



VEGETAL COVER CHANGE AND COMMERCIAL CHARCOAL PRODUCTION IN THE SOUTHERN REGION OF NIGER STATE, NIGERIA

ZMIANA POKRYCIA ROŚLINNEGO I KOMERCYJNA PRODUKCJA WĘGLA DRZEWNEGO W POŁUDNIOWYM REGIONIE STANU NIGER W NIGERII

Jibrin Katun Mohammed*, Usman Abubakar Dzukogi
Federal Polytechnic Bida, Nigeria
Abdulafeez Adewale Olawale,
Federal University of Technology, Minna, Nigeria

Abstract

Vegetal cover change is a threat globally, a phenomenon with less attention concerning charcoal production. This study investigates vegetal cover loss and commercial charcoal production by analyzing three major charcoal depots in Niger south, Nigeria: Tatabu, Badeggi, and Batati. Utilizing a quantitative approach, primary data were collected through 663 questionnaires and secondary data via Landsat satellite imagery of 2010, 2015, and 2020 within a five-kilometer radius of the depots. Relative importance index (RII) was used to analyse primary data, while satellite imageries were processed using ArcGIS 10.8 software. Findings indicate a decrease in vegetative cover in Badeggi from 472.65 ha in 2010 to 269.92 ha in 2020. Key drivers of vegetation loss include deforestation (0.763 RII), farming (0.700 RII), and construction (0.690 RII). The region produces an average of 132 bags of charcoal weekly and ten truckloads monthly. The study emphasizes the urgent need for sustainable environmental management and alternative energy sources.

Keywords: charcoal production, deforestation, land cover change, Niger south, vegetal cover

Streszczenie

Zmiana pokrycia roślinnego stanowi globalne zagrożenie, a zjawisku temu poświęca się mniej uwagi w kontekście produkcji węgla drzewnego. Niniejsze badanie analizuje utratę pokrycia roślinnego i komercyjną produkcję węgla drzewnego, analizując trzy główne składy węgla drzewnego w południowej części stanu Niger w Nigerii: Tatabu, Badeggi i Batati. Wykorzystując podejście ilościowe, zebrano dane pierwotne za pomocą 663 kwestionariuszy oraz dane wtórne za pomocą zdjęć satelitarnych Landsat z lat 2010, 2015 i 2020 w promieniu pięciu kilometrów od składów. Do analizy danych pierwotnych wykorzystano względny wskaźnik ważności (RII), a zdjęcia satelitarne przetworzono za pomocą oprogramowania ArcGIS 10.8. Wyniki wskazują na zmniejszenie się pokrywy roślinnej w Badeggi z 472,65 ha w 2010 r. do 269,92 ha w 2020 r. Głównymi czynnikami powodującymi utratę roślinności są wylesianie (0,763 RII), rolnictwo (0,700 RII) i budownictwo (0,690 RII). Region produkuje średnio 132 worki węgla drzewnego tygodniowo i dziesięć ciężarówek miesięcznie. Badanie podkreśla pilną potrzebę zrównoważonego zarządzania środowiskiem i alternatywnych źródeł energii.

Słowa kluczowe: produkcja węgla drzewnego, wylesianie, zmiana pokrycia roślinnego, południowy Niger, pokrycie roślinne

1. INTRODUCTION

Vegetation is one of nature's most valuable gifts to mankind which is vital to the survival of a large section of the world's population, both humans and animals (Belayneh, Ru, Guadie et al., 2018). Vegetal cover removal is the most usually mentioned impact of charcoal production. In Africa and South America, charcoal consumption is increasing at a faster rate than firewood consumption, and it is now accounting for a huge share of overall wood energy use (Pennise, Smith, Kithinji et al., 2001). Although, investment in forest plantation-based charcoal production is increasing in tropical regions, majority of biomass for charcoal production comes from natural forests, where spontaneous regeneration is the primary source of forest recovery (Chidumayo & Gumbo, 2013). The main reasons why governments, non-governmental organizations and civil society are conscious of the environmental impacts of wood fuel are this general pattern – almost complete reliance on forest resources for charcoal production – as well as perceived unsustainable harvesting and poor post-harvest forest management (World Energy Corporation, 2004).

Rapid changes in Land Use and Land Cover (LULC) due to urbanization have significant effects on biodiversity, ecosystem dynamics, and regional and national climate (Choudhury, Das & Das, 2019). One third (2.4 billion) of the global population depends on charcoal and firewood for most of their cooking and heating requirements (FAO, 2017). For 29 countries primarily in sub-Saharan Africa (SSA), woodfuel constitutes more than 50% of total national energy supply (FAO, 2014). It is estimated that worldwide, approximately half of the wood extracted from forests is used as woodfuel, 17% of which is converted to charcoal (FAO, 2017). In woodfuel-dependent nations, over extraction of woody biomass to supply the energy sector can jeopardize the status of forests and their ability to fulfill their regulatory functions (Bazilian et al., 2011).

An integral part of every human society is the use of forests and trees by human being for various activities ranging from lumbering to construction without leaving behind the use of forest for charcoal production which serve as fuel for cooking in many third world nations. Apart from serving as a strategic measure in environmental conservation, forests and vegetation cover equally present man with various socioeconomic advantages which aids sustainable development. Many studies have attempted a study into vegetal cover change also viewed most times

as Land Use and Land Cover Change (LULCC) (Choudhury, Das, & Das, 2019; Belayneh, Ru, Guadie, Teffera, & Tsega, 2018; Arowolo & Deng, 2018; Akbari, Shea Rose, & Taha, 2003; Hailua, Mammoa, & Kidan, 2020). The impact of LULCC on temperature change was studied by (How Jin Aik et al., 2020; Choudhury et al., 2019). Also, Belayneh et al. (2018) studied the driving forces behind forest cover change while Arowolo and Deng (2018) explored the driving factors of variation and transition of cultivated land use, Akbari et al. (2003) evaluated the effects of landscaped surfaces and urban vegetation on meteorology and air quality while Kiruki et al. (2016) appraised land cover change and the role of charcoal production in woodland degradation.

In the aspect of commercial production of charcoal as a fuel for cooking and its resultant effects on physical and economic environment (Ekpo & Mba, 2020; Chidumayo & Gumbo, 2013; Lynch et al., 2004; Máliš et al., 2021). Historical charcoal burning and coppicing suppressed beech and increased forest vegetation heterogeneity was the focus of Máliš et al. (2021) while Lynch et al. (2004) studied charcoal particle production, size, and transport during the International Crown Fire Modelling Experiment. Choudhury et al. (2019) assess the effects of charcoal production in world tropical ecosystems. It is observed from the literature that none of the research investigates vegetal cover removal and charcoal production as it affect the social, economic and environmental sustainability. It is on this backdrop that this study attempts to fill the gap by evaluating the vegetal cover change and commercial charcoal production in the southern region of Niger State, Nigeria using remote sensing and GIS, in a bid to reveal the level of variation in LULCC over the years while unveiling the endemic effects of charcoal production in commercial volume for cooking fuel on the sustainability of the environment. The study therefore examine; the variation in vegetal cover change from 2011 to 2021 alongside level of commercial charcoal production and factors responsible for removal of vegetal cover in the southern region of Niger State.

2. LITERATURE REVIEW

2.1. Vegetal Cover Change

In many earth system processes, vegetal cover is a critical factor (Hansen et al., 2000). Humans and other creatures rely heavily on vegetation as a natural resource. For resource management and challenges related to land cover change, monitoring and evaluating

the types and extent of vegetation is critical (Rakiya et al., 2018). Today's vegetation is predominantly influenced by human activity, and any understanding of global change must take into account the widespread impact of human activity on land surface conditions and processes. Anthropogenic influences are having a dramatic effect on the urban environment, redefining vegetation and presenting new problems and research opportunities as the human population grows and more people move to urban areas (Rakiya et al., 2018).

The impact of competing biophysical processes on Earth's surface energy balance varies regionally and seasonally, and depending on specific vegetation changes and baseline temperature, can result in warming or cooling (Duveiller et al., 2013). LULCC studies have become an important part of modern natural resource management and environmental monitoring techniques. Recently, the decreasing vegetal cover over Nigeria gives an accurate assessment of the spread and health of the world's grassland, water, agricultural, and land resources being/becoming a top issue (Fanan et al., 2011; Fashae et al., 2017).

2.2. Charcoal Production

Despite the move to cleaner and more energy-efficient fuels like as gas and electricity, charcoal remains a major source of energy for many urban and peri-urban families in Sub-Saharan Africa (SSA), Southeast Asia, and Latin America (FAO, 2017). Affordability and cultural preferences for charcoal, together with high rates of population growth and urbanization in these countries, predict that demand will keep growing for the next thirty to fifty years before it begins to decline (Santos et al., 2017). Because most charcoal comes from natural forests (Chidumayo & Gumbo, 2013; FAO, 2017), addressing this expanding demand is already causing issues in the tropics' energy, forestry, and environmental sectors.

Charcoal is utilized as a fuel in domestic cooking and some companies; particularly those specialized in casting bronze and other metals can be produced all year round, involving woodland exploitation, which enhances deforestation, having varieties of negative consequences such as the loss of valuable resources and the environment, as well as driving climate change through the release of greenhouse gases, reducing the bio-productivity of natural ecosystem by altering the habitats of numerous species, and exposing bare surfaces vulnerable to runoff, thus making the product more expensive (Mwampamba et al., 2018; Silva et al., 2019; Ekpo & Mba, 2020).

Increased accessibility and improved satellite imagery have greatly assisted current understanding of charcoal production technologies over the years, resulting in a revived interest in evaluating the larger consequences of commercialized charcoal production on vegetal cover and habitat (Sedano et al., 2016; Ahrends et al., 2010; Bailis et al., 2017; Ghilardi et al., 2016). Nearly 80% of people in African cities use charcoal as their primary cooking fuel (Zulu & Richardson, 2013). People in rural hinterlands with few economic options accelerate charcoal manufacturing as demand rises as a result of growing urbanization (Chidumayo & Gumbo, 2013; Jagger & Jumbe, 2016; Mulenga, Hadunka, & Richardson, 2017). Commercial charcoal production contributes significantly to environmental degradation and sustainable livelihoods by removing vegetation and disrupting the ecosystem (Hosonuma et al., 2012; Ryan, Berry, & Joshi, 2014).

2.3. Effects of Charcoal Production on Vegetal Cover

Charcoal production entails woodland mining, which contributes to deforestation, which has a lot of negative implications, including the loss of precious resources and severe environmental interference (Martin et al., 2012). As a result, by depleting our natural habitats, deforestation has a negative influence on society and economies in the long run, and sustainable forest management has been a top priority given the potential impact on global biodiversity. Charcoal production necessitates the cutting of trees and the removal of natural vegetation, both of which contribute to species extinction. The loss of genes, populations, species, and ecosystems through removal of tree is rapid and irreversible if fundamental ecological processes are disrupted (Chidumayo & Gumbo, 2013). Biodiversity is the foundation of ecosystem health and ecological service supply. According to Rockstro et al. (2009), species interaction exists in an ecosystem, as such the decline or extinction of one species has an effect on the life span of other organisms and the ecosystem as a whole.

When forest cover is removed, wildlife loses habitat and becomes more prone to poaching (Bailis et al., 2005). Emissions of greenhouse gases from charcoal production in tropical ecosystem in 2019 are estimated at 71.2 million t of carbon dioxide and 1.3 million t for methane (Chidumayo & Gumbo, 2013). Smoking and carbon emissions from wood burning cause physical and mental health problems. Also contributes to climate change that has some health effects. Many trees inside forest reserves serve as source of local herbs for the fringe community, which they use to take care of their health issues. According to the local

homeopathic medicine dealers, deforestation has made them to lose many trees that they use for treatment and some are on extinction (Ekpo & Mba, 2020). Millions of people rely directly on forests for their livelihoods, whether through small-scale agriculture, hunting and gathering, or the collection of forest products like rubber. Vegetal cover change continues to cause serious socioeconomic issues, even violent conflict in certain cases. In the year 2000, global wood production totalled 3.9 billion m³, of which 2.3 billion m³ were used as charcoal, meaning that around 60% of the world's total wood removals from forests and trees are used for energy purposes (FAO, 2008).

2.4. Relative Importance Index

The Relative Importance Index (RII) is one of the widely adopted statistical techniques for assessing variables according to their priority and ranking, especially in social sciences disciplines and sustainability studies. RII provides standardized scores for the relative importance of each factor analyzed. The RII is calculated using the following formula:

$$RII = \frac{\sum W}{A \times N}$$

where:

W – weight assigned to each response,

A – highest possible weight,

N – total number of respondents.

In environmental science research, RII has been extensively adopted to identify and rank risk factors, and performance indicators. For example, RII was adopted by Gündüz et al. (2013) in assessing and ranking delay factors in construction projects, Khatib et al. (2020) used RII to rank delay factors in reconstruction and rehabilitation of projects, while Genc (2023) identified principal risk factors using RII. Rooshdi et al. (2018) adopted RII to analyzed design and construction activities for sustainable green highways. In contrast, Aghili et al. (2019) applied RII to assess green building management. Recent study by Ibrahim et al. (2025) adopted fuzzy RII model to assess lean construction practices.

3. METHODOLOGY

The study area is located between latitudes 8°20'N and 9°45'N and longitudes 4°85'E and 6°80'E. It is an extensive lowland region with about 100-200 metres in height covering eight Local Government Areas of Mokwa, Edati, Lavun, Katcha, Agaie, Bida, Gbako and Lapai, respectively (see Fig. 1).

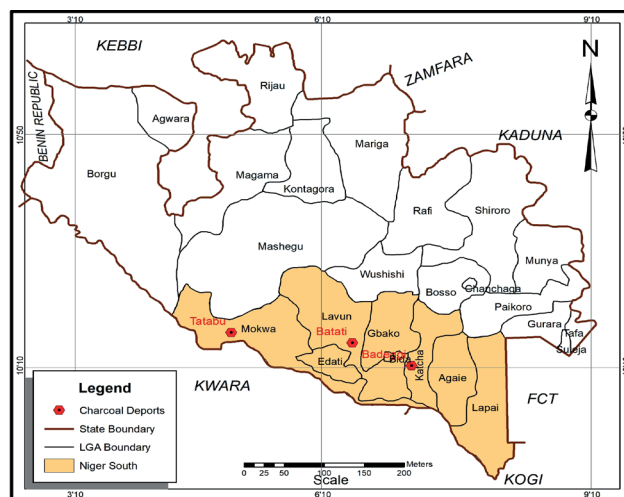


Fig. 1. Location of the Study Area in Niger State, Nigeria
Source: Niger Ministry of Lands and Housing, 2022

Data were sourced from both primary and secondary sources with the help of GIS and remote sensing, physical observations relevant to the study were observed, measured, and recorded with the help of structure closed ended questionnaire and discussion with selected respondents across the eight regions. Secondary data were obtained from relevant texts, journals, newspapers, government publications, magazines, and the internet, which served as a concrete source of insight into charcoal production and deforestation. The sample size was determined based on the entire population of the study area in general, and each of the locations or districts of the region in general. The estimated households of the area were adopted as sample size for more representative and realistic questionnaire administration.

The total population of the LGAs were projected from 2006; the last known population census conducted in the country to one million, six hundred and ninety two thousand, two hundred and thirty three (1,692,233) in 2022. Bartlett sample size formular was adopted to ascertain the sampled respondents of six hundred and sixty three (663) for questionnaire administration (See appendix A). The percentage contribution of each LGAs and districts to the entire population was adopted for eventual administration of structured closed ended questionnaires with a five point likert scale to enable eventual ranking through the relative importance index for the factors contributing to the removal of vegetal cover.

For the vegetal cover analysis, data were collected and analysed via Landsat image classification which involves acquisition of multispectral images, followed by pre-processing (radiometric and

geometric correction, and cloud removal) alongside supervised classification algorithms for categorizing vegetal cover types using training data, while ground trotting enables accuracy and validation as suggested by Mohajane et al. (2018) and You et al. (2022); post processing of data for analysis include spatial filtering and change detection for comparison of different time series/periods (2010, 2015 and 2020) respectively to identify the extent of vegetal cover loss overtime. This is then followed by quantitative and spatial analysis for classifying the extent of vegetal loss overtime and spatial illustration on maps via ArcGIS version10. Relative Importance Index (RII) was adopted in ranking the various factors contributing to vegetal cover loss in the study area.

4. DATA ANALYSIS AND PRESENTATION

4.1. Vegetal Cover Change from 2011 to 2021

The three major charcoal depots including Badeggi, Batati and Tatabu in the study area were selected as the place of interest in satellite image classification. The satellite imageries captured covers 5 km from the charcoal depots. This allows monitoring of the vegetal cover loss over time. The satellite image classifications are presented in Figures 2, 3 and 4.

Findings of the study in relation to Badeggi shown in Table 1 reveals that the vegetation cover in 2010 was 472.65 ha while built-up area covers 706.68 ha and bare land covers 638.69 ha respectively. However, the vegetation cover reduces to 333.94 ha in 2015 while built-up area coverage increased to 1,014.41 ha and bare land equally drops to 469.67 ha in Badeggi. Meanwhile, further decline was observed for 2020 where vegetation cover was estimated to be 269.92 ha, built-up area coverage further rose to 1,231.11 ha and bare land further drops to 316.99 ha in Badeggi axis. As further contained in the table, the 26% vegetal cover in 2010 had declined to 14.85% of the total coverage area in 2020 across the selected radius of the depot in Badeggi while built-up area coverage rose from 38.87% in 2010 to 67.72% in 2020 and bare land equally drops from 35.13% in 2010 to 17.44% in 2020.

Table 1. Classification of vegetal cover in Badeggi

Classification	2010		2015		2020	
	Ha	%	Ha	%	Ha	%
Vegetation	472.65	26.00	333.94	18.37	269.92	14.85
Built-Up Area	706.68	38.87	1,014.41	55.80	1,231.11	67.72
Bare Land	638.69	35.13	469.67	25.83	316.99	17.44

Source: Landsat image 2021.

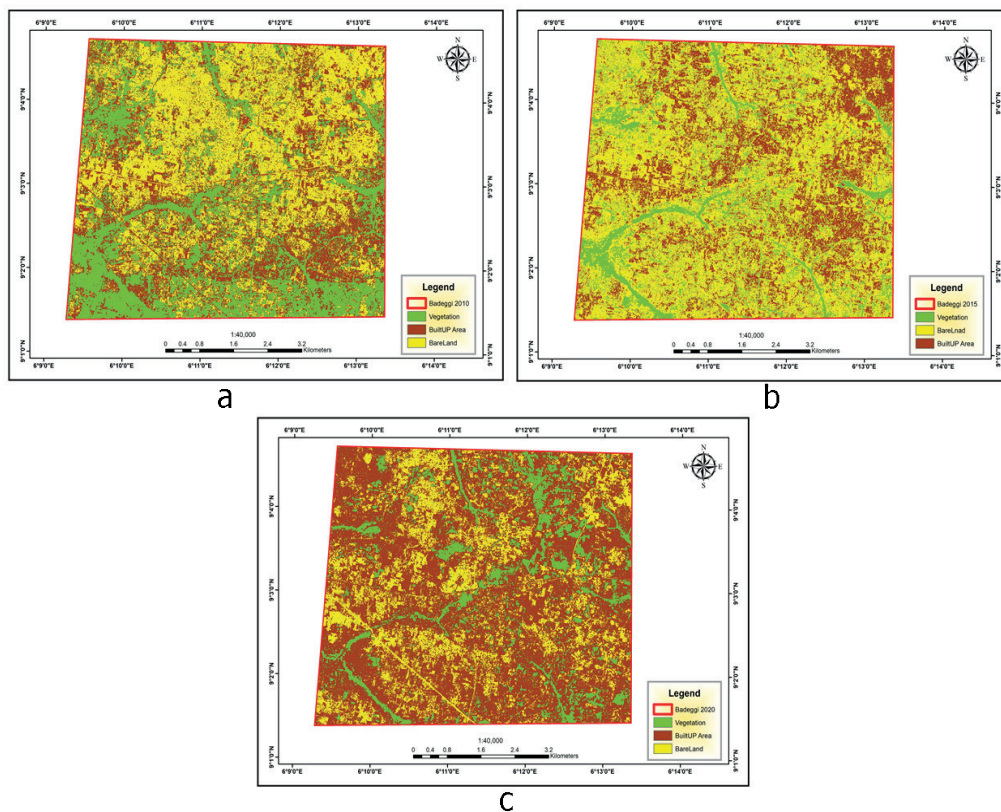


Fig. 2. Vegetal cover change in Badeggi: a) 2010, b) 2015 and c) 2020

The spatial representation of this finding is depicted in Figure 2 where in 2010, the vegetation cover was evidently present in Figure 2a; obvious change in vegetal cover is depicted in Figure 2b where significant increase was observed for built-up area and bare land and vegetation cover decline. A further significant decline in vegetal cover was observed in Figure 2c where greenery is almost invincible and disappearing from the location with more dominant built-up area and bare land resulting from various action of deforestation (farming, mining, construction, charcoal production among others) leading to loss of vegetation

Furthermore, results from Batati presented in Table 2 indicated that the vegetal cover in 2010 was 1,491.75 ha while built-up area covers 708.79 ha and bare land covers 102.43 ha respectively. Meanwhile, the vegetal cover reduces to 687.11 ha in 2015, built-up area coverage rose to 932.4 ha and bare land increased to 683.46 ha in Batati. Similar to the observation in Badeggi, further decline of vegetal cover was observed for 2020 with 351.74 ha vegetation, built-up area coverage further increased to 1244.2 ha and bare land further grew to 707.03 ha in Batati axis. As further depicted in the table, the 64.78% vegetal cover in 2010 had declined to 15.27% of the total coverage

area in 2020 across the selected radius of the charcoal depot in Batati while built-up area coverage rose from 30.78% in 2010 to 54.03% in 2020 and bare land equally rose from 4.45% in 2010 to 30.70% in 2020.

Table 2. Classification of vegetal cover in Batati

Classification	2010		2015		2020	
	Ha	%	Ha	%	Ha	%
Vegetation	1,491.75	64.78	687.11	29.84	351.74	15.27
Built-Up Area	708.79	30.78	932.4	40.49	1244.2	54.03
Bare Land	102.43	4.45	683.46	29.68	707.03	30.70

Source: Landsat image 2021.

The spatial representation of this finding is depicted in Figure 3 where in 2010, the presence of green vegetation was evident in 2010 with over 50% of the entire radius shown in Figure 3a; obvious decline in vegetal cover is depicted in Figure 3b where significant increase was observed for bare land accompanied by declining vegetation. A further significant decline in vegetal cover was observed in Figure 3c where greenery is almost fading away while bare land and built-up area becomes more pronounced compared to Figure 3a as a result of various factors like farming, mining, charcoal production among others leading to loss of vegetation.

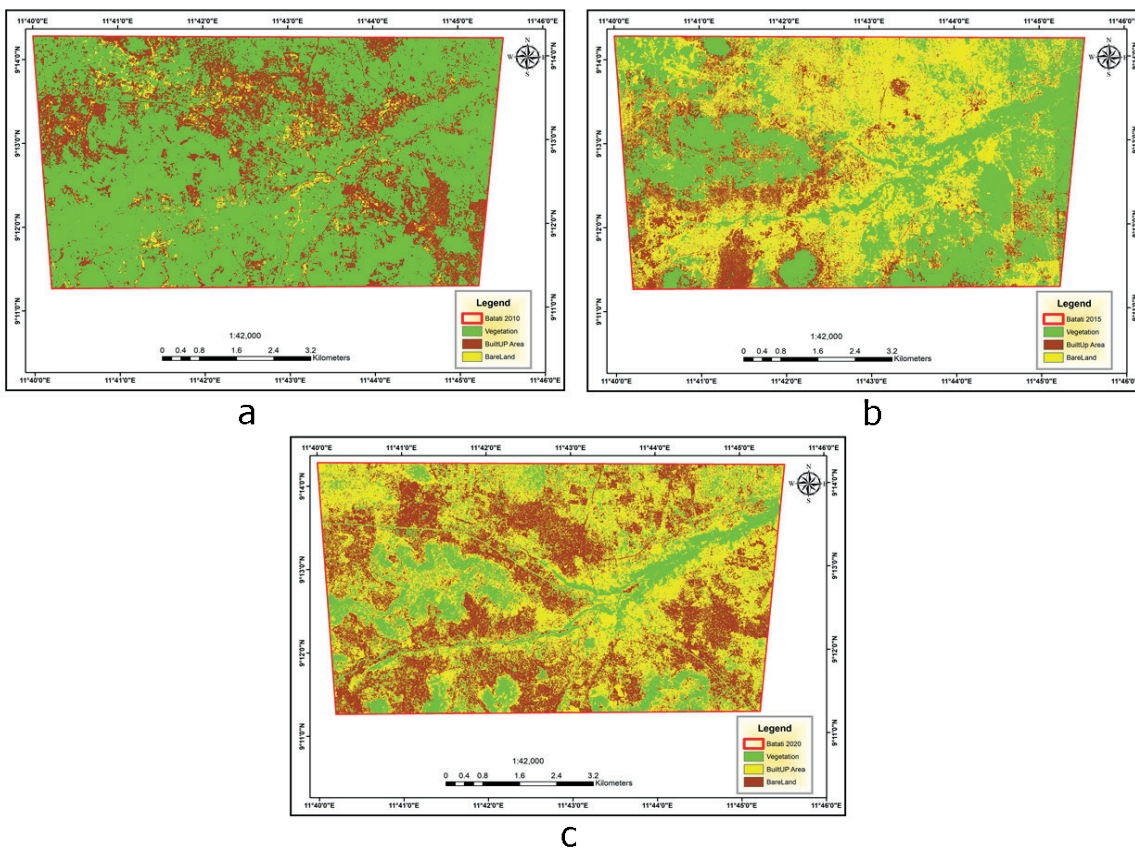


Fig. 3. Vegetal cover change in Batati: a) 2010, b) 2015 and c) 2020

In the same vein, findings of the study from the radius around Tatabu charcoal depot presented in Table 3 indicated 260.08 ha vegetal cover; 76.21 ha for built-up area and 795.69 ha for bare land in 2010 respectively. Variation in coverage was witnessed in 2015 with vegetal cover declining to 178.6 ha; built-up area rose to 197.74 ha while bare land slightly drops to 755.64 ha.

Another variation in coverage was witnessed across the three classifications in 2020 where vegetal cover was 158.49 ha, built-up area rose to 381.35 ha and bare land reduced to 592.14 ha in 2020. As further depicted in the table, the 22.98% vegetal cover in 2010 had declined to 14.00% of the total coverage area in 2020 across the selected radius of the charcoal depot in Tatabu while built-up area coverage rose from 6.73% in 2010 to 33.69% in 2020 and bare land declines from 70.29% in 2010 to 52.31% in 2020.

Table 3. Classification of vegetal cover in Tatabu

Classification	2010		2015		2020	
	Ha	%	Ha	%	Ha	%
Vegetation	260.08	22.98	178.6	15.78	158.49	14.00
Built-Up Area	76.21	6.73	197.74	17.47	381.35	33.69
Bare Land	795.69	70.29	755.64	66.75	592.14	52.31

Source: Landsat image 2021.

This finding is spatially presented in Figure 4 where in 2010, the presence of traceable green vegetation was evident in 2010 shown in Figure 4a; obvious decline in vegetal cover is depicted in Figure 4b where significant increase was observed for built-up areas accompanied by declining vegetation. A further significant decline in vegetal cover was observed in Figure 4c where greenery is almost fading away while built-up area equally drops and bare land and becomes more pronounced compared to Figure 4a as a result of various factors like farming, mining, charcoal production among others leading to loss of vegetation.

4.2. Level of Commercial Charcoal Production in the Study Area

As presented in Figure 5, seventy five (75) bags of charcoal are produced in Tatabu while Badeggi has a production rate of one hundred and twenty (120) bags of charcoal on a weekly basis and the highest charcoal production was observed in Batati with an average of two hundred (200) bags per week. This indicates an average production of one hundred and thirty two (132) bags per week across the three major charcoal depots in the study area.

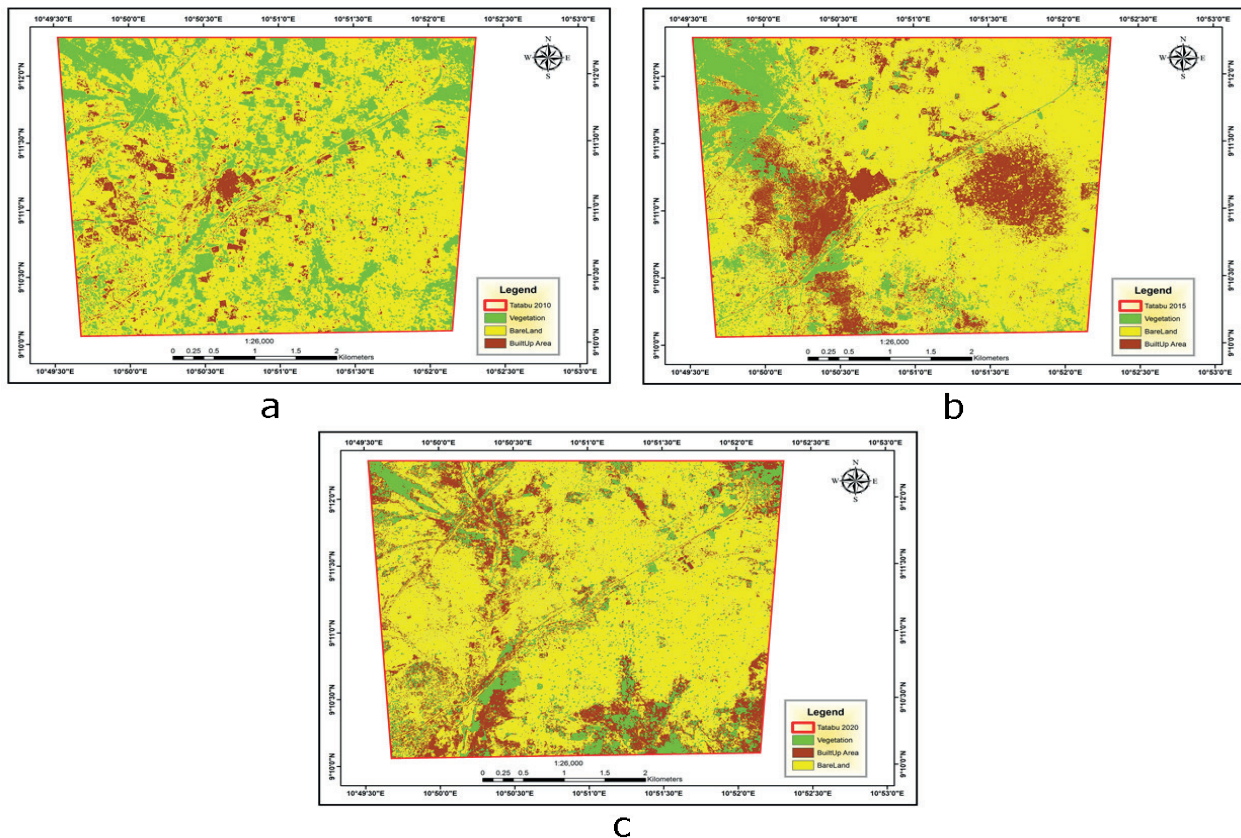


Fig. 4. Vegetal cover change in Tatabu: a) 2010, b) 2015 and c) 2020

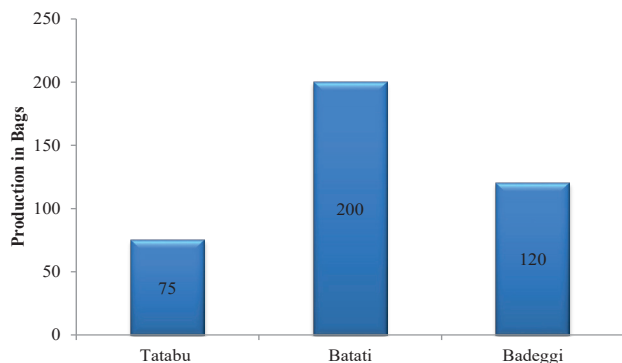


Fig. 5. Weekly production of charcoal (in bags)
Source: Field survey, 2021

Results of the findings in relation to the average kilogram of a bag of charcoal presented in Figure 6 indicated that 19.8% respondents submitting to less than 5 kg, 13.2% are of the opinion that an average bag of charcoal weighs between 6-10 kg, those with the view that it weighs between 11-15 kg are 15.5% while 42.7% submitted that a bag of charcoal has an average weight of 16-20 kg as the remaining 8.8% submitted that a bag of charcoal weighs above 20 kg. By implication, an average bag of charcoal is concluded to weigh between 11-20 kg seeing a total cumulative submission of 58.2% response.

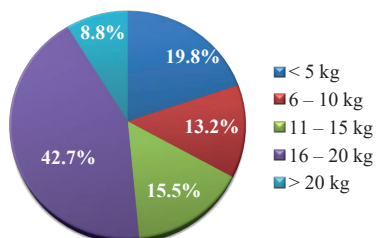


Fig. 6. Average Kilogram per bag of charcoal
Source: Field survey, 2022

Findings of the study according to the average number of trucks export out of the region per month from the major charcoal depots as shown in Figure 7 revealed an average of 3 trucks exported from Tatabu depot while 6 trucks are often exported per month from Badeggi depot while the highest 10 trucks export per month is observed for Batati charcoal depot respectively, giving an average of ten trucks per month with each truck containing within 200-500 bags. By implication, it can be inferred that the region is a large supplier of charcoal both locally across Nigeria and outside the country's border. It also revealed a large volume of trucks loading charcoal out of the region into the south-western part of the country with Lagos the most preferred destination where it is further loaded on ships for eventual exportation out of

the country while Abuja and Kaduna are the preferred destination in the Northern part of the country. See plate 1 and 2 in appendix B for the removal of vegetation for charcoal production and bags of charcoal awaiting export out of the region.

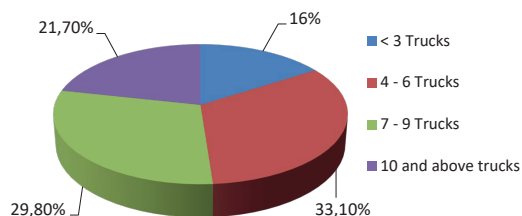


Fig. 7. Charcoal export by trucks per month
Source: Field survey, 2022

4.3. Factors contributing to Vegetal Land Cover Loss

Results presented in Table 4 regarding factors contributing to vegetal land cover loss indicated that; deforestation is ranked highest with 0.763 RII values followed by farming ranked second with 0.700 RII as 0.690 RII was observed for construction exercises ranked third while overgrazing and lumbering were ranked fourth and fifth with 0.682 RII and 0.663 RII values respectively alongside mining ranked sixth with 0.654 RII values. The factor ranked seventh was flooding and excessive rainfall followed by heavy winds with 0.650 RII, slope and gradient of the region was ranked ninth with 0.559 RII as 0.546 RII was recorded for nature of soil and topography while tectonic activity is ranked eleventh with 0.538 RII value and the lowest ranked factor contributing to and responsible for the removal of vegetal cover is climate and weather variation with 0.503 RII values.

Table 4. Summary of Factors Responsible for the Removal of Vegetal Cover

Factors	Mean	RII	Rank
Climate and Weather variation	2.513	0.503	12 th
Nature of soil/Topography	2.728	0.546	10 th
Tectonic activity	2.692	0.538	11 th
Slope and Gradient	2.795	0.559	9 th
Construction (Dam, Buildings, Infrastructures)	3.449	0.690	3 rd
Flooding and Intense rainfall	3.267	0.653	7 th
Overgrazing	3.408	0.682	4 th
Heavy winds	3.248	0.650	8 th
Deforestation	3.816	0.763	1 st
Farming	3.499	0.700	2 nd
Lumbering	3.317	0.663	5 th
Mining	3.269	0.654	6 th

Source: Field survey, 2022.

4.4. Discussion

The findings from the study area indicate significant declines in vegetal cover between 2011 and 2021, with corresponding increases in built-up areas and varying changes in bare land. This trend, which has been seen in Tatabu, Batati, and Badeggi, is indicative of widespread land conversion and deforestation efforts that are primarily motivated by the manufacturing of charcoal. The worst effects of these commercial activities on the environment are shown in Batati, where there has been a reported drop in vegetative cover from 1,491.75 ha to 351.74 ha. These developments are consistent with worldwide patterns in which economic activities like resource extraction, urbanisation, and agriculture drive changes in land use, especially in poor nations (Arifeen et al., 2021). Research from other continents, such as Southeast Asia and South America, also show that urbanisation and agriculture-related deforestation dramatically diminish the amount of forest cover (Destiariono & Hartono, 2022; Sylvester et al., 2024).

Comparatively, similar patterns have been seen throughout Africa, where deforestation is mostly caused by the conversion of forest areas for agriculture, urban development, and the manufacturing of charcoal (Kiruki et al., 2020; Nyarko et al., 2021; Sedano et al., 2022). For example, the growth of urban areas and agricultural land in West Africa has resulted in a significant loss of forest cover (Ziem Bonye et al., 2021). Studies from Kenya and Tanzania have shown that the production of charcoal is a major factor contributing to forest degradation in East Africa (Kiruki et al., 2020; Nyarko et al., 2021). The study's conclusions are consistent with these geographical patterns, suggesting that the economic forces driving up the production of charcoal and land conversion are widespread throughout the continent. This emphasises the necessity of sustainable land management techniques to counteract environmental deterioration while juggling financial requirements.

Deforestation, excessive grazing, mining, building, and farming are among the causes that have been shown to contribute to the loss of vegetative cover. These findings are in line with those from other parts of Africa and the world (Tsegaye, 2019; Musetsho et al., 2021; Hussein, 2023). The primary issue in Lapai and other research areas is deforestation, which is fuelled by activities like the manufacturing of charcoal. Similarly, in the Amazon Basin where deforestation is common for soybean farming and cattle ranching; similar drivers of vegetal loss have been observed

(Hänggli et al., 2023; Alves et al., 2023). The high relative importance index (RII) values observed for mining and deforestation match trends observed in other African nations like Ghana and the Democratic Republic of the Congo, where land clearance for agriculture and mineral extraction are the main drivers of forest loss (Bas et al., 2024; Rieckmann & Muñoz, 2024). The intricacy of managing land resources in the face of many and conflicting economic activity is shown by the study's thorough analysis, which highlights the complex factors influencing changes in land cover.

5. CONCLUSION AND RECOMMENDATIONS

Using remote sensing and geographic information systems (GIS), this study assessed changes in vegetal cover and the production of commercial charcoal in the southern region of Niger State, Nigeria. The results show notable differences in land use and land cover change (LULCC) between 2011 and 2021, with widespread commercial charcoal production serving as the main driver. A striking drop in vegetative cover is shown by the analysis, especially in the vicinity of important charcoal depots like Badeggi, Batati, and Tatabu, where the greenery has been replaced by barren terrain and built-up regions. As revealed by the study, there is a significant amount of charcoal produced; Batati alone may produce up to 200 bags per week, highlighting the activity's economic importance. According to the study, the main causes of the loss of vegetative cover include overgrazing, farming, mining, and deforestation, with the manufacturing of charcoal being the most common reason. These results draw attention to the unsustainable use of forest resources as fuel, which presents serious problems for the sustainability of the ecosystem. In order to maintain the long-term viability of the region's natural resources, the report urges the rapid implementation of sustainable land management techniques that strike a balance between economic requirements and environmental conservation.

In order to tackle the noteworthy reduction in vegetative cover and issues related to environmental sustainability that the study uncovered, it is suggested that the southern part of Niger State adopt sustainable land management techniques. To lessen reliance on charcoal, this entails encouraging other energy sources, implementing stronger laws against deforestation, and stepping up reforestation initiatives. Furthermore, overgrazing and soil

degradation may be lessened by implementing sustainable farming methods and managed grazing. In addition to supporting economic diversification to lessen reliance on ecologically damaging methods, community education and awareness campaigns on

the environmental effects of charcoal manufacturing are essential. Ensuring long-term environmental sustainability and economic stability can be facilitated by collaborating with non-governmental organisations and government agencies.

REFERENCES

- [1] Aghili N., Hosseini S.E., Bin Mohammed A.H., Zainul Abidin N. (2019). Management criteria for green building in Malaysia; relative important index. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 41(21), 2601-2615.
- [2] Ahrends A., Burgess N.D., Milledge S.A., Bulling M.T., Fisher B., Smart J.C., et al. (2010). Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. *Proc. Natl. Acad. Sci. U.S.A.* 107, 14556–14561. doi: 10.1073/pnas.0914471107.
- [3] Aik D., Ismail M.H. Muharam F.M. (2020). Land Use/Land Cover Changes and the How Jin Relationship with Land Surface Temperature Using Landsat and MODIS Imageries in Cameron Highlands, Malaysia. *Land*, 9(10): 1-23, 10.3390/land9100372.
- [4] Akbari H., Shea Rose L., Taha, H. (2003). Analyzing the land cover of an urban environment using high resolution orthophotos, *Landscape and Urban Planning*, 64: 1-14 [https://doi.org/10.1016/S0169-2046\(02\)00165-2](https://doi.org/10.1016/S0169-2046(02)00165-2).
- [5] Alves M.A.B., de Souza A.P., de Almeida F.T., Hoshide A.K., Araújo H.B., da Silva A.F., de Carvalho D.F. (2023). Effects of land use and cropping on soil erosion in agricultural frontier areas in the Cerrado-Amazon Ecotone, Brazil, using a rainfall simulator experiment. *Sustainability*, 15(6), 4954.
- [6] Arifeen H.M., Phoungthong K., Mostafaicpour A., Yuangyai N., Yuangyai C., Techato K., Jutidamrongphan W. (2021). Determine the land-use land-cover changes, urban expansion and their driving factors for sustainable development in Gazipur Bangladesh. *Atmosphere*, 12(10), 1353.
- [7] Arowolo A.O., Deng X. (2018). Land use/land cover change and statistical modelling of cultivated land change drivers in Nigeria. *Regional Environmental Change*, 18(1): 247-259, <https://doi.org/10.1007/s10113-017-1186-5>.
- [8] Bailis R., Ezzati M., Kammen D.M. (2005). Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa. *Science*, 308: 98-103.
- [9] Bailis R., Wang Y., Drigo R., Ghilardi A., Masera O. (2017). Getting the numbers right: revisiting woodfuel sustainability in the developing world. *Environ. Res. Lett.* 12:115002. doi: 10.1088/1748-9326/aa83ed.
- [10] Bas T.G., Sáez M.L., Sáez N. (2024). Sustainable Development versus Extractivist Deforestation in Tropical, Subtropical, and Boreal Forest Ecosystems: Repercussions and Controversies about the Mother Tree and the Mycorrhizal Network Hypothesis. *Plants*, 13(9), 1231. <https://doi.org/10.3390/plants13091231>.
- [11] Bazilian M., Rogner H., Howells M., Hermann S., Arent D., Gielen D., et al. (2011). Considering the energy, water and food nexus: towards an integrated modelling approach. *Energy Policy*, 39, 7896-7906. doi: 10.1016/j.enpol.2011.09.039.
- [12] Belayneh Y., Ru G., Guadie A., Teffera Z.L. Tsega M. (2018). Forest cover change and its driving forces in Fagital Lekoma District, Ethiopia. *Journal of Forestry Research*, 31, <https://doi.org/10.1007/s11676-018-0838-8>.
- [13] Chidumayo E., Gumbo D. (2013). The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. *Energy for Sustainable Development*, 17: 86-94, 10.1016/j.esd.2012.07.004.
- [14] Choudhury D., Das K., Das A. (2019). Assessment of land use land cover changes and its impact on variations of land surface temperature in Asansol-Durgapur Development Region. *The Egyptian Journal of Remote Sensing and Space Sciences*, 203-219, <https://doi.org/10.1016/j.ejrs.2018.05>.
- [15] Destiariono M.E., Hartono D. (2022). Does Rapid Urbanization Drive Deforestation? Evidence From Southeast Asia. *Economics Development Analysis Journal*, 11(4), 442-453.
- [16] Duveiller G., López-Lozano R., Baruth B. (2013). Enhanced processing of 1-km spatial resolution fAPAR time series for sugarcane yield forecasting and monitoring. *Remote Sensing*, 5(3), 1091-1116.
- [17] Ekpo A.S., Mba E.H. (2020). Assessment of Commercial Charcoal Production Effect on Savannah Woodland of Nasarawa State, Nigeria. *Journal of Geography, Environment and Earth Science International*, 24(2): 74-82, DOI: 10.9734/JGEESI/2020/v24i230204.
- [18] Fanan U., Dlama K.I., Oluseyi I.O. (2011). Urban expansion and vegetal cover loss in and around Nigeria's Federal Capital City. *Journal of Ecology and the Natural Environment*, Vol. 3(1), pp. 1-10.
- [19] FAO (2008). The state of food and agriculture; 2008.
- [20] FAO (2014). State of the World's Forests 2014. FAO, Rome.

- [21] FAO (2017). The Charcoal Transition: Greening The Charcoal Value Chain To Mitigate Climate Change And Improve Local Livelihoods. Food and Agriculture Organization of the United Nations, Rome.
- [22] Fashae O., Olusola A., Adedeji O. (2017). Geospatial Analysis of Changes in Vegetation Cover over Nigeria. *Bulletin of Geography. Physical Geography Series*, 13: 17-28 <http://dx.doi.org/10.1515/bgeo-2017-0010>.
- [23] Genc O. (2023). Identifying principal risk factors in Turkish construction sector according to their probability of occurrences: a relative importance index (RII) and exploratory factor analysis (EFA) approach. *International Journal of Construction Management*, 23(6), 979-987.
- [24] Ghilardi A., Bailis R., Mas J.F., Skutsch M., Elvir J.A., Quevedo A., et al. (2016). Spatiotemporal modeling of fuelwood environmental impacts: towards improved accounting for non-renewable biomass. *Environ. Model. Softw.* 82, 241-254. doi: 10.1016/j.envsoft.2016.04.023.
- [25] Gündüz M., Nielsen Y., Ozdemir M. (2013). Quantification of Delay Factors Using the Relative Importance Index Method for Construction Projects in Turkey. *Journal of Management in Engineering*, 133-139. <https://hdl.handle.net/11511/66178>.
- [26] Hailua A., Mammao S., Kidan M. (2020). Dynamics of land use, land cover change trend and its drivers in Jimma Geneti District, Western Ethiopia. *Land use policy*, 99, <https://doi.org/10.1016/j.landusepol.2020.105011>.
- [27] Hänggli A., Levy S.A., Armenteras D., Bovolo C.I., Brandão J., Rueda X., Garrett R.D. (2023). A systematic comparison of deforestation drivers and policy effectiveness across the Amazon biome. *Environmental Research Letters*, 18(7), 073001.
- [28] Hansen M.C., Defries R.S., Townsend R.G., Shlber R. (2000). Global Land Cover Classification at 1km spatial resolution using classification tree approach. *International Journal of remote Sensing*, 1331-1364.
- [29] Hosonuma N., Herold M., Sy V.D., Fries R.S.D., Brockhaus M., Verchot L., et al. (2012). An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, 7(4), 044009. <https://doi.org/10.1088/1748-9326/7/4/044009>.
- [30] Hussein A. (2023). Impacts of land use and land cover change on vegetation diversity of tropical highland in Ethiopia. *Applied and Environmental Soil Science*, 2023(1), 2531241.
- [31] Ibrahim A., Abdelkhalik S., Zayed T., Meshref A.N. (2025). Assessment of Lean Construction Practices in Developing Countries Using Fuzzy Relative Importance Index. *Engineering Management Journal*, 1-21.
- [32] Jagger P., Jumbe C. (2016). Stoves or sugar? Willingness to adopt improved cookstoves in Malawi. *Energy Policy*, 92, 409-419. <https://doi.org/10.1016/j.enpol.2016.02.034>.
- [33] Khatib B.A., Poh Y.S., El-Shafie A. (2020). Delay factors management and ranking for reconstruction and rehabilitation projects based on the relative importance index (RII). *Sustainability*, 12(15), 6171.
- [34] Kiruki H.M., Van Der Zanden E.H., Kariuki, P., Verburg P.H. (2020). The contribution of charcoal production to rural livelihoods in a semi-arid area in Kenya. *Environment, Development and Sustainability*, 22, 6931-6960.
- [35] Kiruki H.M., van der Zanden E.H., Malek Ž., Verburg P.H. (2016). Land Cover Change and Woodland Degradation in a Charcoal Producing Semi-Arid Area in Kenya. *Land Degradation & Development*, 28(2): 472-481, doi.org/10.1002/ldr.2545.
- [36] Lynch J.A., Clark J.S., Stocks B.J. (2004). Charcoal production, dispersal, and deposition from the Fort Providence experimental fire. *Canadian Journal of Forest Research*, 34: 1642-1656, doi: 10.1139/X04-071.
- [37] Máliš F., Bobek P., Hédli R., Chudomelová M., Petřík P., Ujházy K., Ujházyová M., Kopecký M. (2021). Historical charcoal burning and coppicing suppressed beech and increased forest vegetation heterogeneity. *Journal of Vegetation Science*, 32(1): doi: 10.1111/JVS.12923.
- [38] Martin R.M., Kneeland D., Brooks D., Matta R. (eds). (2012). State of World's forests 2012. Food and agriculture organization of the united nations, Rome; 2012.
- [39] Mohajane M., Essahlaoui A.L.I., Oudija F., Hafyani M.E., Hmadi A.E., Ouali A.E., ... Teodoro A.C. (2018). Land use/land cover (LULC) using Landsat data series (MSS, TM, ETM+ and OLI) in Azrou Forest, in the Central Middle Atlas of Morocco. *Environments*, 5(12), 131.
- [40] Mulenga B.P., Hadunka P., Richardson R.B. (2017). Rural households' participation in charcoal production in Zambia: Does agricultural productivity play a role? *Journal of Forest Economics*, 26, 56-62. <https://doi.org/10.1016/j.jfe.2017.01.001>.
- [41] Musetsho K.D., Chitakira M., Nel W. (2021). Mapping land-use/land-cover change in a critical biodiversity area of South Africa. *International Journal of Environmental Research and Public Health*, 18(19), 10164.
- [42] Mwampamba T.H., van Schaik N.L.M., Castillo Hernandez L.A. (2018). Incorporating Ecohydrological Processes into an Analysis of Charcoal-Livestock Production Systems in the Tropics: An Alternative Interpretation of the Water-Energy-Food Nexus. *Frontiers in Environmental Science*, 6:99, doi:10.3389/fenvs.2018.00099.
- [43] Nyarko I., Nwaogu C., Miroslav H., Peseu P.O. (2021). Socio-economic analysis of wood charcoal production as a significant output of forest bioeconomy in Africa. *Forests*, 12(5), 568.
- [44] Pennise D.M., Smith K.R., Kithinji J.P., Rezende M.E., Raad T.J., Zhang J., et al. (2001). Emissions of greenhouse gases and other airborne pollutants from charcoal making in Kenya and Brazil. *Journal of Geophysical Research*, 106: 24143-55.

- [45] Rakiya A.B., Halilu A.S., Mohammed S.O., Vaatyough H.M., Shagari M.S. et al. (2018). Assessing the Drivers of Vegetal Cover Dynamics in the F.C.T, Nigeria using Remote Sensing/ GIS Techniques. *International Journal of Environment, Agriculture and Biotechnology (IJEAB)* Vol. 3(6): 2214-2221, <http://dx.doi.org/10.22161/ijeab/3.6.36>.
- [46] Rieckmann M., Muñoz R.T. (Eds.). (2024). World Review: Environmental and Sustainability Education in the Context of the Sustainable Development Goals. CRC Press. Available at: World Review: Environmental and Sustainability Education in the Context of ... – Google Books.
- [47] Rockstro M.J., Steffen W., Noone K., Person A., Chapin III F., Lambin F. Eton M. (2009). A safe operating space for humanity. *Nature*; 461(7263):472-5.
- [48] Rooshdi R.R.R.M., Abd Majid M.Z., Sahamir S.R., Ismail N.A.A. (2018). Relative importance index of sustainable design and construction activities criteria for green highway. *Chemical engineering transactions*, 63, 151-156.
- [49] Ryan C.M., Berry N.J., Joshi N. (2014). Quantifying the causes of deforestation and degradation and creating transparent REDD+ baselines: A method and case study from central Mozambique. *Applied Geography*, 53, 45-54. <https://doi.org/10.1016/j.apgeog.2014.05.014>.
- [50] Santos M.J., Dekker S.C., Daioglou V., Braakhekke M.C., van Vuuren D.P. (2017). Modeling the effects of future growing demand for charcoal in the tropics. *Frontier Environmental Science*. 5:28. doi: 10.3389/fenvs.2017.00028.
- [51] Sedano F., Mizu-Siampale A., Duncanson L., Liang M. (2022). Influence of charcoal production on forest degradation in Zambia: a remote sensing perspective. *Remote Sensing*, 14(14), 3352.
- [52] Sedano F., Silva J.A., Machoco R., Meque C.H., Siteo A., Ribeiro N., et al. (2016). The impact of charcoal production on forest degradation: a case study in Tete, Mozambique. *Environ. Res. Lett.* 11:094020. doi: 10.1088/1748-9326/11/9/094020.
- [53] Silva J.A., Sedano F., Flanagan S., Ombe Z.A., Machoco R. et al. (2019). Charcoal-related forest degradation dynamics in dry African woodlands: Evidence from Mozambique. *Applied Geography*, 107:72-81, <https://doi.org/10.1016/j.apgeog.2019.04.006>.
- [54] Sylvester J.M., Gutiérrez-Zapata D.M., Pérez-Marulanda L., Vanegas-Cubillos M., Bruun T.B., Mertz O., Castro-Nunez A. (2024). Analysis of food system drivers of deforestation highlights foreign direct investments and urbanization as threats to tropical forests. *Scientific Reports*, 14(1), 15179.
- [55] Tsegaye B. (2019). Effect of land use and land cover changes on soil erosion in Ethiopia. *International Journal of Agricultural Science and Food Technology*, 5(1), 026-034.
- [56] World Energy Corporation (2004). 2004 survey of world energy resources. <http://www.worldenergy.org/wecgeis/publications/reports/ser/biomass/biomass.asp2004>.
- [57] You H., Tang X., Deng W., Song H., Wang Y., Chen J. (2022). A study on the difference of LULC classification results based on Landsat 8 and Landsat 9 data. *Sustainability*, 14(21), 13730.
- [58] Ziem Bonye S., Yenglier Yiridomoh G., Derbile, E.K. (2021). Urban expansion and agricultural land use change in Ghana: Implications for peri-urban farmer household food security in Wa Municipality. *International Journal of Urban Sustainable Development*, 13(2), 383-399.
- [59] Zulu L.C., Richardson R.B. (2013). Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa. *Energy for Sustainable Development*, 17(2), 127-137. <https://doi.org/10.1016/j.esd.2012.07.007>.

APPENDIX A

SAMPLE SIZE

S/N	LGAs	Districts	Population	% contributed	Sample Size	Returned Valid
1	Lapai	Lapai	64,403	3.6	24	19
		Shaku	13,108	0.8	5	5
		BirninMaza	10,349	0.6	4	5
		Duma	11,668	0.7	5	4
		Gulu-Vatsa	8,781	0.5	3	5
		Kpada	12,204	0.7	5	3
		Ebbo	5,447	0.3	2	5
		Bata	7,863	0.4	3	2
		Muye	14,741	0.8	5	3
		Gupa	9,099	0.5	3	5
		Total	152,922	8.9	59	51
2	Agaie	Agaie	78,149	4.5	30	28
		Kintifin	25,918	1.5	10	8
		Tagagi	11,468	0.6	4	4
		Baro	29,814	1.7	11	11
		Fogbe	12,668	0.7	5	5
		Kusoyaba	11,462	0.7	5	5
		Goyiko	8,617	0.5	3	3
		Total	172,741	10.2	67	64
3	Katcha	Katcha	74,107	4.2	28	27
		Kateregi	41,218	2.4	16	16
		Baddegi	27,681	1.6	11	11
		Bakeko	19,873	1.1	7	7
		Total	157,982	9.3	62	71
4	Bida	Bida	249,996	14.3	95	78
		Total	242,479	14.3	95	78
5	Gbako	Lemu	60,070	3.7	24	20
		EtsuAudu	65,608	3.8	25	23
		Edozhigi	41,281	2.4	16	15
		Total	165,760	9.9	65	58
6	Lavun	Kutigi	74,849	4.3	27	19
		Dabban	44,418	2.5	17	17
		Kp...	36,612	2.1	14	14
		Jima	39,841	2.3	15	12
		Doko	46,689	2.7	18	17
		Gaba	40,224	2.3	15	13
		Total	274,135	16.2	107	94
7	Edati	Enagi	119,248	6.8	45	39
		Sakpe	96,075	5.5	37	35
		Total	208,849	12.3	82	74
8	Mokwa	Mokwa	124,741	7.1	47	41
		Muwo	44,908	2.6	17	17
		Takuma	56,251	3.2	21	14
		Kudu	38,004	2.2	15	15
		KedeTifin	33,407	1.9	13	12
		KedeTako	29,892	1.7	11	10
		TOTAL	317,365	18.7	124	107
GRAND TOTAL			1,692,233	100	663	597

Source: NPC (2006); NBS (2012); Authors projection (2022)

APPENDIX B



*Plate 1. Vegetal removal during charcoal production
Source: Authors Survey, 2022*



*Plate 2. Bags of charcoal awaiting transport
Source: Authors Survey, 2022*

Acknowledgement

The authors would like to thank the Tertiary Education Trust Fund (TETFUND) of Nigeria for sponsoring this research.