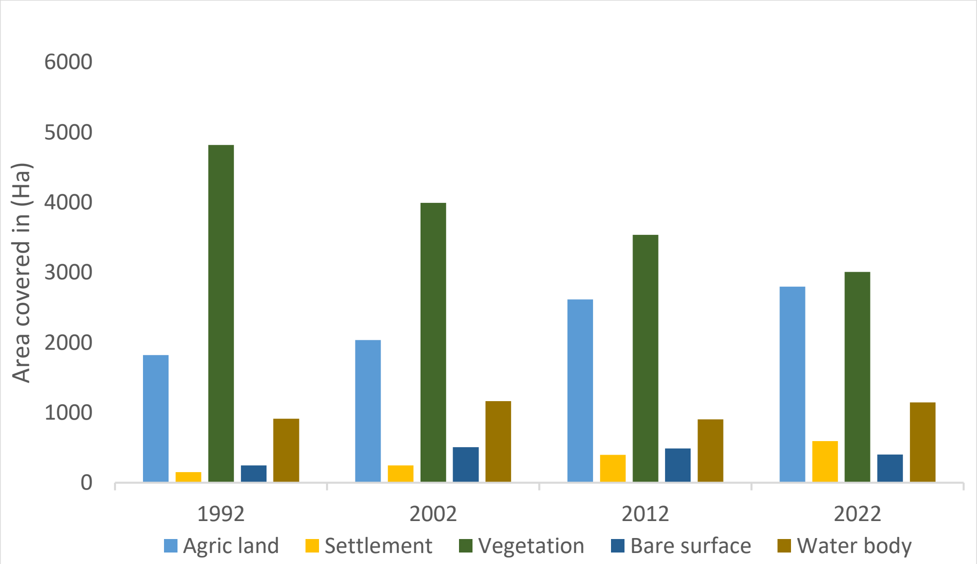


Figure 4: Land cover types and area extent from 1992 to 2022 (Ha)

The study area has witnessed deforestation, this is reflected in the reduction of the area occupied by natural vegetation from 4819.38 ha in 1992 to 3005.57 ha in 2022, and this is largely due to an increase in farming practices and population. The harvesting of forest products by the occupants resulted in a significant loss of forest area and an increase in settlements and farmland. Other factors contributing to the damage of natural forests include the encroachment of new settlements and infrastructure development in the area.

Spatial extents in settlement and non-vegetated areas show an overall obvious increase in settlements. Changes in this land use type depict higher changes from plantation, natural forest. Most of the emerging towns portray an increase in settlement area signifying an increment in population. The high population growth has translated into rapidly increasing demands for land in terms of food, shelter, energy (in particular, fuelwood), and construction materials. Conversely, settlement and non-vegetated area expansion is primarily due to population increase during the period.

Main Drivers of Land Cover Change

Table 3 presents the proximate factors causing land cover change in Rurum. Fuelwood exploitation contributed the highest 48.1% to the main causes of land cover changes in the study area, these activities were usually undertaken in the forest areas, which can result in a situation where repeated wood collections are undertaken on the same site beyond what the forest can recover from. The heavy dependence on fuelwood indicates that the demand for these resources will be higher in the future, with an increase in population entailing cutting down more trees. Agricultural land expansion is the second highest 26% to the main causes of land cover changes in the study area which resulted in the conversion of Forested land into Agricultural land. Although Charcoal production contributed the least (3.9%) to the cause of land cover changes in the area, the findings of the study reveal that most of the activities are human-related. Thus, deforestation in Rurum is caused by man.

Table 3: Proximate Perceived factors causing land cover change in the study area

Description	Responses	Percent
Fuelwood exploitation	37	48.1
Tree lumbering and logging	10	13
Charcoal production	3	3.9
Population growth/settlement expansion	7	9.1
Agricultural land expansion	20	26
Total	77	100

The major perceived underlying causes of land cover change in the study area are poverty followed by settlement expansion which both accounted for 84.4% cumulatively, while Demand for timber, government policies, and Lack of law enforcement account for the least 6.5%, 6.5%, and 2.6% respectively (Table 4). Poverty exacerbates inadequate access to clean and affordable energy sources in Rurum ward, impoverished households depend heavily on fuelwood for cooking and heating. This practice results in the continuous clearing of forests and woodlands, contributing to significant land cover changes. Informal settlements arising from poverty are often unplanned, and encroach on forests and other natural areas, resulting in chaotic land use patterns and unplanned land cover changes.

Table 4: Perceived underlying causes of land cover change in Rurum

Description	Responses	Percentage
Poverty	52	67.5
Settlement expansion	13	16.9
Demand for timber	5	6.5
Government policies	5	6.5
Lack of law enforcement	2	2.6
Total	77	100

The Rate of Deforestation in Rurum, Rano LGA

Respondents expressed their opinion on the rate of deforestation in the study area. 66.2% of the respondents believed that there is a high rate of deforestation, and 33.8% of respondents believed that it was moderate. It can be inferred that 100% of the respondents are aware of the moderate and high rate of deforestation in the study area and are also concerned about it. It is important to note that: High rates mean 200 trees, or more are being cut annually, moderate; less than 200 but more than 100 trees are being cut annually. This has further made Rurum susceptible to the extreme events of windstorms and erosion, which reduces the soil fertility in the study area.

The respondents in Rurum correctly perceived that the built-up areas and agricultural land had increased over the past years with a corresponding decrease in Forest Cover/vegetation. Also, as observed during field visits, there is an indication of increased demand for the conversion of Forest Cover into agricultural land and built-up areas. The older respondents (above 45 years) gave an accurate historical narrative of the land cover changes in the study area, which corroborated the results of the findings from the analysis of the land-use changes from remote sensing data of the period 1992 - 2022. Similar findings by other researchers show that land cover change occurs in a similar setting. For example, woodlands declined by 88.5 percent as urban areas increased by 143 percent between 1984 and 2013 in the Linkangala River catchment in Malawi (Pullanikkatil *et al.*, 2016).

However, according to one of the community heads:

"Some decades ago, there were few farmlands and houses in this area, but now there are more houses and agricultural land that you hardly count, most of which were forested areas before, but were now turned into farmlands, bare surface, and built-up areas"

Impacts of Land Cover Change

Data on the impacts of land cover change was captured using quantitative and qualitative data collection methods. Before filling in the questionnaire, it was gathered from the local communities that the high rate of felling down of trees in the area exacerbates the impacts, and the increasing rate of using firewood in the areas compounds the impacts. Tables 5 and 6 show the mean interpretation rate and responses of the local people on the effects of felling down trees in the area.

Table 5: Mean interpretation rate

	Mean Range	Response Mode	Interpretation
4	3.26-4.00	Strongly Agree	Very High
3	2.51-3.25	Agree	High
2	1.76-2.50	Disagree	Low
1	1.00-1.75	Strongly Disagree	Very Low

Table 6: Responses on the impacts of land cover change in the study area

Impacts of land cover change	4	3	2	1	Mean	SD	Remark
Forest resource scarcity increases conflicts among communities	7(9.1)	22(28.6)	32(41.6)	16(20.8)	2.26	0.894	Low
felling down of trees causes food shortages	6(7.8)	24(31.2)	39(50.6)	8(10.4)	2.36	0.776	Low
Fuel wood extraction leads to a decrease in tree population	49(63.6)	28(36.4)	0(0.00)	0(0.00)	3.64	0.484	V. high
Felling down of trees causes windstorms and soil erosion	28(36.4)	39(50.6)	9(11.7)	1(1.13)	3.22	0.700	High
Felling down of trees can affect the grazing of animals	17(22.1)	32(41.6)	24(31.2)	4(5.2)	2.81	0.844	High
Felling down of trees leads to the loss of some tree species	55(71.4)	21(27.3)	1(1.3)	0(0.00)	3.70	0.488	V. high
The felling of trees affects soil fertility.	31(40.3)	31(40.3)	15(19.5)	0(0.00)	3.21	0.749	High
Destruction of wildlife habitat	39(50.6)	33(42.9)	5(6.5)	0(0.00)	3.44	0.618	V. high
Overall average	29(37)	28.7(37.3)	15(20.3)	3.6(4.69)	3.08	0.694	

Table 7: Results on effective strategies to curtail the act of felling down of trees

Effective strategies	4	3	2	1	Mean	SD	Remark
Provision of other sources of affordable, available fuel can reduce the felling down of trees	52(67.5)	21(27.3)	4(5.2)	0(0.00)	3.62	0.586	Very high
Reforestation and afforestation projects improve control measures	29(37.7)	44(57.1)	4(5.2)	0(0.00)	3.32	0.572	Very high
Promoting the Agroforestry technique can accelerate the planting of trees	28(36.4)	34(44.2)	13(16.9)	2(2.6)	3.14	0.790	High
Introduction of Community-Based Forestry can decelerate deforestation	23(29.9)	40(51.9)	14(18.2)	0(0.00)	3.12	0.688	High
Provision of sustainable job opportunities for firewood sellers	54(70.1)	21(27.3)	0(0.00)	2(2.6)	3.65	0.623	Very high
Enforcement of laws can help to reduce the rate of felling down of trees	35(45.5)	34(44.2)	7(9.1)	1(1.3)	3.34	0.700	Very high
Overall Average	36(47.9)	32.3(42)	7(9.1)	0.8(1.1)	3.36	0.659	

According to Figure 5, all the respondents 100%, agreed that the biggest evidence of the effect of felling down of trees is seen in the decrease in tree population in the area followed by loss of various biodiversity in the area 98.7%, Destruction of wildlife habitat 93.5%, windstorm and soil erosion 87%, effect on soil fertility 80.6%. and impacts in the form of animal grazing 63.7%. Similarly, the local people agreed that many tree species are cut down in the area and the rate is ever-increasing.

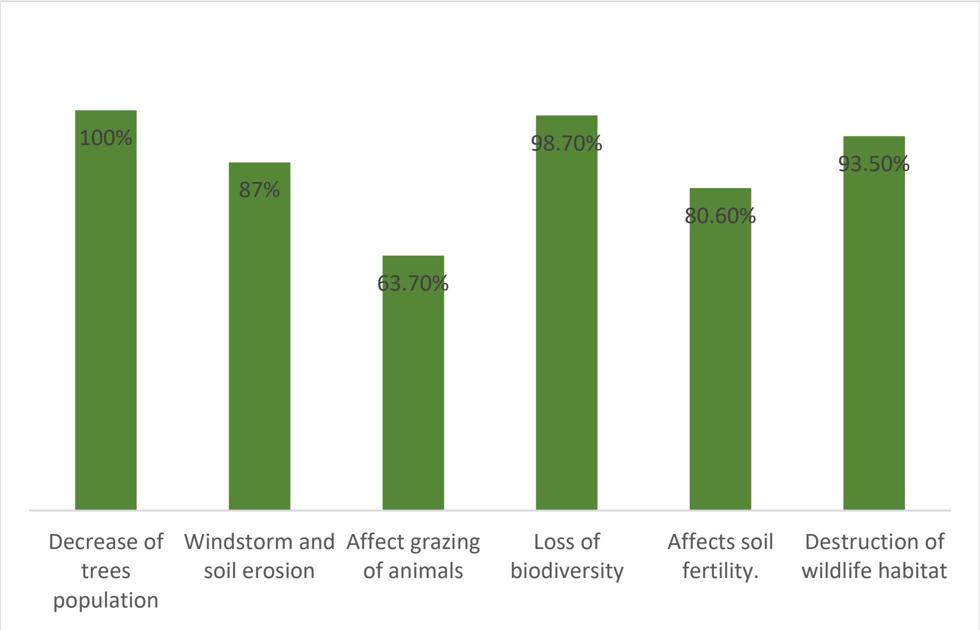


Fig 5: Shows the different forms of impacts of land cover changes

Effective Strategies to Curtail the Act of Felling Down of Trees

Accordingly, data were also collected on the effective strategies to curtail the act of felling down trees in the study area. The responses to this by the local people are indicated in Table 7.

Figure 6 presents the respondents' responses on the possible measures that can be employed to mitigate deforestation to avoid its impacts on forest degradation and the local communities as a whole. From the data obtained, 94.8% and 89.7% of the respondents did agree that embarking on sustainable reforestation and afforestation activities such as tree planting and enforcement of laws on deforestation can go a long way as effective mitigation measures against deforestation in the area, whereas 97.4%, 80.6%, 81.8%, and 94.8% of the respondents stated that provision of more job opportunities, Promoting Agroforestry technique, introducing community-based forestry as well as provision of readily available and cheap sources of fuel to the rural people are also potential mitigation measures if properly applied.

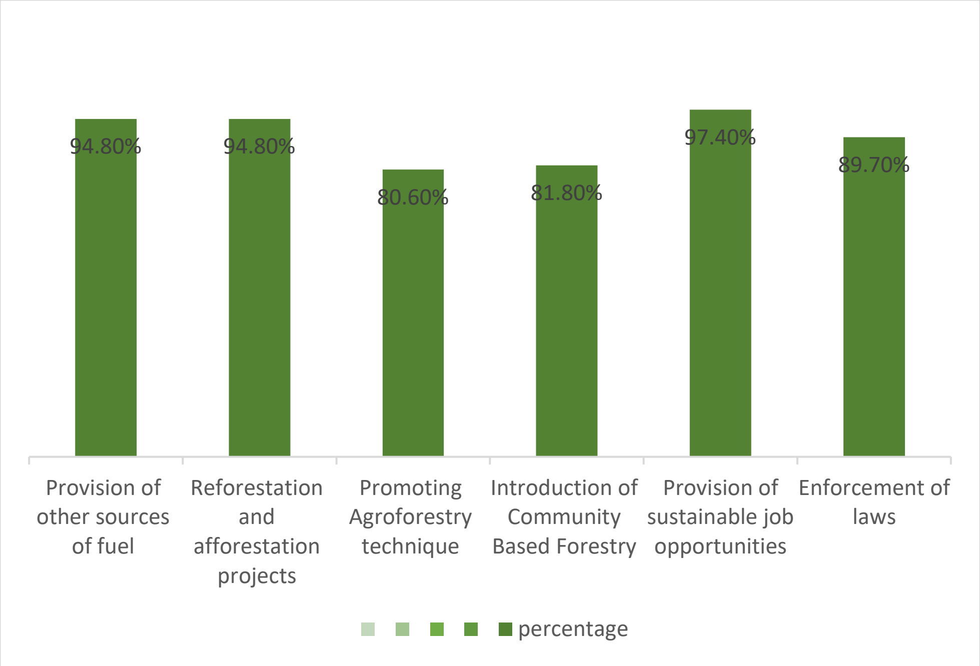


Fig 6: Shows the mitigation measures of deforestation

CONCLUSION

This study examined land cover changes and endangered tree species in Rurum of Rano LGA in Kano state using remote sensing, Geographic Information System (GIS) techniques, questionnaires, and interviews. The findings indicate that human activities have significantly impacted land cover, leading to settlement expansion, agricultural land, bare surfaces, and water bodies alongside a rapid decline in forest cover that led to some species being endangered. The primary drivers of these changes are fuelwood exploitation, agricultural land expansion, logging, poverty, and population growth. The study also reveals that the local population is aware of the significant land cover changes and their negative impacts but lacks the resources to address them effectively.

Based on the findings of the study, it is recommended that states and local government authorities should fund research into alternative energy sources like solar power and promote the sustainable use of natural resources. Efforts should be intensified on poverty-eradication programs and creating employment opportunities through skills acquisition programs, particularly targeting rural women and youths, to reduce deforestation rates. Public education on the harmful effects of deforestation and climate change should be disseminated through various media, and acceptance of alternative energy sources should be encouraged. The study also recommends conducting further research to predict future scenarios, enforcing regulations on firewood collection, imposing strict penalties, and limiting overgrazing that damages vegetation.

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REFERENCES

Adenle, A.A. and Ifejika Speranza, C. (2020). Social-ecological archetypes of land degradation in the Nigerian Guinea Savannah: Insights for sustainable land management. *Remote Sensing*, *13*(1), 32.

Aderele, M.O., Bola, T.S. & Oke, D.O. (2020). Land use/land cover changes of Ago-own Forest Reserve, Osun state, Nigeria using remote sensing techniques. *Open Journal of Forestry*, *10*(4), 401-411.

Amna, B., Rabia, S., Sheikh, S. A. & Neelam, A. (2015). Land use change mapping and analysis using remote sensing and GIS: A case study of Simly Watershed, Islamabad, Pakistan. *The Egyptian Journal of Remote Sensing and Space Sciences*, 18(2), 251-259. https://doi.org/10.1016/j.ejrs.2015.07.003

Asokan, A., Anitha, J., Ciobanu, M., Gabor, A., Naaji, A. & Hemanth, D.J. (2020). Image processing techniques for analysis of satellite images for historical maps classification—An overview. *Applied Sciences*, *10*(12), 4207.

Ayele, G.T., Tebeje, A.K., Demissie, S.S., Belete, M.A., Jemberrie, M.A., Teshome, W.M., ... & Teshale, E.Z. (2018). Time series land cover mapping and change detection analysis using geographic information system and remote sensing, Northern Ethiopia. *Air, Soil and Water Research*, *11*.

Chen, X. (2002). Using remote sensing and GIS to analyze land cover change and its impacts on regional sustainable development. *International Journal of Remote Sensing*, 23, 107-124. https://doi.org/10.1080/01431160010007051

De Frenne, P., Lenoir, J., Luoto, M., Scheffers, B. R., Zellweger, F., Aalto, J., ... & Hylander, K. (2021). Forest microclimates and climate change: Importance, drivers and future research agenda. *Global Change Biology*, *27*(11), 2279-2297.

Erasu, D. (2017). Remote sensing-based urban land use/land cover change detection and monitoring. *Journal of Remote Sensing & GIS*, *6*(2), 5.

FAO (1997). State of the World's Forests. Food and Agricultural Organization Forestry Department, Words and Publications Eds, Oxford, UK.

Global Forest Watch (2020). *Nigeria-Taraba. Available online from https://www.globalforestwatch.org/dashboards/country/NGA/?lang=en*

Ibrahim, E.S., Ahmed, B., Arodudo, O.T., Abubakar, J.B., Dang, B.A., Mahmoud, M.I., Shaba, H.A., Shamaki, S.B. (2022). Desertification in the Sahel region: A product of climate change or human activities? A case study of desert encroachment monitoring in North-eastern Nigeria using remote sensing techniques. *Geographies*, 2(2): 204-226.

Jensen, J.R. (2005). *Introductory Digital Image Processing: A Remote Sensing Perspective.* New Jersey:

Kacholi, D.S. (2019). Assessment of tree species richness, diversity, population structure and natural regeneration in Nongeni Forest Reserve in Morogoro region, Tanzania. *Tanzania Journal of Science*, 45(3):330-345.

Kirkpatrick, J. (2024). A Big History of Land Clearance and Deforestation. *Journal of Big History*, *7*(3), 1-18

KNARDA (2019). Annual report. Monitoring and Evaluation Department, Kano. Kano State Government

Oboho, E.G. (2014). *Silviculture for Beginners*. UNIBENPRESS. University of Benin, Ekehuan campus, Benin City 263pp.

Ojeh, V.N., Yusha'u, A.M. & Usman, D.S. (2022). Assessment of changes in land cover by deforestation in Kurmi LGA, Taraba State, Nigeria using remote sensing/geographic information system. *Aswan University Journal of Environmental Studies*, *3*(1), 67-87.

Olokeogun, O.S. Iyiola, O.F. Iyiola,K.(2014) Application of Remote Sensing and GIS in Land Use/Land Cover Mapping and Change Detection in Shasha Forest Reserve, Nigeria. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8, 2014 ISPRS Technical Commission VIII Symposium, 09 – 12 December 2014, Hyderabad, India. Accessed on27-07-2021 from *https://www.researchgate.net/publication*

Pearce, D. and Brown, K. (2023). Saving the world's tropical forests. *In*: *The causes of tropical deforestation* (pp. 2-26). Routledge. Prentice-Hall. Pp. 467-494.

Pullanikkatil, D., Palamuleni, L.G. & Ruhiiga, T.M. (2016). Land use/land cover change and implications for ecosystem services in the Likangala River Catchment, Malawi. *Physics and Chemistry of the Earth, Parts A/B/C*, *93*, 96-103.

Quan, B., Xiao, Z., Römkens, M., Bai, Y. & Lei, S. (2013). Spatiotemporal Urban Land Use Changes in the Changzhutan Region of Hunan Province in China. *Journal of Geographic Information System*, 5, 136-147. https://doi.org/10.4236/jgis.2013.52014

Richards, J.A. and Richards, J.A. (2022). Supervised classification techniques. *Remote Sensing Digital Image Analysis*, 263-367.

Sekela, T., and Manfred, F. B. (2019). Land-use and land-cover (LULC) change detection in Wami River Basin, Tanzania. *Land*, 8, 136.

Shamaki, S.B. (2022). Relationships between tree slenderness coefficients and stand characteristics for major plantation grown species in north-western Nigeria. *Journal of Agriculture and Environment,* 18(2): 125-134.

Tudunwada, I. Y. (2012). Vegetation Change Detection due to Anthropogenic Activities in Falgore Game Reserve, Kano State, Nigeria. *International Conference Geotunis 6th session.*

Wada, Umar A.F., Bello U. Musa, Tasiu M., Bilyaminu H., Mubarak M., Ibrahim M.I., Abubakar A., (2019), Assessment of deforestation level in some selected forest in Nigeria. A case study of Duddurun Gaya forest reserve, Department of Geography, Kano University of Science and Technology Wudil, Kano state. *A Journal of Public Health and Environmental Technology,* 4:1-7

Zhanliang, Y., Aiguo, L. and Ting, Y. (2008). Research on Date Collecting and Rapid Map Updating of Forest Resources Based On 3s Technology. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, School of Surveying and Mapping, Henan Polytechnic University, Jiaozuo, 454000, 1694-0814.