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Assessment of vegetation cover dynamics in the agro-ecological Zones of Nigeria

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Abstract. The drastic vegetation loss of about 22% in 12 years across agro-ecological zones (AEZs) in Nigeria, which can be attributed to the impact of climate and anthropogenic activities on vegetation dynamics within the context of socio-economics, calls for concern. In this study, remotely sensed data from the European Space Agency Land Use/Land Cover dataset, TAMSAT rainfall data, and MODIS NDVI dataset were used to examine changes in vegetation dynamics and monitor vegetation health in the AEZs based on the Normalised Difference Vegetation Index (NDVI). The study showed that vegetation cover has been decreasing tremendously at an alarming rate in most of the zones, while different drivers (change agents) have been responsible for the losses. The analysis shows that, between 2003 and 2018, the forestland cover gained 9,768.88 km^2 and lost 40,891.6 km^2, with a total net decrease of 31,122.73 km^2. Contribution to the net change in forestland is usually converted to wetland, urban, cropland and grassland, across the varied ecosystem. The need for up-to-date and accurate land-cover information is key to developing an appropriate mitigation strategy within the context of socio-economic sustainability across AEZs in Nigeria.

Introduction

Vegetation cover is a principal source and sink in biogeochemical interactions, so changes in the ecosystem structure, or shifts between biome, do alter the exchanges between the ecosystems and the atmosphere, with no clarity as to how such changes influence the climate (Nzabarinda et al. 2021). Climate controls the broad-scale distributions of vegetation in general, since temperature and precipitation influence the growth and development of vegetation cover (Nemani et al. 2003; D'Onofrio et al. 2020; Schulz et al. 2020). Anthropogenic factors influencing vegetation change and regional ecological services include overgrazing, urbanisation and road construction (Wu et al. 2015).

Globally, a net area of 178 million ha of forest has been lost since 1990, while the rate of loss has decreased substantially over the period 1990–2020, due to a reduction in deforestation, afforestation and the natural expansion of forests (FAO 2020). The world loses about 15 million ha of forest annually, with most deforestation in the tropical region of the developing world (EFC 2010; Nzabarinda et al. 2021). The devastation of tropical vegetation has resulted in a decline in number of plant species and natural vegetation distribution.

Africa had the highest annual rate of net forest loss in 2010–2020, at 3.9 million ha, due to the increase in deforestation rate since 1990, although there was a modest decrease in the rate in 2015–2020 compared with 2010–2015. It should be noted that most of the deforestation took place in Eastern and Southern Africa (2.20 million ha per year) and Western and Central Africa (1.90 million ha per year) to support rapid population growth, socio-economic activities and infrastructure provisions, among others (FAO 2020). In Southern, Eastern and Western Africa, there is a significant decrease in biomass production, while the central part witnessed increased vegetation activities between 1981 and 1999 (Myers 1988; Herrmann et al. 2005; Adeyewa and Aweda 2011; Anyamba et al. 2014; Schlesinger and Jasechko 2014).

Forested landmass constitutes about 12.18% of the total landmass of Nigeria, providing varied ecosystem services and sources of livelihood (Ogundele et al. 2016). Roby (1991) reported an annual deforestation rate of 400,00 ha in reserved and unreserved forests between 1976 and 1990 in Nigeria. The periods 1981–1985 and 1986–1990 witnessed deforestation rates of 3.48% and 3.57%, respectively (FAO 1992). In addition, between 2000 and 2005, the country lost 55.7% of its primary forests, and the rate of forest loss increased by 31.2% to 3.12% per annum (Ogundele et al. 2016). Furthermore, in the period 1990 to 2010, Nigeria nearly halved her forest cover, from 17,234 to 9,041 hectares (FAO 2010; FORMECU 1996). The carbon emissions from deforestation also account for 87% of the total carbon emissions of the country (Akinbami 2003). The negative impacts of deforestation due to poaching and habitat destruction (Khan et al. 2008) will severely affect Nigeria's ecosystem services and wide biodiversity of 899 bird species, 274 mammals, 154 reptiles, 53 amphibians and 4,715 species of vascular plants.

Going by the Business as Usual Scenario (BUS), the forest area of Nigeria would disappear by the end of the current decade (≈2030), based on current rates of deforestation and anthropogenic activities without an effective and efficient policymaking process, planning or investment. Thus, understanding vegetation dynamics and its response to climatic changes and anthropogenic activities is an important factor in protecting the ecosystem and curbing the imminent vegetation loss that is increasing due to the enormous human activities and urbanisation processes of recent centuries, most especially in the cities.

Such knowledge is critical for developing appropriate climate-change adaptation strategies needed to address the varied challenges that climate change and anthropogenic activities present for the environment (Jiang et al. 2017). It should be noted that vegetation phenology has a close relationship with climatic variability (Suepa et al. 2016), with rainfall being a key determinant of vegetation and crop growth, influencing the timing of plant growth and development, especially in dry, Sub-Saharan Africa. Soil moisture is an index of the portion of the rainfall that is made directly available to plants and a better indicator of the greening or increased photosynthetic capacity (Famine Early Warning Systems Network FEWS NET 2009). This has initiated several studies on vegetation responses to climate change based on climate data and Normalised Difference Vegetation Index (NDVI) time series (Li et al. 2015; Zhou et al. 2015; Yin et al. 2016).

In sub-Saharan Africa, it is evident that rainfall has a strong relationship with NDVIwith the best correlation between NDVI and rainfall belonging to that between multi-month moisture totals and NDVI lagging rainfall (Herrmann et al. 2005; Olsson et al. 2005; Sendzimir et al. 2011).

Increasingly, there are extreme weather events across the ecological zones of Nigeria associated with climate variability and change. These influence the nutrient cycles, microbial activities and physiological activities of plants (Ward et al. 1999; Odjugo and Ikhuoria 2003). This has brought about a mandatory change in both natural and human activity, triggering a shift in the various ecological zones and their respective vegetation covers (Wazis 2016).

Information needed to validate and calibrate remote-sensing data for vegetation studies at agro-ecological zone (AEZ) scale in Nigeria are unclear, uncertain and difficult for decision-makers to access without significant effort (FEWS NET 2009). Thus, this study examines the annual vegetation cover dynamics based on NDVI of the AEZs of Nigeria in the period 2003–2018, in order to provide a workable socio-economic sustainability plan within the zones and to provide information for decision-makers on issues relating to ecological protection and sustainable development in Nigeria.

Regional setting

Nigeria is located on the west coast of Africa between the Bight of Benin to the fringes of the Sahara Desert (between Benin Republic and Cameroon) region and lies between longitudes 3° E and 14° E and latitudes 4° N and 14° N (Fig. 1). Nigeria is the most populous country in Africa, accounting for approximately one-sixth of Africa's people (Akinyemi and Isiugo-Abanihe 2014; *The World Factbook* 2018, 2020).

Nigeria's most expansive topographical region is that of the Niger and Benue River valleys, which merge into each other and form a Y-shaped confluence at Lokoja (Encarta 2007). Plains rise to the north of the valleys. South-west of the Niger there is a "rugged" highland, and in the south-east of the country there are the Benue hills and mountains like Chappal Waddi (which, at 2419 m, is the highest peak in Nigeria, situated in Gashaka Gumti National Park, Taraba, towards the border with Cameroon). Coastal plains characterise the south-west and the south-east. Inland from the south-eastern coast are progressively higher regions, like the Udi Hills north-west of the Enugu escarpments with dipping rock strata. Farther east, along Nigeria's border with Cameroon, lie the eastern highlands, which are made of several distinct ranges and plateaus, including the Mandara Mountains, the Shebeshi Mountains, the Alantika Mountains and the Mambila Mountains. In the Shebeshi is Dimlang (Vogel Peak), at 2,042 m (6,699 ft).

The geographical location of the country allows it to experience nearly all the different types of weather and climate found in the West African subregion. Nigeria rainfall is characterised by the movement of trade winds and a mean annual rainfall of 1,165 mm, with low rainfall in the northern part, which gradually increases towards the southern part of Nigeria.

Temperatures across the country are relatively high with a very narrow variation in seasonal and diurnal ranges (22–36°C). There are two basic seasons; a wet season that lasts from April to October and a dry season that lasts from November until March. The dry season commences with Harmattan – a dry, chilly spell that lasts until February (Fig. 2). This period is associated with lower temperatures, and a dusty and hazy atmosphere brought about by the north-easterly winds that blow from the Arabian Peninsula across the Sahara; the second half of the dry season (Feb–Mar), is the hottest period of the year of temperature ranges of 33 to 38°C. The extremes of the wet season are felt on the south-eastern coast, where annual rainfall can

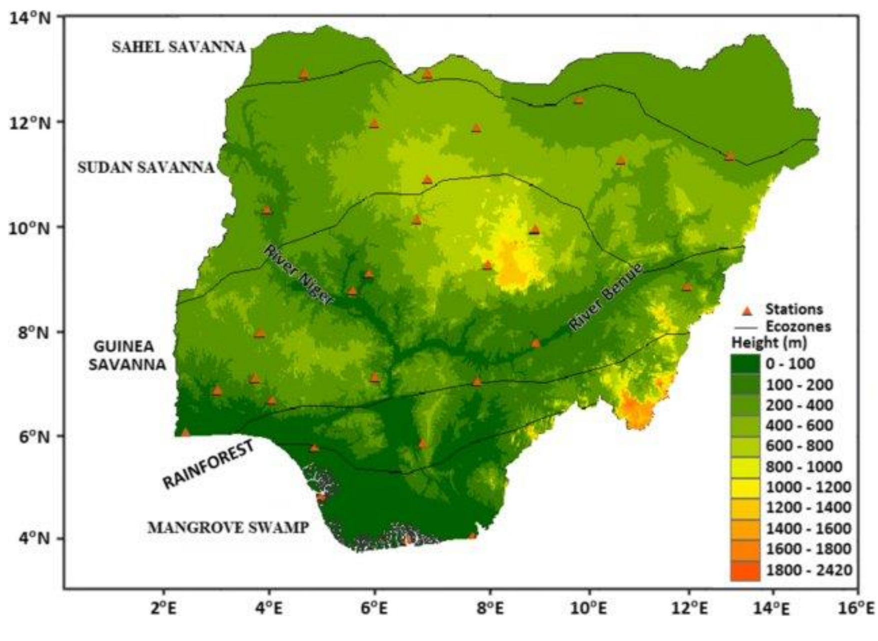

Fig. 1. Ecological zones and topography of Nigeria (Shiru et al. 2020)

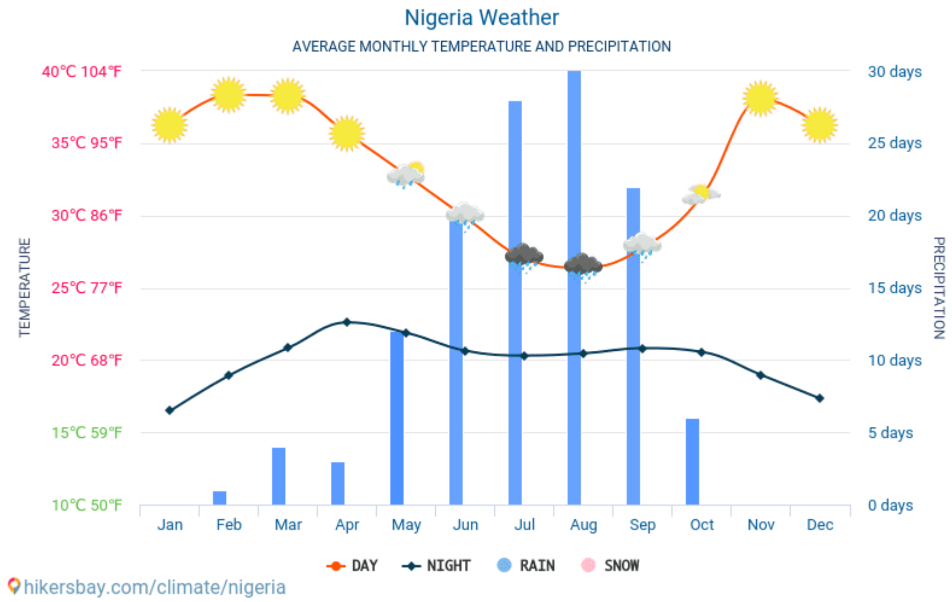

Fig. 2. Mean monthly temperature and rainfall distribution in Nigeria

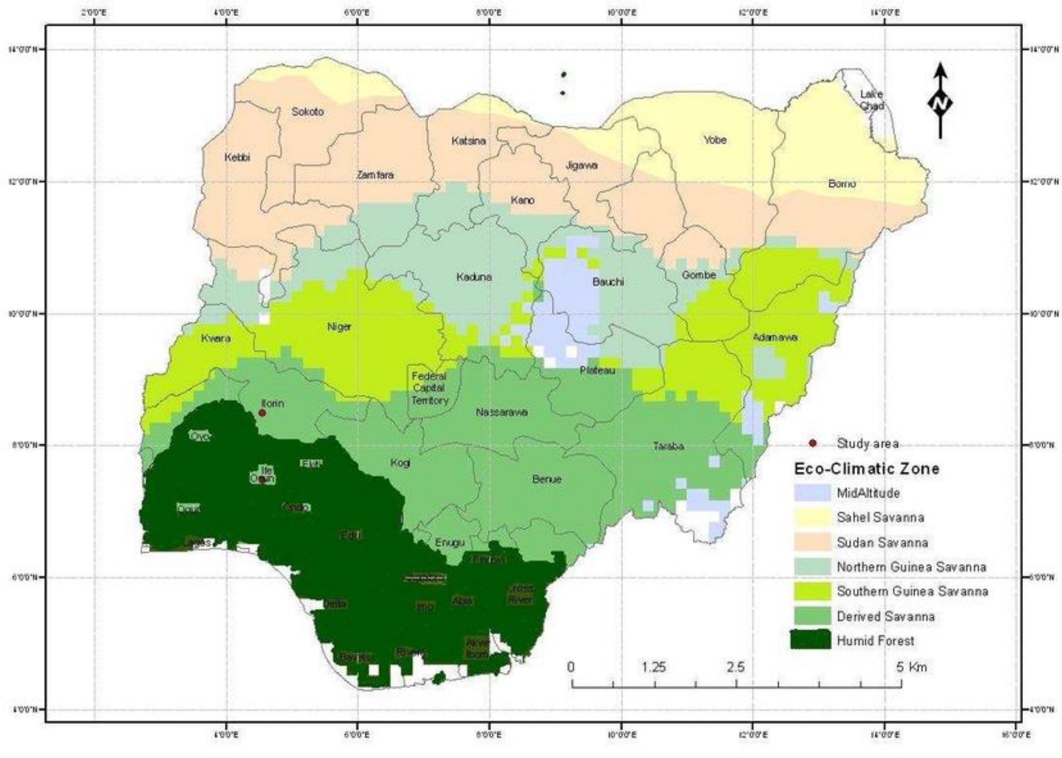

Fig. 3. Eco climatic zones of Nigeria

exceed 3,000 mm; while the aridity and high-temperature extrema of the dry season are felt in the northern third of the country (FORMECU 1998; FGoN 2018).

Nigeria has a total land area of 923,773 km^2, of which 773,783 km^2 is in the savanna zones; 75,707 km^2 is in the derived savanna zones and 133,717 km^2 is in the forest zone. The vegetation varies regionally in consonance with the climatic pattern (FGoN 2018). Thus, biogeographically, the Nigerian landscape encompasses mangrove swamps and freshwater swamp forests, and savanna communities and scrublands characteristic of the semi-arid Sahel zones (Fig. 3). Mangroves are dominated by the following tree species: *Rhizophora racemosa, R. mangle, R. harrisonii, Avicennia africana* and *Laguncularia racemosa*, while the freshwater swamp forest trees include Raphia palm (*Raphia hookerii*), *Mitragyna ciliata* and *Uapaca spp.* The Lowland Rain Forest Ecological Zone is characterised by a number of species belonging to the Sterculiaceae, Ulmaceae and Moraceae families. The Montane Region Ecological Zone consists of Mist Forest like *Polyscias ferruginea, Entandrophragma angolense, Turreanthus africanus* and *Schefflera hookeriana*, and species of Ficus and Conopharyugia. The endemic species peculiar to the Jos Plateau include *Terminalia brozenii, Morea zambesiaca* and the orchids *Disperis johnstoni* and *Disa hircicornis*. The Guinea Savanna Ecological Zone tree species include *Lophira lanceolate, Terminalia glaucescens, Daniellia oliveri* and *Uapaca togoensis*. The Sudan Savanna Ecological Zone consists of acacia species, *Ceiba pentandra* (silk cotton) and *Adansonia digitata* (baobab). The main tree species of the Sahel Savanna Ecological Zone include varieties of acacia and date palms.

Methodology

The study methodology entails the use of geospatial techniques to evaluate vegetation dynamics, sensitivity and health across the AEZs of Nigeria between 2003 and 2018. In the study, satellite remote-sensed datasets were acquired to assess the rate of transformation of land cover into land use, and change detection as well as vegetation dynamics were modelled. The Methodology Framework (Fig. 4) provides the schematic flow of the dataset and procedures used in the study.

The rainfall data were acquired from the Tropical Applications of Meteorology based on satellite data and ground-based observations (TAMSAT) at a spatial resolution of 0.0375° (https://www.tamsat.org.uk/). The Land Use/Cover dataset was acquired from the European Space Agency website of the Globe Cover of Africa at Medium Resolution Imaging Spectrometer Full Resolution (MERIS FR) level 1B data with land surface reflectance mosaics at spatial resolution of 300 m (https://www.esa.int/ESA_Multimedia/Images/2017/10/African_land_cover). The monthly MODIS (Moderate Imaging Spectroradiometer) NDVI at spatial resolution of 250 m were also obtained from the Famine Early Warning System Website (https://earlywarning.usgs.gov/fews) for the period between 2003 and 2018. The egro-ecological map for Nigeria was obtained from the Department of Forestry, Federal Ministry

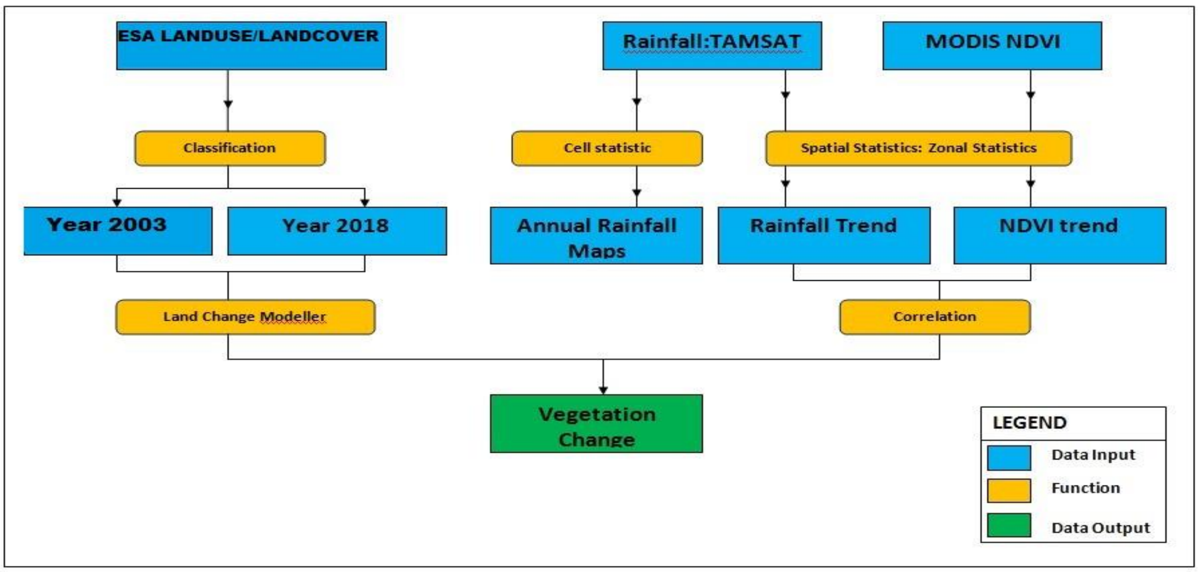

Fig. 4. Methodological framework

of Environment, Nigeria for proper delineation of the AEZs during the data processing and analysis phase (Table 1).

The data processing procedure entails the delineation of the AEZs' boundaries using Arcmap 10.6. Meanwhile, ArcGIS Spatial Analyst Multivariate tool was used in computing the seasonal rainfall pattern for the study period (1983–2018) using the cell and zonal statistics tools as expression in Eq. (I).

$$\text{Average RAIN}x = (JANRAIN + FEBRAIN + MARRAIN + \ldots DECRAIN) / 12$$

where, RAINx is rainfall for year x and JANRAIN, FEBRAIN … DECRAIN stands for RAIN of particular months in that year. The Maximum Value Composite (MVC) procedure was applied to the calculation of NDVI values at a 10-day interval to get the maximum annual NDVI in order to minimise the effects of cloudiness and/or compensate for geometrical changes in sensor view (Eq. II).

$$\text{NDVI}i = \max(\text{NDVI}ij)$$

The original NDVI values range is -2,000 to +10,000 for the MODIS NDVI data. Thus, the dataset was rescaled using the Raster calculator (which is an algebraic and mathematical operation tool within ArcMap10.6) to the expected range from -1 to +1 as quantified in Eq. (III).

$$\text{Nn} = \text{N}_0 / 10000$$

Where Nn is the New NDVI image values, and N0 = Original NDVI image values.

In addition, the Land Use/Cover was reclassified to generate six new classes for the period 2003 and 2018, in order to change detection in each of the AEZs of Nigeria. Furthermore, the Standard Precipitation Index (SPI) was computed for each AEZ, in order to estimate wet and dry conditions based on the precipitation variable. The monitoring of the wet or dry condition on a variety of time scales from sub-seasonal to inter-annual scales are easy using the SPI. The SPI is a drought index (expressed in standard deviations) that evaluates the observed precipitation's deviation from the long-term mean, for a normal distance and fitted probability distribution (McKee et al. 1993).

Results and discussion

Land Use/Land Cover Distribution

The Land-Use/Land-Cover spatial distribution across the AEZs (Fig. 5) shows incremental LU/LC changes in urban areas, wetlands and water bodies from 2003 to 2018 (Table 2) as derived from Globe Cover of Africa at Medium Resolution Imaging Spectrometer Full Resolution (MERIS FR) level 1B data. Table 3 depicts that the urban

Table 1. Data sources and characteristics

Type	Data source	Charac-teristics (Spatial Res.)	Date	Use
Rainfall	Tropical Applications of Meteorology using SATellite data and ground-based observations website (TAMSAT)	0.0375° (*c.*4 km)	1983–2018	Spatio-temporal variation of rainfall
Land use/cover	European Space Agency Globe Cover of Africa website (ESA)	250 m	2003–2018	Land use/ land cover detection
MODIS NDVI	Famine Early Warning System Website	300 m	2003–2018	Vegetation cover change
Agro-ecological map	The Department of Forestry, Federal Ministry of Environment, Nigeria			Delineating agro-ecological boundaries

Source: own elaboration

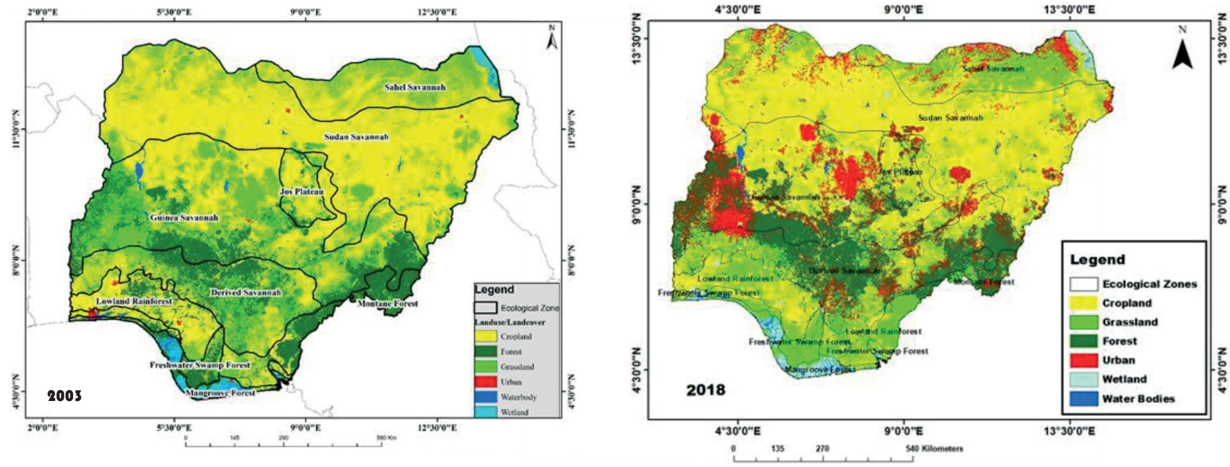

Fig. 5. Land use/ land cover pattern across agro-ecological zones in Nigeria (2003–2018)

Table 2. Land use / land cover distribution among agro-ecological zones in Nigeria (2003 & 2018)

	Class	Cropland	Grassland	Forest	Urban	Wetland	Water bodies
2003	Guinea	103,783.60	84,015.92	72,145.13	465.28	36.40	3010.11
	Sudan	260,026.20	42,986.26	3,513.95	577.92	58.87	1,709.63
	Sahel	49,136.49	32,246.29	242.26	47.20	3,695.57	347.44
	Mangrove	1,648.51	575.86	5,183.16	430.65	8,676.71	3,453.61
	Montane	229.99	1,271.92	13,374.18	2.65	7.16	1.86
	Jos	14,703.01	5,066.60	3,428.10	52.79	0	21.10
	Derived	32,091.17	31,169.33	41,252.39	560.26	61.32	815.37
	Lowland	38,217.65	8,067.29	26,977.28	862.96	93.12	125.30
	Freshwater	6‘897.41	2,019.79	11,101.73	553.79	553.79	1,044.19
2018	Guinea	94,445.93	33,058.53	75,872.10	55,807.54	1,194.21	3,078.11
	Sudan	238,179.70	37,985.01	3,900.05	25,187.97	1,837.48	1,782.54
	Sahel	29,203.41	36,316.49	47.10	15,641.23	4,165.66	341.36
	Mangrove	1,111.89	5,672.68	219.49	260.51	9,149.15	3,554.77
	Montane	112.94	2,901.69	9,841.88	2,013.61	15.80	1.86
	Jos	11,384.22	5,130.38	3,661.43	2,917.78	145.61	32.18
	Derived	19,297.17	25,405.70	46,674.87	12,385.82	1,368.77	817.53
	Lowland	31,412.77	34,514.03	5,350.65	1,035.85	1,854.85	175.44
	Freshwater	4,886.47	14,104.41	527.88	472.67	1,149.49	1,029.76

Source: own elaboration

area (comprising human habitation developed for non-agricultural uses like building, transport and communication) increased from 3,553.50 km² (2003) to 115,722.97 km² (2018), with a net addition of 112,169.48 km². This is due to urban expansion and population increase in this study area during the study period. The wetland ecosystem of permanently or seasonally flooded areas increases from 13,182.95 km² (2003) to 20,881.04 km² (2018) with a net increase of 7,698.09 km². Waterbodies (comprising river system, lakes and smaller pools of water and, more rarely, puddles) increase from 10,528.62 km² (2003) to 10,813.56 km² (2018) with a net increase of 284.94 km². Net decreases of 76,699.42 km², 12,330.36 km² and 31,122.73 km² were recorded for crop, grassland and forestland cover, respectively. The land-use/land-cover (%) distribution (Fig. 6) across AEZs (Fig. 7) in 2003 shows that the Sudan Savanna (51%), and the Montane forest (5%) AEZs had the maximum and minimum cropland. The Guinea Savanna (41%) and Mangrove forest (28%) AEZs recorded the highest and lowest grassland. Sahel Savanna (14%) and Guinea Savanna (41%) AEZs had the minimum and maximum total forest cover, respectively.

The lowland rainforest and the montane forest AEZ constitute about 24% and 7% of the total urban land use, respectively. The mangrove forest and montane forest AEZs constitute about 33%

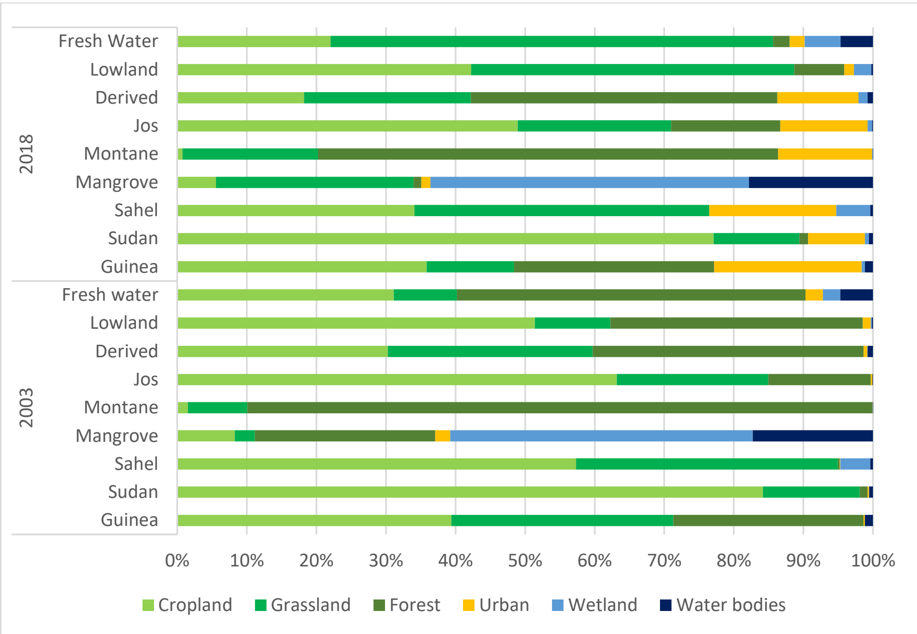

Fig. 6. Land use / land cover (%) distribution across agro-ecological zones

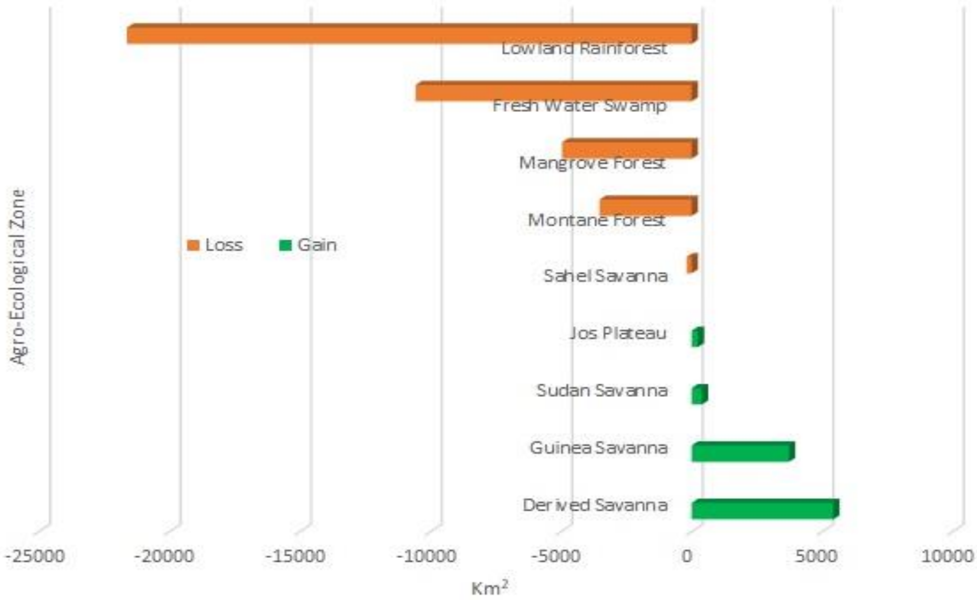

Fig. 7. Net change in forestland (2003–2018) in agro-ecological zones (Nigeria)

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Table 3. Land use/ land cover distribution

Land use / land cover	Area (km²)		Change (km²)	Percentage change
	2003	2018		
Cropland	506,733.95	430,034.53	-76,699.42	-15.14
Grassland	207,419.27	195,088.91	-12,330.36	-5.94
Forest	177,218.18	146,095.45	-31,122.73	-17.56
Urban	3,553.50	115,722.97	112,169.48	3,156.59
Wetland	13,182.95	20,881.04	7,698.09	58.39
Water bodies	10,528.62	10,813.56	284.94	2.71

Source: own elaboration

and 2% of the water bodies, respectively. Mangrove forests constitute about 67% of the wetland.

Based on the 2018 land-use/land-cover distribution across the AEZs, the Sudan Savanna (55%) and the Montane Forest (3%) AEZs had the highest and lowest cropland, respectively. The maximum and minimum grassland are recorded in the Sudan Savanna (19%) and Montane Forest (2 %) AEZs, respectively. The Guinea Savanna and Sahel Savanna AEZs constitute about 52% and 3% of the total forest cover, respectively. The Guinea Savanna (48%) and the Mangrove Forest (2%) had the highest and lowest corresponding wetland. Highest and lowest urban land use were estimated in Mangrove Forest (44%) and Montane Forest (1%) AEZs, respectively. Mangrove Forest (33%) and Montane Forest (2%) AEZs had the highest and lowest water bodies.

The net change of forestland cover between 2003 and 2018 depicts gains (9,768.88 km^2) and losses (40,891.6 km^2), with a total net decrease of 31,122.73 km^2. Forestland cover gain was recorded in the Derived Savanna (5,422.48 km^2), Guinea Savanna (3,726.97km^2), Sudan Savanna (386.10 km^2), and Jos Plateau (233.33 km^2) AEZs. The Derived Savanna is losing its primary forest to secondary growth forest while Guinea Savanna and Sudan Savanna gained from the conversion of forestland to woodland, and Jos Plateau benefits from undisturbed upland forestland. Forestland cover losses are recorded in the Freshwater Swamp (10,573.9 km^2), Lowland Rainforest (21,626.6 km^2), Mangrove Forest (4963.67 km^2), and Montane Forest (35,32.3 km^2) as well as Sahel Savanna (195.16 km^2) AEZs (Fig. 7).

The unprecedented land-use changes result from the need to meet the socio-economic development of the growing population and related land governance issues being addressed with no consideration for environmental preservation. These issues, among others, have been considered as the cause of the unprecedented large-scale land depletion and degradation pattern, most especially in sub-Saharan Africa (David 2008; United Nations Environmental Programme (UNEP) 2012; Osunmadewa et al. 2016; Mustapha 2020). The region has also been known to suffer from both natural (Sahalian drought, climate change) and anthropogenic factors.

Rainfall distribution across AEZs in Nigeria

The annual rainfall shows that the major rainfall patterns are generally oriented from the Mangrove Forest to the Sahel Savannah, with maxima and strong rainfall gradients along the Lowland Rainforest and the Montane Forest, decreasing upward to the Sahel Savannah with rainfall ranging between 120 mm and 1,000 mm. Generally, rainfall decreases with latitude with essentially zonal isohyets in West Africa. (Nicholson 2000). In addition, the Montane Forest, Mangrove Forest, Freshwater Swamp and Lowland Rainforest zones receive high amounts of rainfall compared to the Sahel and Sudan Savanna AEZs, which experienced very low annual rainfalls of 531.30 mm and 776.40 mm, respectively. In general, the rainfall trend shows that there was a dry spell across the AEZs in the year 1985. Popoola et al. (2020) noted that rainfall amounts were generally high in the equatorial/

mangrove climatic zone, which is characterised by maxima double those of other climatic zones (i.e., Sudano-Sahelian, Guinea Savanna and Montane). The increasing rainfall in the coastal zones (Fig. 8) may be partly responsible for the increase in flood events devastating the coastal cities of Warri, Lagos, Port Harcourt and Calabar, while the low rainfall zones of Sudan and Sahel regions and some parts of Guinea Savannah regions are subjected to drought (Odjugo 2010; Akinsanola and Ogunjobi 2014).

The rainfall standardisation index (Fig. 9) for the study period (1983–2018) shows that, on average, the year 1986 was the driest (-2.47) while the wettest year is 1998 with an index of 1.59. During the specified period, on average, the ecosystem mostly experienced near normal (78%), followed by moderately wet (14%) conditions, while frequency of extremely dry, moderately wet and severely wet conditions were 3% each. The driest ecosystem remains the Sudan Savanna with an extremely dry index of -3.14 (1986), while the Mangrove Forest with an index of 2.98 (extremely wet conditions) was the wettest in 2018.

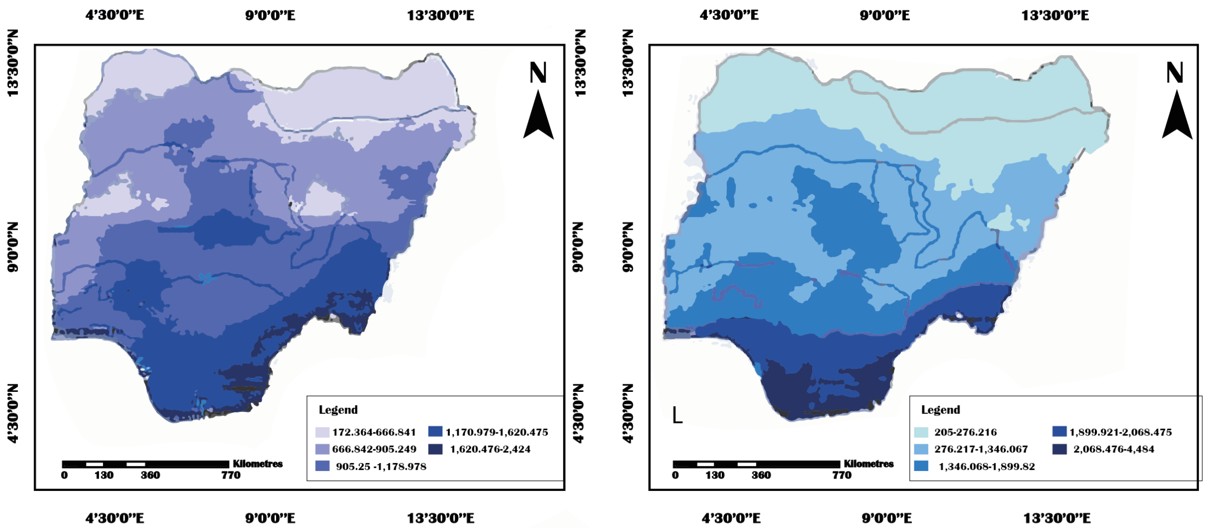

Fig. 8. Rainfall distribution across agro-ecological zones in Nigeria

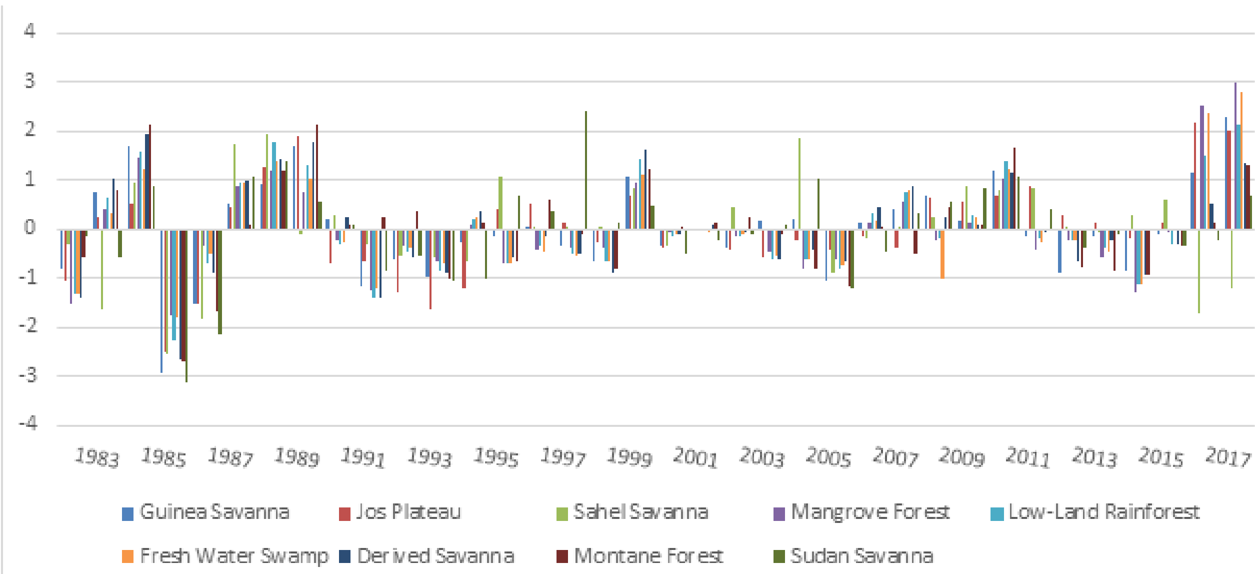

Fig. 9. Standardised rainfall index across agro-ecological zones in Nigeria (2003–2018)

NDVI distribution across AEZs in Nigeria

The healthiness quality index as depicted by the NDVI (Fig. 10) of the agro-ecological zones (AEZs) for the study period (2003–2018) shows averages of 0.39 (±0.12) and 0.35 (±0.1) for 2003 and 2018, respectively. In 2003, the Lowland Rainforest recorded the highest NDVI (0.56) followed by the Freshwater Swamp and the Mangrove Forest which had 0.52 and 0.47, respectively. Montane Forest, Derived Savanna, Guinea Savanna and Jos Plateau had 0.45, 0.42, 0.33 and 0.32, respectively. Sudan and Sahel Savanna had the lowest, at 0.26 and 0.22, respectively. Freshwater Swamp (0.48) had the highest NDVI in 2018, followed by the Lowland Rainforest (0.45), Mangrove Forest (0.45), Montane Forest (0.44), Jos Plateau (0.28), Guinea Savannah (0.28), Sudan Savannah (0.23) and Sahel Savannah (0.22). The NDVI standardisation index (Fig. 11) for the period 2003–18 shows that, on the average, a declining change in vegetation growth and vegetation health was also evident in 2005 (-1.84), while the 2013 conditions (1.82) depict growth and healthier vegetation. The AEZs of concern, as evident in the NDVI standardisation, include Freshwater Swamp

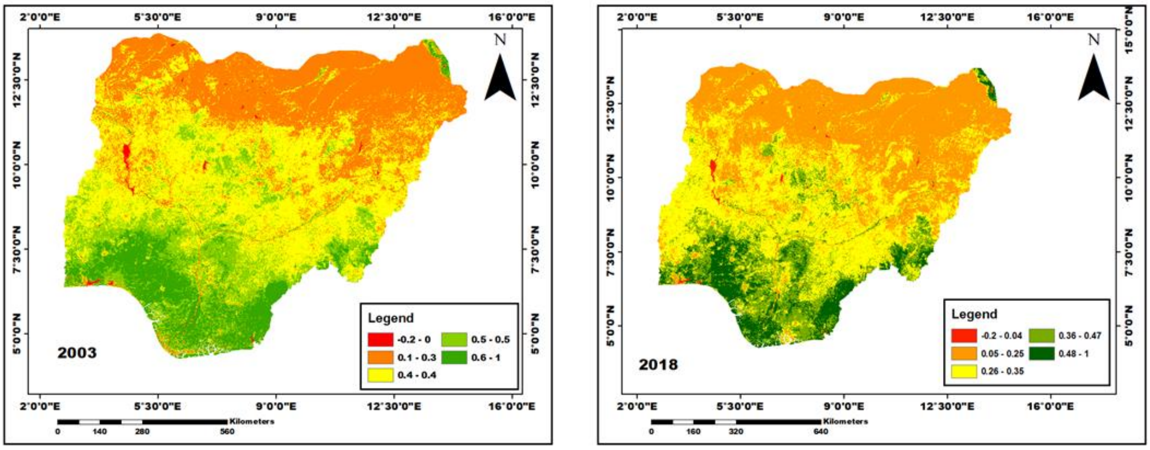

Fig. 10. NDVI distribution in Nigeria (2003–2018)

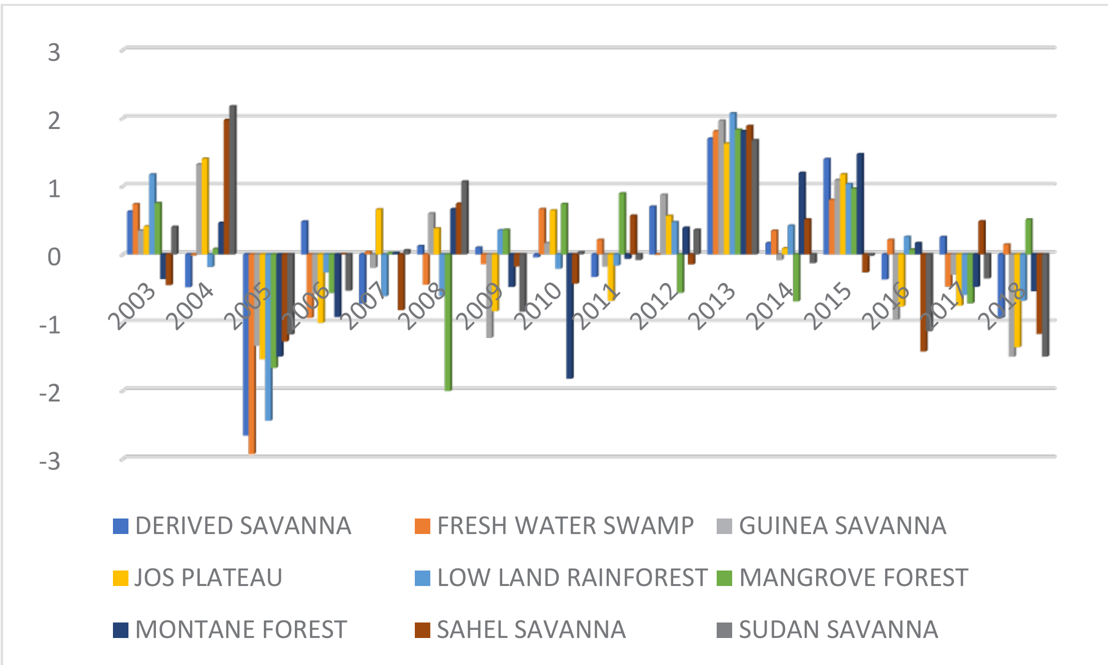

Fig. 11. Standardised NDVI index across agro-ecological zones in Nigeria (2003–2018)

(-2.93), Derived Savanna (-2.66), Lowland Rainforest (-2.44) during 2005, and Mangrove Forest (-2.00) in 2008. The Sudan Savanna region mainly consists of dispersed and degraded vegetation, as a result of seasonal drought and erratic rainfall patterns. It is a corridor of deciduous plants (Mustapha 2020). Interannual NDVI variability is higher in the Savanna and Sahelian but lowest in Forest, Mangrove and Derived Savanna regions (Adepoju et al. 2019). This is attributed to both rainfall variability and anthropogenic activities such as overgrazing of animals and poor agricultural planning in the zones. The vast loss of vegetal covers in the Guinea Savanna and Montane Forest may be associated with changes in land cover induced by human activities such as deforestation (tree harvesting), urban expansion, poor agricultural plans, and the creation of artificial ponds and lakes (Wiens 2016; Brandt et al. 2017; Mustapha 2020).

Conclusion and recommendation

This study shows that vegetation covers are being depleted at an alarming rate in the southern zones. Major land-cover changes in agro-ecological zones (AEZs) in Nigeria include agricultural activities in northern savannas while in the southern zones, activities like urban expansion, deforestation, lumbering and agricultural are evident. The Sudan and Sahel Savanna AEZs had the lowest NDVI values, which accounts for the poor vegetation health. The major drivers of vegetal change in the northern zones are rainfall variability and human induced activities, while the southern zones are experiencing urban expansion and massive deforestation. The unprecedented rate of plant species loss has a significant impact on the ecosystem well-being, resulting in a varied degree of environmental conflicts (Chuai et al. 2013; Hula and Ukpong 2013). It is obvious that rainfall is an active driver of vegetal cover change in the AEZs. It was further concluded from the study that temporal variations of NDVI are closely linked with precipitation, and that timely monitoring of the vegetal cover can be achieved with the aid of remote sensing.

There is a need for appropriate land-use/land-cover information and climate-change-mitigation strategies tailored for appropriate land-use planning. Such plans must address a comprehensive vegetation monitoring scheme using geospatial technology. There is a need to provide suitable guidelines on afforestation and reforestation strategies. Reforestation and afforestation should be practised to ensure the replenishment of forest reserves through the allocation of designated areas for green preservation, while an alternative source of energy should be explored to reduce pressure on plants, and legal government enforcement should be put in place to tackle the illegal destruction of the green reserve. This is necessary considering the roles of vegetation cover across the zones and their significant impact on the ecosystem and need for good land-use practices.

Disclosure statement

No potential conflict of interest was reported by the author.

Author contributions

Study design: OA; data collection: OAded, OL; statistical analysis: OA, OL; result interpretation: OA, OL; manuscript preparation OA, OL, OAk; literature review: OA, OL, OAk.

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