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Resilient Waterfront Architecture And Planning To Curb Urban Sprawl Along Water Bodies – The Case Of Weija Reservoir, Ghana

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ABSTRACT

Urban sprawl is a problem that has generated a lot of debate in policy-making and the academic sector. The degradation of green areas, an outcome of urban sprawl, is identified as one of the issues affecting the natural ecosystem. Studies show that reserved lands meant to protect water bodies continue to face deterioration due to uncontrolled development. After its creation in 1977, the Weija Reservoir has been facing encroachment due to rapid urbanisation in its surrounding environment. The pragmatism worldview drove this research to determine the encroachment issues by urban sprawl on riparian vegetation of the Weija reservoir. With the aid of Geographic Information Systems (GIS) and remote sensing technology, the designated buffer for the Weija reservoir was mapped for the Ga-South Municipality - Ghana, within which a more significant portion of the reservoir is. The study observed available satellite data for 1991, 2017, and 2021. The study observed that about 13% of the Weija reservoir's buffer(per requirements) had been encroached on by settlements by 2021. The reasons for the encroachment of the Weija reservoir's buffer raised from the study were the lack of collaboration among the various stakeholders within the reservoir's use and management framework. The research explored using urban design principles to develop resilient proposals for the selected site to improve the ecological and aquatic lives of the people at the Weija waterfront. The study findings concluded that the management of wetlands in Ghana should take a turn; various stakeholders should educate communities to participate in decisions concerning waterfront developments, and stakeholder collaborations should be enhanced.

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1. Introduction

1.1 Background

The study on urban sprawl, starting in developed countries [1-4], has gained importance in developing countries, especially in sub-Saharan Africa in studies by Boateng, 2018 [5]; Oloukoi et al., 2014[6]; Yiran et al.,2020[7]. As defined by Karacayaci (2016) [8], urban sprawl is a hinterland between rural and urban areas. This definition means urban sprawl areas are lands that have lost their rural characteristics but cannot be classified as urban.[8] Urban sprawl is characterized by leapfrog developments, low density, disorganized, and is usually uncontrolled [8][9]. According to Yiran et al. (2020)[7], Sub-Saharan cities need help managing urban sprawl. The inability of institutions to manage urban sprawl in Ghana is a problem recognized in literature [5][10]. The weak nature of institutions, inadequate planning schemes, neo-liberalization, and non-enforcement of planning regulations have led to urban sprawl development in cities like Accra [5] and along water bodies in Ghana [11,10].

Water reservoirs dating back to 3000 BC have developed a multipurpose nature over the years, making them essential features of the landscapes of many countries [12]. The high impact of reservoirs on society and the environment has made it a topic of interest [11-15]. In Ghana, studies on water basins and reservoirs so far have been geared toward assessing the impact of reservoirs on water quality [16], changes in land use around water basins [11,17], and the impact of water impoundments on aquatic lives [18]. The Weija Reservoir is a primary water source for many parts of Accra, supplying about 54.2 mega gallons per day (MGD) to about five million people in Accra. Studies over the years have shown that reserved riparian vegetation meant to protect water bodies in Ghana continues to face deterioration [11,17,19]. “Wetlands are under siege,” as Cobbinah et al. (2022)[10] put the situation. Over the years, there has been encroachment on the Weija reservoir, evident in the changes in land use trends [11-16]. With a reduction in riparian vegetation, there is a threat to the water quality of the reservoir and its aquatic habitats [16-20].

A system's resilience is its ability to maintain stability when faced with disturbances [21]. Much attention is given to ocean and coastal ecosystems in their management and resilience studies [22]. However, researchers give little attention to the resilience of inland freshwater bodies such as lakes and rivers. Reserves have been the cornerstone of biodiversity conservation. While they will continue to be crucial for species protection, it is necessary to understand their significance as sources for ecosystem renewal and reorganization in managed landscapes and seascapes [23]. A thorough evaluation of the wetlands' ecosystem health is required to direct conservation and restoration efforts[22]. Wetland ecosystem health can be evaluated at various temporal and spatial scales using geospatial analysis of remotely sensed data and Geographical Information Systems (GIS). Remote sensed data and GIS provide a more efficient, reliable, and convenient way of assessing ecosystem health [22] and characteristics [10-11]. Sprawl mitigation has focused on the general outlook [5,9,23] without concentrating on riparian vegetation.

2. Methodology

2.1 Study Context

The study focused on the sprawl of riparian vegetation of the Weija reservoir. The researchers chose Ga South municipality since it covers a more significant percentage of the reservoir and also because it is the municipality with communities surrounding the reservoir. The municipality occupies a total land area of about 341.838 square kilometres with about 95 settlements. The land area of the Ga South municipal is underlain by shallow rocky soils, with its vegetation being mainly coastal grassland, which lies wholly in the coastal Savannah agroecological zone [24]. The Municipality lies in the dry equatorial climatic zone with double rainfall seasons. The mean annual rainfall varies

between 790mm along the coast to about 1270mm in the extreme north. The annual average temperatures range between 25.1ºC in August and 28.4ºC in February and March, the hottest months. It has a relative humidity of about 75% in February and March [24]. Fig. 1 below shows the Ga South municipality with neighbouring municipalities.

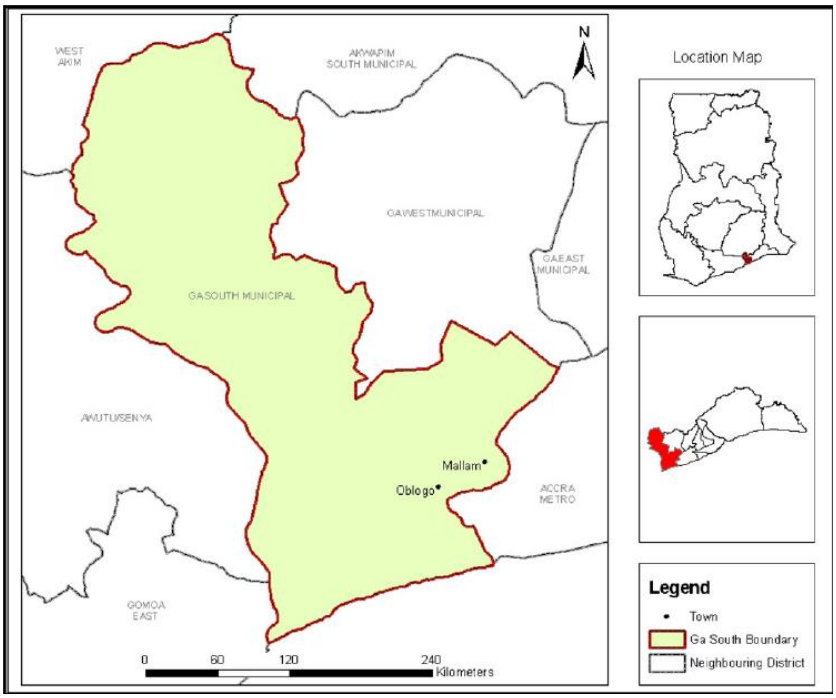


Fig. 1. Map of Ga South municipality with neighbouring municipalities.
(Source: Frimpong *et al., 2019*)

The research used deductive and inductive evidence concerning the sprawl issue; a mixed-method approach was ideal. The study was divided into two parts. The first part sought to determine the degree of encroachment of the buffer by urban sprawl (quantitative), and the second part sought to determine the reasons for the encroachment, followed by ways in which the reservoirs' front can be used to curb urban sprawl through resilient architecture and planning (qualitative).
The research took the form of an explanatory case study, with the need to place-specify sprawl [25] as the basis of the research design. The research occurred in two distinct but interactive phases; the first phase determining sprawl on the riparian buffer and the second phase finding out the reasons for the sprawl on the Riparian buffer. Remote sensing (RS) technologies and geographical information systems (GIS) were used in the first phase. Using this combination of remote sensing and GIS, land use/cover distribution can be mapped [11,9,7]). For phase two, semi-structured interviews were used to find out the reasons for encroachment from residents falling within the buffer [10].

2.2 Sampling Methods

The researchers applied the non-probability sampling technique. Stakeholder institutions were purposively sampled for the study. These institutions were the Ga-South Municipal Assembly, the Environmental Protection Agency, the Land Commission and the Ghana Water Company – Weija. The researchers engaged the institutions that responded to letters in an interview: the Environmental Protection Agency (EPA), the Development Planning Department (TCPD) of the Ga-South Municipal - Ghana, and the Ghana Water Company Limited - Weija (GWCL). The researchers conveniently chose officials from these institutions based on availability and exposure to management, use and

development around the Weija reservoir. Three communities, Domeabra, Afuaman and Ngleshi Amanfro of the Ga South Municipal, were purposively selected based on their proximity to the reservoir. Members of the communities chosen were above 18 years old and had lived and/or worked within the community for at least five years.

2.3 Source Of Data

The primary data used for the study was highly influenced by literature. Firstly, previous studies involving satellite images for determining land use change in urban areas in Ghana [11,10] provided a minimum background for the study. Secondly, studies on urban sprawl and its measurement by OECD, 2018[3] and Seevarethnam et al., 2021[9] formed a predominant backbone for the study. Tab. 1 shows literature that guided the selection of the variables for the study.

Table 1
Previous studies that guided the choice of instruments, variables, and sampling for the study.

Author(s) of literature	**Study**	**Research Instruments**	**Variables/data**	**Selection Criteria-Sample/study area**
(Cobbinah *et al*., 2022)	Contested urban spaces in unplanned urbanization: Wetlands under siege.	1. Spatial Data 2. Interviews 3. Field Survey	<u>Spatial Data</u> ● Delineating built-up areas and wetlands <u>Institutional Interviews</u> ● Planning responses ● Management Regimes(systems) ● Challenges to wetland protection in the Cities <u>Residents Interview</u> ● Understanding residents' perspectives and perceptions of urban planning in Kumasi ● how these perceptions informed their attitudes towards wetlands in terms of management and use; ● the communities' constructs and/or socio-cultural practices that influence wetland use and management Field Observations were conducted along banks of communities	Two officials from each of the following institutions in interview conversations: ● Environmental Protection Agency (EPA) ● Town and Country Planning Department (TCPD) ● Kumasi Metropolitan Assembly ● Water Resource Commission (WRC) ● Friends of Rivers and Water Bodies (FRWB), an NGO ● Residents falling within buffer distance: 10 from the selected community

(Eduful *et al*., 2020)	Management of catchment for the protection of source water in the Densu River basin, Ghana : implications for rural communities Management of catchment for the protection of source water in the Densu River.	1. Observations 2. Interviews 3. Household survey	<u>Institutions</u> ● Water Resource Management in the Densu Basin. ● Policies and Regulations-catchment strategies and implementations ● Stakeholder participation <u>Residents</u> ● Demographics, socio-economic and livelihood characteristics ● Residents Adaptive mechanisms ● Communities' awareness ● Economic challenges resulting in implementation	● Communities are selected based on proximity to the Densu River. ● WRC, Environmental Protection Agency, Forestry Commission, Minerals Commission, Hydrological Service Agency, Metro- logical Agency, and Irrigation Development Agency
(Antwi-agyakwa, 2014)	Assessing the Effect of Land Use Land Cover Change on Weija Catchment	Spatial Data	<u>Spatial Data</u> ● Land use classification ● Spatial Projection	● Rapid urban expansion
(Aryal, 2008)	Phewa Lake Watershed Area: A Study on the Challenges to Human Encroachment.	1. Field Observation 2. Interviews 3. Questionnaires 4. Secondary data	● Land use patterns ● Source of Pollution around the lake ● Appropriate distance for land acquisition ● Need for environmental management ● People's perception of the sustainability of the Phewa Lake Watershed	● Persons in direct contact with the lake. ● People who are knowledgeable about the lake and its problems: older adults, boatmen, and environmental activists.
(Seevarethnam *et al*., 2021)	Geospatial analysis for characterising urban sprawl patterns in the Batticaloa municipal council, Sri Lanka	1. Spatial data 2. Demographic data.	<u>Spatial Data</u> ● Land use classification ● Spatial Projection ● Sprawling characteristics	● Rapid population growth ● Arbitrary
(OECD, 2018)	Rethinking Urban Sprawl	1. Spatial data	<u>Spatial Data</u> ● Sprawl indicators	-

Source: (Author's field survey, 2022)

2.3.1 Spatial data

2.3.1.1 Satellite image acquisition

Landsat images were downloaded from the United States Geographical Society - USGS website as used by OECD (2018)[3], Adjei et al. (2019)[11] and Cobbinah et al. (2022)[10]. Multi-spectral bands, a constituent in Landsat images, hold information on vegetation, water features and built area [11,10,6]. The resolution of images used in the study was 30m X 30m, and downloaded images had less cloud coverage to improve the study's quality. The maximum cloud coverage used in the research was 22%. The study used the Thematic Mapper (TM) and the Operational Land Imager (OLI)/ Thermal Infrared Sensor-(TIRS). The years chosen for the study were 1991, 2017 and 2021 due to their availability, resolution and minimal cloud coverage around the Weija reservoir. The details of the satellite images downloaded for the study are shown in Tab. 2 below.

Table 2
Satellite images used for the study

Spatial data					
Data	Year	Date acquired	Spatial resolution	Cloud cover	Bands used
TM	1991	10/01/1991	30 X 30m	22	1,2,3,4,5,6,7
OLIS/TIRS	2017	15/04/2017	30 X 30m	3.85	1,2,3,4,5,6,7
	2021	22/12/2021	30 X 30m	0.94	1,2,3,4,5,6,7

Source: (Author's construct, 2022)

The following are the various representations of the bands used for the study.
Band 1- Coastal Aerosol
Band 2-Blue
Band 3-Green
Band 4-Red
Band 5- Near Infrared (NIR)
Band 6- Short-wave Infrared (SWIR-1)
Band 7- Short-wave Infrared (SWIR-2)
Source: (USGS, 2018)

Fig. 2 below shows a sample image of downloaded Landsat images used for this study.

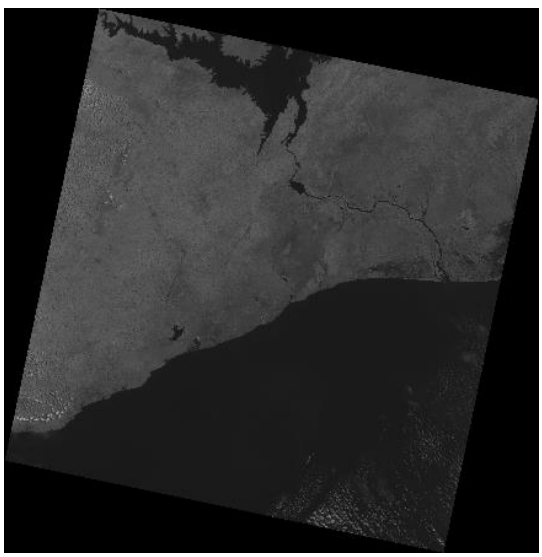
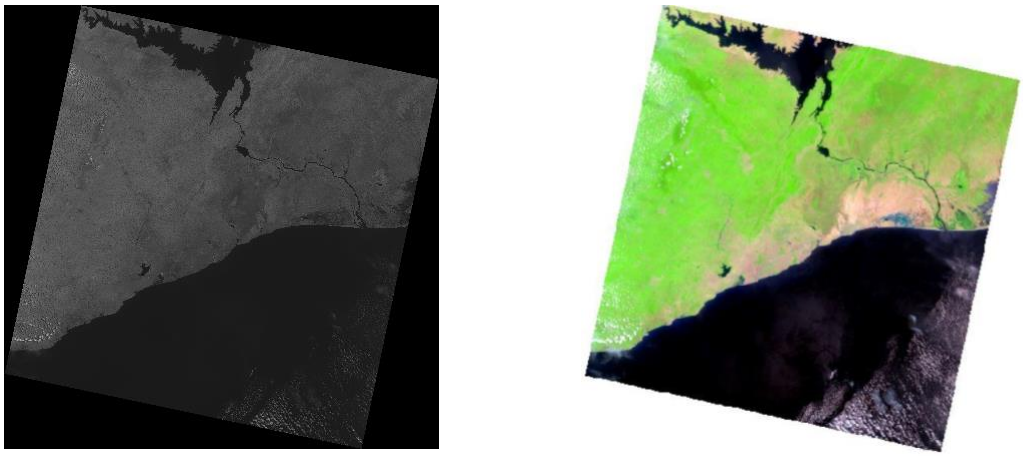


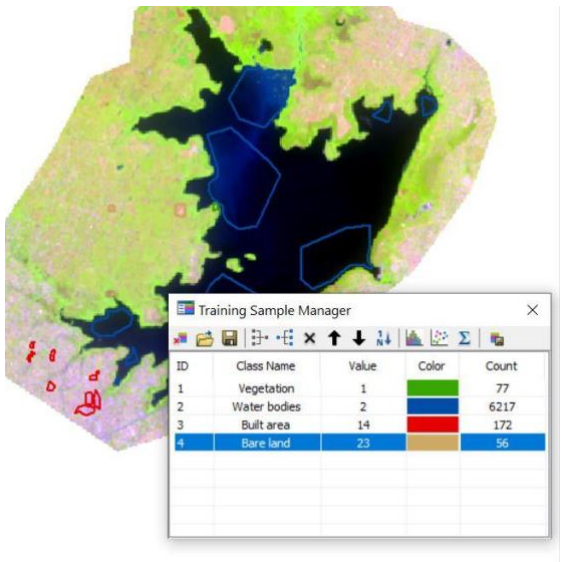
Fig. 2. Satellite images downloaded from the United States Geographical Society – USGS.(Source: *USGS, 2022)*

2.3.1.2 Image processing

The downloaded images were geo-referenced with the World Geodetic System (WGS84). The boundary for the Ga South Municipal was digitized from the Open Street Map (OSM) component in the ArcGIS 10.7 software application. Composite images were created for the studied years - 1991, 2017, and 2021, after which these images were clipped with the Ga South boundary shapefile [26] as shown in figure 3 (a)(b) below. The researchers classified the clipped images with training samples from the 1991, 2017, and 2021 composite images. Classification for this study was supervised [11,9] (fig. 3c), and the land use types used were bare land, built-up, greenery and water bodies. To focus on the characteristics of the built-up, the various constituents of vegetation, i.e., forest, farmlands, shrubs and grass, were grouped and named greenery [9].



(a) (b)



(c)

Fig. 3. Image processing of Satellite images (a) Raw Landsat Image (b) Composite image (c) Supervised classification of composite images. (Source: *Authors' Survey 2022)*

2.3.2 Determining urban sprawl characteristics

Measuring the degree of sprawl development was developed based on adopting sprawl measures from reviewed literature [1,3,9]. The study adopted the urban grid area used by the OECD (2018)[3]. The sprawling characteristics of the study area were then determined using the distribution of the built-up area across the grids. The characteristics of urban sprawl observed in the research were built-up density, leapfrog development and scattered pattern [9]

2.3.3 Determining the degree of encroachment on riparian buffer

The Riparian Buffer Policy of the Ministry of Water Works and Housing – Ghana states that water bodies such as the Weija reservoir should have a buffer of 60 – 90 m [27]. A 90-metre buffer used for this research was operationalised using the buffer function under the Geo-processing menu of the ArcGIS 10.7 software application. The Intersection function was then used to intersect the buffer's shapefile and the classified shapefile for the years being studied. Figure 4 below summarises the framework used to determine the extent or degree of sprawl on the Weija reservoir's buffer.

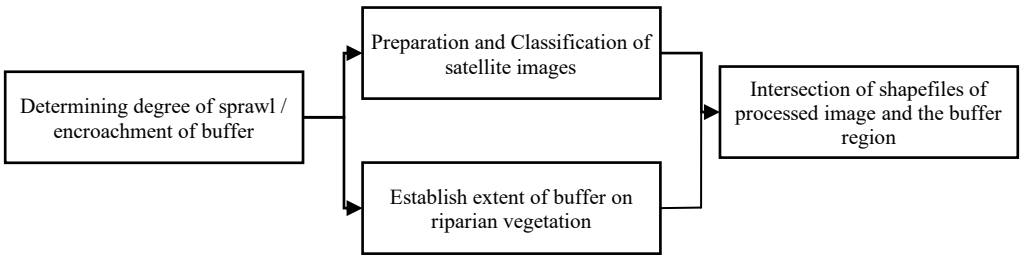


Fig. 4. Framework for measuring the extent of sprawl/encroachment on the Weija reservoir's buffer. (Source: Author's construct)

2.3.4 Interviews

To answer research objective two - to identify issues affecting the implementation of the Buffer policies of the Weija reservoir, interviews were conducted with the regulatory agencies and the selected communities. The study used semi-structured interviews to collect data on the agencies' knowledge of the challenges faced in implementing the riparian buffer policy and how best they have been involved in the planning and development around the reservoir. The stakeholders identified for the management of the Weija Reservoir were the Water Resource Commission (WRC), The Environmental Protection Agency (EPA), and the Weija Water Works. The researchers interpreted the generated map from the ArcGIS 10.7 software to identify the communities encroaching on the reservoir's buffer. The researchers then interviewed inhabitants about their perception of the management of the reservoir, their awareness of the riparian buffer policy, the roles the community is supposed to play, and the activities that influence the reservoir and its management. The locations of the encroached areas from the generated map in ArcGIS 10.7, as shown in Fig.5, when interpreted with a Google Earth image, as shown in Fig. 6, drove the study to Tomefa, Maheame and Ngleshie-Amanfro: communities of the Ga-South Municipality.

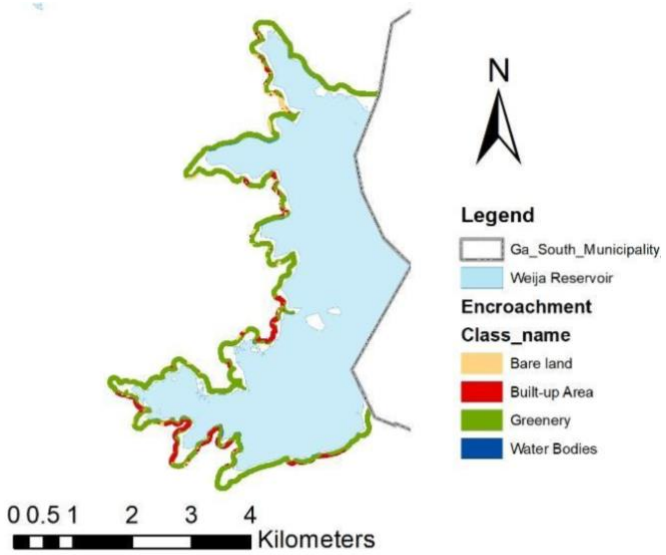


Fig. 5. Weija reservoir's 90m buffer in Ga South Municipality from ArcGIS-10.7. (Source: Author's field survey, 2022)

Fig. 6. Google Earth image showing the location of case study communities-Maheame (a), Tomefa (b) and Ngleshie-Amanfro (c). (Source: Author's field survey, 2022)

A total of 14 inhabitants were interviewed: two from Ngleshie-Amanfro, seven from Maheame, and five from Tomefa. Tab. 3 shows the distribution of the people interviewed at the communities and institutions.

Table 3
Number of respondents for community and institutional interviews

Community	Maheame	Tomefa	Ngleshie-Amanfro	Institutions	Total
Respondents	7	5	2	3	17

Source: (Author's field survey, 2022)

2.3.5 Data collection instruments

The spatial data for the study was downloaded from the USGS website. The preparation of downloaded data for analysis was done with the ArcGIS 10.7 software application. The study primarily used semi-structured interviews; interview guides were prepared separately for the institutions and the inhabitants of the community. Interviews were recorded by phone, after which the researchers transcribed the recorded files. Map images used for the study were obtained using Google Earth Pro software. Tab. 4 below summarises the primary and secondary data sources used for this study and the instrument for collection.

Table 4
Sources of data used for the study.

DATA	SOURCE	SAMPLING TECHNIQUE	METHOD OF COLLECTION
PRIMARY DATA			
-Landsat Satellite images	Geographic Information Systems (GIS) United States Geological Survey (USGS) https://earthexplorer.usgs.gov Ekumah *et al*., (2020), OECD,(2018), Cobbinah *et al*., (2022), Adjei *et al*.(2019)	-	Map Images
Buffer Policy, Policy Implementation, and Challenges Faced	Municipal planning authorities Inhabitants	Purposive Sampling	Semi-structured Interview
State of the Community	Community, Inhabitants Municipals Statistics(Ghana Statistical Service (GSS), 2014)	Purposive Sampling Snowballing (Cobbinah *et al*., 2022)	Case study approach, observation, Interview
SECONDARY DATA			
Resilient Architectural and Planning Strategies-Eco-system resilience	Karlenzig, (2010); Prayitno, (2018); Vargas-Hernández & Zdunek-Wielgołaska, (2021); Williams, (2007)	-	Literature review
Ecological Architecture -Spatial considerations -Design Strategies	Precedence studies Williams, (2007) www.Arcdaily.com www.aldoleopold.org	-	Literature review

Source: (Author's construct, 2022)

2.4 Data Analysis

2.4.1 Analyzing spatial data

The spatial data for the study were analysed using ArcGIS 10.7 software to determine sprawl characteristics—built-up density, leap-frog developments, scattered developments, and the degree of encroachment on the reservoir's buffer [9,11]. Analysis was performed on processed Landsat images for 1991, 2017, and 2021.

2.4.2 Analyzing interviews

Interviews were analysed using NVIVO qualitative research analytical software [10]. In the software, transcribed recordings of interviews were uploaded by the researchers and using thematic analysis, various codes were developed to gather the views and perceptions of the respondents. The themes for coding for the analysis were strictly based on the purposively sampled inhabitants and available institutions.

3. Findings

3.1 Sprawling Characteristics

3.1.1 Built-up patterns from 1991 to 2021 (Scattered and Leap-frog development)

The built-up area helps identify the characteristics of urban sprawl. The built-up spatial patterns identified the characteristics of the urban sprawl in the Ga South Municipality. The built-up patterns are presented in generated maps for the years 1991, 2017, and 2021 to understand the sprawling characteristics of the Ga South Municipality. The built-up area of the Ga South municipality had an extent of 162 hectares in 1991, which increased to 3742.3 hectares in 2017. In 2021, the built-up increased to 6005 hectares. Tab. 5 shows the extent of the built-up area in the Ga South municipality for 1991, 2017 and 2021.

Table 5
The extent of the built-up area in the Ga-South Municipality.

Year	1991	2017	2021
Built-up area	162 hectares	3742.3 hectares	6005 hectares

(Source: Author's field survey, 2022).

Figures 7 (a), 7 (b), and 7 (c) show the built-up pattern of the Ga South municipality for 1991, 2017, and 2021.

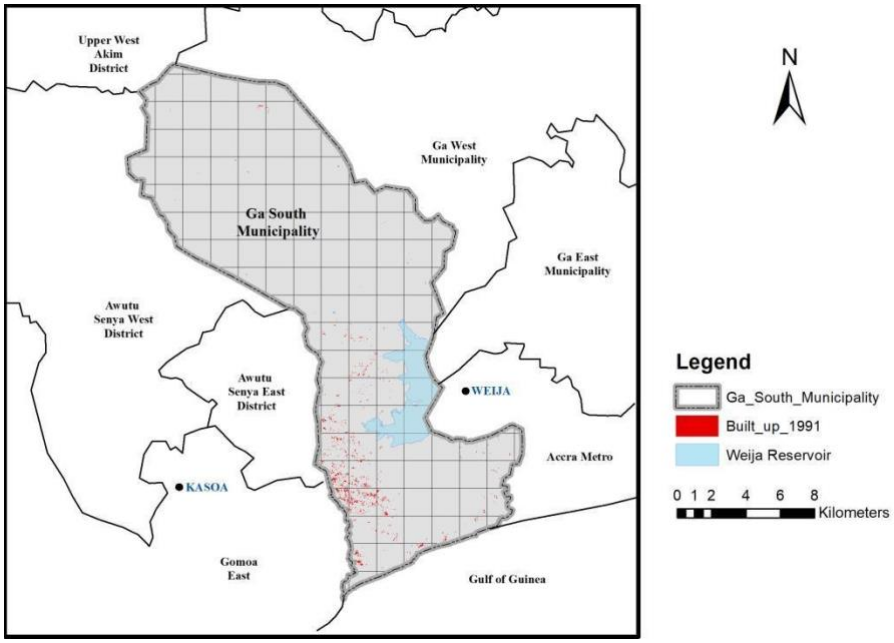


Fig. 7. (a): Built-up pattern in Ga-South Municipality in 1991.
(Source: Adapted from Seevarethnam et al., 2021)

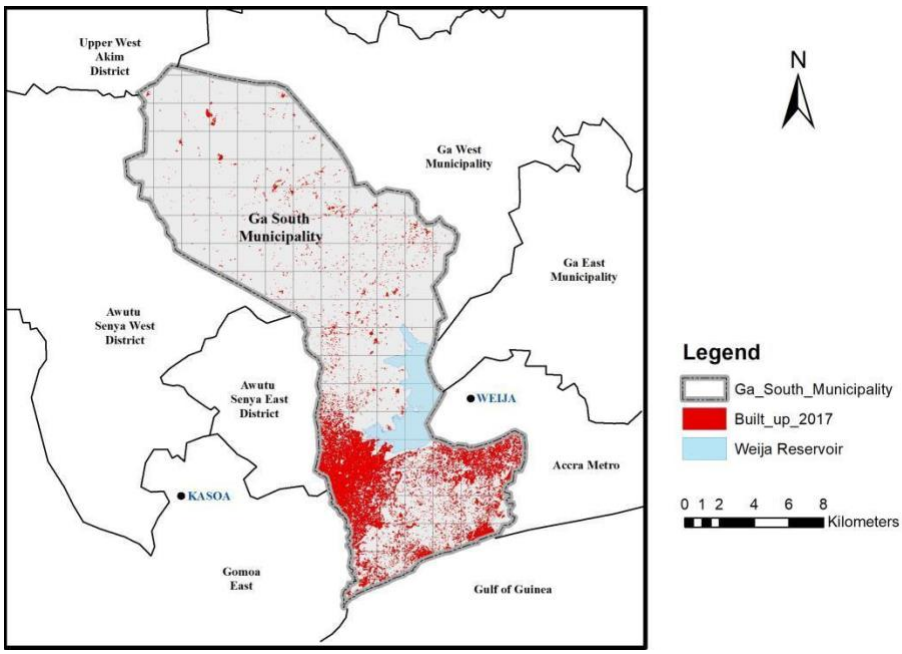


Fig. 7. (b): Built-up pattern in Ga-South Municipality in 2017.
(Source: Adapted from Seevarethnam et al., 2021)

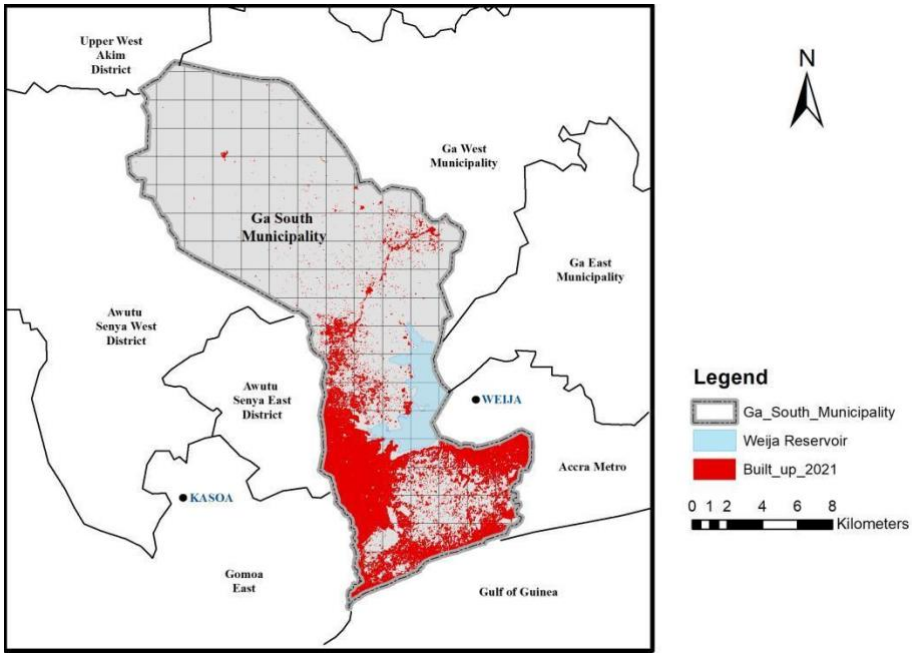


Fig. 7. (c): Built-up pattern in Ga-South Municipality in 2021.
(Source: Adapted from Seevarethnam et al., 2021)

From the built-up pattern, it was observed that the development around the reservoir was scattered in 1991, 2017 and 2021. Though scattered, the development of the Ga-South municipality appeared to be continuous. From observation, the development pattern originates from Kasoa, a thriving urban region on the left and Accra, the capital of Ghana. (Fig. 7 (d)).

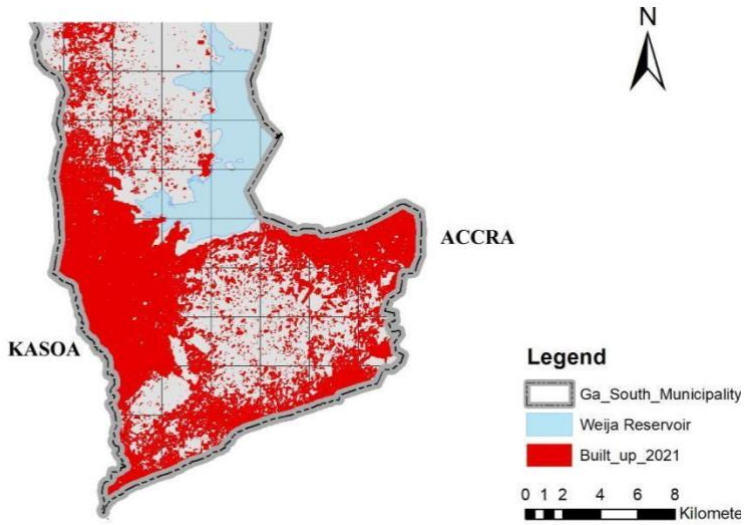


Fig. 7. (d): Built-up pattern in Ga-South Municipality in 2021.
(Source: Adapted from Seevarethnam et al., 2021)

Areas that showed leapfrog characteristics were regions around the periphery of the Weija reservoir and close to the Kasoa-Amasaman road. (Fig. 8)

Fig. 8. : Google Earth image showing Kasoa-Amasaman road.
(Source: Google Image, 2022).

The Housing and Population Census 2021 reported a significant increase in housing units from 2010 to 2021 (Fig. 9). The most prevalent types of dwelling units in the country are separate houses (detached) (63.3%) and compound houses (20.9%). Separate houses (detached) are, however, more prevalent in rural (76.6%) than urban (53.8%) areas [24].

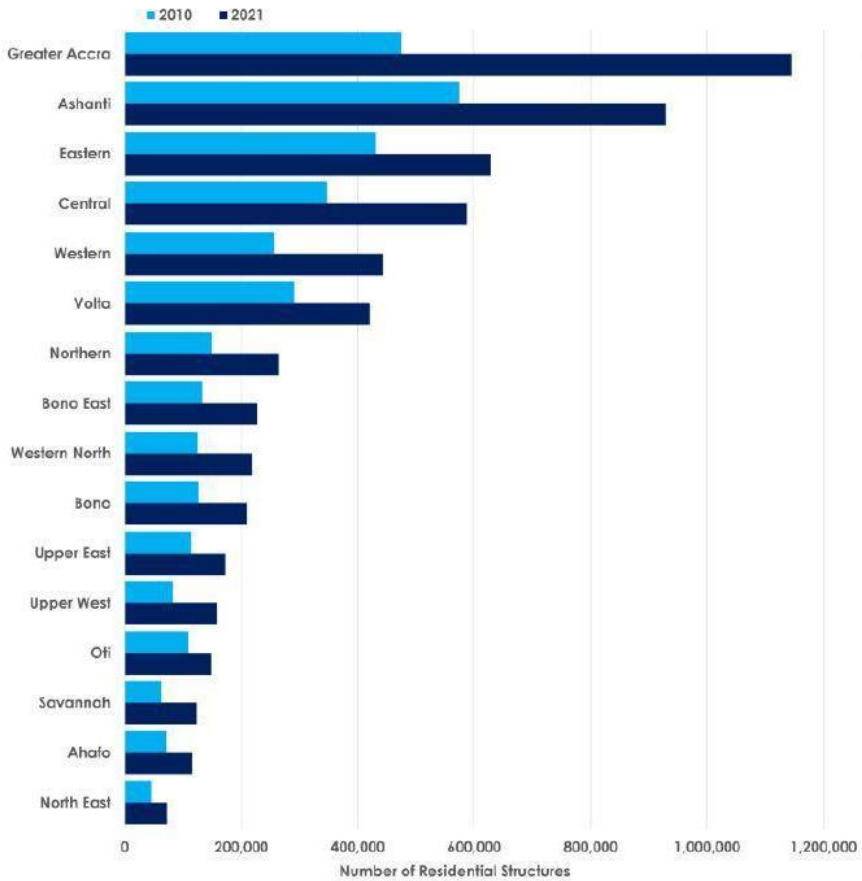


Fig. 9: Number of residential structures in Ghana in 2021.
(Source: Ghana Statistical Service, 2021)

3.1.2 Built-up density

The built-up density of the Ga-South Municipality was observed to be reducing from city centres such as Kasoa toward the Weija reservoir's buffer, as shown in Fig. 10(a),(b) and (c). Areas with low and very low density were determined using the generated built-in density map of the Ga-South Municipality, which allowed for the adaptation of an acceptable development plan to this location.

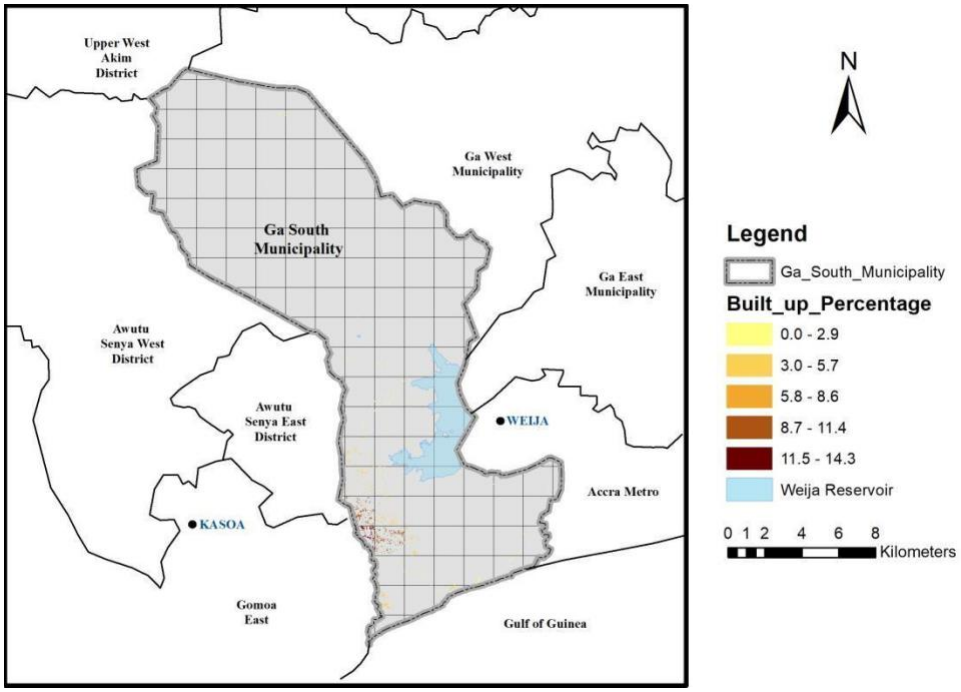


Figure 10(a): Built-up density in Ga-South Municipal in 1991.
(Source: Adapted from Seevarethnam et al., 2021).

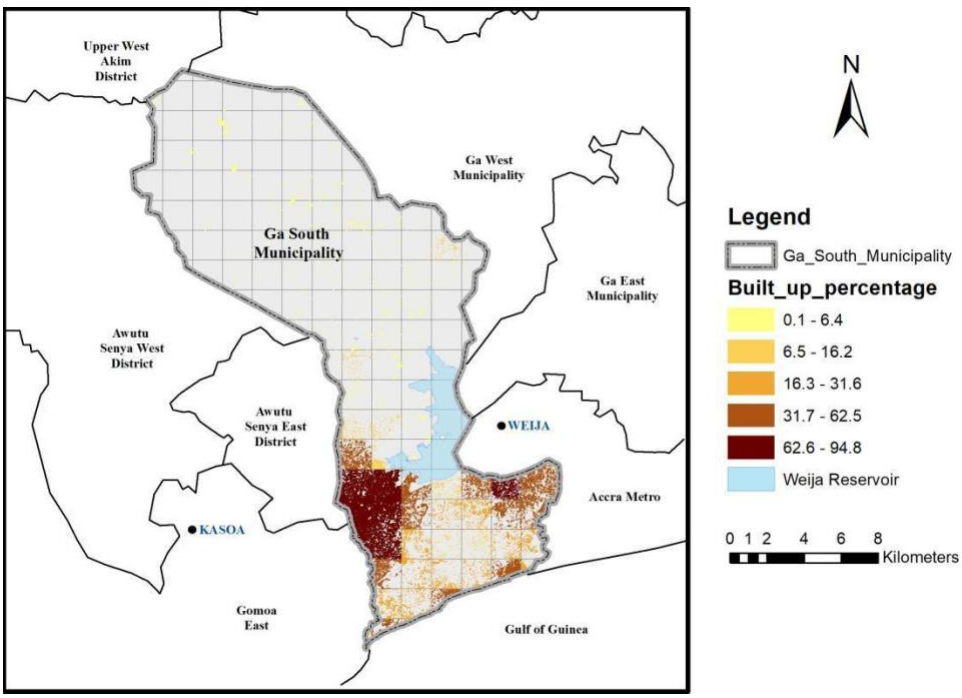


Figure 10(b): Built-up density in Ga-South Municipal in 2017.
(Source: Adapted from Seevarethnam et al., 2021)

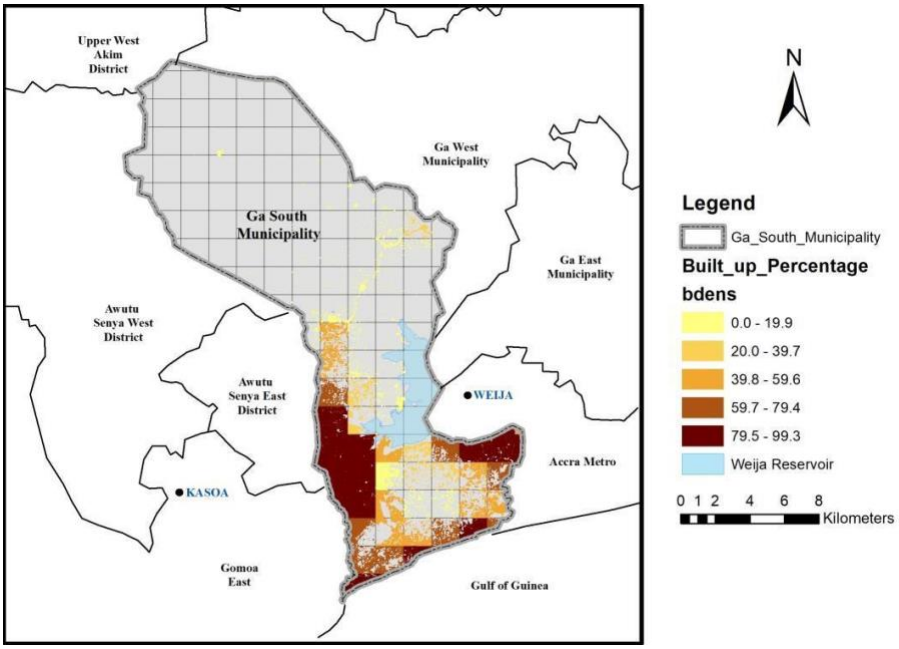


Figure 10(c): Built-up density in Ga-South Municipal in 2021.
(Source: Adapted from Seevarethnam et al., 2021).

3.2 Degree Of Encroachment On The Weija Reservoir's Buffer

The Spatialo-temporal analysis showed that the size of vegetation declined from 25,900 hectares in 1991 to 12,915 hectares in 2017 and 10408 hectares in 2021. The above is illustrated in Tab. 6 below. The reduction of vegetation from literature, according to Adjei et al. (2019)[11] and Aduah et al. (2015)[17], is attributed to the rapid population growth in the Densu catchment. From Figure 11 below, Vegetation cover reduces with the increase of the built-up area.

Table 6:
Vegetation cover in Ga-South Municipality in 1991, 2017 and 2021.

Year	1991	2017	2021
Vegetation	25,900 hectares	12,915 hectares	10,408.5 hectares

(Source: Author's field survey, 2022).

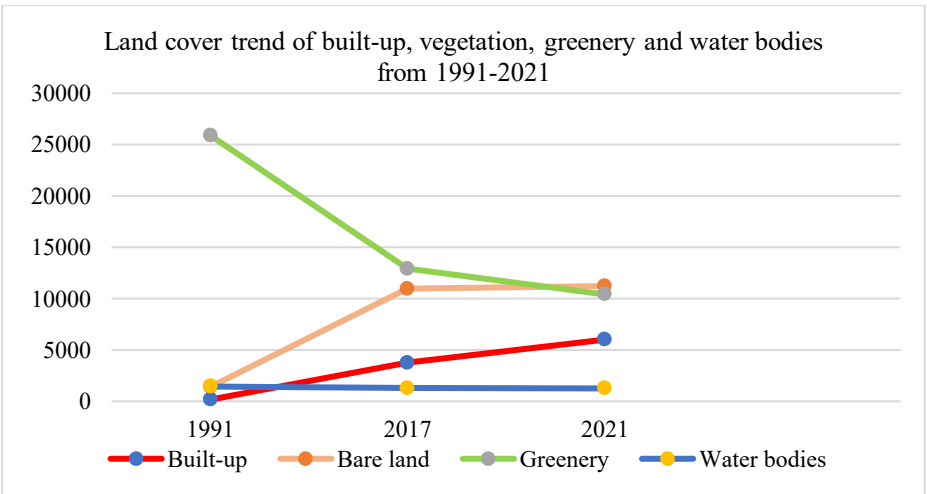


Fig. 11: Land cover trend in Ga-South Municipality in 1991, 2017 and 2021.
(Source: Author's field survey, 2022)

The municipality's growing trend impacts the reservoir's water quality [11]. The findings reinforce the study of Adjei et al. (2019)[11]. Figures 12(a),(b), and (c) show the land cover distribution in the Ga-South Municipality in 1991(a), 2017(b), and 2021(c).

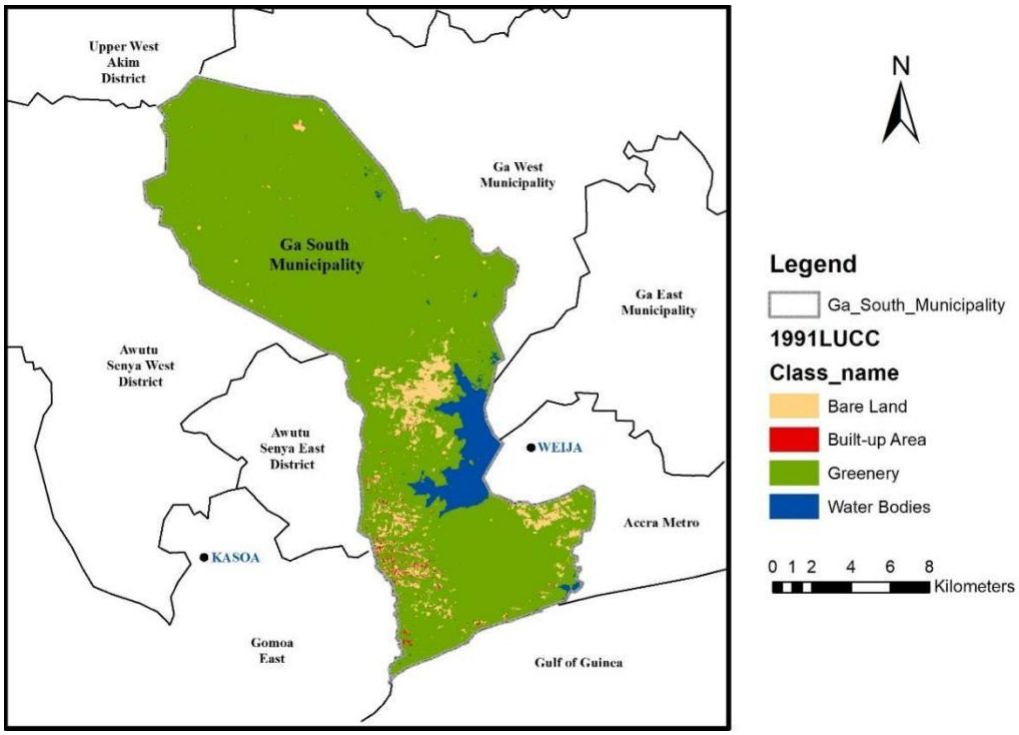


Fig. 12(a): Land cover distribution in Ga-South Municipality in 1991.
(Source: Adapted from Adjei et al., 2019)

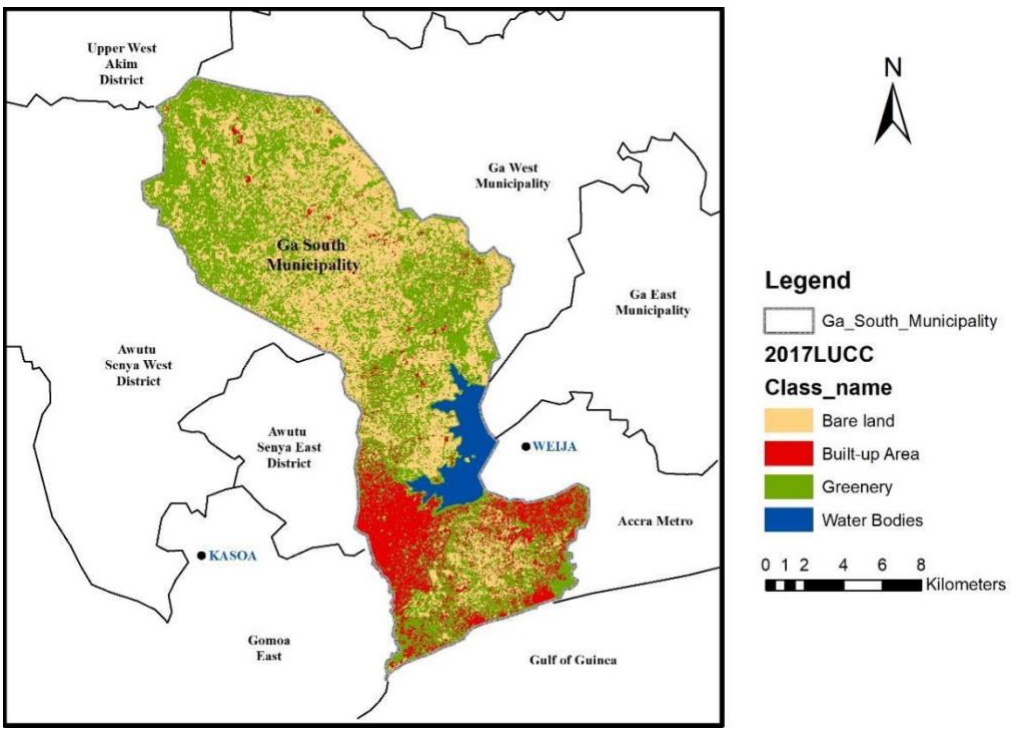


Fig. 12(b): Land cover distribution in Ga-South Municipality in 2017.
(Source: Adapted from Adjei et al., 2019)

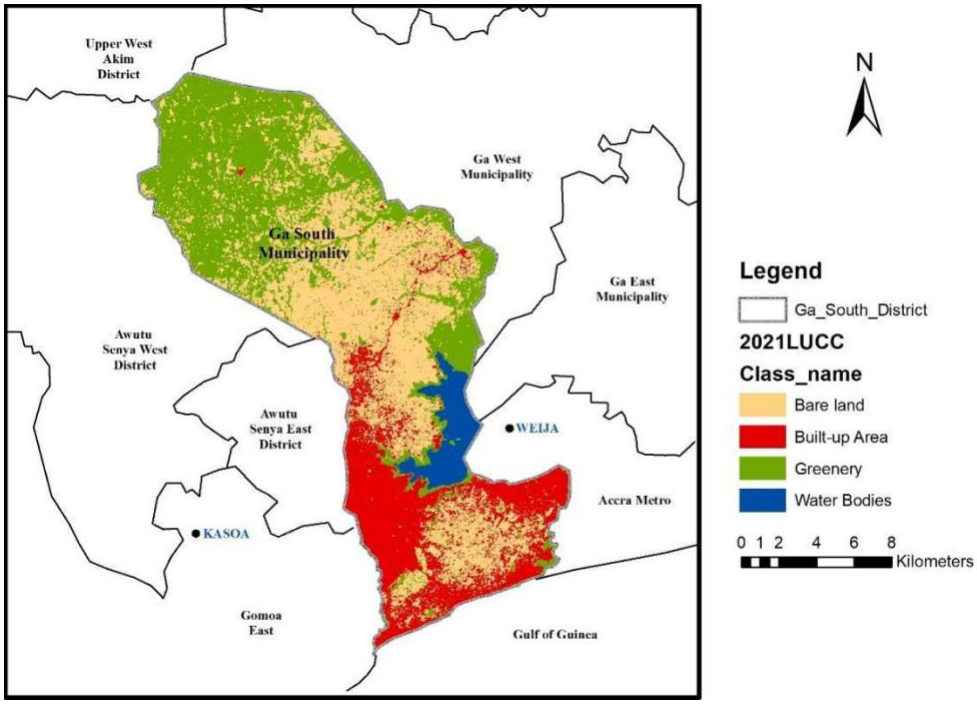


Fig. 12(c): Land cover distribution in Ga-South Municipality in 2022.
(Source: Adapted from Adjei et al., 2019).

The Riparian buffer states a maximum of 90 metres as a buffer for municipal water, such as the Weija reservoir. After delineating the required buffer for reservoir protection (Figure 13), it is observed that the reservoir's buffer, which is to occupy an area of about 259 hectares, has lost about 13 percent to built-up areas, about 6 percent to bare land, and 1 percent to water bodies. Tab. 7 shows the areas covered by the different land uses within the Weija reservoir's 90m buffer.

Table 7:
Land cover classes for the Weija reservoir's 90m buffer.

Land cover	Area(Ha)	Percentage
Bare land	14.837458	5.7%
Built-up Area	**34.234463**	**13.23%**
Greenery	206.797134	79.9%
Water Bodies	2.873628	1.12%
Buffer region	258.742683	

(Source: Author's field survey, 2022)

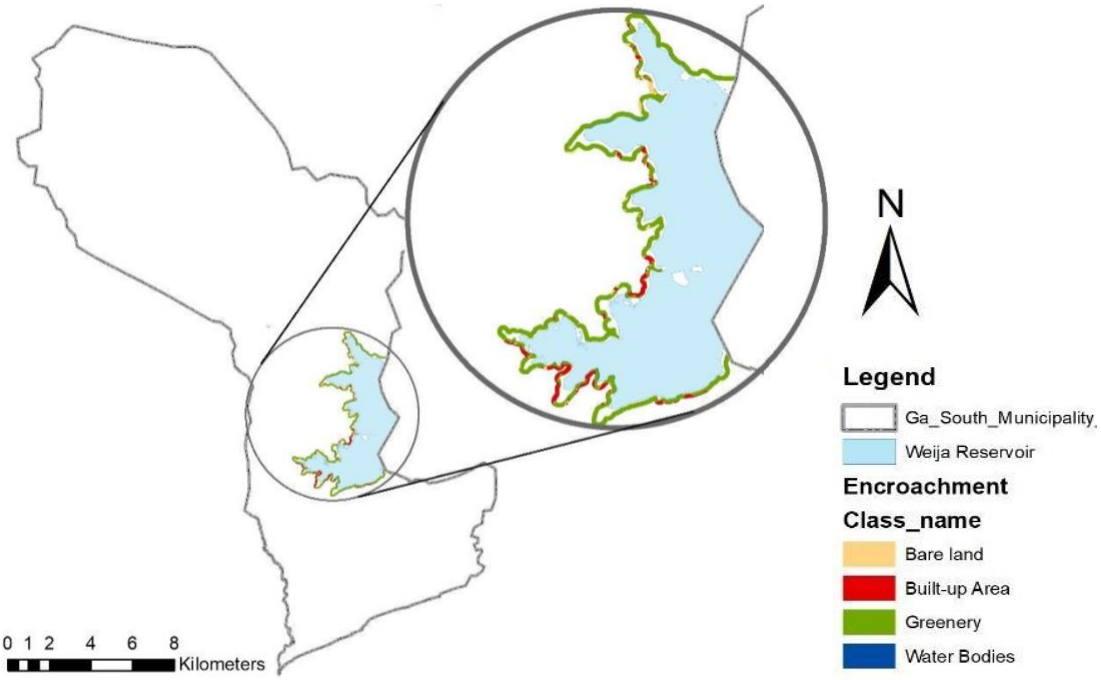


Fig.13: Degree of encroachment on the Weija reservoir in Ga-South Municipality in 2021 (Source: Author's field survey, 2022).

3.3 Inference from Interview Responses

This section discusses the responses obtained from interviews with inhabitants of the case study communities and the regulatory institutions. The themes that arose from the interview responses were grouped under three overarching themes: encroachment, planning policy implementation, and socio-economic characteristics.

3.3.1 State of Weija waterfront management and use

Wetlands, in general, are of great importance and value. The importance of reservoirs cannot be downplayed [12], nor can wetlands meant to protect water bodies be ignored [21]. In some parts of Kumasi, streams and rivers have lost their value [10]. Adjei (2019) and Cobbinah (2022) agree that the protection of water bodies is the responsibility of both inhabitants and institutions[10,11]. This section discusses the response to the management and use of the Weija reservoir from the perspective of the institutions and the inhabitants. The section also presents the challenges faced by institutions in reservoir management. The institutions use policies for the management of the reservoir and development around the reservoir. The policies of the EPA are not specific, claimed one of the EPA officials. The issue of land ownership was identified by interviewing the inhabitants and the institutions. All three institutions referred to the government as the landowners around the reservoir. Respondents affirmed their knowledge of the ownership of the reservoir surrounding them.

3.3.2 Attitudes and perceptions toward reservoir management and use from case study communities

The respondents from the communities held varied opinions on the reservoir's use. Primarily, the fishing folks revered the reservoir as a source of income. From the interviews (14 inhabitants), the primary use, as expressed by the inhabitants, was the use of the reservoir for commercial and domestic purposes. Farming, which used to be practised, is no longer being done. The reservoir waterfronts, according to respondents, were seldom monitored.

3.3.3 Planning and protection of the Weija waterfront

There is a need for broader stakeholder participation in urban planning because decisions affect a wide range of people whose actions and inactions impact the community. For an urban plan to succeed, it rests on how well and widely the views of the various stakeholders are considered. The above cannot be said about the communities studied. Most of the respondents consider themselves separate from the planning processes of the community. From institutional interviews, the Environmental Protection Agency (EPA) and the Town and Country Planning Department (TCPD) agreed that engaging stakeholders helped manage wetlands and reserves, and their coming together is essential. An Official from the EPA cited the Ramsar Conversion on Wetland project in Accra as an example, attributing the project's success to its international involvement. Stakeholder engagement, according to an official from the TCPD, helps to change the perception of both inhabitants and regulatory bodies of the importance of the reservoir, in the official's words. From interviewing the institutions, the challenges the institutions face in managing the reservoir and planning around the reservoir echo the challenges pointed out by Cobbinah (2022)[10] in studying the case of wetlands in Kumasi. The challenges from the institutional responses included lack of stakeholder consultation, fear of land guards, lack of participation from the traditional authorities, and monitoring issues.

The lack of stakeholder consultation was a problem emphasized by an official from the TCPD of the Ga South Municipality. It was observed that the challenges present among institutions regarding the management and protection of the Weija reservoir fall under the implementation of policies and the nature of the planning processes. Institutions cannot carry out policies due to lack of funding and inadequate staffing [10]. The role of the planning processes has indirectly fallen on the traditional authorities who sell the lands as they wish. This view supports the study by Cobbinah et al. (2022)[10] in Kumasi, where planning occurs concurrently between the planning department and the traditional authorities.

The Ministry of Water Works and Housing's Riparian Buffer Zone Policy applies to all developments, with an exception for developments that the TCPD had approved before the policy issuance. It's important to assess the activities of the surrounding community and their impact on the Weija reservoir and its buffer. Dumping refuse and waste into the Weija reservoir leads to a high cost of water treatment for consumption.

4. Resilience

4.1 Concepts of Resilience

Different dimensions used in determining resilience reveal that inhabitants of disaster-prone areas, resistant buildings, and green infrastructures are indicators of resilience. Building resilience of ecosystems and ecosystem services can be based on green infrastructure and technology, response biodiversity, and an adaptive management approach [26,28,21,36].

4.1.1 Blue Green Infrastructure

When natural vegetation, green approaches, and technologies mimic ecosystem processes for societal benefits, they are termed green infrastructure [21]. Urban green area elements and ecological interventions are critical for the sustainable growth of urban communities as they improve residents' lives, provide ecosystem services to benefit the inhabitants, and help achieve environmental and sustainability goals [21]. Green infrastructure provides important ecosystem services, promoting human health and acting as a buffer to disasters and other urban disturbances. Green infrastructure, used for recreation, urban aesthetics, water retention and water purification, can combine numerous urban functions in one instrument to promote benefits and alleviate some urban issues [26]. Blue infrastructure refers to water elements like rivers, canals, ponds, wetlands, floodplains, and water treatment facilities. According to Kimic and Ostrysz (2021)[29], Blue and Green Infrastructure (BGI) combines water management and green infrastructure to ensure that natural water cycles are

maintained. BGI solutions provide a multidimensional increase in the resilience of cities to urban pressures and counteract the adverse effects of climate change [29].

4.1.2 Smart Growth

Smart growth is a broad urban-generated planning and transportation theory that promotes growth in the city centre to reduce urban sprawl and promotes compact, transit-oriented, walkable, bicycle-friendly land use, such as neighbourhood schools, complete streets, and mixed-use development with a diverse range of housing options [30]. Smart growth covers a range of development and conservation strategies that help protect our health and natural environment and make our communities more attractive, economically stronger, and more socially diverse [31]. Smart growth strategies are characterized by compact development and redevelopment of the city's built-up area [32].

4.1.3. Adaptation as a planning concept

As urbanisation rapidly increases, countries try to adapt their waterfronts to these changes to prevent disasters [33]. The vulnerability of the urban waterfront is in four different capacities: threshold, coping, recovery, and adaptive capacities [34]. Adaptation strategies mostly follow vulnerability assessments and are developed for systems found vulnerable.

One adaptation concept is mainstreaming, which considers adaptation options that yield benefits within a short period while reducing the long-term effects of climate change. Hallegatte et al. (2012)[35] call it the no-regret option. As explained by Dal Cin et al. (2021)[33], mainstreaming is practical when considering waterfront adaptation. Although mainstreaming comes with benefits such as improving the effectiveness of policies and reducing the cost of implementation, the adaptation process is sped up by mainstreaming, and it is limited to a strategic level, ignoring the operational level or gradual processes of urban planning and development [33]. A significant determinant of the success of adapting waterfronts to climate change is the processes involved in urban renewal. These processes are more likely to create opportunities for new ways of adaptation. This theory of urban dynamics (urban renewal and transition), according to Veelen (2018)[36], counteracts the urgency of adaptation portrayed by the concept of mainstreaming. Veelen (2018) explains the former as having the potential to create opportunities and unseen ways of adaptation and the latter as a more abrupt approach[36]. The need for adaptation in urban renewal and development is highly recognized by researchers [36]. This hinged on the theory that the actual instances or moments of change that happen through urban renewal and development offer 'windows of opportunity', allowing for adopting adaptation measures at relatively low cost. The nature of adaptation of the waterfront then sets in after the urban dynamics have set the pace. Neighbourhood lifecycle-based adaptation opportunities are also stated by [37]. This adaptation first involves developing and transforming green and brown fields and, secondly, renovating buildings. The mentioned methods of waterfront adaption both require high levels of predictability and continuity of urban development and maintenance. It is important to recognize the other factors of urban dynamics, such as ownership, political incentives, market conditions and values, because they may not be easily determined using the mentioned adaptation methods at the project level [33].

4.1.4. Resilience and Planning

Sustainability goals, procedures to achieve these goals, and adaptive capacity management are all components of a resilient city [38]. By considering our urban areas as living entities, each with specialised yet basic requirements, we better understand transforming these environments from random structures (sprawl) to dynamic high-performance systems [39]. Karlenzig (2010)[39] proposes using sustainability strategies under seven thematic areas for resilient planning. These areas are planning, mobility, built environment, economy, food, resources and management, as shown in Tab. 8 below.

Table 8: Resilient planning strategies.

Themes	Strategies
Planning	-Developing mixed-used communities -Higher-density regional centres -Protecting agricultural, watershed and wildlife
Mobility	-Investing in quality pedestrian, bicycle and public transportation with shared connectivity and information
Built Environment	-Retrofitting existing buildings for energy and resource efficiency -Properly designing new buildings and related landscapes.
Economy	-Providing quality local jobs with renewable technologies and services
Food	-Regional food production -Food distribution networks
Resources	-Efficient use of water -Reuse of resources where possible
Management	-Engage all Stakeholders: government, businesses, and the citizens Tracking and recording progress, hindrances and opportunities

(Source: Karlenzig, 2010).

A precedent worth considering in resilient planning is the Rio Nuevo master plan. The Rio Nuevo master plan encompasses two coincident plans: a ten-year development plan and a long-range vision plan that incorporates projects that may be implemented within the ten-year life of a new Tax Increment Finance District (created in 1999) and projects that may extend well into the future. The plan approaches the project from an economic, cultural, and environmental sustainability perspective by healing and restoring the disrupted areas' natural systems and cultural heritage. Figure 14 below show the sketch of the Rio Nuevo master plan.

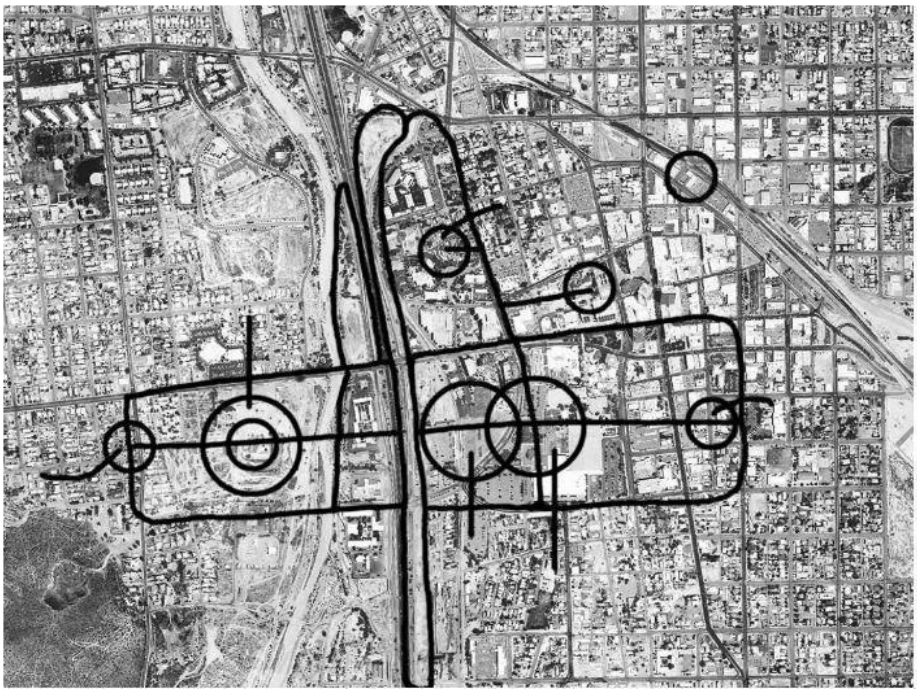


Fig.14: Image showing a sketch of Rio Nuevo
(Source: William, 2007) [40].

The Rio plan began with restoring the river and reweaving the eastern and western neighbourhoods together. The stakeholders reconstructed islands, sandbars, and natural terraces to slow the water to a more even and natural pace, providing resting places for fish, birds, and other wildlife.

5. Conclusions

The study was undertaken to identify the reasons hindering the observation of the buffer zone policies at the Weija reservoir and explore ways in which resilient architecture and planning can help to protect the reservoir from its sprawling surroundings. The researchers achieved objective one through the use of satellite images, and the use of a semi-structured interview guide for selected institutions and selected communities achieved objective two. Objective three was acquired from a comprehensive desk survey (literature review).

With the aid of Geographic Information Systems (GIS) and remote sensing, the designated buffer of 90m for the Weija reservoir was mapped for the Ga-South Municipality. It was observed that for 2021, about 13% of the Weija reservoir's buffer had been encroached by settlement. About 6 percent of the reservoir's buffer is registered as bare land. These characteristics increase run-off into the reservoir and lead to bank instability. It was observed that the surrounding development of the reservoir possessed characteristics of urban sprawl, which was interpreted using ArcGIS 10.7 software to understand the nature of the sprawling developments for the years 1991, 2017, and 2021. Therefore, It can be concluded that the Weija reservoir has been encroached on, not with plain words but with measured evidence. The findings demand more attention from government institutions, developers and urban ecologists.

The study engaged the stakeholders responsible for managing and using the reservoir and its surroundings. Respondents from the institutions attributed the failure of implementing buffer policies to the lack of stakeholder collaboration and participation and the ineffectiveness of monitoring actions. The issues identified by respondents resonated with studies from other parts of the country[10,11]. The trend in land cover changes shown in the findings revealed the consistency of the vegetation loss of wetlands, which was reinforced through the study. Although institutions are doing their best, the lack of participation of stakeholders is an overarching roadblock.

From the critical review of literature on the characteristics of urban sprawl, urban sprawl measures and strategies for controlling urban sprawl, the study discovered that what makes urban sprawl a problem for reservoirs or water bodies, in general, is the impact that urban sprawl has on the ecosystem of water bodies. Ecosystems of water bodies have important functions and need to be protected. According to (Vargas-Hernández and Zdunek-Wielgołaska, 2021)[21], ecological interventions are critical for the sustainable growth of urban communities because they help achieve environmental and sustainability goals. First and foremost, designated buffer regions for reservoirs are to be observed. Planning along these buffer regions should take conscious efforts to control runoffs to the reservoir.

The city and the ecological system interface have been a dynamic and ever-transforming area. The urban communities' demands are shifting away from the formerly cherished traditional zone standards and toward other economic gain-driven uses of riverbanks as development accelerates. In Ghana, the depletion of wetlands is echoed in most of the country's cities [10,11,41]. The study aimed to identify the reasons hindering the observation of the buffer zone policies meant to protect the Weija reservoir and explore ways resilient architecture and planning can help protect the reservoir. From the literature, ecosystems of water bodies can be protected by enabling the ecosystems. Better ways of coexistence between humans and nature can be achieved by enabling the ecosystems. Urban regions should be studied simply because of their expanding impact on the earth's surface [42]. The fact that people live in cities is a compelling argument for knowing how cities function ecologically. There is a need for proper management to uphold a reasonable standard of living for the future [42]. The management of wetlands in Ghana should take a turn; communities should be educated and made to participate in decisions concerning waterfront developments. Better planning and policing systems are needed to manage sustainable urban sprawl, considering future urban developments and the health of biodiversity and ecosystem services [21]. There should be participatory approaches to planning the waterfront, which ensures that design and planning implementations are well received.

Through remote sensing and Geographic Information Systems, the research outlined a procedure for identifying the level of encroachment for a given water body provided the required buffer distance is known. Future research can be channelled toward identifying how best development along water bodies can contribute to the ecological balance of the ecosystems of these water bodies. The need for densification was recognised as an anti-sprawl mechanism. Researchers could look into the materials that have minimal impact on the ecosystems of these environments.

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