NIGERIAN JOURNAL OF PUBLIC SECTOR MANAGEMENT (NJPSM)

GIS-Based Assessment of Rural Road Networks and Settlement Patterns: Implications on Sustainability of Socio-economic Development in Ondo State, Nigeria

Akinbebije, D[1*]., Agbonifo, J. O[2]., Adetunji, K. L[3]., Kemisola, O.[4] & Akinbebije, M. N [5].

[1,2 &3]Osun state University, Osogbo, Nigeria
[4]National Open University of Nigeria, Abuja
[5]Federal University of Technology, Akure
E-mail: progeo2003@yahoo.com., johnagbonifo@uniosun.edu.ng., kehindeal@uniosun.edu.ng., kowoniya@noun.edu.ng & michealakinbebije@gmail.com
Corresponding E-mail: progeo2003@yahoo.com

Abstract

This study utilized Geographic Information Systems (GIS) to map road networks, assessed the extent and physical road conditions, accessibility of rural road networks and traffic counts in Ifedore and Akure North Local Government Areas of Ondo State, Nigeria. Using GIS for spatial mapping of road networks, land use, settlement patterns or clustering system and socio-economic surveys to examine the role of rural roads in shaping agricultural productivity, market access, healthcare and education. A descriptive statistics method was used with analysis of expert and community perspectives. Findings revealed that scarce funding, poor maintenance, and flood-induced damage significantly constrain rural livelihoods, increase transport costs, and perpetuate poverty cycles. GIS analysis highlighted settlement clustering along road corridors, showing strong correlations between connectivity and socio-economic outcomes. Rural roads crossing 1st and 2nd stream order without proper construction definitely become inaccessible and affect the socio-economic development of those communities. The study concluded that road investments, supported by GIS tools, can strengthen rural-urban linkages, reduce food insecurity, and advance progress toward Sustainable Development Goals (SDGs 9 and 11). It is hereby recommended that a Global Information System (GIS) be introduced as a spatial mapping tools for infrastructure (road transport inclusive) to provide support for integrated rural development plan, reinforce agricultural transformation and land use.

Keywords: GIS, Rural Roads, Socio-Economic Development, Accessibility, Sustainable Development, Ondo State

Introduction

Rural roads are vital enablers of socio-economic development, linking communities to markets, healthcare, education, and broader economic opportunities. Angmor (2012) opined that adequate road transportation is essential to agricultural development, as it will allow farmers to get inputs and data within a reasonable time and sell their harvest at realistic prices to cover their total cost with profits. In Nigeria, poor rural road infrastructure continues to undermine agricultural productivity, food security, and rural livelihoods. Ondo State is a key food-producing region in Southwest Nigeria, suffers from deteriorated rural roads that raised transport costs and hinder service access. This study focuses on Ifedore and Akure North LGAs to assess how road networks shape socio-economic development outcomes. GIS is employed as a powerful tool to map road conditions, traffic flows, and accessibility, thus providing evidence for data-driven infrastructure planning. Rural areas in Africa are made up of people who are poor and characterized by low educational standards. These African rural areas can offer the highest opportunity capable of transforming the continent through adequate agricultural production reinforced by reliable and adequate transportation (Olorunfemi and Adenigbo, 2017).

Rural areas in Nigeria are yet to witness any rapid development despite her major role in the process of economic liberation before the beginning of oil production (Gbadamosi and Olorunfemi, 2016). Various postulations have been made to be the reasons for the neglect of rural areas in Nigeria most especially in the provision of road infrastructures. Okakunori (2006), Ugwuanyi and Chukwuemeka, (2013), and Olorunfemi and Basorun, (2013) revealed that the lack of infrastructural facilities particularly the abandonment of road transport infrastructure has resulted in the pitiable quality of life with its consequential implication on the rural dwellers.

Literature Review

Previous studies affirmed that rural roads reduce poverty and increase agricultural productivity by lowering transport costs and improving access to markets and services. Poor roads, however, contribute to high post-harvest losses and rural poverty. GIS has been widely applied in infrastructure analysis due to its capacity for spatial mapping, overlay analysis, and decision support. In Nigeria, road development projects like the Rural Access and Mobility Project (RAMP) highlight the critical role of accessibility in rural transformation. Despite this, comprehensive empirical assessments linking GIS-based road mapping to socio-economic development in Ondo State remain limited. According to Berg *et al.* (2015), as reported by Oluwatoyin (2022) that, roads with the availability of good rural transport networks make the movements of agricultural produce easy and allow marketers to access markets for enhanced income and improved socio-economic development.

Nearly all agricultural produce across the world is huge and quickly destroyed if not well preserved, in Nigeria is no exception (Yeboah 2015). They need to be transported from where they are being produced to the place of consumption for the farmers to earn more income. Conversely, as reported by Adeniyi *et al.* (2018), many farmers in Nigeria and most especially in Ondo State, despite every effort bring into being towards increasing agricultural output in the area, are still facing the challenges of how to maximize income due to the problem of bad roads.

GIS a Spatial Mapping Tools

Geographic Information System (GIS) is a descriptive tool, which can be used with other tools to show the impact of a project on the environment. The GIS software plays a significance role in contributing to overlay analysis for descriptive and selection purposes because it has a high ability to manage large volumes of spatial data and consider many factors from a variety of sources. Geographic information systems (GIS) have a high ability to deal with the constraints of necessary social, environmental, and economic activities Al-Ruzoup (2017). Combining GIS with data from Remote Sensing can be used to describe any environment or its ecosystem. The new application of GIS open source was created to obtain the specific sites. The GIS has been used for a range of applications in various fields, including the assessment of groundwater pollution potential, soil environment, healthcare, and urban planning. In the literature, many researchers have used a combination of GIS software and other tools to delineate structures and carry out reconnaissance survey on infrastructures for study purposes Ako *et al.* (2019).

Chakwizira *et al.* (2010) established the connection between rural road as a means for good transportation, agriculture, and rural development as contained in the skills from Mhlontlo Local Municipality South Africa, integrated infrastructure Atlas. He used the bicameral method to provide a source for protrusive transportation and agricultural infrastructure in the study area. The study recommended that a Global Information System (GIS) as a spatial mapping of infrastructure (road transport inclusive) should be provided to support an integrated rural development plan and reinforce agricultural transformation and land use. However, the researchers failed to highlight the state of the infrastructure investigated. Orakwue *et al.* (2015) studied the effects of road transport on agricultural productivity in Ayamelum Local Government Area of Anambra State, Nigeria.

They identified rural access roads as a transportation channel, which is the most significant factors that affect the development of agriculture and the socio-economic status of people. Samuel (2020) reported that road transport possessed both negative and positive consequences on agricultural development and the general socio-economic status of the communities in the study area. The study recommended that adequate road infrastructure should be put in place to further facilitate agricultural production in the area. Bonsu (2014) showed that adequate road transport infrastructure will provide suitable ways of transportation and distribution of agricultural products. He concluded that adequate road accessibility will in turn increase agricultural production although, the author did not provide information on the road transportation challenges encountered by farmers in the study area.

Theoretical Framework for the Study

The theoretical framework for this study was from the Theory of Infrastructure and Socio-Economic Development, which posits that infrastructure, including rural roads, plays a pivotal role in fostering socio-economic development in rural areas Aschauer (1989), World Bank, (1994), Calderón and Servén, (2004). According to this theory, improvements in infrastructure lead to enhanced accessibility, which, in turn, positively affects various socio-economic indicators, including income, education, healthcare, and overall human development. This framework provides the foundation for understanding how rural roads contribute to the sustainability of socio-economic development in the specific context of Ifedore and Akure North Local Governments in Ondo State, Nigeria.

Research Methodology

Description of the Study Area

Akure North Local Government Area (LGA) with the headquarter in Iju/Itaogbolu comprises major communities and rural settlements like: Iju, Ita-Ogbolu, Oba Ile, Igoba, Igbatoro, Imafon, Igunsin, Adewole camp 1, Adewole camp 2, Olomo, Jojo, Onipanu, Olobi, Olokuta, Egbeda, Olomodan, Kajola, Ala, Iluabo, Agamo camp, Odudu, Igede, Osi, Abo Asakin and Ogbese in Akure North LGA (Figure 3.(1-3)). These communities are located between latitudes 5˚45' and 7˚52'N and longitudes 4˚20' and 6˚05'E. The population of the Local Government area is approximately 198,000 from the 2006 National Population Census. The communities have numerous drainage patterns (Ala, Oluwa, and Ogbese River).

While Ifedore Local Government Area is in Ondo state, with the headquarters in Igbara Oke and bounded to the North and East by Akure South Local Government Area to the south by Osun State, and to the west by Ekiti State (Figure 1). located within longitude 4.89° E and latitude 6.89° N. The LGA comprises several towns and villages such as Elemo, Ajebamidele, Omijaka, Erigi, Osunsin, Bolorunduro, Owena, alaranogun, Ibuji, Isarun, Ijare, Ilara, Ipogun, Amaye, Imokuti, Odo-Oja, Odo-Esi, Ibulu, Akunrin, Ogbontitun, Amaye and Imokuti.. The estimated population of Ifedore LGA is given as 201,774 inhabitants. Geographically, Ifedore LGA covers a total area of 295 square kilometers. Both LGAs are agrarian regions with populations of approximately 200,000 each. Key major livelihood is farming, which include cassava, yam, cocoa, cashew, tomatoes, pepper and palm oil production.

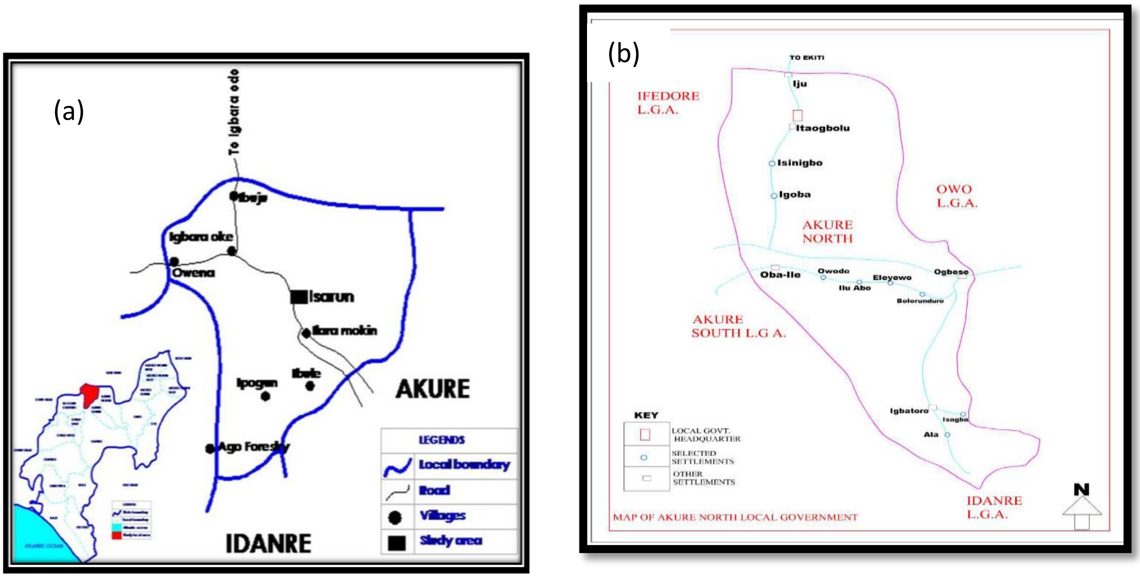

Figure 1 (a and b) Map of Akure North Local Government Area showing Towns (Source: ArcGIS™ 2.0.)

Data Collection

A mixed-methods design was adopted. Data were collected through structured questionnaires using Likert scale of 1-5, which were administered to 200 respondents across 10 communities, expert and community leader interviews, GIS spatial mapping using ArcGIS

2.0, and traffic counts of pedestrian, motorcycle, bicycle, and vehicle movements. Data analysis is descriptive statistics or analysis and GIS spatial overlays for mapping settlements, road density, land use, stream order and drainage networks.

Results and Discussions

GIS Mapping of road networks: Figures show dense road networks around major hubs with sparse connectivity in farm camps. Settlement clustering follows accessible roads. Figure 1(a and b) depicts the generalized map of Ifedore and Akure North LGA showing the road networks and communities/ settlements as generated using ArcGIS™ 2.0.

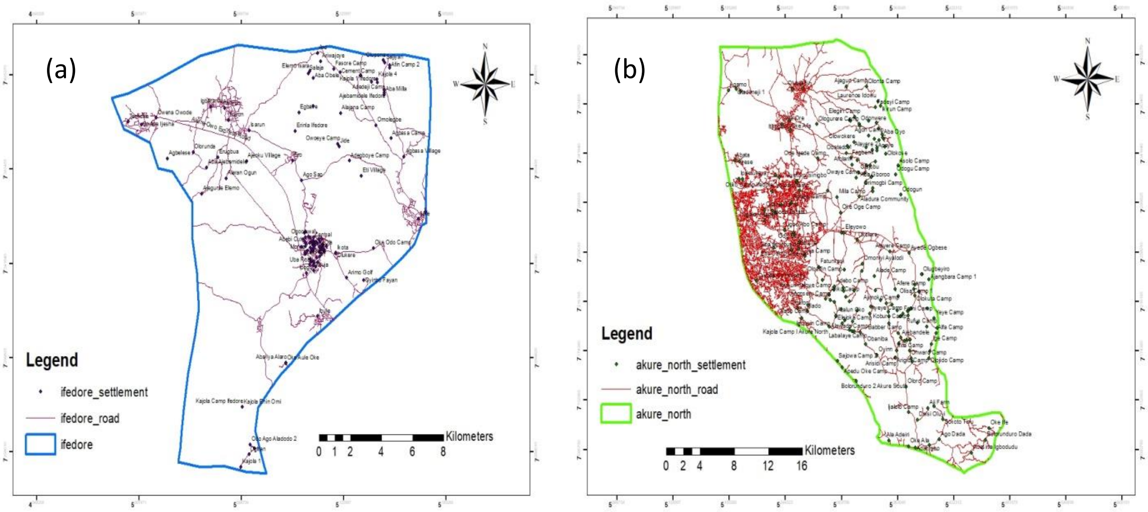

Figure 2 (a and b): Generalized Spatial Map of Ifedore and Akure North LGA showing Road Networks and Communities/Settlements. (Source: ArcGIS™ 2.0.)

The map of Ifedore Local Government Area (LGA) in Figure 2 (a), illustrates a moderately dense network of roads and settlements within the administrative boundary. The road networks are more concentrated in the northeastern and central zones, radiating outwards from the main urban hub around Igbara-Oke, Igbara-Odo, and Ilara Mokin. The settlements show clustering in areas such as Igbara-Oke, which appears to be a central town with multiple connecting roads extending towards peripheral and exterior settlements like Kajola Camp, Abule Oke, Akaran Ogun, Aba Obele and Eti community. The road structure appears to include primary routes, likely paved and linking major settlements, and secondary or feeder routes that connect farm settlements and rural villages. The southern part of Ifedore shows relatively sparse road density with scattered settlements like Fasore camp, Erigi camp, Oke odo camp, Ajegunle Elemo, and Adegbaye camp, The map of Akure North Local Government Area (LGA) in Figure 2(b), depicts a dense distribution of road networks and settlements within the administrative boundary. The road networks shows a web-like structure with significant concentration in the southern and central regions, connecting numerous rural and peri-urban (sub-urban) communities such as Oba-Ile, Igoba, Ogbese, Iju, Ita-Ogbolu, and Ayede. These major settlements appear to be focal nodes of transportation, with multiple feeder roads extending towards satellite villages and agricultural camps like Kajola Camp, Aladura Community, Agamo, Ago Dada, Elejoka and Ajagun camp.

The settlements are dispersed across the entire region, though they cluster more heavily along accessible road corridors. This spatial pattern aligns with settlement development models where proximity to transportation infrastructure always enhances growth opportunities and roads connecting farm camps facilitate the transportation of farm produce to urban markets in nearby towns, thereby increasing farmers' income. The presence of numerous farm camps highlights the region's reliance on agriculture as a primary livelihood source which may reflect limited accessibility due to rural road conditions and rural land use patterns. Concentration of settlements around road networks will ensure better delivery of social amenities such as schools, clinics, and skill acquisition centers. This will directly improve literacy, healthcare and other socio-economic development outcomes. Findings from the maps and physical assessment shows that settlements concentrated along major roads enjoyed better economic opportunities, while dispersed rural settlements faced higher costs of accessing infrastructure. Also, those clustering settlements along key roads improved school attendance and healthcare utilization by reducing travel time and cost.

Land Use Patterns and Rural Road Interactions

The land use map of Ifedore (0–8 km scale) reveals a landscape dominated by extensive Cropland (estimated 60–70% coverage), concentrated in Central and Western zones, reflecting the region's agrarian economy. Built areas cluster along the edges of cropland and rangeland, indicating settlement patterns tied to agricultural and pastoral livelihoods. Rangeland appears to be peripherally, often adjacent to cropland and facilitating mixed farming systems. Forest zones exist as fragmented patches, while water bodies (likely rivers or lakes) traverse the landscape linearly.

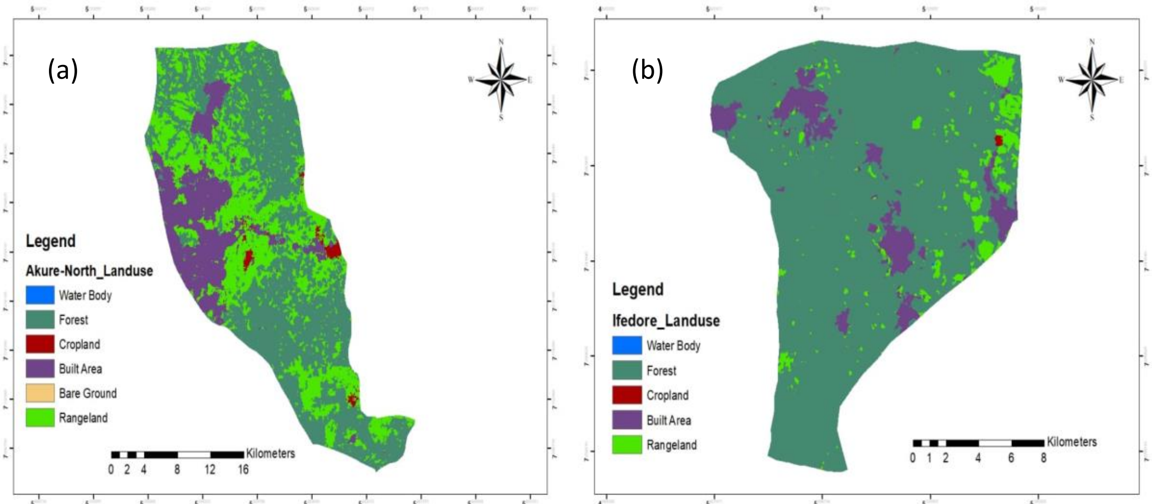

Figure 3(a and b): Generalized Spatial Land use Map of (a) Akure North LGA and (b) Ifedore LGA (*Source: ArcGIS*^{TM} *2.0.)*

The land use map of Akure North LGA is (0–16 km scale) revealed a spatially stratified landscape dominated by cropland (estimated 50–60% coverage), concentrated in Central zones, and with built areas clustered along its periphery indicating settlement-agriculture interdependencies. Rangeland forms transitional belts between cropland and forest patches, while water bodies appear as linear features, likely rivers or reservoirs. Bare ground fragments the landscape, suggesting degraded or underutilized areas. Rural roads exhibit hierarchical connectivity: dense networks link built areas to cropland for crop transport, while dispersed roads to access rangeland for pastoral mobility. Crucially, forest and water body zones show minimal road penetration, reflecting informal conservation buffers. This pattern creates a double-edged effect: roads amplify farm productivity but fragment ecosystems and isolate peripheral communities.

Stream Order Patterns and Implications on Rural Road Planning

Based on the GIS map of the study area, using spatial analysis, the streams order is categorized and visualized in the hierarchical structure of the streams network. Numerical values were assigned to each segment of the stream based on the complexity of its tributaries. The first-order streams started with the smallest tributaries, which are given an order of 1. When two segments of the same stream order combined, their order increases by 1. This continues until the highest order of tributaries is reached. First-order streams of 1 represent the lowest order, indicating smaller and thinner streams. As the order increases to 2, 3, 4, and 5, the streams become progressively larger and thicker within the GIS map as shown in Figure 4(a-d). This provided valuable insights into the hierarchy and structure of the streams network.

The stream partern or order map (Strahler classification, scale 0–8 km) revealed a high drainage stream density (DSD) orders of (1 to 5) with dendritic hydrological network dominated by first and second order streams (headwater tributaries) forming dense networks in the Northern upland areas, converging into fewer 3rd and 4th order channels in Southern lowland zones. This hierarchical structure creates natural corridors that profoundly influence rural road placement and sustainability. Road networks inevitably intersect streams especially 1st and 2nd order channels requiring frequent crossings of (culverts, fords, or bridges). However, these intersections pose significant risks,: where un-engineered roads crossings on 1st and 2nd order streams account for 60–70% of road washouts and damage during rainy season or flooding in these studied regions. While roads paralleling 3rd and 4th order channels will often trigger bank erosion and sediment pollution. Streams order connectivity guide road alignments, providing cost-efficient routes to isolated communities. Rural roads crossing 1st and 2nd stream order without proper construction will definitely become inaccessible and affect the socio-economic development of those communities. In contrary, any roads that following 3rd and 4th order will increases market access and raising agricultural incomes by 30% through water transportation by rural dwellers.

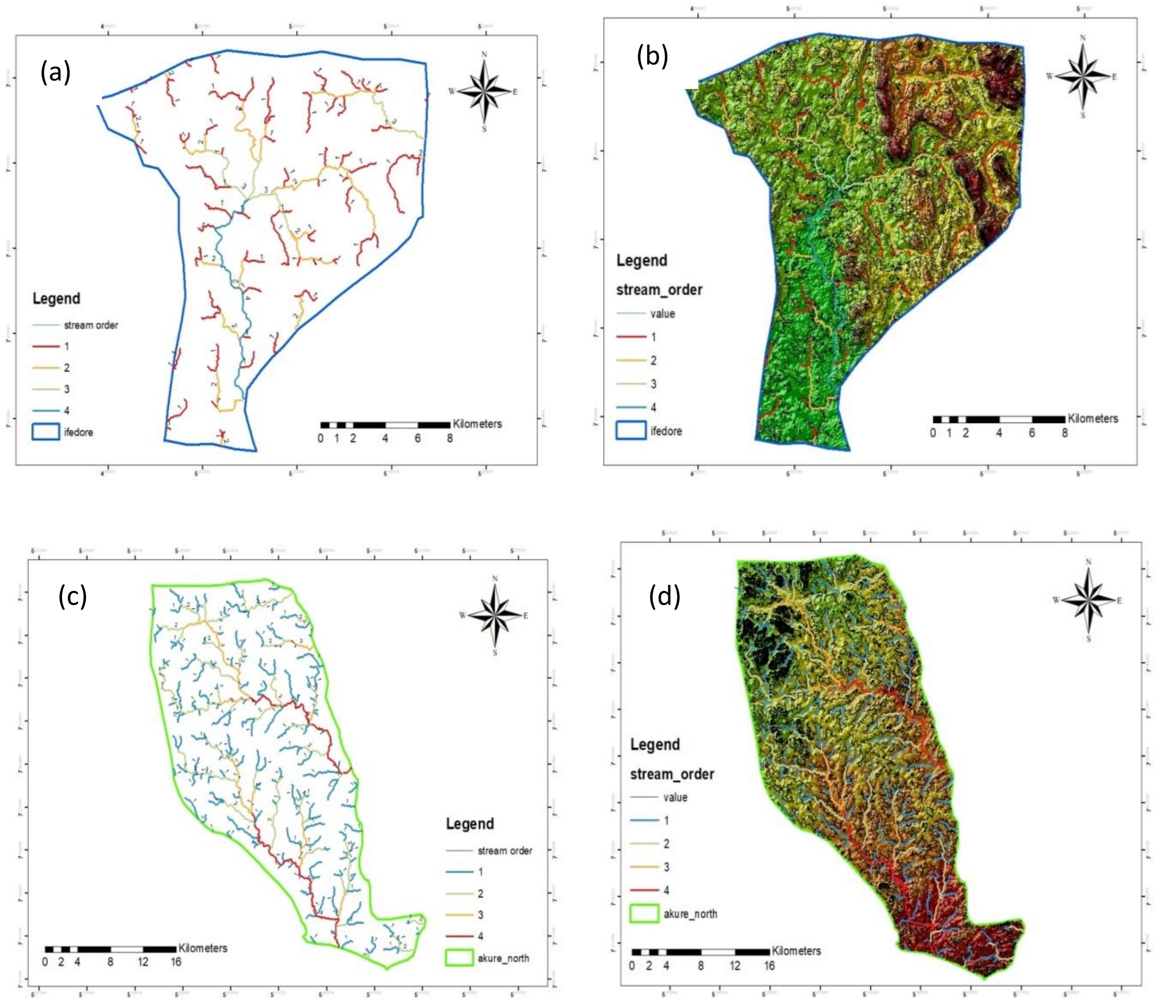

Figure 4 (a-d): Generalized Spatial Stream Order of (a and b) Ifedore LGA and (c and d) Akure North LGA (*Source: ArcGIS^{TM} 2.0.)*

Figure 4(a and b) shows the topographic contour analysis of Ifedore and Akure North Local Government Area (LGAs), delineated by elevation values ranged from 280 meters to 640 meters above sea level. Elevation, topographic or contour data derived from Digital Elevation Models (DEMs) is crucial in road network mapping because terrain slope, relief, and elevation gradients significantly caused roads surface degradation due to high intensity of runoff and also influence road construction, maintenance and traffic flow.

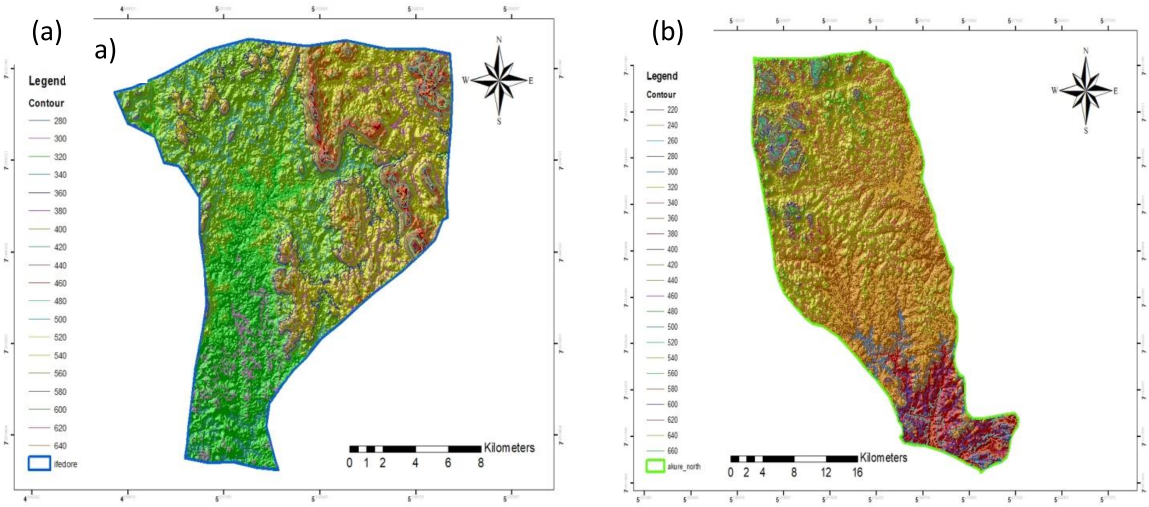

Figure 5(a and b): Generalized Spatial Contour map of (a) Ifedore LGA (b) Akure North LGA

Source: **(***Source: ArcGIS^{TM} 2.0.)*

Topographic Contour Analysis

High elevation zones in the Northeast and Central areas (closely spaced contour lines) present steep gradients, making road construction and maintenance costly and prone to erosion-related degradation. Lowland areas in the Southern and Northwestern regions (widely spaced contours) are more favorable for road expansion and heavy traffic flow due to lower construction costs and reduced slope-related hazards. Integrating these terrain data with road mapping, supports GIS-based infrastructure planning, enabling targeted maintenance in erosion-prone areas and efficient placement of traffic count stations. The road network and settlement patterns have direct implications for sustainable development in Ifedore and Akure North LGA. Well-connected settlements along primary roads show higher commercial activity, while remote rural communities face marginalization due to poor road access.

Limited transport links to elevated rural areas restrict healthcare, education, and emergency service delivery, impacting human capital development. Construction in steep terrains without proper drainage increases erosion and landslide risks, threatening both infrastructure longevity and agricultural productivity. This report revealed that, by integrating topographic information with road network datasets in a GIS environment, it can identify areas susceptible to erosion, flooding, or structural wear, which directly impact road conditions. Furthermore, elevation patterns can guide traffic count analysis, as steep gradients or rugged terrain may slow down vehicular movement and affecting traffic density patterns. The maps does not depict road alignments directly alone, but, provides a geospatial base map layer that supports the overall objective of combining GIS techniques for comprehensive road infrastructure assessment and traffic analysis.

Road Traffic Counts and Networks

Table 1 shows the population of those communities sampled and the population ranged from 43-137. Geospatial maps, traffic count and physical assessment of the rural roads indicates the networks pattern of the rural roads and feeder routes connecting multiple dispersed agricultural settlements within Ifedore LGA and Akure North LGA in Ondo State.

Table 1: Community Population and Road Traffic Count on Mode of Transportation

MODE OF TRANSPORTATION		POPULATION (*NPC- 2006*)	MOTOR/ VEHICLE	MOTOR CYCLE	BICYCLE	LEGS
LGA	**COMMUNITY**					
IFEDORE LGA	Fasore Camp	111	0	11	7	25
	Erigi/Erinla Camp	104	1	15	4	40
	Oke-Odo Camp	128	2	21	5	23
	Ajegunle Camp	43	0	12	8	32
	Adegboye Camp	118	3	17	4	46
AKURE NORTH LGA	Agamo Camp	131	5	34	4	28
	Ago Camp	122	2	22	3	30
	Elejoka	69	0	19	13	23
	Aladura Camp	137	3	33	12	11
	Ajagun Camp	48	0	20	9	22

(*Source: Author's Field Work, 2025)*

Communities like Fasore Camp, Erigi/Erinla Camp, Oke-Odo Camp, and Ajegunle Camp in Ifedore LGA, as well as Agamo Camp, Ago Camp, Elejoka, Aladura Camp, and Ajagun Camp in Akure North LGA, are linked primarily through unpaved and semi-paved roads. The roads radiate from minor junctions into farmlands, forming dendritic patterns typical of rural landscapes dependent on agricultural production. However, the connectivity varies significantly, with some settlements accessible only through narrow lateritic tracks that become less navigable during the rainy season as a challenge to sustainability of infrastructural and socio-economic development.. That implies that, road quality and it's conditions in rural Nigeria is a primary determinant of market access and service delivery.

The transportation survey (Table1) was done through traffic counting which revealed a predominance of motorcycles and walking (Pedestrian) as the major means of mobility, with limited use of motor vehicles. For instance, in Ifedore LGA, Fasore Camp records 25 people walking and 11 using motorcycles, while Erigi/ Erinla Camp has the highest walking prevalence (40) people, with motorcycles (15) as a secondary option. In Akure North LGA, Agamo Camp shows heavy dependence on motorcycles (34) and walking (28), with minimal vehicle (5) use. They highly relied on non-motorized transport (walking and bicycles) suggests limited affordability, availability, or suitability of motor vehicles due to poor road conditions. Therefore, transportation mode choices in rural areas are closely tied to road accessibility and which will influence the economic profile of residents.

It has implications on socioeconomic sustainability in the sense that, poor transportation infrastructure and limited mobility options can constrain socioeconomic development and its sustainability. In these studied settlements, the dominance of motorcycles and walking limits the volume of goods that can be transported, thereby restricting agricultural market integration and access to urban centers for trade. This significantly revealed that, rural poverty persistence in Sub-Saharan Africa due to poor road networks and transport services. Socially, limited connectivity affects access to healthcare, education, and employment opportunities, which in turn hampers human capital development. Economically, inadequate road infrastructure increases post-harvest losses, reduces farmers' bargaining power, and slows rural-urban linkages factors detrimental to long-term sustainability. From this study, it is observed that, communities and their rural roads within Ondo State exhibit lower motor vehicle penetration and weaker integration into regional supply chains. Those in better connected areas, paved feeder roads and public transport services foster greater economic diversification, while most of the mapped settlements, their socioeconomic status and livelihood opportunities remain largely subsistence-based. The sustainability of socioeconomic development in these contexts requires targeted investment in rural transport infrastructure, improved road maintenance, and the introduction of affordable, higher-capacity transport services. Such interventions, as recommended by the World Bank (2020), can reduce inequality and promote inclusive socioeconomic growth and its sustainability.

More so, enhancing all-weather road connectivity, could reduce rural isolation and increase access to services. GIS scenario modeling further suggests that upgrading just 15% of the unpaved road network to all-weather surfaces could significantly improve motor vehicle access and reduce travel time to key markets by 30–45%. This infrastructural investment would also aligned with SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities), ensuring equitable mobility and fostering rural economic growth.

This table 2, indicates the perception of officials and road planners regarding the utility of Geographic Information Systems (GIS) in rural road planning. Overall, responses reflect strong agreement and affirmation of GIS's value. Key variables such as accurate mapping of rural roads, physical road assessment, and prioritization of maintenance all scored equally high (mean = 4.7, SD = 0.48), The critical factors of accurate mapping of rural roads, road conditions, and maintenance priorities all had identical high ratings (Mean = 4.7, SD = 0.48), which indicated that 70% of the participants "strongly agree" with these statements and 30% "agree". The low standard deviation reflects strong agreement and belief in GIS as a technical tool. This mirrors findings by (Adepoju *et al.,* 2019), who identified GIS as an indispensable tool for rural transportation planning.

Assessment of the efficacy of existing GIS tools received a slightly lower Mean of 4.5 (SD = 0.71), perhaps indicating slightly greater perceptual variability, possibly through personal experience of technical limitations. In addition, the integration of traffic data into

GIS was positively viewed (Mean = 4.4, SD = 0.52), reinforcing the consensus that GIS provides a multi-dimensional benefit to road planning.

Table 2: Road officials, Planners and GIS Utility Perception

Road Officials and Planners: GIS Utility Perception									
Variable	**n**	**Strong Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Sum**	**Mean**	**SD**
GIS is essential for accurately mapping the rural road network	10	0 (0%)	0 (0%)	0 (0%)	3 (30%)	7 (70%)	47	4.7	0.48
GIS improves the efficiency of physical road assessments	10	0 (0%)	0 (0%)	0 (0%)	3 (30%)	7 (70%)	47	4.7	0.48
GIS helps identify priority areas for road maintenance/construction	10	0 (0%)	0 (0%)	0 (0%)	3 (30%)	7 (70%)	47	4.7	0.48
Current GIS tools are adequate for rural road management	10	0 (0%)	0 (0%)	1 (10%)	3 (30%)	6 (60%)	45	4.5	0.71
Integrating traffic data into GIS aids planning	10	0 (0%)	0 (0%)	0 (0%)	6 (60%)	4 (40%)	44	4.4	0.52

(*Source: Author's Field Work, 2025)*

Table 3: Field Engineer/Assessors: Data Collection and GIS Integration (*Source: Author's Field Work, 2025)*

Variable	**Rating**						**Sum**	**Mean**	**SD**
	n	**Poor**	**Fair**	**Good**	**Very Good**	**Excellent**			
Ease of inputting field data into GIS	10	0 (0%)	0 (0%)	0 (0%)	5 (50%)	5 (50%)	45	4.5	0.53
Reliability of methods used for road traffic counts	10	0 (0%)	0 (0%)	2 (20%)	4 (40%)	4 (40%)	42	4.2	0.79
Consistency in physical road condition assessment	10	0 (0%)	0 (0%)	3 (30%)	5 (50%)	2 (20%)	39	3.9	0.74
Usability of GIS outputs (maps, reports) for decision-making	10	1 (10%)	1 (10%)	1 (10%)	3 (30%)	4 (40%)	38	3.8	1.4

Accuracy of GIS mapping of rural road locations	10	0 (0%)	1 (10%)	2 (20%)	7 (70%)	0 (0%)	36	3.6	0.7

(*Source: Author's Field Work, 2025)*

This Table 3, focuses on the perspectives of field engineers and perspectives on data integration within GIS. Responses are generally positive, though slightly more variability than among planners.

The ease of data input into GIS was also rated high (Mean = 4.5, SD = 0.53), reflecting strong agreement with current GIS practices. Similarly, the reliability of road traffic count methods was rated as good to excellent (mean = 4.2, SD = 0.79), though the relatively higher SD reflects divergent field experiences. Consistency in physical road condition assessment (Mean = 3.9, SD = 0.74) and usability of GIS outputs for decision-making (Mean = 3.8, SD = 1.4) indicate moderate satisfaction, yet also indicate problems in standardization and interpretability of outputs. The accuracy of GPS/GIS mapping was the lowest in this category (Mean = 3.6, SD = 0.7), suggesting room for improvement in geospatial accuracy or technological familiarity in the field. This gap reflects operational challenges such as inadequate field hardware, insufficient training, or low-precision GPS devices, which is consistent with challenges reported in Nigerian rural GIS projects (Olawole and Adeyemi, 2021).

Table 4:: Community Leaders/Informed Residents: GIS Data Importance

Variable	Rating						Sum	Mean	SD
	n	Poor	Fair	Good	Very Good	Excellent			
Creating detailed maps (accessible/inaccessible roads)	10	0 (0%)	0 (0%)	3 (30%)	0 (0%)	7 (70%)	47	4.7	0.48
Regularly assessing and recording road conditions	10	0 (0%)	0 (0%)	4 (40%)	0 (0%)	6 (60%)	46	4.6	0.52
Using mapped information to plan road repairs effectively	10	0 (0%)	1 (10%)	4 (40%)	0 (0%)	5 (50%)	44	4.4	0.7
Sharing road condition maps for public awareness	10	1 (10%)	1 (10%)	1 (10%)	0 (0%)	7 (70%)	43	4.3	1.34
Counting vehicles, motorbikes, and people to assess traffic patterns	10	0 (0%)	2 (20%)	5 (50%)	0 (0%)	3 (30%)	41	4.1	0.74

(*Source: Author's Field Work, 2025)*

The Table 4, assessed the perceived GIS data importance among community leaders and well-informed residents. The evidence reports widespread support for the application of GIS in rural infrastructure management. The creation of detailed maps for road accessibility

(Mean = 4.7, SD = 0.48) and regular condition assessments (Mean = 4.6, SD = 0.52) were rated very high, suggesting support for space-informed decision-making in the community. Similarly, using mapped data for effective planning of repairs was viewed positively (Mean = 4.4, SD = 0.7), affirming the relevance of participatory planning.

Slightly lower Mean scores were observed for public awareness through map sharing (Mean = 4.3, SD = 1.34) were observed, indicating higher variability of opinion, potentially due to communication limitations or differences in digital access. The lowest Mean (4.1, SD = 0.74) was assigned to traffic counting activities, possibly due to uncertainty concerning the capability of locals to effectively carry out and utilize such information. However, variability in responses for public map sharing due to unequal access to ICT tools or varying levels of map literacy among communities as observed by (Makinde, 2019).

Overall, the comparative results suggest that while technical professionals (Tables 3 and 4) focused on system adequacy and operational efficiency, community stakeholders (Table 5) prioritize accessibility and decision-support functions of GIS. The integration of both perspectives is essential for optimizing GIS deployment in rural road infrastructure management (UNECA, 2020).

Conclusion

Rural roads significantly influence socio-economic outcomes in Ifedore and Akure North LGA of Ondo State, particularly in agriculture, market access, and human capital development. Poor road quality, erosion, and inadequate maintenance as a result of lack of funding reduce the sustainability of these outcomes. Geographic Information Systems (GIS) was used to map the road networks/ density, settlement patterns, land use, topography/ elevation, streams order and physical assessment to access the existing road conditions, field surveys, expert opinions, community perceptions about effects of rural roads on their socio-economic development, challenges and opportunities, and variables that can enhance sustainability of those socio-economics benefits derived from rural roads accessibility. GIS mapping provided an evidence-based approach to prioritizing interventions, highlighting settlement clusters and road vulnerabilities.

GIS mapping provided a comprehensive picture of settlement-road interactions and networks, showing that settlements closer to well-connected roads experienced better service delivery and higher income levels. Seasonal variations highlighted sharp inequalities; dry season accessibility fosters trade and mobility, whereas rainy-season incurred flooding and erosion which isolated communities, increased losses, and exacerbate poverty gaps. Findings highlight the centrality of rural roads in reducing poverty, promoting agricultural productivity, and improving service delivery. Poor connectivity increases transport costs, limits healthcare and education access, and perpetuates rural inequality. The integration of GIS provides innovative tools for planning resilient, cost-effective rural road networks, aligning with global best practices. This aligned with SDG 9 and 11, also with similar studies in India, Kenya, and Ghana, which demonstrated that rural road improvements enhance food security and socio-economic well-being.

Recommendation

Strengthen GIS-driven planning where GIS tools should be institutionalized for rural road monitoring, prioritization of repairs, and efficient resources allocation. Integrate findings into state development plans, as aligned with the achievement of SDGs 9 and 11. Future road construction and maintenance must adopt climate-resilient rural road designs where planners should integrate drainage structures, raised pavements, wheel axle load limit and erosion control measures to mitigate flood damage. Strengthen governance through transparent funding and an independent oversight board, while formalizing community-based maintenance programs to ensure local ownership and sustainable management.

REFERENCES

Adeniyi, J. O., Akinrinmade, Y., Abiodun, A. L. (2018). Analysis of Road Transport Impact on Rural Development In Nigeria: A Study On Akure North Local Government Area, Ondo State. *International Journal of New Technology and Research*, 4: 102–110.

Ako, R. H, Rafea, H. A and Zeren J. G. (2019). A multi-criteria GIS model for suitability analysis of locations of decentralized wastewater treatment units: Case study in Sulaimania Iraq. *Heliyon* Vol. 5, No. 3, pp 2-4.

Angmor, E.N (2012). *The Role of Road Transportation Service in the Development of Traditional Market's: A Case of Asesewa and Agormanya Traditional Markets in the Eastern Region, Ghana.* Master Thesis Submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Ghana.

Al-Ruzouq, R, Shanableh, A, Abdullah, G.Y, AlaEldin, I, Sunanda, M, Mohamad, A. K and Mohamed, B. A. G, (2019a). *Dam Site Suitability Mapping and Analysis Using an Integrated GIS and Machine Learning Approach*. Civil and Environmental Engineering Department, University of Sharjah, Sharjah, UAE. Water Resources Management Policy and Governance, Vol. 11, No 9, pp1880-1882.

Aschauer, D. A. (1989). Is public expenditure productive? *Journal of Monetary Economics*, *23*(2), 177-200.

Berg, C. N., Deichmann U., Liu Y., and Selod H. (2015): Transport policies and development. https://doi. org/10.1596/1813-9450-736.

Calderón, C., and Servén, L. (2004). *The effects of infrastructure development on growth and income distribution*. The World Bank Policy Research Working Paper Series.

Chakwizira, J. and Mashiri, M. (2009). *The contribution of transport Governance to Social Economic Development in South Africa*. SATC, 2009 Pretoria South Africa

Chakwizira, J., Whemachena, C., & Mashiri, M. (2010). *Connecting transport, agriculture and rural development: Experiences from Mhlontlo local municipality integrated infrastructure Atlas*. Proceeding of the 29th South African Transport Conference (SATC, 2010) Pretoria, South Africa

Gbadamosi, K. T and Olorunfemi, S. O (2016): Rural Road Infrastructural Challenges: An Impediment to Health Care Service Delivery in Kabba-Bunu Local Government

Area of Kogi State, Nigeria. *Academic Journal of Interdisciplinary Studies* 5(2):34-43

Makinde, E. O. (2019): ICT access and digital literacy in rural Nigeria: Implications for participatory GIS. *African Journal of Science, Technology, Innovation and Development*, 11(3), 361–369.

Okakunori, O.K. (2006). *Transportation Management.* Grovani Publishers

Olorunfemi, S.O and Basorun J. O. (2013): Appraisal of Regional Mobility in Lokoja, Nigeria. *Journal of Society and Communication 2013: 420-446*

Olorunfemi, S. O and Adenigbo, J. O. (2017). *Road transportation challenges to food security in Ikere Ekiti Local Government Area of Ekiti State, Nigeria*. Paper presented at the Quantitative Methods for Integrated Food and Nutrition Security Measurements-Lessons to be learned Conference organized by European Commission and International Food Policy Research Institute held at Thon Hotel Brussels.

Oluwatoyin, O. (2022). *Impact of rural transportation networks on farmers' income in Ilaje Local Government Area of Ondo State, Nigeria*. Department of Agricultural Economics and Extension, Faculty of Agriculture, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria. DOI: 10.2478/ats-2022-0002 Agricultura Tropica ET Subtropica, 55 OV, pg. 9–18.

Orakwue, C.O Umeghalu, I.C.E and Ngini, J.O (2015):.Effects of Road Transport on Agricultural Productivity: A Case Study of Ayamelum Local Government Area of Anambra State, Nigeria. *International Journal of Applied Science Engineering,* 3(1):1-4

Ugwuanyi, B.I and Chukwuemeka, E.O (2013). Enhancing Rural Development in Nigeria: Periscoping the Impediments and Exploring Imperative Measures. *Singaporean Journal of Business Economics, And Management Studies, 1(8)55-61*

Samuel, O. O, (2020). Rural Road Infrastructural Challenges: An Impediment to Agricultural Development in Idanre Local Government Area of Ondo State, Nigeria, Department of Transport Management Technology, Federal University of Technology, Akure; *Ghana Journal of Geography Vol. 12 (2), pages 108- 124.*

UNECA. (2020). *Geospatial information for sustainable development in Africa: A strategic framework*. United Nations Economic Commission for Africa.

Yeboah, S. (2015).Influence of Condition of Road Transport Infrastructure on rural Agricultural Development in the Jaman South District. Published Master Thesis Submitted To The School of Graduate Studies, Kwame Nkrumah University of Science And Technology, Ghana.