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Spatio-Temporal Measure of Urban Expansion in Erelu Waterworks Zone, Oyo State, Nigeria

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Abstract-* The quick expansion of cities in developing countries is often not accompanied by enough development of infrastructure. This paper focuses on how sixty years of urban growth in the Erelu Waterworks Zone of Oyo State has increasingly overstretched the municipal water production capacity. The analysis of multi-temporal satellite images of the area from 1982, 1992, 2002, 2012, and 2023 has been done through GIS-based supervised classification and population projection and water demand calculation techniques. Urban land coverage grew rapidly from 6.56 km² in 1972 to 96.06 km² in 2022, an increase of sixteen times. It happened through three distinct stages; the first was until 1992, where the growth pattern was characterized by infill development within traditional districts; after that came extensive urban sprawl along transport corridors, especially the Ibadan-Ilorin Expressway, which currently accounts for more than 80% of construction activities. This most intensive period of growth took place during the period 2003–2012 when 13.14% was added to the urban area, more than any decade before. Simultaneously, the capacity of the Erelu waterworks facility had been stagnant since 1962, with an average of 5,600,000 liters/day. As a result, urban water demand rose from 5.6 million to 79.18 million liters/day-a fourteen fold increase, while the plant could only meet 7.07% of its limited coverage area. Daily water supply per capita fell from 48.28 liters in 1972 to 12.28 liters in 2022, which is critically below the WHO's minimum demand of 50–100 liters/day. By 2032 and 2042, this will be reduced further to 8.32 and 5.68 liters, respectively. Uncontrolled urban growth has made Erelu waterworks infrastructure inadequate. Immediate action towards improvement in water treatment plant capacity, distribution systems' rehabilitation, and effective urban-water planning is imperative to avoid total breakdown of the system.

I. INTRODUCTION

Urban expansion is the process by which an increasing proportion of the population comes to live in urban areas, with associated growth in population, infrastructure, and land use, often at the expense of natural ecology and rural practices. This is a key attribute of urbanization and can have significant social, economic, and environmental implications (Angel et al, 2011; Seto,2017). It is the continuous physical, spatial, demographic, and environmental extension of urban limits beyond their existing boundaries, typically resulting in the conversion of rural lands into urbanized landscapes (UN-Habitat, 2009). The World Bank (2015) describes urban expansion as the outward growth of cities, involving the development of new infrastructure, housing, and economic activities on previously undeveloped or rural land. Rapid urban expansion frequently outstrips the development of essential infrastructure, including water treatment plants, distribution networks, storage facilities, transportation systems, and utilities. This mismatch results in congestion, service inadequacies, inefficiencies, and insufficient coverage (World Bank, 2018). Urban growth leads to increased population density and higher per capita water consumption, thereby elevating water demand beyond the capacity of existing supply systems (World Bank, 2010; Vorosmarty et al., 2010). Consequently, waterworks facilities often become inadequate to meet rising demand, leading to suboptimal treatment outcomes (Nosenko, 2020).

The rate of urbanization in Nigeria is alarming, and the major cities are growing at rates between 10-15%

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per annum (Yusuf, 2007; Imamuddin & Hidayat, 2022). As population grows and urban areas increase in size, more potable water is demanded. Unfortunately, water treatment and distribution infrastructures are not attracting the required attention in many urban areas of Nigeria. There was a steep decline in access to urban pipe-borne water supply from 32 percent in1990 to 3 percent in 2015, a margin of 29 percent. At the national level, access to piped water on premises declined from 12 percent in 1990 to 2 percent in 2015. Most noticeably, access to piped water in Nigeria is below that of most countries in Sub-Saharan Africa. In 2013, UNICEF listed Nigeria as one of the ten countries where two-thirds of the global population lives without sufficient access to potable water sources, and virtually all urban areas of Nigeria suffer water supply shortages relative to demand. The decline is attributed to rapid urbanization, lack of investment, institutional constraints, and environmental change (Ofoegbune et al 2011, Falaye et al 2015, Kareem et al 2015, Amusat et al 2019, Olasunkanmi et al 2021, Okon and Njoku 2017).

In some urban contexts, water supply is intermittent, available only during limited hours, which inconveniences residents and disrupts daily activities. Issues such as discoloration, unpleasant taste, or odor further diminish consumer satisfaction and trust in the water supply (Khattak et al., 2016).Urban water supply systems often fail to provide equitable access across all neighborhoods. Low-income or informal settlements typically have restricted access to potable water, resulting in disparities in potable water availability and quality across urban areas. This inequity exacerbates social inequalities, as marginalized populations are often excluded from the benefits of urban development (Gilbert & Gugler, 2012). Water scarcity remains a critical challenge in many regions, intensified by factors such as population growth, climate change, and excessive groundwater extraction (Falkenmark & Rockström, 2006). Studies on urban coverage of potable water infrastructure have not been critically carried out in the Oyo zone. Likewise, existing studies are not specific in pointing out how urban expansion specifically affects the existing water infrastructure.

Urban expansion can take various forms, and it often depends on local factors, urban planning policies, and geographical constraints. Common forms of urban expansion include: (i) Urban sprawl refers to the uncontrolled and often low-density expansion of cities into surrounding rural areas (Ewing &Hamidi, 2015). (ii) Infill development involves the utilization of vacant or underutilized parcels of land within existing urban areas for new construction or redevelopment (Roodman, 2007).(iii) Greenfield development refers to the creation of entirely new urban areas on previously undeveloped land, often on the outskirts of existing cities (Deakin &Allwinkle, 2007).(iv) Brownfield redevelopment focuses on repurposing abandoned or contaminated industrial sites within urban areas for new commercial, residential, or mixed-use developments (Trencher et al, 2013). (v) Vertical expansion involves the construction of high-rise buildings or skyscrapers within an urban area to accommodate population growth and maximize land use in densely populated areas (Glaeser&Gyourko, 2005). (vi) Transport-Oriented Development focuses on creating mixed-use, high-density developments around public transportation hubs (e.g., train stations or bus stops) (Cervero&Kockelman, 1997). (vii) Gentrification involves the transformation of lower-income neighborhoods through investment, infrastructure improvements, and the influx of more affluent residents (Smith, 1996).

The water demand is projected to increase significantly over the coming years. For instance, the projected water demand in Nigeria is expected to rise from 627,529 cubic meters per day in 2016 to 989,049 cubic meters per day by 2030 (Ojo & Sohail, 2024). This increase highlights the growing need for improved water supply infrastructure to meet the rising demand. Water demand in Nigerian cities is influenced by various factors, including population growth, urbanization, and economic activities. Socio-economic factors play a crucial role in determining water demand in urban areas. In Osogbo, for instance, households in low-density areas consume more water compared to those in high-density areas. The average daily water consumption in low-density areas is 960 liters per household, compared to 735 and 517.5 liters in medium- and high-density areas,

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respectively (Adedotun et al, 2024). This variation underscores how economic status and residential density impact water consumption patterns.

Efforts to improve urban water supply are crucial for reducing reliance on traditional and potentially unsafe water sources. The Nigerian government has declared a State of Emergency in the water sector and launched initiatives aimed at achieving universal access to sustainable water services by 2030. These efforts include strengthening public water systems and promoting safe water practices to reduce health risks associated with traditional water sources (Veriv Africa, 2024).The estimates of water demand in Nigerian cities reflect broader systemic issues within the water supply sector. Addressing these challenges requires comprehensive strategies that enhance public water infrastructure and promote safe water practices. By doing so, Nigeria can reduce its reliance on traditional water sources and improve overall public health and well-being.

Based on early waterworks established in Nigeria, Oyo State can be grouped into nine water zones. These are Ibadan, Oyo, Ogbomoso, Eruva, Ighoho, Igbetti, Kisi, Saki and Iseyin. Archival records indicated that Erelu waterworks was constructed on the Aawon River, along Iseyin Road, by the Water Corporation of Western Nigeria. The water project was commissioned on the 30th of November, 1962, by the then Commissioner for Works and Transport in Western Nigeria, Mr Adeniyi Williams. Oyo State Government (2025) has it that the Water Corporation of Oyo State evolved out of the then Western Nigeria Water Corporation through the Enabling Water Corporation of Oyo State Edict No 24 of 1977 and as reviewed by the Water Corporation of Oyo State Amendment Law of 2006. The Water Corporation of Oyo State is a public utility fully owned by the Oyo State government. It is responsible for the provision of potable water to the urban areas of the state.

Settlements jointly served by Erelu waterworks are: Oyo, Awe, Akinmorin, Ilora, Fiditi and Iware. As at 1961, they were considered worthy of a pipe-borne water supply because of their relatively large sizes. Erelu water project was built with a treatment plant capacity of 7.5 million liters of potable water per day. The Dam has an impoundment area of 161.07 ha, surface area of 13,106 Ha, maximum height of 13.106 meters, and a catchment area of 243.36 km. The water treatment plant utilizes a conventional method and was about 6.4 kilometers from the township in 1961 (Ufoegbune et al 2011, Kareem et al 2018, Amusat 2020).

Potable water is a type of water that can be used safely by humans without causing any harm to health over a lifetime (Khalmirzaeva, 2022). Any water that complies with required quality standards, considers human right principles, conforms to the sustainable development objectives, and is safe for human consumption is regarded as potable. Not only does it taste good or look good, but it is water that has been properly treated, monitored, and guarded against unfriendly elements, and that can be consumed without any negative health consequences. The notion of drinkable water is a backbone of environmental health, policy, and sustainable development. In the modern context, potable water has scientific, technical, and legal connotations. Scientifically, it must meet microbial safety standards and chemical contaminant limits as codified in statutory instruments such as the European Union Drinking Water Directive and National Drinking Water Standards in various countries (EU Directive, 2020; Cherkashyna et al 2025). Technically, potable water must address issues of accessibility and reliability as formalized by the global monitoring systems. In this regard, the WHO/UNICEF Joint Monitoring Programme (JMP) defines potable water that is on site and accessible as and when required, as well as free of contamination (WHO and UNICEF, 2025).

In this study, the focus is to examine how the service area of Erelu waterworks has increased in size in time and spatial contexts between 1972 and 2022. This is to portray the present potable water demand level, as well as the waterworks capacity needed to meet the present potable water needs in the zone.

1.2 The Study Area

Oyo urban zone enjoys a tropical wet and dry (tropical savanna) climate (Aw). Rainfall is enjoyed between April and October, while dry weather with occasional rainfall features between November and March. The climate is consistently warm throughout the year. Available Rainfall data revealed that a monthly average of 796mm is recorded. The annual average, however, is 1163mm. The rainy spell commences in March and terminates in October, while the dry season is felt between November and February. The mean temperature is about 27˚Celsius. The highest temperature is often recorded during April, while the lowest is in August. The mean maximum is around 32˚C, while the mean minimum is 20˚C. Temperature conditions remain virtually unchanged throughout the year. The average minimum and maximum temperatures are respectively 18°C and are 32 C. The annual mean temperature is 27 C. The highest temperature often occurs at the onset of the rainy season in April. The coldest month occurs in August (Weather Spark 2025, Time and Date 2026, Climate Data 2026)

Riparian forest/forest outlier with open undergrowth is common along stream banks. They have irregular (fewer complexes) structure but are denser than similar woodland in the savanna area. They are associated with moist lowlands or hollows, river valleys, relics on stony hilltops, sites which are inaccessible for farming, valleys within the marrif, and sacred forest groves.

Based on the topographical maps of Oyo (NW, NE, SW, SE), the Erelu water zone is located on the wide upland plains to the south of western plateaus. Rocky outcrops and lateritic beaches and outcrops occur along the major break of slope as one approaches the valley. The land rises slowly from the northwestern riverside towards the southeastern end. The ridges gradually attain a height of 1,100metres along Akinmorin Road from 850 meters at Oroki. Areas that can be taken as important heights are Soro, Mogi, Yidi, Low Cost Height, Kosobo Height, Miracle Center, Oke Border Awe, Mogi, Olivet, among others. These are quartzite ridges. They provide the source for streams named by source region: Awe (Amo), Awe (Sogidi), Awe (Akinmorin Road), Kosobo, Ilaka, Jabata, Odo Ogunmola, Sawmill, and many others. These streams originated in the East and flow westward to join the Aawon and Ogun rivers in the west.

Aawon stream is of subsequent category, being a tributary to the Ogun River, a consequent river. Dendritic pattern persists throughout the basin area, and the streams display youthful, mature, and old age characteristics (topographical maps of Oyo NW, NE, SW, and SE). The basin valleys vary considerably in shape. Common types are the V- shape, saucer shape, U-shape, and broad floor valleys. Broad floor valleys are known for periodic water logging. Streams swell up to the fullest between May and October, and dry up almost completely between January and March. Awon and its consequent tributaries carry a lot of materials in suspension and in solution on a yearly basis (Oyelami 2012). Streams that originated within the township possess water along their courses all year round due to household liquid wastes that normally find their way into them

1.3 Method of Data Analysis

A mixed–methods approach was employed. Landsat (low resolution) images were downloaded from Earth Explorer. These images included (i) Landsat Thematic Mapper of 1982 and 1992, (ii) Landsat Operational Land Imager of 2002, and (iii) Landsat Enhanced Thematic Mapper 2012 and 2023. For data analysis, a geographical information system was used to analyze multi-temporal satellite imagery. Landsat images were explored in ArcGIS, where they were limited to the study area. The images were then overlaid electronically on the high-resolution image of 2023 to produce a feature-oriented map. A supervised classification algorithm was used to classify the complete image according to the training samples (built area, roads, river, and open spaces). Geometric correction was performed on the image to ensure that the final map reflected real coordinates of the world, and by implication, the coordinates of the study area. Map production was followed by ground identification, capturing and measurement of features.

Population Density was calculated by dividing the Population by Area. Water Demand was calculated by equating the urban size of 6.56 sq. km (1972 figure) to Erelu Daily Production Capacity (5,600,000 liters). Daily Water Supply (/sq km) was calculated by dividing Daily Production Capacity by Area. Daily Water Supply Per Capita was calculated

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by dividing the Daily Production Capacity by Population. The projected area size for the year 2032 was determined by calculating the average rate of expansion over the previous six decades. The same procedure was followed to arrive at the year 2042 figures.

II. THE RESULTS

2.1 Urban status of Erelu waterworks zone in 1972

Settlements jointly served by the Erelu public pipe-borne water system are: Oyo, Awe, Akinmorin, Ilora, Fiditi and Iware. As at 1962, these were settlements worthy been called urban or peri-urban, and they were considered for pipe-borne water supply because of their collective size. The settlements were made up mainly of traditional districts; however, modernity made an imprint through the emergence of elite districts, particularly along the peripheral areas of Oyo town. Oyo urban land area was just 02.47% compared with its present size in 1972, and the entire urban spaces were sufficiently and adequately served by public pipe-borne water. Generally, settlement in Oyo zone can be said to be growing mostly organically before 1972. Organic growth is that in which the city grows slowly over a long period of time and has not been subjected to any comprehensive planning effort (Springerlink 2019). They are characterized by narrow streets and alleys that are densely packed with shops, markets, mosques, and other amenities, which allow the residents to find their daily needs within a short walk. Generally, organic communities are structured based on administrative and historical (cultural) considerations.

Among the traditional districts that fall into the present Afijio Local government area are: Akibio, Atuke, Jagun, Odofin, Balogun Ogunlade, Balogun Abopa, Bode, Oluwo, Oluosun, Alagbara, Obanisola, Onikooko, Aribonbo, Atente (Ilora), Jaafu, Ojueru, Oleyo, Abese, Agbaakin, Owode (Fiditi), Alagbede, Asalu, Gbodooya, Lalemu, Oke-bata, OkeOdofin, Isale Baale, Olode Isale (Awe), Akinmoorin, Iware.

Oyo is made up of three local government areas – Atiba, Oyo East and Oyo West. Traditional districts that fall under Atiba local government are: Aremo, Basorun, Agunpopo, Ashipa, Okeebo/Adikuta, Adesina, OkeOlola, Lagbondoko, Iyalamu, Oke Oroki, Koso, Bango Isale Oyo, Sabo, Amejiogbe, among others.Traditional Districts in Oyo East local government area are: Agboye, Molete, Ajagba, Alaodi, Apaara, Apinni, Balogun, Jabata, Oke Apo, Oluajo, Kanga, Idiape, Tengba, Bara, Olomoodo, OkeEletu, Alebiosu, Ilaka, Oja, Okeloogun, Odo–aro, Alalubosa, among others. Traditional Districts in Oyo West local government area are: Akeetan, Akeugberu, Iseke, Isokun, Iyaji, Opapa, Pakoyi, Ojongbodu, Kolobo, Ogbeyo, Alalubosa, Gudugbu, idode, among others (Oyelami 2013).

Each traditional district is made up of many compound houses. Isale Oyo, for instance,has over 164 compound houses. Traditional district and compound names featured prominently in the naming of subsequent developments, as urban land expands outward over time. Areas featuring an appreciable number of modern houses as at 1972 are: Jabata, Owode, Araromi, Alagbon, Akeetan, Atingisi, New Iseke, New Akeetan, Tengba, Kosobo, among others. Modernity features significantly in terms of infrastructure, schools, roads, markets, police station, pipe-borne water facilities, and prominent structures that beautified the settlements' landscape. Streams played a significant role in the development pattern and shape of urban space. Marshy land and areas liable to seasonal springs were less settled, possibly because they did not allow for appreciable longevity of mud houses (See Figure 1).

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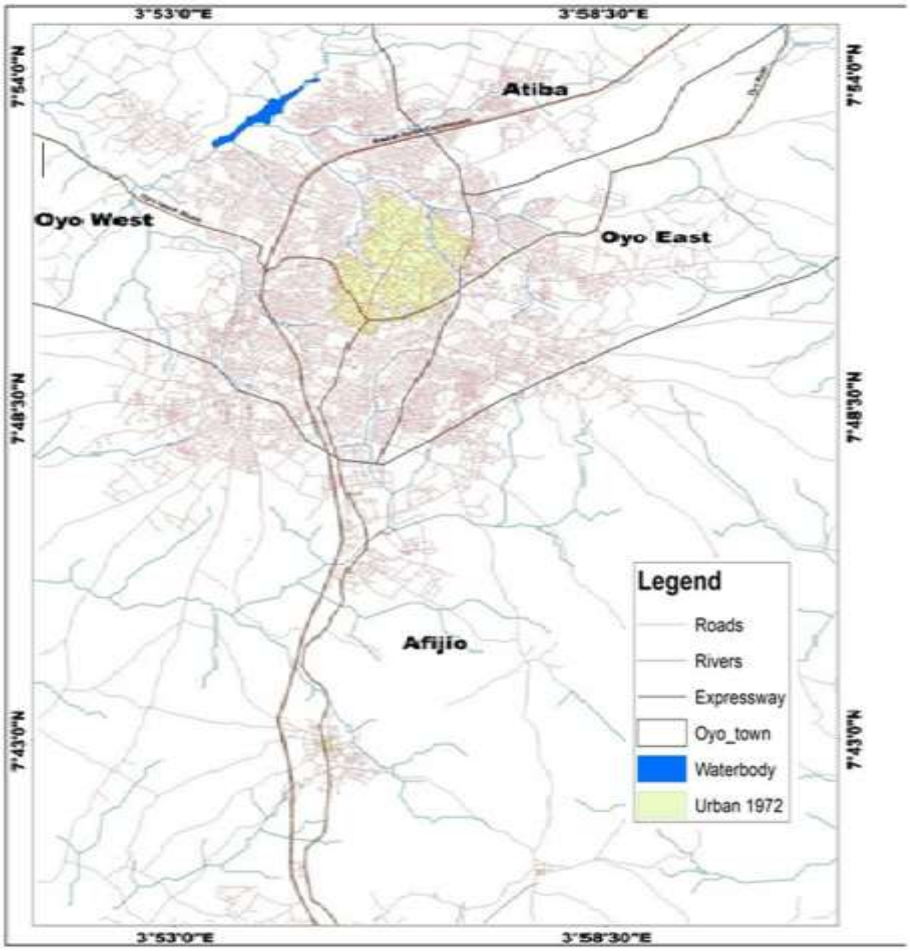

Figure 4.1.1: Urban Status of Erelu Service Area in 1972

2.2 Urban Expansion between 1973 and 1982.

Areas captured as an increment to urban size between 1972 and 1982 were of two categories. In the first, we have areas along traditional settlements that were not effectively captured by the aerial camera in 1972, possibly because of the mapping scale, scattered status of structures as of the period, or possibly for the abundance of tree cover. A sufficient number of such scattered open spaces appear to have been developed between 1972 and 1982. Such developments allow for accurate capture in 1982. These are Ogbegbe/Ogbeyo, Opapa, Moja, Ilora, Sabo, Awe, Cele, Akinmorin, Tengba, Boroboro, Oke-Olola and Ahumaro Awe, Ilora, Akinmorin, Fiditi and Sabo.

The second category was the emerging modern residential districts that have been developing gradually as outliers since the colonial and post-independence periods. These are Inner Araromi, Inner General Hospital, Cele, behind Olivet, Elewi, Elekara, Idigba, Saw-mill, Odo-eran, and Isola Motors. Minor imprints were equally made along Ogbomoso Road from Owode to Bode (See Figure II).

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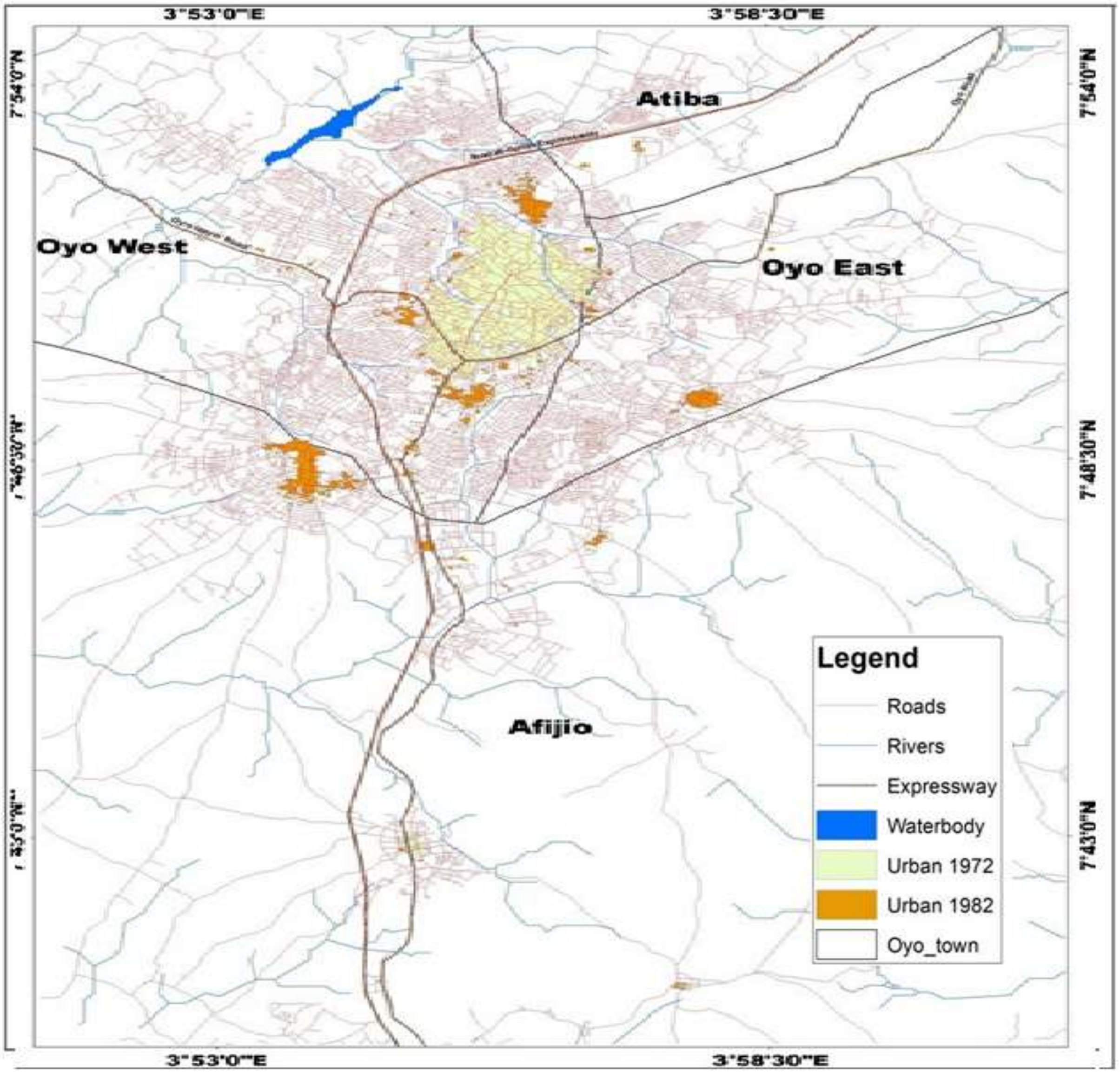

Figure II: Urban Expansion in Erelu Waterworks Zone (1973- 1982).

2.3 Urban Expansion between 1983 and 1992.

Nearly all urban expansion of the period occurred in Oyo Township; it forms a wide circle around the existing developments with Sabo in the lead. Traditional districts that were along the township periphery as at 1982 expand outwards in Atiba LGA. These are: Oke-Olola, Agunpopo, Isale Yidi andAjegunle. Sabo gained prominence and was extended to Liresa, Oranyan and Sooro while Isale Oyo increased towards Aatan and Sakutu watersides. In the present Oyo East area, modern housing districts like Kosobo, Odo Ogunmola/Mabolaje, Araromi, Folatyre/Sawmill received further development. And in the present Oyo West LGA, the first set of modern housing districts like Ladigbolu, Odo-eran, Iseketitun, Akeetantitun, Mobayoji, and Cele gained more prominence.

One observable feature of urban expansion between 1982 and 1992 was the general occupation of riparian forests along the streams within Oyo township. This privilege was afforded by the general adoption of concrete cement in the construction of houses. This is particularly so along Jabata, Idiope, Sanga, Ogbegbe,

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Opapa, Ilaka, Basorun, Agunpopo, Isale Oyo, among others.

Urban expansion in Awe was highly concentric along the periphery of the old housing district; they are scattered in Ilora and take the form of infilling in Fiditi. Structural developments were also felt in Akinmorin and Iware between 1982 and 1992 (See Figure III).

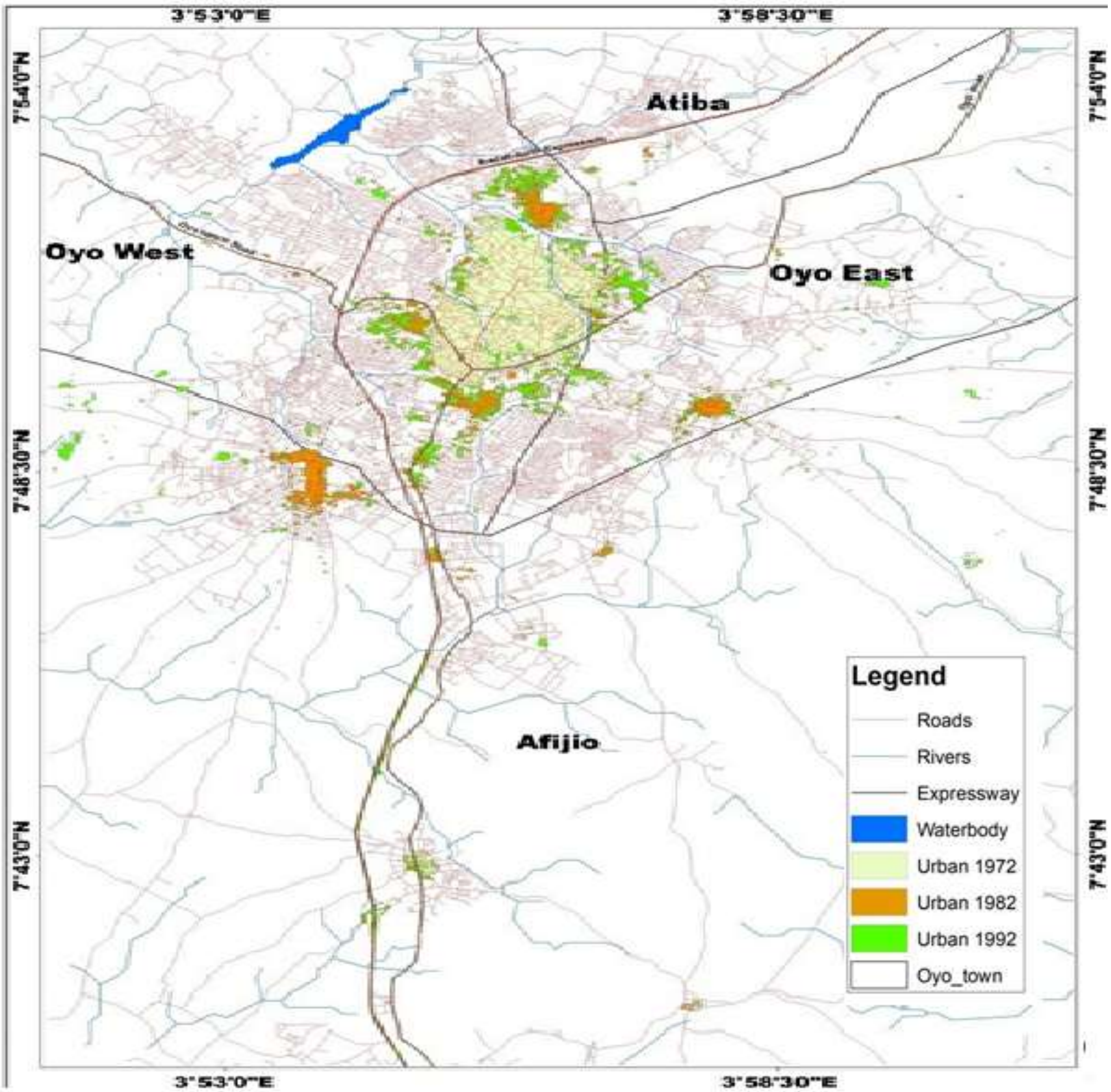

Figure III: Urban Expansion in Erelu Waterworks Zone (1983- 1992)

2.4 Urban Expansion in Erelu Waterworks Zone (1993 - 2002)

Generally, the developments covered a very wide area compared with the 1983 to 1992 period. Six zones recorded an impressive expansion and these are: (i) Mabolaje, Okooba and Agodongbo in Oyo East LGA, (ii) Boroboro, Ajegunle, Alafin, Oranyan, Alasela and Elere in Atiba LGA, and (III) Isokun, Idigedu, New Iyaji (Winners) and Tobacco in Oyo West LGA The highest concentration of

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developments during the 1992 – 2002 period were recorded along New Iyaji, Idigedu, Farinu, Alasela, Alaafin, among others. Developments started assuming a scattered form, implying the colonization of more expansive land markets along the peripheral areas, particularly in Oyo township (see Figure IV)

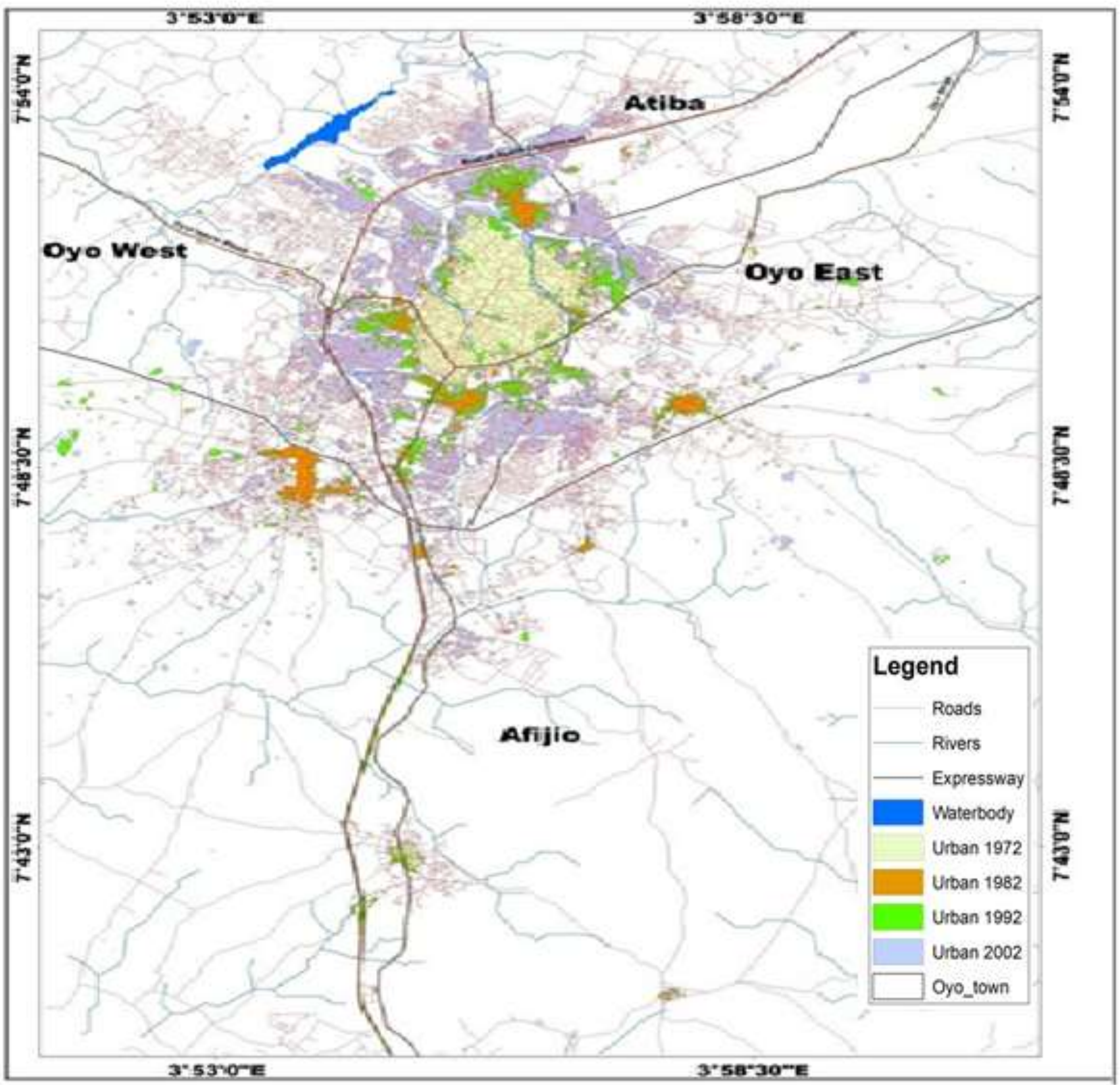

Figure IV: Urban Expansion in Erelu Waterworks Zone (1993- 2002)

2.5 Urban Expansion in Erelu Waterworks Zone (2003 -2012).

The major feature was that developments were heavily scattered over a very wide area along the periphery of the developed zone in the entire Erelu urban space. Areas that recorded impressive urban expansion were: Idigba/ Elekara/Jobele, and Ilora (Afijio). Akinmorin road (Oyo East). Oranyan, Owinni, Alasela, Koso express, Oroki express, Oyo London, Alasela express, and Elere (Atiba LGA). Golden rock, Ifeniyi, Onigbongbo, Onireke, Faniyi. Iseyin Road, Ayetoro, Olooro, Erelu waterworks, Mogaji, Obananko road, and Iyaji Express in Oyo West LGA (see Figure V).

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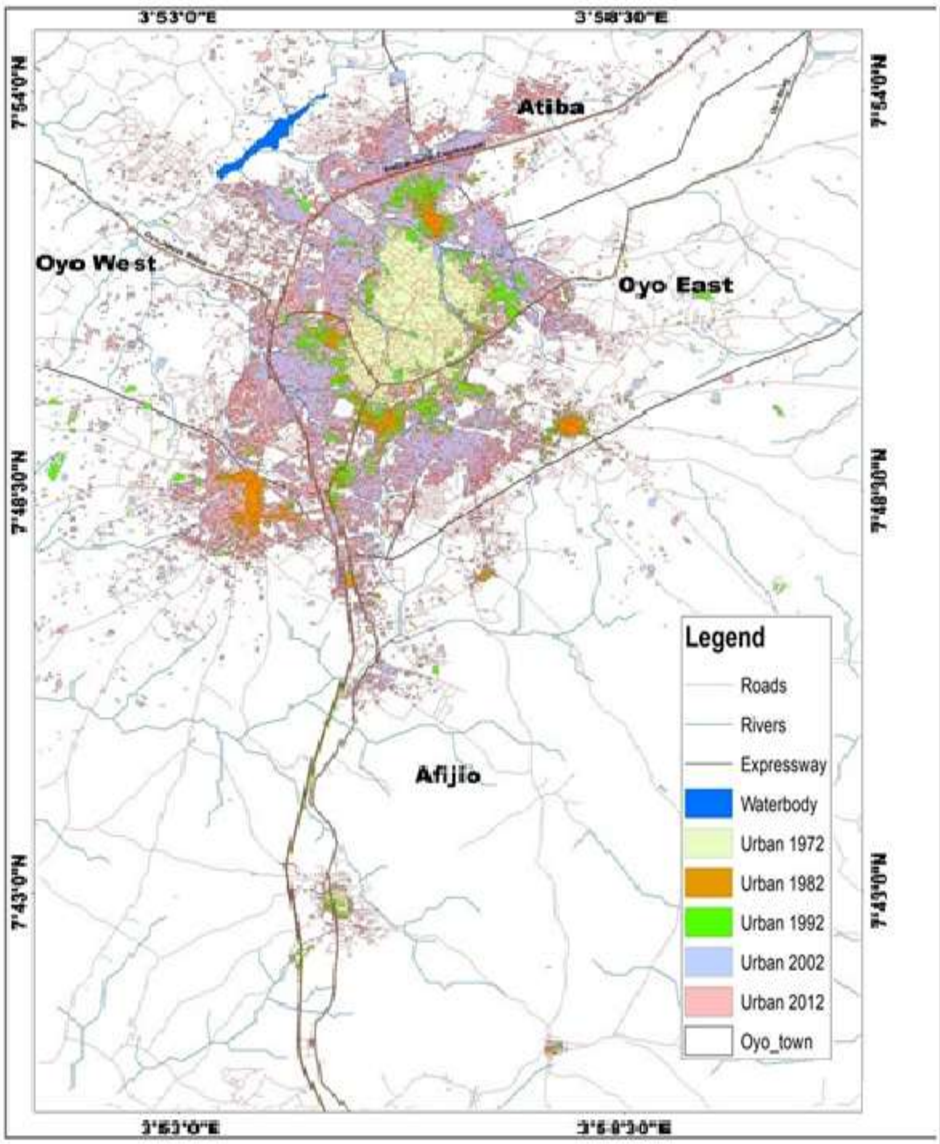

Figure V: Urban Expansion in Erelu Waterworks Zone (2003- 2012)

2.6 Urban Expansion between 2013 and 2022 in Erelu Waterworks Zone

It is important to state here that spaces created by the scattered pattern of development which characterized the 2003 to 2012 period were filled up to an extent during 2013 to 2022 years. Developments were, however, considerably high towards Kosobo (Oyo East), Awe, Akinmorin (Afijio), Alausa circuit, south of Ilora, Ilupeju housing scheme (Phase I and II), Mogi, Ahoyaga, Olooro, Ayetoro, and Mogaji areas (Atiba LGA). In Oyo West, new developments are at Ojongbodu Express, Ayetoro Scheme (Bonke, Irepo, waterworks).Scattered forms of development enveloped the entire urban space at varying degrees of concentration, showcasing and representing the continuous process of initialization and consolidation of the expansion process (see Figure VI)

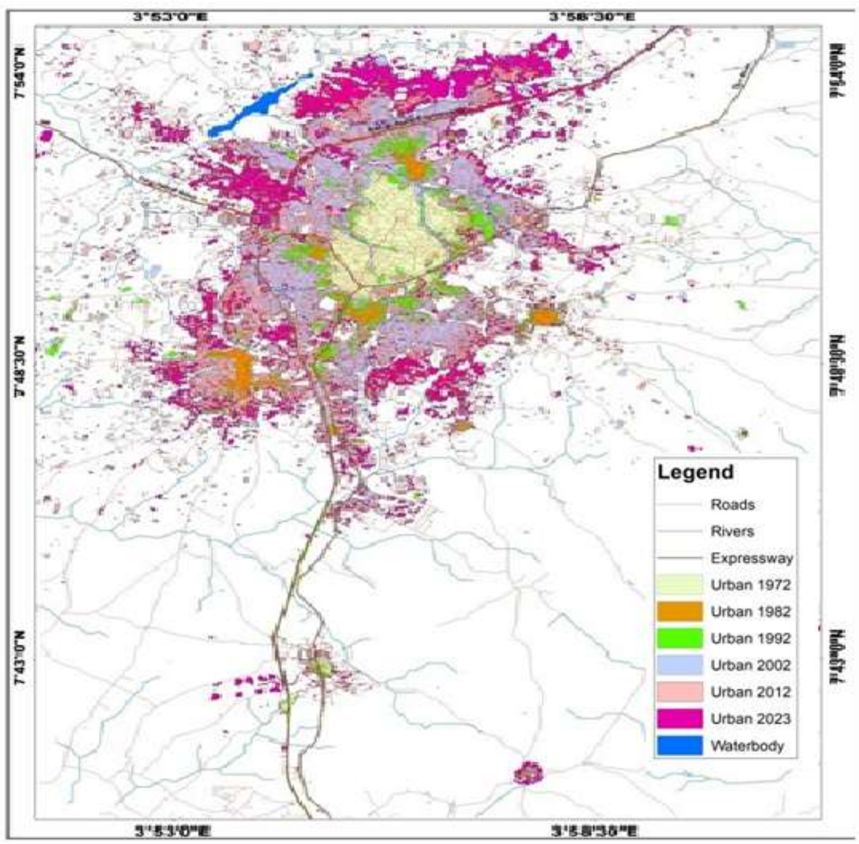

Figure VI: Urban Expansion in Erelu Water Zone (2013- 2022).

2.7 Overview of Urban Expansion in Erelu Waterworks Zone

Specifically, urban areas in Erelu Waterworks Zone did not record impressive growth till of recent. The urban size in 1972 was 6.56 square kilometers (sq km), though the figure was in terms of the only area with sufficient measure of conglomeration. By 1982, an additional 1.03 percent development was recorded. This increase was very considering the age-long imprint, as at 1972 when elements of organic city growth were still felt. However, there was evidence that greater parts of the development captured in 1982 had been in existence by 1972 but were not sufficiently extensive or not sufficiently exposed to the sensor of the aerial camera. Impact of Rapid City expansion was first recorded between 1983 and 1992, when an additional 7.64% increase was made within a decade. By implication, the urban space increased by three times compared with the 1982 size and four and a half times compared with the 1972 size.

Between 1993 and 2002, the urban area expanded by an additional 5.68%. It is important to note that, though the increase was substantial, the growth rate of the period was low compared with the 1983 – 1992 period, possibly due to a downturn in the economy or government policy. The unprecedented expansion in the size of the urban area was at its height between 2003 and 2012. Urban size increased nearly twofold compared with 1993 – 2002 urban size, and 6.56 times the urban size of 1972. Between 2012 and 2022, an additional 6.15% increase was recorded in the urban size in the zone. This was low about 2003 to 2012 expansion rate. On the whole, urban size increased to 96.06 square kilometers in 2022, an increase that was 16 times bigger compared with the 1972 size (see table).

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Table I: Summary of Urban Expansion in Erelu Waterworks Zone

Year	Area (sq/km)	Percentage	% Increase.
0000 - 1972	6.56	02.47	- -
1973 - 1982	9.30	03.50	1.03
1983 - 1992	29.64	11.14	7.64
1993 - 2002	44.74	16.82	5.68
2003 - 2012	79.69	29.96	13.14
2013 - 2022	96.06	36.11	6.15
Total	265.99	100	Average 6.73%

Summarily, settlements in Erelu water zone manifest the following pattern of expansion: Greenfield development, as defined by Deakin and Allwinkle (2007), was emphasized immediately after independence around Oyo main town, and this was when Araromi, Kosobo, Ladigbolu, Iseke titun, Atiba and Akeetan titun were gaining prominence. Much more impressive imprint, however, is the infill development as proposed by Roodman (2007). Infilling was emphasized at Awe, Ilora, Akinmoorin, and Fiditi till around 1982. Infill development was given premium in Oyo up till 1992 when all the riverine vacant parklands were developed. Emphasis on infill development up till 1992 might not be unconnected to the need to be close to the source of pipe-borne water supply.

Urban expansion in the zone since the 1990s takes the form of urban sprawl. According to Ewing and Hamidi (2015), urban sprawl is that involving mainly the development of single-family homes, shopping centers, and roads over wide areas. In this case, little consideration was given to recreation, industrial, institutional, and other land uses. It is important to state that transport-oriented development, as expressed by Cervero and Kockelman (1997), is of considerable impact in Oyo. This is particularly so along Fiditi, Iseyin, Eleke, Elegbo and Akinmoorin roads. The newly constructed express road from Ibadan to Ilorin is presently attracting more than 80% of new constructions in Oyo.

III. EFFECT OF URBAN EXPANSION ON PIPE-BORNE WATER PRODUCTION IN ERELU WATERWORKS ZONE

3.1 Urban Expansion and Reduction in Per Capita Water Consumption

The water treatment infrastructure, like the low-lift pumps, aeration chamber, flocculation chamber, sedimentation tank, filtration tank, disinfection chamber, clean water tank, and the high-lift pumps, were originally designed to produce 7,500 cubic meters (7,500,000 liters) of water per day, but the operational capacity is approximately 5,600 cubic meters (5,600,000 liters) per day. Assuming potable water production is increasing constantly with increases to urban size over the past 64 years, the daily water requirements in 2022 would be 79,184,000 liters per day. Erelu waterworks capacity can only satisfy just 7.07% of 2022 urban space, and this will be reduced to 3.31% by 2042.Treated water production capacity would need to be upgraded 14.14-fold, going by the 1972 standard. And by 2042, the 1962 production capacity will be able to meet just 3.31% of the total urban spatial water demand, while infrastructural upgrade will have to be 30.26 times. The daily water supply per capita got reduced from 48.28 liters per head in 1972 to 12.28 liters in 2022. This result did not consider periods of electrical outages, the condition of water treatment infrastructures, the condition of high-lift pumps, among others

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3.2 Urban Expansion and Reduction in Per Capita Water Consumption

Year	Area (sq/km)	Population	Population Density (sq/km)	Water Demand per day (in liters)	Daily Water Supply per sq/km (in liters)	Daily Water Supply Per Capita (in liters
1972	6.56	116,000	17,682.93	5,600,000	853,658.54	48.28
1982	9.30	149,000	16,021.51	7,952,000	602,150.54	37.58
1992	29.64	194,000	6,545.21	25,256,000	188,933.87	28.87
2002	44.74	257,000	5,744.30	38,192,000	125,167.64	21.79
2012	79.69	341,000	4,279.08	68,040,000	70,272.31	16.42
2022	96.06	456,000	4,747.03	79,184,000	58,296.90	12.28
2032	140.39	673,000	4,793.79	119,840,000	39,888.88	8.32
2042	198.444	985,286	4.965.06	169,400,000	28,219,55	5.68

Existing water treatment infrastructure was not adequate to meet the per capita potable water standard established by WHO since 1972, but it must have been the yardstick in 1962; though, pipe-borne water supply was still manageable till 1992. The baseline volume of water required per capita per day is governed by international public health and engineering benchmarks designed to ensure human survival and dignity (Amatobi & Umezuruike, 2023). According to the European Commission (2026) established World Health Organization (WHO) standards, an absolute minimum of 50 to 100 liters of water per person per day is required to satisfy basic domestic needs (Hutton & Chase, 2017). This volume is calculated to cover core physiological and hygienic requirements, including hydration, food preparation, personal bathing, and basic household sanitation (Amatobi & Umezuruike, 2023).

When a water system falls below the basic threshold of 50 liters per capita daily, public health outcomes deteriorate rapidly as individuals are forced to ration water for personal hygiene (Hutton & Chase, 2017). A service delivery level that provides only 25 liters per capita per day is classified by international bodies as a "basic asset constraint," carrying high public health risks due to the inability to maintain effective household sanitation (Mndzebele, 2026). In many developing rural topographies or underserved urban informal settlements, utilities struggle to consistently deliver even this critical survival threshold (Mndzebele, 2026).

In highly industrialized urban centers across developed nations, the target allocation scales up dramatically to between 150 and 300 liters per capita daily (Hejazi et al., 2013). This elevated consumption volume accommodates advanced municipal infrastructure, automated household appliances, commercial operations, and the maintenance of urban green spaces (Dias & Ghisi, 2024). Engineering specifications for urban water distribution networks in these regions are explicitly designed around these high volumetric demands to maintain stable network pressures (Kakwani, 2025).

Conversely, water management policies in arid and water-scarce regions focus on aggressively lowering the per capita daily consumption footprint through efficiency mandates and smart technologies (Das & Singha, 2024). Nations like Singapore and Israel have deployed extensive public re-education campaigns and advanced water-saving appliances to safely drive domestic per capita demand down toward 100 to 130 liters per day without compromising public health (Wang et al., 2022). This shows that the upper bound of water requirement is highly dependent on a nation's technology and environmental context (ElZein et al., 2022).

Ultimately, calculating per capita daily water requirements is a foundational element of municipal engineering and macroeconomic planning (Owais et al., 2023). Utilities must utilize these volumetric benchmarks to dimension the capacity of water treatment plants, size trunk distribution mains, and project future raw water abstraction needs (Tabesh et al., 2019). Ensuring that a population has reliable, daily access to these internationally mandated water volumes remains a primary metric for evaluating global human development (Stojanović et al., 2020).

3.3 Inability of Government to meet the needs of an Expanding Urban Environment

Governments are increasingly confronted with the challenge of efficiently allocating limited resources to meet the diverse socio-economic needs of society, including the demand for urban potable water infrastructure. Historically, approaches to waterworks rehabilitation have been fragmented rather than comprehensive. For example, in 2019, a budget of 1.4 billion Naira was allocated for the rehabilitation and expansion of the Erelu water treatment plant; however, these funds were only sufficient to procure the necessary 16-inch pipes and initiate the construction of a standard sedimentation tank (Oyo State Ministry of Energy and Water Resources [OSMEWR], 2025). Similarly, in 2016, the construction of the Earth Dam at Fiditi commenced with a federal budget allocation of 10 billion Naira, and the project was scheduled for completion within nine months. By 2020, however, the dam project had evidently been abandoned (OSMEWR, 2025). The costs involved in the rehabilitation or construction of a comprehensive waterworks today are considerably substantial, and this discourages investment. In Kogi State, for instance, the government proposed a 100 billion Naira budget for the extensive revitalization of the greater Lokoja waterworks in 2025. Likewise, in Lagos State, the Adiyan II water plant project, expected to produce 140 million gallons (approximately 529,958 cubic meters) of potable water daily, was valued at 50 billion Naira in 2025 (Lagos State Ministry of the Environment, 2025). Nonetheless, such large-scale projects remain exceptional and infrequent in recent years, particularly in Nigeria. A significant challenge confronting the government is the rapid and uncontrolled expansion of existing urban centers, coupled with the emergence of new urban areas on a decadal basis.

IV. RECOMMENDATIONS.

The study posits that urban growth is not supported by appropriate institutional support in terms of conveniences that would allows for functional organization of space. Attempt to determine the disparity between urban growth and potable water availability in this study would assist policy decisions on how the challenge can be resolved Pipe-borne water is indispensable to man and shortfall in its provision would unconditionally consequent in the patronage of alternative sources. The extent of alternative sources in the society can be used to determine the extent and length of neglect the concerned society had suffered.

Human efforts on how to control diseases, improve human quality of life, and ensure sustainable development must therefore focus on the availability of potable water. One way of addressing these challenges is the availability of potable water. Effort of nations, as expressed through Millennium Development Goals and Sustainable Development Goals, can better be captured through the availability of accessible potable water sources.

Academic research is still at its infancy with regard to urban potable water accessibility in Nigeria. The approached to this research considers actual increments to the urban space, unlike available literatures that measures urban growth by virtue of population data. The study will therefore open a new approach to studies on urban water accessibility.

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