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URBAN GROWTH IN KANO METROPOLIS NIGERIA- THE MODELS HOW IT IMPACTS THE ENVIRONMENT

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Abstract

Rapid urban and population growth in the KNMA is distorting environmental quality. The initial data was obtained with the aid of geographical information systems (GIS) and remote sensing (RS) within 35 years (1984 to 2019) with three study periods of 1984, 1998, and 2019. While water pollution samples were taken and analyzed in the laboratory for physicochemical elements. The air pollution parameter consists of carbon monoxides (CO) and carbon dioxides (CO_2) emission sensed. The Structural Equation Modelling (Smart PLS-SEM) is employed. However, this study solely covers the model development of the urban growth (land use changes, water, and air pollution). The Result uncovers that urban growth in KNMA = $\propto$ + RPG(Pβ1 + Pβ2+ Pβ3+ Pβ4+P β5)+ GPC(Gβ1+ Gβ2+ Gβ3+G β4)+ IEA (E β1+EB2+E β3+E β4)+ NT(Nβ1+N β2+N β3), Air Quality Indicator in KNMA = $\propto$ + P1 + P2, + P3 + P4 + P5 +P6 + P7 + P8 + P9. Water quality, WP = f (P+L+D+A). This calls for deep and strong study on effective urban management framework applications for the metropolis and it's alike globally. The framework model applications will help in the integration of sustainable land use change principles and techniques, low carbon society development (LCSD) for air pollution mitigating water pollution with its management techniques.

Keywords: Urban growth, air pollution, water pollution, theoretical model, Kano metropolis (KNMA)

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INTRODUCTION

Land use classification is a technique employed for land-use study planning. It involves the categorization of the study area into land uses like built-up areas, water bodies, and vegetal cover, among others. Periods of study of the trend of urban expansion are usually divided into desired phases for analysis purposes. Meanwhile, Trinder and Liu (2020) evaluated the period of the study for 30 years and its classification of the land uses was carried out with the aid of Indi frag software and it covers (a) vegetation, (b) buildings, (c) water and soil. Rathayake, Jones, and Soto-Berelov (2020) added human biophysical activities as factors significantly affecting land use land cover changes (LULCC) in Sri Lanka. Landsat series between 1993 to 2018 was utilized for the study. Ustaoglu, and Aydiooglu (2020) commented on the criteria for the study to include (a) Accessibility, (b) Physical features, (c) Water resources, (d) Urban land, (e) Vegetation, and (f) Geology. Liu, Shaker, Jiang (2020) mentioned that the study considered (a) cropland, (b) woodland, (c) shrub, (d) grassland, (e) bare land, (f) water bodies, and (d) impervious surface. The study period is 1990, 1998, 2009, and 2018. Several remote sensing technologies for land use changes have been developed. Yuan (2017) revealed a classification of land uses that employed (a) impervious surface, (b) forest, (c) cropland, and (d) water bodies. The study period undertaken was from 1971 to 2003. Rathayake et al. (2020) depicted human biophysical activities as factors that significantly affect land use land cover changes (LULCC) in Sri Lanka. Landsat series between 1993 to 2018 was utilized for the study.

Land use change indicators in the study of Dempsey, Plantinga, Kline, Lawler, Martinuzzi, et al. (2017), include (a) Built-up area, (b) Forest, (c) Grass and Shrub, and (d) Agriculture. Land use parameters studied by Rathayake et al. (2020) revealed land cover utilized in the study, which include (a) homes, (b) forests, (c) gardens, (d) plantations, paddy peri-urban, (e) shrub, (f) urban, and (g) waterbodies. The study employed a total of 2117 pixels which ranges from 50 as the lowest and 600 as the highest. The study by Conway, Khan, and Esak (2020) indicates that green infrastructure is rapidly receiving multi-disciplinary contributions for policy-making and discussion. There is tremendous research in the United States and European Countries. In Ontario, green infrastructure policy covers definitions of (a) Green infrastructure, (b) Natural heritage system, (c) Green land system, and (d) Low impact development. Urban growth periods of study vary with researchers' interest. Hu et al. (2020) studied and utilized the categories of land use changes indicator, which are (a) Farmland, (b) Woodland, (c) Grassland, (d) Water bodies, (e) Impervious land, and (f) Unused land.

Shih, Mabon, and Puppim de Oliveira (2020) stated that the IPCC classifies land use into, forest land, settlement, wetland, cropland, grassland, and others. Conversion of grassland as revealed by the cropland significantly alters temperature. Parveen, Basheer, and Praveen (2018) revealed that land uses are categorized under four major phases and categories. Category 1 covers agricultural land, built-up area, grazing land, forest, wetland, wetland, and water bodies. Category 2 which includes built is divided into rural and urban, architecture, grazing land, forest, wetland, grazing/wetland, and water bodies. Besides, category 3 handles built-up areas into eight sub-categories as residential, commercial, transportation and communications, public utilities, recreational, mixed land uses industrial and vacant land. The last category shows that built areas is subdivided based on densities as low, medium, and high densities and included all in the mentioned above. Kaim, Cord, and Volk (2018) opined agricultural management is facing challenges from land use allocation with the sole intention of ecosystem and biodiversity services provision.

Land Use Planning

This is rational coordination, integration, and separation of various categories of land uses which range from residential, commercial, industrial, transportation, and recreational among others with the sole aim of zoning compatible and separating non-conforming land uses for sustainability. This is an integral tool for contemporary spatial planning. It received enormous from scholars like Lima, Chmeli, Guedes et al. (2020) who explained land use planning laws governing occupation vary because of differences in aspiration, ambition, and level of complexity. This is due to disparity in culture, tradition, politics, and geographical location. Principles and practice in land use planning are in scholarly contributions of Graciela (2017) who stated the principles and practice of land use planning have the following considerations, namely (a) Legal and socio-political context, (b) Integration and participation, (c) Scale relevance and vertical integration, (d) Sectoral coordination, (e) Functionality of the land, (f) Best palling policies and practice, and (g) Land use planning care studies. Hersperger, Oliveira, Pagliarin, Palka, and Verburg et al. (2018) argued driving forces of land use planning include, natural, cultural, socio-economic, political, and technological. Additionally, for effective land-use planning, planning and policy cycle that attract the driving forces needs to follow the cyclical nature of land use planning with the following stages, which are (a) Problem identification, (b) Goal formulations, (c) Relevant data collections, (d) Scientific analysis, (e) Alternative plans productions, (f) Evaluations of the alternative plans, (g) Selections of the best plan base on cost-benefit analysis, (h) implementations of the selected plans, and (I) Reviewing of the plans to suit the present and future needs.

Editorial (2019) contributed and considered plans for land development under two broad sub-headings, which are (a) Single developer with the land development model, and (b) Different planning situations for utilities social provisions whereby (1) both developers and local government acquired information, (2) some developers acquired the desire but the government does not provide it, (3) all developers acquired information but the government does not provide it, and (4) only government provides information. The study by Calbick, Day, and Guoton (2003) assessed practice implementation regarding five innovative planning agencies with regard to land use planning in North America. Wang, Shen, Xiang, and Wang (2018) studied the connection between theory and practice about the characteristics of an urban community resilient. It correlates with resilience strategies and concepts. The study by Allam (2020) discussed ways smart city concepts could be used to promote and standardize data sharing and disseminating data for disaster outbreaks in urban areas. Honey-Roses, Anguelovski, Bohigas, Chiren, Daher, et al. (2020) highlighted that the study concentrates on city design concerning a pandemic. Changes between population lockdown and public space required intensive study for the post-pandemic urban planning and design globally. Steiner (2018) focused on the city of Austin's principles to cover liveable, natural and sustainable, creative, educated, prosperous, mobile, and interconnected, values and respect of people. The study by Kumar (2018) centered on the development of building regulations in the hill town in India with a focus on problems and issues connected to it. It compasses Himalayan hill town natural hazards with careful and very deep thought to comprehend its building regulations for safety. Dempsey, Plantinga, Kline, Lawler. Martinuzzi et al. (2017) added that zoning regulation is the major tool for controlling land use and land cover change. Yan, and Sakairi (2019) mentioned that Geo CPS could be applicable in the following areas, which are (1) Construction equipment and construction industries, (b) Resources management and environmental conservation, (c) Infrastructure and wastewater management, and (d) Mobility accessibility management. Christodoulou and Nakos (1990) showed land use planning involving these comprehensive flow charts.

Lopes, Cavalcante, Vale, and Loureino (2020) revealed that stakeholders divergent interest creates great challenges complex in nature to city planning expertise. This is because of its multidisciplinary and communication gap within the specialists from closely associated disciplines. Wang, Ma, Zhong Hunt, Zhang, et al. (2019) depicted that the study handles integrated land use and transportation forecasting models based on the Baltimore PECAS Demo Model.

GIS Application in Land Use Planning

Modern and contemporary land-use planning employed spatial remote sensing and GIS data in its urban growth and related studies. This is because remote sensing and GIS tools are of high accuracy, wide area coverage, and save both time and resources. Town planners solely focus on spatial data for decision-making. The study by Trinder and Liu (2020) in this context indicates that land use changes are conducted in two cities, which are Wuhan in China and Western Sydney in Australia. The study employed Multiple Endmember Spectral Mixture

Analysis (MESMA) and Super-Resolution Mapping (SRM). The classification is further processed with the aid of Indi frag software to evaluate the exact status of fragmentation. The study relates to the SDG sustainable development goal. Bolous and Geraghty (2020) revealed that GIS technologies could help in the outbreak through public events, site selection, supply chain, resources, locators, and drones. Suleman, Waheed, Sahar, and Aisha (2020) depicted in their study the application of GIS tool identification of affected zones and a proper recommendation to the authority. GIS is applied under the following, are (1) Developing GIS capacity building for controlling, (2) Identifying and revealing epidemic outbreak cases and their court, (3) Mapping for epidemic through spatial segmentation, (4) Arrangement of data considering location, time and peoples involved, (5) Hypothesis test development concerning demand and supply of medical facilities, and (6) Evaluation of supply of materials and its transportation. The study by Patra, Sahoo, Mishra, and Mahapatra (2018) pertaining to geographical information system indicate a significant correlation between land use land cover changes, and anthropogenic activities in the urban setting.

Geographical information systems (GIS) and multi-criteria decision analysis (MCDA) are intensively utilized for urban growth analysis. The work of Ustaoglu, and Aydiooglu (2020) commented that urban suitability is very complex because it desired both environmental and geophysical information and expertise for proactive analysis. GIS and MCDA were the most effective combined tools for these indicators, which are (a) Built-up areas and infrastructure, (b) Vegetation cove blue and green amenities, and (c) Geophysical attributes and access roads. These are employed for land use sustainability studies. Trinder and Liu (2020) explained Landsat is characterized with an intermediate resolution for urban area classification. The study employed Multiple Endmember Spectral Mixture Analysis (MESMA) and Artificial Neural Network (ANN) for the generation of very high resolution. Mouratidis (2020) stated that the study interconnects neighborhood deprivation and neighborhood characteristics together with well-being, using survey geospatial data also from green space, public transport, and local amenities. Rofl, Dielh, Zasada, and Wiggering (2020) added green infrastructure was developed in European Countries with the sole aim of integrating it into policies. Its objectives include (a) Green economy promotion, (b) Social cohesion increasing, (c) Biodiversity conservation, and (d) Climate change adoption. Cost-benefit of megacity evaluation is demonstrated by You, Li, Wang, and Pan (2020) mention that the economic and ecological benefits evaluation of megacities of urban land use is not easily applicable to megacities suburban that therefore, developed population theory. A population economy-space includes factors of land use benefits, population, economy, and space. Benefits of the theory include horizontal benefits, longitudinal benefits, and overall benefits.

Land Use

This is the present or anticipated use of a given piece of land in both rural and urban settings. It is very essential in urban growth study because of its dynamic nature. The dynamism of land use is directly connected with human actions. Iwasaki (2019) studied and categorized residents in the research into clusters, which are (a) Urban professional cluster, (b) Nuclear families with children residing in a rental accommodation (Housing), (c) Area without residents cluster, (d) Blue collar workers cluster, (e) Manufacturing and industrial workers cluster, and(f) Typical farmers cluster. Additionally, Cluster B influences population growth in the study area. It concentrates on sub-urban areas and away from densely populated areas. Trender and Liu (2020) showed the paper handles land use cover changes (LUCC) within urban Wuhan in China and Western Sydney in Australia. The scholars' work dwells under (a) a Comparison of the LUC metric for both Wuhan and Sydney from 1987/8 to 2017, and (b) Land use change in Wuhan and Sydney. Meanwhile, Unger, Bennet, Lemmen, Zeeuw, Zevenbergen, et al. (2020) indicate that land administration and disaster risk management policy transfer should consider (a) Transfer agents (who), (b) Transfer content (what), (c) Transfer process (who), (d) Transfer output (where and when), (e) Transfer outcome (why), and (f) Transfer limitations (why not). Lopes, Cavalcante, Vale, and Loureire, (2020) opined urban planning or urban space planning in Brazil is quite like other similar developing nations cities with an emphasis on Land Use Transportation Integration (LUTI) as a recent transportation sector development. MacDonald and MCKenney (2020) explained that the study covers these subjects' ecology, biology, forestry, environmental science, economics, and, geography with emphasis to its methodology from biodiversity, carbon and remote sensing.

METHODOLOGY

The study solely covers the model development of the urban growth of the studied parameter impacts (land use changes, water, and air pollution). Land Use Change data is obtained with the aid of geographical information system (GIS) and remote sensing (RS) within 35 years (1984 to 2019). The study employed three periods 1984, 1998, and 2019. Water pollution samples were taken from the existing historic ponds in the metropolis and the sample water was analyzed in the laboratory for physicochemical elements. The air pollution parameter in Kano metropolis consists of carbon monoxides (CO) and carbon dioxides (CO_2) emission sensed with the aid of 707 Crowcon Gasman 19259H gas detector device and SD Card Loger CO_2/Humidity/Temp/Data Recorder MCH-383SD for both indoor and outdoor. The Structural Equation Modelling (Smart PLS-SEM) is employed for the analysis with references to measuring the magnitude of impacts of each parameter. Three models of urban growth in KNMA theoretical model, the theoretical model of air pollution, and the theoretical model of water pollution of KNMA. These are mathematically presented.

STUDY AREA

Kano Metropolis is geographically located within Latitudes $12^{o}25^{I}$ to $12^{o}40^{I}$ N and Longitude 8^{o} 35^{I} to 8^{o} 45^{I} E. It is the most developing and urbanized city and commercial center of Northern Nigeria. It has an annual growth rate of 3% with a population of (3.5 million, 2010) projected to (4.3 million 2018). It is highly crowded with 1000 people per square kilometer (KM^2) and its climate is wet and dry based on Koppen's classifications (Hashim, Gobi, and Ho 2020). Medugu (2010), as Hashim, Gobi, and Ho 2019 stated that the dramatic urbanization processes going on within the Kano metropolis over the past decades is a significant factor. In addition, Kano metropolis is the major commercial active center of Northern Nigerian states. Kano Metropolis is the most industrialized with heavy and light industries. The metropolis is also a commercialized metropolis in Northern Nigeria that attracts immigration of both skilled and skilled labour from and outside the region (Hashim et al, 2019). Figures 1a, 1b, and 1c demonstrates the study area as in Hashim (2021)

Figure 1a: Showing of Nigeria Showiing Kano State

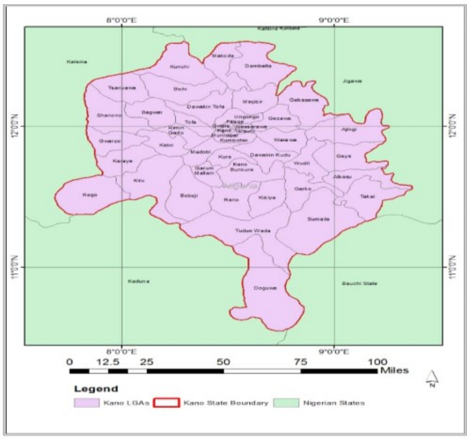

Figure 1b: Showing Kano State

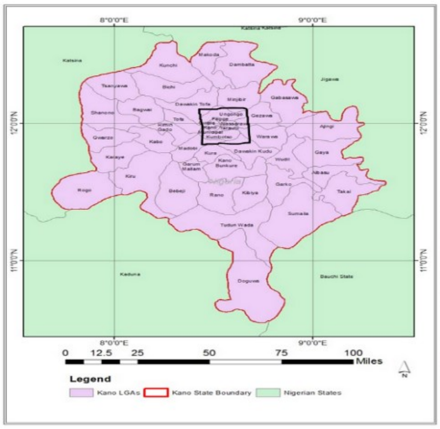

Figure 1c: Showing Kano State Metropolis

FINDINGS OF THE STUDY

The historic population growth trends of KNMA are recorded from 1820 when the ancient settlement of Kano city was 30,000 to 40,000 thousand dwellers. The population rose to 60, 000 people by 1851 and it significantly rose to 83,000 in 1932 inhabitants as the total population censused by the colonial government. The population as spelt by the colonial government dramatically shifted upward to 250, 000 in 1963. In 1991, the national population census recorded 1.5 million people and by 2006, the population reached 2 million people (Barau et al.2015). This indicates that within the study period which is thirty-five years (35 years), the population closely doubled its initial total values. The study projected the year 2020 population to 2040 which is the plan period of the study. The results of the projection are 6,529,393 people. This implies that if all factors influencing the population growth in the metropolis remain constant, the population will rise relatively in the future.

Results of Land Uses Pattern

Urban Growth in KNMA Theoretical Model

The study revealed that factors responsible for dramatic urban growth in the metropolis could be categorized into three broad headings. These factors caused the speed and direct conversion of the existing agricultural land uses into physical structures ranging from residential land use, commercial land use, and transportation land use to mention but few. The factors are statistically stated as:

Urban Growth in KNMA = $\propto + RPG\ (P\beta 1 + P\beta 2 + P\beta 3 + P\beta 4 + P\ \beta 5) + GPC\ (G\beta 1 + G\beta 2 + G\beta 3 + G\ \beta 4) + IEA\ (E\ \beta 1 + EB2 + E\ \beta 3 + E\ \beta 4) + NT\ (N\beta 1 + N\ \beta 2 + N\ \beta 3)$

Where RPG= Rapid Population Growth
$P\beta1$= Belief of the Residents
$P\beta2$= Marriage Type (Polygamous)
$P\beta3$= Fertility Rate
$P\beta4$= Timely Marriage
$P\beta5$= Immigration

Where GPC= Government Policy and Customs
$G\beta1$= Land Administrations
$G\beta2$= Infrastructural Development
$G\beta3$= Land Tenure System
$G\beta4$= Housing Provision/Loan

Where IEA = Intensive Economic Activities
$E\beta1$= Numerous Specialized Markets
EB2= Industrial Activities
$E\beta3$= Large Job Opportunities
$E\beta4$= Large Market Forces

Where NT= Nature of the Terrain
$N\beta1$= Suitable Topography
$N\beta2$= Available Local Building Materials
$N\beta3$= Sufficient Surface and Underground Water Reservoir
$N\beta3$= Regional Geographical Location

Theoretical Model of Air Pollution

Based on the study findings with regards to the rapid populations and its compositions reference to the number of households per house (NHH), number of people per household (NPH), number of rooms per house (NRH), number of rooms rented (NRR) and Monthly rent per room (MRR), the theoretical model is developed. In addition, the research results concerning the amount spent by respondents on energy sources (AMT), Frequency of buying energy sources (FRQ), number of hours respondents used generator (HR –GEN while town services mean of transportation (TWN-SRV), types of energy (TYP ENG) and the purpose for the energy usage (USE ENG), provided bases for the study theoretical framework.

Air Quality Indicator in China

Xu (2017), in the study titled impact ofurbanization on urban quality in China 2017 mathematical arrived. The mathematical relationship is stated below;

Air Quality = *β*++*β**(urban_pop) + *β*#(gdp)+ *β*0(gdp_capita) + *β*<(manufacturing)+ *β*%(man_pro) + *β*=(coal)+ *β*>(gas)+ *β*? (N_S) +*β*@(E_NE) + *ε* (3).

The scholar gives emphasis on the urban population, gross domestic products, manufacturing, man production, coal, gas, the difference in geographical location, and the element above in China North South, East, and North East.

Energy Demand and Carbon Emission in US Residential Buildings

Rong (2006), the scholar mathematically arrived at the work impact of urban sprawl US residential energy use. The find of total energy demand concerning population is stated below;

Total Energy Demand = ∝ + B1 ln (House Size) + B2 House Type + B3House Built Year + B4 Household Income + B5 Householder Race + B6 Number of Household Adults + B7 Number of Household Children + B8 ln (Energy Price) + B9
HDD + B10 CDD + Other Controls + μ

The scholar gives emphasis to House size (B1), House type(B2), age of house(B3), household income category(B4), Race of the householder(B5), Sum up adult in the household(B6), sum of the children in the household(B7), price of energy(B8), Heating degree per day (B9, cooling degree per day(B1)

Theoretical Air Quality Model in KNMA Modified from China and US Studies

Air Quality Indicator in KNMA = ∝ + P1 *(Number of Households in a House, NHH)* + P2 *(Number of People Per House, NPH)*+ P3 *(Number of Rooms in a House, NRH)* + P4 *(Amount Spent for Energy, AMT)* + P5 *(Frequencies of Heating and Cooling, FRQ)* +P6 *(Time Spent Using Generators, HR –GEN)*+ P7 *(Town Services Trips Generation, TWN-SRV)* + P8 *(Type of Energy Sources Used, TYP-ENG)*+ P9 *(Purposes for the Uses of Energy, USE ENG).*

The study gives-emphasis to the demographic elements and energy demand

Where;
PI = Number of Households in a House,
P2= Number of People per House,
P3= Number of Rooms in a house,
P4= Amount Spent for Energy,
P5=Frequencies of Heating and Cooling,
P6= Time Spent Using Generators,

P7=Town Services Trips Generation,
P8= Type of Energy Sources Used,
P9= Purposes for the Uses of Energy(P9).

Theoretical Model of Water Pollution of KNMA
The study uncovers that the existing historic mining ponds in Kano metropolis is because of the interaction of four major parameters. The parameters are very high population, land use type, density, and residential and attitude of the Residents.

The mathematical representation is:

$$WP = f\,(P+L+D+A)$$

Where:

P = Population
L = Land Use Type
D = Density of Land Use
A = Attitude of the Residents

Results of Land Uses Pattern
Pattern of Urban Growth in Kano Metropolis Nigeria 1984-2019
The study uncovers variations in the pattern of urban growth in the area. Each study period has uniqueness and peculiarities regarding factors responsible for urban growth within that specific period. Government attitudes towards infrastructure provision also vary greatly from one administration to another. The economic base of the residents is also a key factor that leads to significant variations in the pattern and form of urban growth in the metropolis.

Nucleated and Concentric Urban Expansion Organic Growth 1984 in KNMA
The year 1984 is the first period of the study employed for the study for assessment of the trend of land use changes with much emphasis on the conversion of agricultural land into physical structures. Emphasis is on the farmland/open fields, trans-cape/irrigated fields, built-up areas, and water bodies. The study unveiled the understated factors as the characteristics of the determinants that favored this pattern of growth. First, organic/unplanned development, which is mostly seen and visible in very high densities of the traditional walled city (old Kano town or Birnin Kano). In some parts of the ancient city roads constructed in the pre-automobile age are still in existence. The roads are far below planning standards. This makes some areas not vehicular accessible. Second, weak zoning regulations, that is also obvious within high densities within the metropolis. This is also seen in the conversion of residential plots into commercial. This period covers the intensification of commercial activities because of the population growth. Third, irregular plot sizes below

planning standards, whereby the study shows that layouts were basically at the mercy of the farm owners.

Nucleated Concentric and Disperse Pattern of Urban Expansion in KNMA 1998

The study shows the following factors as responsible for the urban growth expansion at this axis. It includes the construction of a dual carriage Zaria Kano Road, which is the major key factor that intensified commercial activities between the states. This also led to immigration to the metropolis thereby leading to a high population increase. This resulted in physical development to accommodate growing populations. The Kano State government's efforts in infrastructure provisions include new road construction, upgrading of the existing ones, and demolishing and connecting roads of substandard roads, especially in the ancient part of the metropolis. The study shows the nucleated concentric and dispersed pattern of urban growth and expansion in the study area.

Nucleated Compacted/Concentric and Isolated Pattern of Urban Growth in KNMA 2019

This study therefore explains and shows the trend of rapid urban growth in the study area between 1984 and 1988 that continued to intensify from 1998 to 2019. The determinant factors responsible for this dramatic growth as depicted by the study include (a) road infrastructural Development from 1998 to 2019, (b) fly-overs, through and road upgrading within Central Business Districts, (c) Intensity of commercial activities within neighbouring states, (d) Influx of immigrants from insurgent zones, (e) Rapid population growth, (f) Layout development by the state governments, (g) States creations and economic development, (h) Inter-states linkages, (I) Effective inter-states transport services (Kano Line) that travel across the country, (j) Cities lay-out development, (k) Land values appreciations, (l) Carved out lay-outs from residential to commercial land use, and (m) Conversion of residential land use to commercial. Thomas (2013) in his work in Woodbury discovers these affecting land use land cover changes about rapid urban growth. The factors include economic growth, population growth, policies of the government, and technological growth.

RECOMMENDATIONS

This calls for deep and strong study on the effective urban management framework applications for the metropolis and its alike globally. The framework model applications will help in the integration of sustainable land use change principles and techniques, low carbon society development (LCSD) for air pollution parameters with mitigating water pollution with its management techniques.

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