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Full Length Research Paper

Microbiological quality of stream and borehole water in Lushoto District, Tanzania

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A study was conducted to assess the microbiological quality of water in two streams and three boreholes from Sunga and Mbaru wards in Lushoto district, Tanzania. Water samples were collected in duplicate from the streams and boreholes. Three locations were selected along the stream including unpopulated forest areas, highly populated and less populated areas both with agricultural activities. Analysis of data was done by R-Software and means separated by Turkey's honest significance test at p<0.05. Significant differences (p<0.05) in *Escherichia coli* and *Salmonella* contamination were observed along the three locations of the streams. Although the unpopulated forest areas were not contaminated by either microorganism except for one sample, the rest of the areas were contaminated. Highly populated agricultural areas were found to be contaminated by *E. coli* and *Salmonella*, followed by the less populated agricultural areas. Generally, water samples from the streams failed to meet the TZS 789 Standard and WHO 2011 water guidelines, a risk to water borne disease outbreaks. With the exception of *E. coli* from boreholes in Madukani, all other borehole water samples were within the limits stipulated in both the TZS 789 Standard and WHO 2011 Guidelines. Communities should be warned about the dangers of water contamination especially at the sources. In addition, water should be treated regardless of its source to improve its safety and quality for human consumption.

Key words: Water, *Escherichia coli, Salmonella* species, safety, quality, contamination, WHO.

INTRODUCTION

In spite of its official recognition by the United Nations in 2010, the human right to water remains a contested notion (Fantini, 2020). Consuming safe drinking water is a challenge in many areas especially in the developing countries (Treacy, 2020). It is reported that one in three people globally do not have access to safe drinking water (WHO, 2019). About two thirds of drinking water consumed worldwide is derived from various sources such as lakes, stream, rivers and open wells. On global perspective, groundwater offers potable water to about

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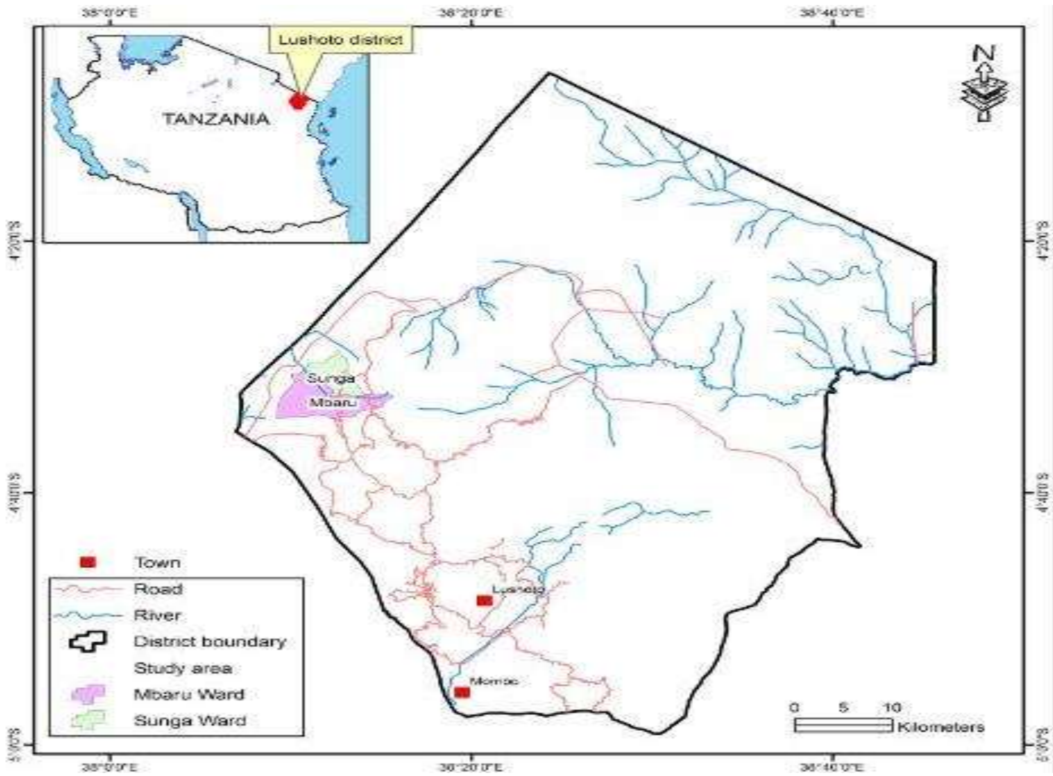

Figure 1. A map showing Sunga and Mbaru wards in Lushoto districts of Tanga, Tanzania.
Source: Wickama et al., 2014) with modifications.

1.5 billion people daily. Groundwater has an important role in improving health in sub-Saharan Africa (Lapworth et al., 2017). These sources however, can easily be contaminated by sewage discharges or fecal contamination from domestic or wild animals (WHO, 2019). Natural water is susceptible to microbial and chemical contamination as well as other pollutants regardless of the source (Onyango et al., 2018). Consumption of contaminated water can cause illnesses like diarrhea, dysentery, and gastroenteritis to infants, young children and the elderly (Bharadwaj and Sharma, 2016). Waterborne diseases account for 23,900 deaths per year and the most affected people are children under 5 years of age (Elisante and Muzuka, 2016). *Escherichia coli* compromises the safety and quality of water consumed by people worldwide (Lukubye and Andama, 2017). The presence of *E. coli* and Enterobacter species in water is considered as a possible indicator of the presence of pathogens like *Clostridium pefringens*, *Salmonella* species and protozoa. In developing countries, illness and mortality due to waterborne Salmonellosis has increased (Lyimo et al., 2016). The current study therefore focused on the assessment of the microbial quality of water sources especially those accessible by communities in the rural areas to ensure consumption of safe water.

MATERIALS AND METHODS

This study was carried out in Lushoto District, Tanga Region in Tanzania. Water samples were obtained from Shagayu and Daa streams in Mbaru and Sunga wards, respectively. Borehole water was also obtained from the same wards. Lushoto District is situated in the Northern part of Tanga Region. It lies between latitude 4°25 and 4° 55'S, and longitude 30° 10 and 38°35E (Figure 1). It is one of the eight districts of Tanga Region, with a total area of 4092 km^2 (URT, 2013). The main sources of water for the district are springs, streams and boreholes, where streams flow down the slopes of Usambara Mountains (URT, 2013).

Previously, these streams were flowing throughout the year but recently the volume of water tends to decrease especially during the dry season (Personal observation). Changes in water quantity are attributed to replacement of natural forests by pine plantations as well as deforestation.

Materials used for this study were water samples from boreholes and streams in the two wards. Other materials included, weighing balance-Model PL202-S (Mettler Toledo, USA) cool box, distilled water, filtration system-Bio vac Model 331/631 (Rocker scientific, India), micro filter 0.45 um, Petri dishes, measuring cylinder, pipettes, bottles (glass and plastic), and Incubator- Memmert (Fisher scientific, German).

Study design

Cross sectional design was used in this study for collection of water samples from both the stream and boreholes. Water samples were analysed for *E. coli* and *Salmonella* to assess microbiological safety.

Sampling plan and data collection

Water samples were collected from Shagayu and Daa streams and boreholes in Mbaru and Sunga wards in Lushoto district, Tanzania. A total of 24 samples were collected from the streams in duplicates at three points namely the forest area, populated area with agricultural activities, less populated area with agricultural activities from each village. Duplicate samples were also collected from three boreholes found in each ward, making a total of 24 samples. The boreholes had been fitted with taps/nozzles to allow dispensing of water. Groundwater is pumped from underground through pipes. Taps are fitted at the exit to allow water to be conveniently filled/dispensed into the containers. Before collection of water from the boreholes, the pipe/nozzle was swabbed with cotton wool soaked in 70% v/v ethanol and allowed to run for 3 min. The aim was to sterilize the taps/nozzles before drawing representative water samples for microbiological analysis. All water samples were collected in the morning. They were kept in clean transparent sterile autoclavable glass bottles, with a capacity of 500 mL. Sampling was carried out during the dry season from November to December 2018. Samples were stored in an insulated cool box maintained at 0 to 4°C and transported to Tanga Water Authority Laboratory for microbiological analysis.

Method of analysis

All samples collected from both the stream and borehole water were analysed in triplicates. The aim was to minimise errors and obtain representative samples.

Detection and enumeration of *E. coli*

Enumeration of *E. coli* in borehole and stream water samples was determined according to ISO method no. 9308-1 (2014) *Enumeration of Escherichia coli and coliform bacteria Part 1: Membrane Filtration method for water with low bacterial background flora*. Results were expressed in cfu/100 mL.

Detection of *Salmonella* spp.

Salmonella was determined according to standard operating procedure ISO method no. 19250 (2010) *Water Quality-Detection of Salmonella* spp. Results were expressed in cfu/100 mL.

Statistical analysis

Nested design was applied using the following model:

$$Y_{ijk} = \mu + \beta_j + \alpha_{(j)i} + \varepsilon_{ijk}$$

and

$$Y_{ijk} = \mu + \lambda_k + \rho_{(k)\chi} + \varepsilon_{ijk}$$

where Yijk = dependant variable, μ= general mean, βj= 1, 2, (stream), α (j)i = 1, 2,3 (effect of location nested within stream), λk = 1,2 (ward), ρ (k)χ= (effect of borehole nested within the ward), and εijk= random error.

Data was analyzed by R statistical package software. Nested design was applied on the stream and boreholes water to determine the effect of location nested within a stream and effect of boreholes water in the wards. In addition, analysis was carried out to find if there were significant differences between the location within the stream and/or boreholes water between the wards. Means were separated using Tukey's Honest significance test at p<0.05.

RESULTS AND DISCUSSION

Location nested within and between the streams

Table 1 summarises the mean count for *E. coli* and *Salmonella* spp. which were expressed in cfu/100 mL. It also compares the microbiological parameters obtained with the TZS 789 (Tanzania Bureau of Standards, 2016) and WHO 2011 Guidelines as indicated in the table.

Prevalence of *E. coli* and S*almonella* among the stream water found in two wards

E. coli is a member of total coliform group of bacteria that is found only in the intestines of mammals, including humans and animals. The presence of *E. coli* in water indicates recent fecal contamination and may also indicate the possible presence of disease causing pathogens, such as bacteria, viruses, and parasites.

Results obtained revealed that 83% (5 out of 6 locations along the streams) of the samples collected from the two streams (Shagayu and Daa) within the three locations (forest, highly populated and less populated areas with agricultural activities) were contaminated by *E. coli* whereas only 17% (1 out of 6 locations) of samples were free from *E. coli*.

Furthermore, the mean results for *E. coli* obtained from two streams ranged from 0 to 18.00±1.79 cfu/100 mL (Table 1). Significant differences in *E. coli* contamination (p<0.05) was observed in the three locations. Samples collected from forest areas in both streams were lower and significantly different in microbial contamination at p<0.05 from all other areas (highly populated and less populated with agricultural activities). It was generally observed that samples collected from the highly populated agricultural areas had the highest microbial load. Although a low *E. coli* count (< 2 cfu/100mL) was observed in forest sample collected from Daa stream, none was detected from forest sample in Shagayu stream. Non detection of *E. coli* observed at the source (forest) confirms lack of human activities/settlement and animals which could contribute to fecal (*E. coli*) contamination. The detection of *E. coli* at the source in Daa stream might be associated with wild animals which could defecate directly into water bodies and pollute water. Researchers from Lesotho also found *E. coli*

Table 1. Mean colony count *of E. coli and Salmonella* spp. found in Daa and Shagayu streams in Lushoto district, Tanga.

Stream	Locations	Microbiological Parameters (cfu/ 100 mL)	
		E. coli	***Salmonella* spp.**
Daa	Forest	1.67±0.52[a]	*0.00±0.00[a]
	Less populated	9.33±1.63[b]	7.67±1.51[b]
	Highly populated	10.33±2.34[b]	7.33±1.63[b]
	Mean	7.11±4.28	5.00±3.83
Shagayu	Forest	*0.00±0.00[a]	*0.00±0.00[a]
	Less populated	7.67±1.51[b]	1.67±0.52[a]
	Highly populated	18.00±1.79[c]	11.00±2.09[c]
	Mean	8.56±7.69	4.61±4.47
TZS 789 Standard		Absent	Absent
WHO 2011 Guidelines		Absent	Absent

Values in the same column having the same superscript letters are not significantly different (p > 0.05) (Tukey's Honest). *Complied with the Standards/Guidelines.
Source: Authors

contamination in various water sources (Gwimbi et al., 2019*)*. Detection of *E. coli* at the forest in this study also corroborates with a study by Goto and Yan (2009) who reported *E. coli* contamination in Manoa stream, Hawaii which was adjacent to the forest. A study by Rochelle-Newall et al. (2016) that was carried out in Laos, Thailand and Vietnam also found *E. coli* contamination in the stream. The researchers concluded that vegetation type, through land use and soil surface crusting, combined with mammalian presence play an important role in determining the presence of *E. coli*.

E. coli contamination at Ludende village in Shagayu stream was twice of that observed at Kwamamkoa which is a highly populated agricultural area. Contamination at these areas might be due to poor water management and exposure to contamination from human or animal wastes. In addition, the behavioral and hygienic practices of the community members might also be the contributing factors. During the survey, it was observed that communities in the study area used stream water for bathing and washing clothes. This would eventually contribute to water contamination. Application of cattle manure was also observed among farmers near both streams. This could also contribute to the presence of *E. coli* to the nearby stream since cattle are commonly considered as a principal reservoir of *E. coli.*

Similar results were obtained by other researchers who analysed water samples near agricultural areas (Johnson et al., 2003). Davies-Colley et al. (2004) found high concentrations of *E. coli* in stream water of Sherry River, New Zealand which was near agricultural area. In addition, the finding by Garcia-Armisen and Servais (2007) in stream water of Seine River which was adjacent to agricultural area indicated high number of *E. coli* with mean value of 47 cfu/100 mL. *E. coli* was found in water from areas with intense agricultural activities in South America

Moreover, water samples collected from Komboheo and Kumbamtoni which are less populated agricultural areas, were contaminated by *E. coli*. Contamination of water by this pathogen was not surprising since the area is surrounded by some human settlements where livestock keeping and crop cultivation are practiced. Hence, *E. coli* could be attributed to discharge of livestock feacal waste and other sewage wastes from the settlements. Comparing the mean value of *E. coli* from both streams, it showed that both were contaminated by *E. coli* as indicated in Table 1. However, with exception of samples collected from forest in Shagayu stream, the average concentration of *E. coli* at three locations in two streams complied with neither the Tanzania Standard TZS 789 (Tanzania Bureau of Standards, 2016) nor the WHO Guidelines (2011) which state that *E. coli* should not be detected in drinking water. Therefore, with regard to *E. coli,* water from both streams is not safe for human consumption.

The presence of *Salmonella* spp. in community water is of great concern hence was tested in the current study. Results obtained from the two streams ranged from 0 to 11 cfu/100 mL. About 33% of samples tested in two streams were free from *Salmonella* and these had been collected from the forest, while 67% of samples detected *Salmonella* from the rest of locations. There were significant differences (p<0.05) in *Salmonella* spp. count among the three locations (forest, highly and less populated agricultural areas) of the streams. However, no

Table 2. The mean colony count (cfu/100 mL) for *E. coli* and *Salmonella* from borehole water located in Sunga and Mbaru wards in Lushoto district.

Ward	Location	Microbiological parameter (cfu/100 mL)	
		E. coli	***Salmonella* spp.**
SUNGA	Alufea	ND	ND
	Madukani	*2.00±0.63[a]	ND
	Kwemashu	ND	ND
MBARU	Ludende	ND	ND
	Masereka	ND	ND
	Chambogo	ND	ND
	TZS 789 Standard	Absent	Absent
	WHO 2011 Guidelines	Absent	Absent

Values in the same column having the superscript letters are significantly different ($p < 0.05$) (Tukey's Honest). cfu-Colony Forming Unit, ND-Not detected. *****Failed to meet standards.
Source: Authors

significant differences (p>0.05) in *Salmonella* between water samples collected from the forest in both streams and those from less populated area with agricultural activities (Shagayu streams) were observed, except for low detection at Kumbamtoni. *Salmonella* was not detected in samples from the forest in both streams most probably due to lack of human activities. Moreover, the detection of Salmonellae at Kumbamtoni might be associated with application of organic manure which is released into nearby stream due to irrigation practices done by farmers. Samples collected from highly populated agricultural areas in both streams were heavily contaminated by *Salmonella*. This could be due to sewage discharges from the household and application of organic manure to farms. A study by Patchanee et al. (2010) found that 58.8% of water sample collected at different streams which were near residential areas and 50% near agricultural activities were contaminated by *Salmonella*. Other observations regarding *Salmonella* contamination in various streams due to agricultural activities have been reported by Walters et al. (2011) in California; Johnson et al. (2003) in Canada; and Poma et al. (2016) in Bolivia. Water from both streams were above the limit as per TZS 789 (Tanzania Bureau of Standards, 2016) and WHO Guidelines (2011), with regard to *Salmonella* and hence not safe for human consumption.

Generally, water contamination by *E. coli* and *Salmonella* in both streams, especially in agricultural areas (both populated and less populated) is associated with poor agricultural practices and poor hygienic conditions. This is especially for communities living in populated areas located upstream. As a result, people consuming water downstream are also at risk of waterborne diseases. It is therefore important to preserve and conserve water sources so as to rescue community members living around these areas.

Prevalence of *E. coli* and *Salmonella* among the borehole water in the two wards

Results for the microbiological parameters from the six boreholes studied between the two wards are presented in Table 2. These results summarize the mean colony counts for *E. coli* and *Salmonella* which were expressed in cfu/100 mL.

The mean results obtained for *E. coli* varied from not detected to 2.00±0.63 cfu/100 mL. *E. coli* contamination was only detected in water samples collected from Madukani area in Sunga ward. No *E. coli* contamination was detected in Mbaru ward. The *E. coli* contamination in the water samples from Madukani might be attributed to close proximity to an open pit/hole which was clearly visible during the survey. The hole was contaminated by animal feaces and other wastes which were dumped into it. The same hole had previously been used as a source of water (it was left open and hence contaminated). In addition, farming activities such as application of organic manure was observed in the area. All these could seep into the soil and end up in the borehole. Furthermore, some researchers argue that the presence of rusty pipes used in water distribution might allow seepages of microbial contaminants into the borehole (Adogo et al., 2016). Several researchers have documented *E. coli* contamination in borehole water (Obioma et al., 2017; Bashir et al., 2018; Bekuretsion et al., 2018; Lutterodt et al., 2018; Takal and Quaye-Ballard, 2018).

A study by Thani et al. (2016) in Kenya reported 18.75, 14.3 and 65.8%, respectively for *E. coli* contamination in borehole water. The presence of *E. coli* in drinking water is a risk to public health since the bacterium causes human illness such as diarrhea in both children and adults (McNarnan, 2017; Elfaday et al., 2018; Taonameso et al., 2018). *E. coli* was not detected in water samples collected from most of the boreholes. Other researchers did not detect *E. coli* contamination in borehole water (Kanyerere et al., 2012; Bello et al., 2013; Isa et al., 2013). Since the presence of *E. coli* is associated with faecal contamination, its absence indicates that these boreholes were well positioned to prevent water contamination. All boreholes in both wards were constructed around the same area roughly between 200 and 300 m from human settlements.

Results indicated that none of samples collected from boreholes in both wards were contaminated by *Salmonella*. Although some researchers (Izah and Ineyougha, 2015; Palamuleni and Akoth, 2015; Takal and Quaye-Ballard, 2018) detected *Salmonella* from borehole water samples collected, this was not the case in the urrent study. A study by Nwandkor and Ifeanyi (2015) in Nigeria indicated that out of 50 borehole water samples tested for *Salmonella* only one was contaminated, due to shallow depth. Comparing the wards, boreholes found in both wards were free from *Salmonella* hence complied with both TZS 789 (Tanzania Bureau of Standards, 2016 and WHO Guidelines (2011). It may thus be concluded that all the boreholes in the study location had water that was free from *Salmonella* contamination hence safe as far as this pathogen is concerned.

Conclusion

Microbiological parameters tested indicated that both streams near populated and less populated agricultural areas were contaminated by *E. coli* and *Salmonella*. There was no contamination by *Salmonella* in the borehole water samples, whereas *E. coli* contamination was observed only for samples from Madukani borehole water. Water safety and quality can only be successful upon engagement of relevant government authorities and community members in programs such as good agricultural practices and good hygienic practices to prevent water contamination.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Ecosystem modification and land use change in South East Nigeria: Realities and prospects for conservation

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Ecosystem modification is increasing in scale and presents the need to provide suitable conservation strategies to address dearth in policy guidelines. This work elucidated the dynamics of land use change, prevalent forest use and policy, and conservation strategy. Geometrically rectified satellite imagery data were processed for 40 years; covering three epochs. Questionnaires were distributed across four locations: 50 questionnaires per location. Results of land use change showed that vegetation cover changed from 11666.6 ha to 6067.2 ha; bare surface: 2833.8 to 1831.4 ha; built up: 1084.4 to 6378.1 ha; farmland: 81.1 to 1407.5 ha and water body: 25.5 to 5.9 ha. Built up area had much land use change gains while vegetation cover recorded much loss. Results showed that individual ownership of forest areas dominated the area. As much as 83% are not aware of rules guiding forest use, details are neither known to a vast majority (88%), nor were the people's interests considered when making such rules (up to 84%). Principal component analysis showed strategies for promoting conservation: Making and enforcing laws ensuring forest loss reduction, regulation of forest resource use and awareness on the implications of overharvesting, establishing small reserves, planting new forests and inclusion of local people in management.

Key words: Biodiversity, forest management, land use change, tropical ecosystem.

INTRODUCTION

Ecosystems provide the basis for existence and help to achieve multiple development objectives across different landscapes. However, they are lost and modified at alarming rates such that only about 39% of land has not been affected by human use and as much as 265,000 km^2 of that small proportion are lost each year (De Palma et al., 2018; Hurtt et al., 2020). Such alterations by humans has indeed led to loss much of terrestrial habitats (Estrada et al., 2017) and ultimately reduced/ affected the ecosystem services and functions of such

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landscapes. Indices that contribute to the decline experienced in ecosystems abound and are quite varied across spatial scales. These are mainly seen as direct drivers and are grouped into categories such as expansion of infrastructure, agricultural expansion and wood extraction (Geist and Lambin, 2001). Agriculture seems to be increasing in scale due to a growing human population with escalating need for food, energy and fibre, and consequent pressure and degradation of ecosystems (Foley et al., 2005; Drescher et al., 2016). With such trends, agriculture is seen as key driver of deforestation and loss especially in the tropics (Gibbs et al., 2010). However, since the drivers of forest loss vary regionally and change over time (Rudel et al., 2009; Hosonuma et al., 2012), more attention is needed to understand the dynamics at such scales in order to holistically address arising concerns.

While these realities in loss of biodiversity and altered ecosystems are of global concerns, the rates at which they occur vary across ecosystems and landscapes. Developing countries and landscapes are at the epicentre of such losses and equally lack detailed information on the drivers of deforestation and forest degradation (Hosonuma et al., 2012). As a result, forest losses are still ongoing at scales that are alarming with no concrete timeline or strategy on abating such trends. Much of sub-Saharan Africa including Nigeria is characterized by such scenarios and their ability to render ecosystem services-particularly the provisioning and regulating services are much hampered. Across south east Nigeria, pressure on forest landscapes appear intense and worrisome. With a high population density and a small total land area, human impacts on the ecosystem are quite visible and debilitating. Forest reserves and protected area in the zone are highly degraded, overtaken by agricultural activities, settlements and fragmented by anthropogenic activities (Igu et al., 2017). Urban development and sprawl is increasing in proportion in the area, housing development and gentrification is equally escalating in semi-urban and rural areas in the zone. These patterns of development have increased in recent times due to the return of many people from the zone from other parts of Nigeria and abroad, quest of many people to own their own homes, and the upsurge in housing estates across the region. Since these dynamics in the area have resulted to changes in land use, forest cover and natural ecosystems have continued to be altered and degraded at the same proportion.

Addressing such concerns has become pertinent in order to preserve the biodiversity as well as the ecosystem services in the region. Land use changes normally promotes the utilization or supply of certain ecosystem service(s) of interest at the expense of others (Rodriguez et al., 2006; Fedele et al., 2018) or the use of land for a certain activity at the expense of other uses. Effort to accommodate and integrate different land uses within a given area should rather be promoted; especially in areas such as the south east with small land area. Achieving such would involve holistic approaches that combine science and policy frameworks targeted at ensuring forest management even though the land will still serve other purposes. This work is a step to actualizing such initiative in a part of south east Nigeria where forest modification and land use change dynamics are intense. It will equally elucidate the realities and pattern of land use change in the zone and show realistic policies that need to be adopted to enhance ecosystem conservation and management.

MATERIALS AND METHODS

Study area

Awka south local government area (Anambra, south east Nigeria) (Figure 1) is made up of notable towns, among which is the state capital (Awka). The topography is characterized by a rugged relief that lies completely on Awka Orlu upland.

Generally, the average height ranges from 91m in the western parts to 160.2m in the eastern zone (Ojiako, 2018). The climate of the region is tropical wet and dry type following Koppen's classification. Dry season in the zone is between November and March and the wet season is from April to October. Mean minimum and maximum temperatures are 23.5°C and 32.1°C, respectively, while the mean annual rainfall is about 1900.5m.

Awka south lies within the Anambra basin and the sedimentary rocks are mainly made up of Nkporo shale, Mamu formation, Ajali sandstone and the Nsukka formation as the main deposits. Most of the original rain forest in the region has been lost due to clearing for farming and human settlement. It is commercially defined by large rudimentary markets where varieties of goods are sold. The area serves as administrative, commercial, agricultural, educational centres; hence the dwellers are engaged in different livelihood options.

Data collection

Data used for the work are secondary data of geometrically rectified satellite imagery, results and primary data elicited from questionnaire survey conducted in the study area in 2022. The LANDSAT data were downloaded from USGS Earth Explorer for three epochs: 1981, 2001 and 2021. The Thematic Mapper (TM) image was downloaded for 5th January, 1981. The Enhance Thematic Mapper plus (ETM+) image was downloaded for 17th February, 2001 and the Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) for 8th January, 2021.

All the images were pre-processed by the USGS to rectify any geometric or radiometric distortions of the image. This correction process employs both Digital Elevation Models and Ground Control Points to achieve a product that is free from distortions related to the Earth (curvature, rotation), satellite (attitude deviations from nominal), and sensor (view angle effects). The USGS also geometrically corrected and georeferenced both images to the WGS1984 datum and Universal Transverse Mercator (UTM) zone 32N coordinate system. For the Landsat TM, ETM+ and OLI, a False Colour Composite (FCC) operation was performed using the ArcGIS 10.4 software and the images were combined in the order of band 5, 4 and 3 for Landsat TM and ETM+ while that of Landsat

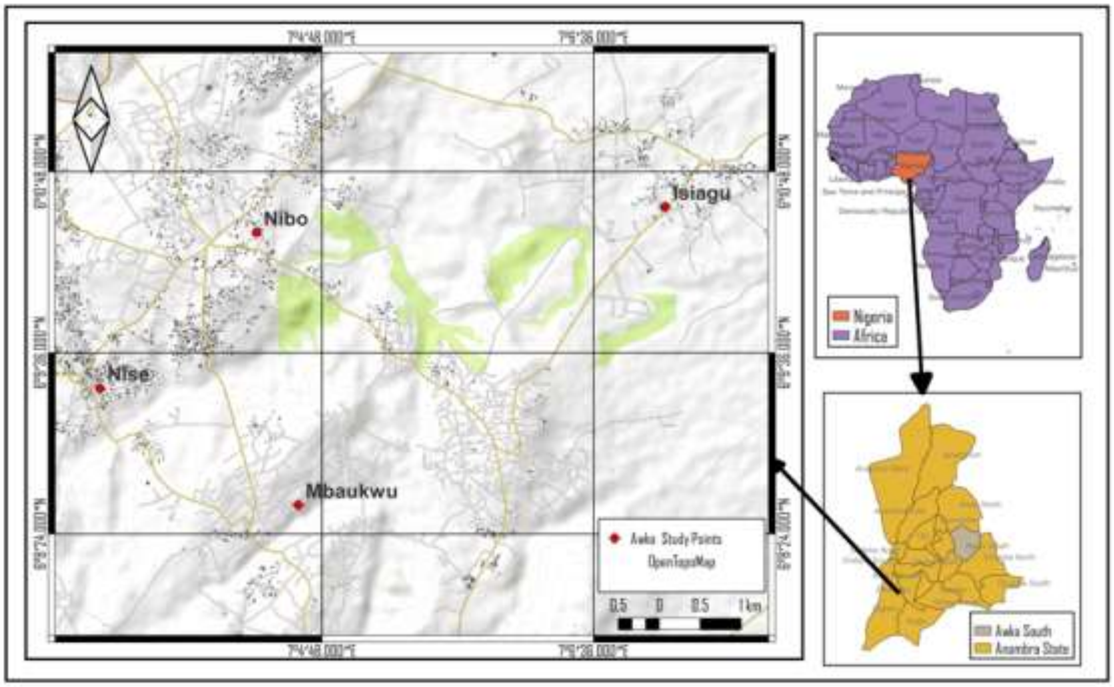


Figure 1. Map of the study sites, Awka south, Anambra state and Nigeria inset.
Source: Authors

OLI was in the order of band 6, 5 and 3 due to change in sensor. The images were then clipped to the boundary of AMAC to allow more detail and accuracy. A supervised classification scheme with the Interactive Selection algorithm (Muavhi, 2020) was used for the classification.

The supervised classification was performed by creating a training sample, and based on spectral signature curve, various land-use classes were created namely: Water Body, Built-up, Farmland, Bare Surface, and Vegetative Cover.

These classes were observed distinctively on the clipped image and were used for the classification. Questionnaire was used to elicit information on forest use and policy, tree management and conservation practiced in the area, as well as the needed strategies to be adopted. In order to show variations in responses from the questionnaire survey, two towns each were selected among the peri-urban (that have boundaries with Awka town) and more remote locations.

Hence, out of the eight towns within the local government, four locations (being Nibo and Nise for peri-urban and Mbaukwu and Isiagu for remote zones) (Figure 1) were selected to provide insights on the dynamics surrounding land use change and how to address the conservation and management concerns in the zone. Across each location, fifty respondents were randomly selected for the survey; hence, a total of two hundred responses were elicited. The questionnaire used was structured with options and partly with four point likert scale: strongly agree, agree, disagree and strongly disagree for conservation section.

Analysis

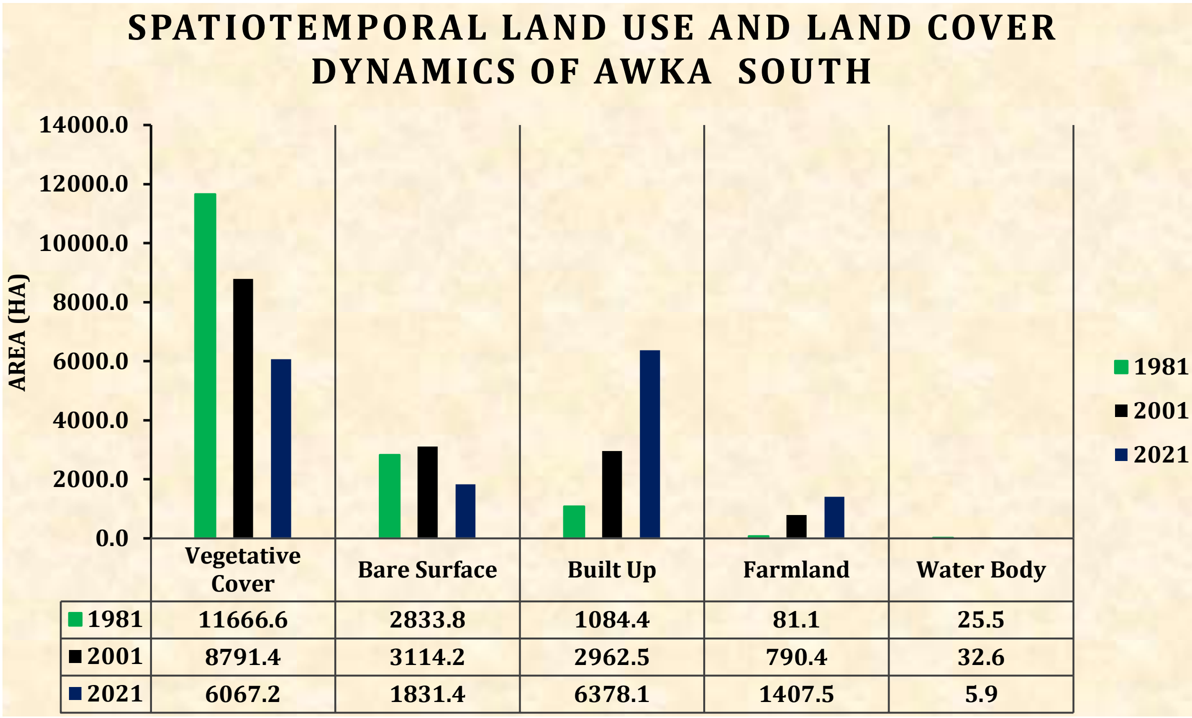
Descriptive statistics which includes: frequency, mean, standard deviation and total percentages were used to show the pattern of forest use and policy that exist within the region. Principal component analysis (PCA), a multivariate statistical tool was employed to simplify the relationship between large bodies of variables on methods to adopt in achieving ecosystem conservation.

RESULTS AND DISCUSSION

Overview of land use and land cover change (LULC) in the area

There was much change in the area from 1981-2021 (Figure 2). Figures 3 to 5 captured the map of the area and the presentation of land use and land cover for 1981, 2001 and 2021, respectively. Changes encountered within the area was seen to vary across the different LULC within the area; with vegetative cover experiencing the highest loss in extent and built up area experiencing the highest gain in extent (Figure 6).

Though much of the vegetative cover (about 5599.4 ha (55.994 sq km); Figure 6) were lost over the years in the area, as much as 6067.2 ha (60.672 square km) (Figure 2) of the area still constituted vegetation. This fraction needs to be conserved. Both farmland and built up area experienced much increase (gained more land than they had initially); though not at the same proportion. Built up area had a more visible gain in land (Figure 6) and hence showed the need for targeted conservation. Similarly, in



	Vegetative Cover	Bare Surface	Built Up	Farmland	Water Body
1981	11666.6	2833.8	1084.4	81.1	25.5
2001	8791.4	3114.2	2962.5	790.4	32.6
2021	6067.2	1831.4	6378.1	1407.5	5.9

Figure 2. Dynamics of LULC for Awka South between 1981-2021.
Source: Authors

Suleja, Buba et al. (2016) revealed that built-up area which is the major land use in the zone was seen to increase from 650.60 Ha in 1980 to 3061.13 Ha in 2015. Such change (increase in built-up area) encroached into the vegetation and agricultural land use and was attributed to growth in population and proximity of the town to Abuja. Increase in built-up areas were observed in other areas that are not necessarily settlement locations in some other parts of Nigeria, such as grazing routes and agricultural locations as seen in Benue state (Odiji et al., 2022). While such zones are reserved for agriculture, built up areas were observed to grow alongside agriculture; with consequent loss of much of the forests and grasslands. Other researches on land use and cover change across Nigeria such as Fashae et al. (2022) for southwest, Echebima et al. (2019) for southeast, Bariweni and Andrew (2017) for southsouth and Nwilo et al. (2020) for northern Nigeria have shown that built up areas are increasingly becoming the dominant land use occupying much of the land areas at the expense of much decline in the (forest) ecosystems. Such trends across the nation show the much decline in vegetation and the need to conserve it accordingly.

Forest use and policy

Across the communities, much of the people (79%) accepted the view that forest ecosystems and green areas provide benefits to landscapes. However, in terms of verifying if they derived benefits from the ecosystem across the communities: 0-20% of the populace was the highest acclaimed beneficiaries (73 responses). 21-40, 41-60 and above 60% of the populace were attributed 59, 45 and 23 responses, respectively. Such opinion showed the population dynamics and orientation of the people, the urbanizing nature of the zone, and/or the reality of the degraded state of the ecosystem and inability to provide much benefit to the populace. Much of the forest areas/landscapes are owned by individuals (48%) and communities (23.5%). Such ownership structure ultimately determines to a great extent how such landscapes are managed and the rate at which become degraded. Trees and forest resources have higher tendencies of being lost or degraded in individual land holdings than would be the case in a communal land. Land fragmentation and parcelization arising from land tenure system and land inheritance would equally contribute to ecosystem degradation more in individual ownership structure. Such land tenure and parcelization concerns complicate management of such land and do not guarantee continual existence of such landscapes (D'Amato et al., 2010). Community land ownership/ management seems to have lower tendencies to parcelization and sale of land since a group of persons are involved in its decision making.

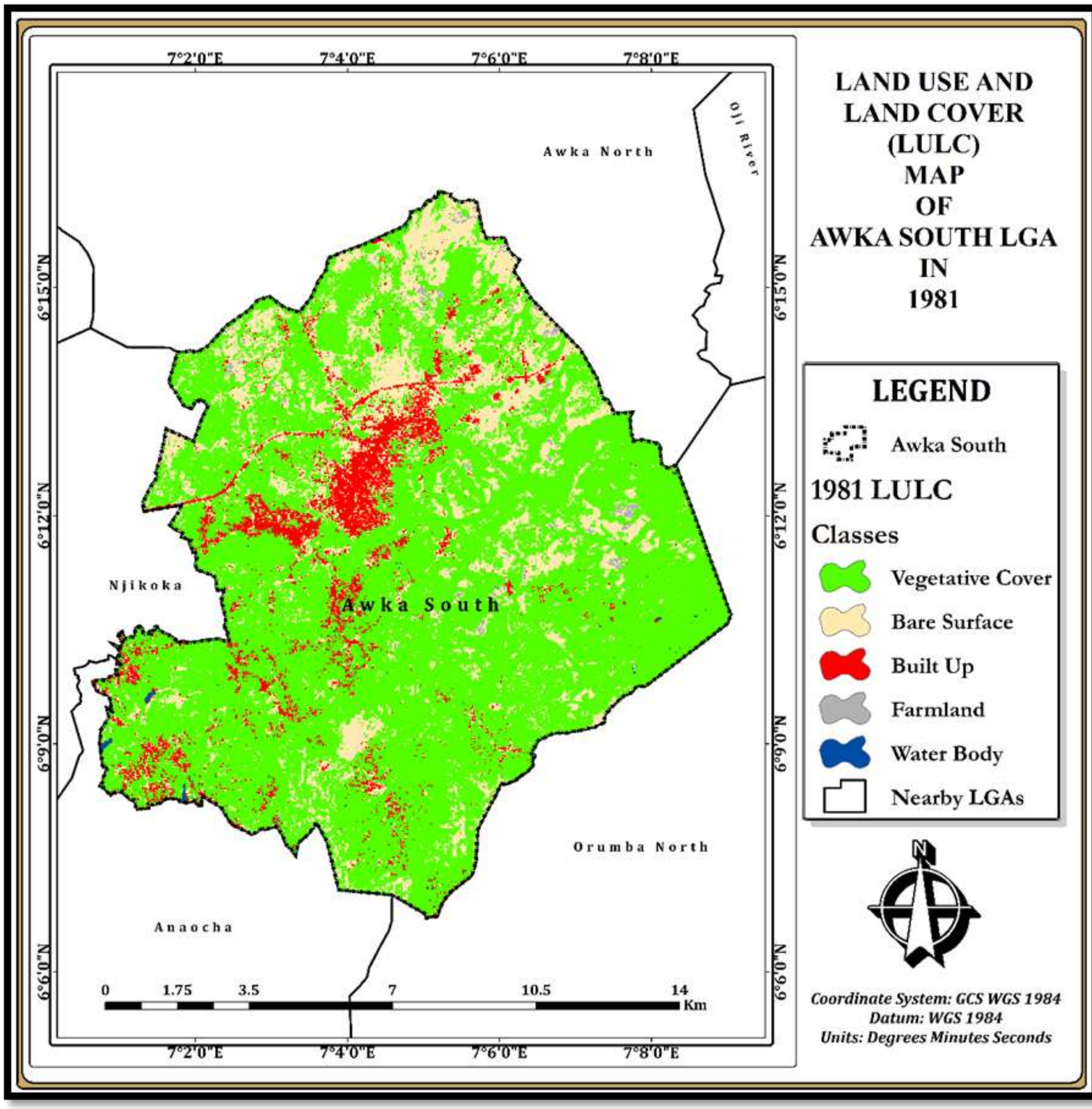


Figure 3. Map of the Awka south showing the LULC for 1981.
Source: Authors

Irrespective of the ownership status of the locality, due consideration should be given to proper rules that should guide forest use. A greater proportion of the populace (83%) are not aware of any rule guiding forest use in the area and even if they exist as only 17% affirmed, the rules are not clear to up to 88% of the people. This is not surprising then that the people (84%) could attest that the interests of the people are not considered when making rules on how forests should be used. Involving local people in "shaping, implementing and evaluating programmes" tailored towards forest management, has a lot of benefits (Kimengsi and Ngu, 2022) and should be practiced in the study area as well as other landscapes. Such participation is a proven method of achieving forest management and affords the people involved the opportunity to influence programme outcomes and experience personal developmental opportunities and growth (Kimengsi et al., 2016).

Ecosystem conservation

Much of the responses were explained by component 1 and 2; 29.992 and 24.758%, respectively and then

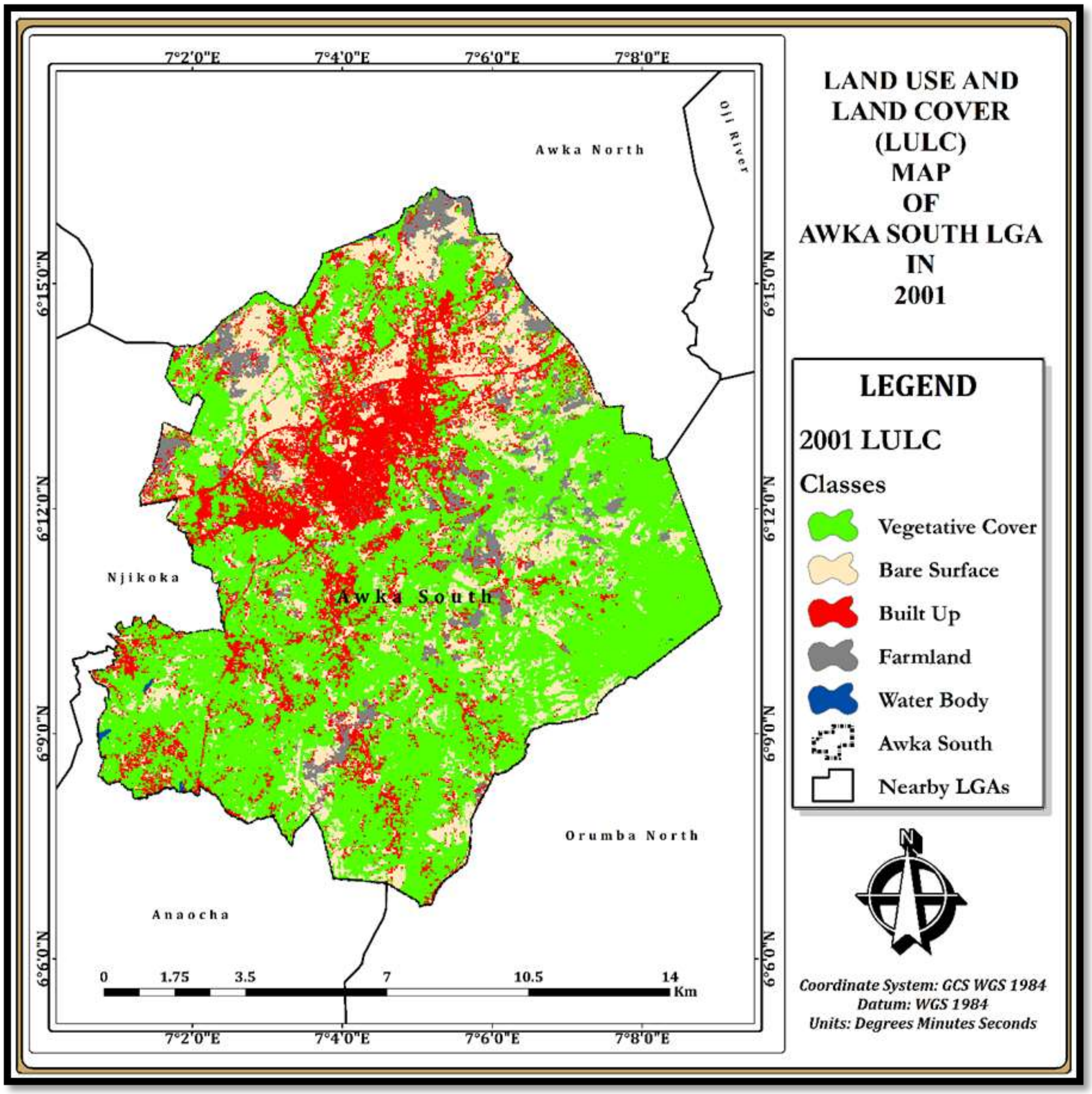


Figure 4. Map of the Awka south showing the LULC for 2001.
Source: Authors

component 3 with much lower (12.716%) percentage variable explanation. These made up 67.466% cumulative explanation for the strategies that needs to be adopted (Table 3). MESPC and RFRUH were deemed to be (in decreasing proportion) the most appropriate strategies to be adopted according to component 1 (Table 3). Making and enforcing laws to stop cutting down of trees are effective ways of promoting conservation (MESPC). It was indeed the first step that addressed the challenge of ecosystem conservation as such laws (to achieve effective conservation) may not really be in existence, and where they exist, much people are not really aware of it. There is every need to downscale existing national laws (which are mostly what exists) to regional and importantly, landscape scales to achieve conservation goals. Landscape/local scales are in sincerity where these need to be expounded to tackle ecosystem loss and efforts to achieve this. Enforcing the existing laws is as important as making the laws and will indeed require the cooperation of the populace. There is need to restrict or regulate forest resources (firewood, wild fruits, leaves, timber) use and harvest (RFRUH; 24.758%) as a means of achieving conservation. This strategy is much needed considering that forest resources are not infinite and

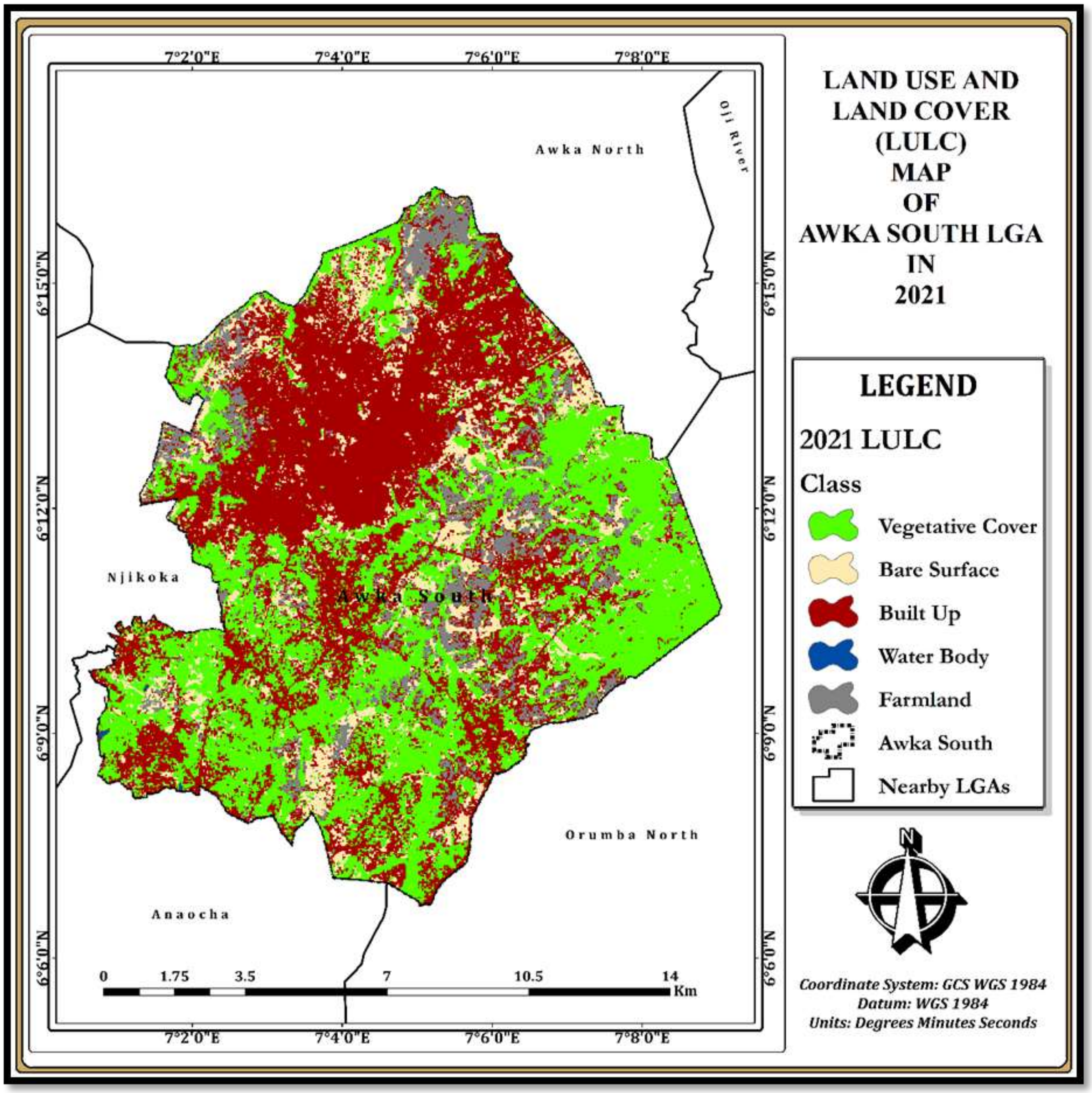


Figure 5. Map of the Awka south showing the LULC for 2021.
Source: Authors

would require being protected from degradation arising from unregulated and increasing usage. Table 1 show the label codes for strategies for enhancing ecosystem conservation. Establishing reserves in portions of the community where forests or green areas exist and compensating the land owners (RFGC), as well as setting aside some portions of land in each community for establishing (planting new) forests (SALEF) are viable steps to actualizing conservation (component 2). The idea of establishing reserves in portions of land where there are existing forests will only require changing the ownership of such portions of land (from individuals or communities to government), and so are strategies that could be easily achieved. However, for such to be seamlessly effective, due compensation for land and willingness of the owners to part with the land should not be compromised. The use of coercion or force (though legally) from government through decrees, (such as land use act and policies) are counterproductive and should not be encouraged (Igu, 2017). Conversely, establishing (planting new) forests by setting aside some portions of land in each community are viable strategies that will

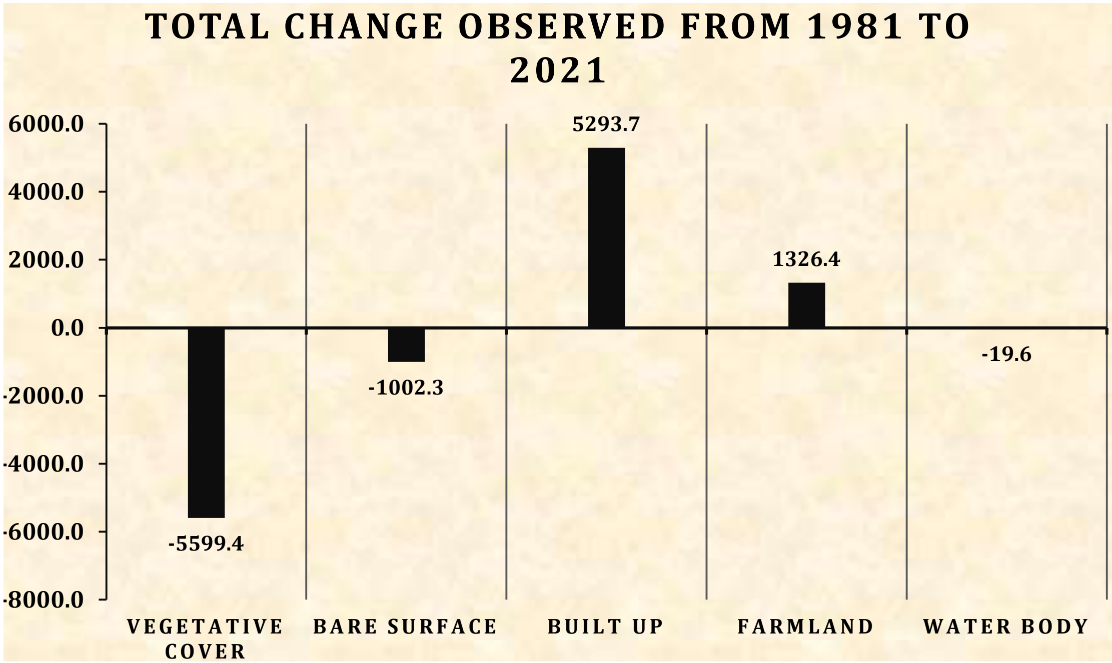


Figure 6. Total changes for all the LULC between 1981 and 2021.
Source: Authors

Table 1. Label codes for strategies for enhancing ecosystem conservation.

Name of variable	Label code
Restricting or regulating forest resources (firewood, wild fruits, leaves, timber) use and harvest can promote conservation	RFRUH
Making and enforcing laws to stop cutting down of trees are effective ways of promoting conservation	MESPC
Encouraging people to use other forms of fuel such as kerosene and gas cookers instead of firewood will help conserve the forests	PFCF
Set aside some portions of land in each community for establishing (planting new) forests	SALEF
Establish reserves in portions of the community where forests or green areas exist and compensate the land owners	RFGC
Involving community leaders in forest/green area protection are effective ways of promoting forest management	CFPFM
Handing over the forest areas to Government to manage will be more effective	HGME
Recruiting people from the villages to protect/manage the forests will be more effective	RVPF
Advocating (awareness) against over-harvesting of the forests or forest resources will promote conservation	AOFC

Source: Authors

ensure that green zones exist at community levels. Though it will require establishing forest landscapes from the preliminary stage, it however helps to ensure that choice locations (with requisite features) that are void of land related cases and disputes are selected. More so, it would be much easier to establish species that are both most suited for each environment and most appropriate for the desired aim. RFGC and SALEF have good correlation (0.602; Table 2) and could be readily adopted in land scarce regions such as (the study area) south east Nigeria as well as in other landscapes where a myriad of land competing interests are hampering conservation efforts.

Strategies such as advocating (awareness) against over-harvesting of the forests or forest resources will promote conservation (AOFC) and recruiting people from the villages to protect/manage the forests (RVPF), are seen as being effective in achieving forest management (component 3). Advocating against overharvesting is much needed in the area, considering that much of the

Table 2. Correlation matrix of the strategies for enhancing ecosystem conservation.

	RFRUH	MESPC	PFCF	SALEF	RFGC	CFPFM	HGME	RVPF	AOFC
RFRUH	1.000								
MESPC	0.690	1.000							
PFCF	0.176	0.243	1.000						
SALEF	-0.193	-0.090	0.130	1.000					
RFGC	-0.164	-0.110	0.169	0.602	1.000				
CFPFM	0.068	0.039	0.164	0.401	0.497	1.000			
HGME	0.449	0.476	0.296	0.025	0.112	0.367	1.000		
RVPF	-0.004	-0.124	0.319	0.212	0.274	0.313	0.149	1.000	
AOFC	-0.025	-0.018	0.357	0.244	0.259	0.268	0.139	0.445	1.000

Source: Authors

Table 3. Varimax rotated component matrix.

	Component 1	Component 2	Component 3
MESPC	0.874*	-0.076	-0.044
RFRUH	0.851*	-0.152	0.012
HGME	0.744	0.231	0.185
RFGC	-0.083	0.844*	0.157
SALEF	-0.131	0.805*	0.098
CFPFM	0.223	0.746	0.195
AOFC	-0.035	0.177	0.783*
RVPF	-0.072	0.201	0.768*
PFCF	0.310	0.037	0.686
Eigen value	2.699	2.228	1.144
% of variable explained	29.992	24.758	12.716
Cumulative % explained	29.992	54.751	67.466

*significant loading ≥ 0.76.
Source: Authors

forest resources are already scarce and needs to be conserved by all. Such approach is vital because it will create the needed awareness on resource decline and importantly, change the mindset of the people that such resources are (erroneously) always available and can be easily replenished. Forest resources (especially across tropical landscapes) can be more effectively conserved when the populace (forest users, owners and dependents) becomes more aware on the inherent processes of decline, little resilience of most ecosystems, their services and the reality that ecosystems could be completely lost. Employing local people to protect forests in their localities are strategies that could be adopted to promote conservation efforts. Such persons are known to the people, live among them and are part of the system; hence will no doubt ensure more commitment, accountability and be more affordable. Initiative that creates employment opportunities for local persons and could be easily managed; without necessarily depending on government to fund and oversee its operations. The need to protect ecosystems from unauthorized persons and unregulated forest resource extractions are quite topical and requires a paradigm shift from the norm, if the ultimate goal of conservation is to be realized.

Conclusion

Forest loss is increasing in scale across much of the tropics and was seen to reflect in the study area; with much gain for built-up areas and much loss for forest/vegetation. Land ownership status, poor awareness on rules guiding forest use, poor involvement of the populace in the design and implementation of rules guiding forest use and management, were indices that contributed to vegetation loss in the region. Making and enforcing laws to stop cutting down of trees, regulating forest resource use and harvest, setting aside land and establishing reserves, were effective ways elicited for promoting conservation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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