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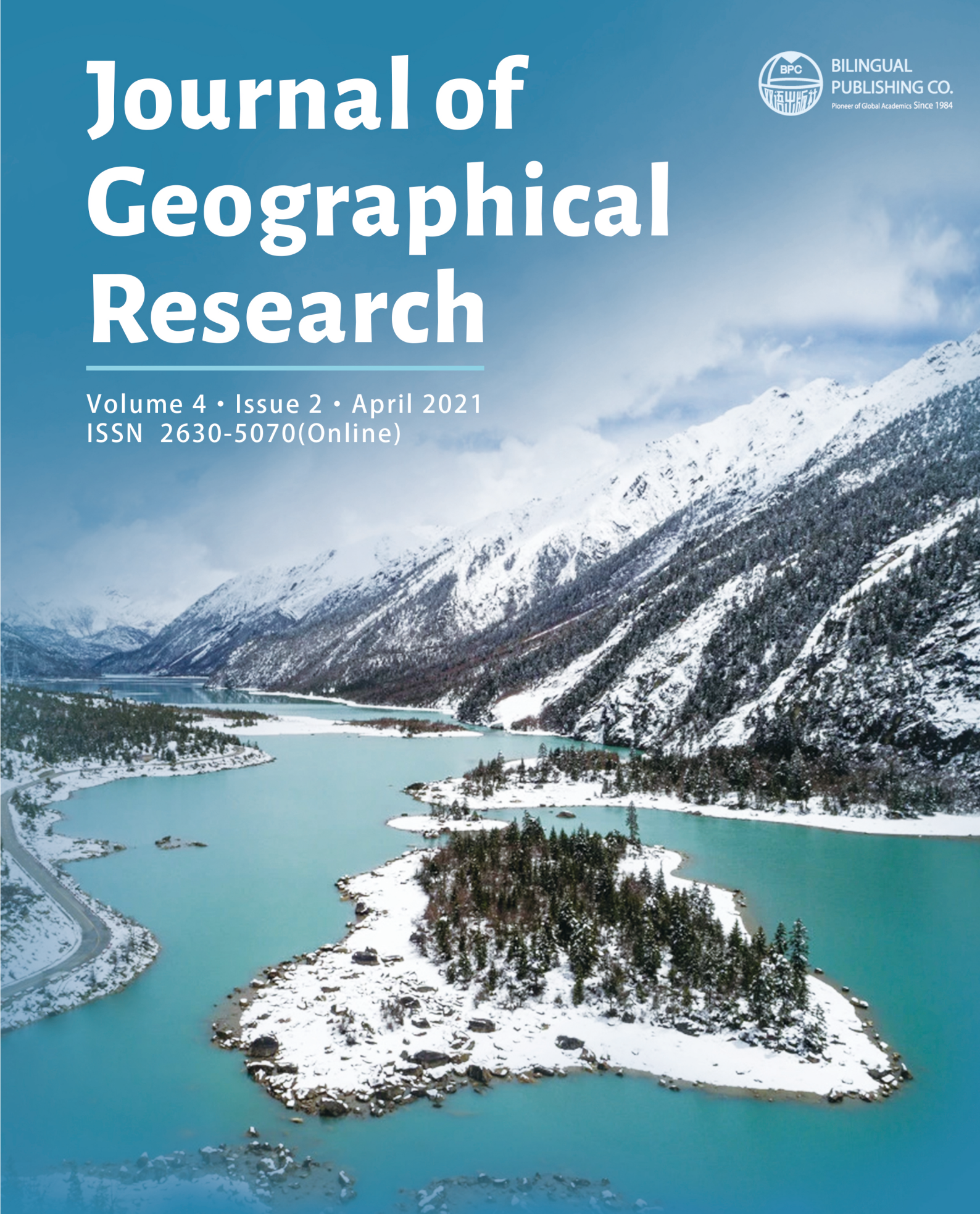

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ARTICLE

Analyzing Urban Expansion and Spatial Growth Patterns in Barahathawa Municipality of Central Tarai Region, Nepal

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ABSTRACT

The rapid transformation of rural settlements into municipalities in Nepal has brought significant changes in land use, and urban expansion and growth patterns mostly through the conversion of agricultural land into the built-up area. The issue is studied taking a case of the rapidly growing town, Barahathawa Municipality of Tarai Region of Sarlahi District. After the declaration of the municipality, several new roads have been opened and upgraded; and the municipality is well-connected to the national transportation network. After promulgated the Constitution of Nepal 2015 and functioning the elected local body, the municipality budget has been increased significantly as a result of increasing municipal investment in socio-economic and physical infrastructure development and environmental protection which has attracted people, goods, and services creating the zone of influence on the municipality. One of the changes found in the municipality is the increasing built-up area and expansion of urban growth through the decreasing agricultural land. Urban growth has been observed taking place around the Barahathawa Bazaar and main roadsides. The built-up area in Barahathawa municipality has remarkably increased by 183percent with the decrease of shrub and agricultural land within 10 years. Implications of such spatial and temporal dynamics have been a core issue of urban planning in most of the newly declared municipalities in Nepal.

1. Introduction

In Nepal, urbanization has generally practiced analyzing regarding the number of municipalities and people livings in them, and these municipalities are at the flux of the struggle to achieve better living standards in the developing countries [1] and are concentrated mainly in the valleys (Kathmandu, Pokhara), inner Tarai and main highway corridor and in the towns nearer to the Indian border. These urban areas are becoming a center of attraction of the people and are expected to serve as a hub to provide markets for goods and services, and improve living conditions, and employment for the city dwellers as well as those in the surrounding rural localities [2]. Urban growth is inevitably linked to peri-urban areas [3] through the process of spatial expansion of the functions in the periphery [4] and there also exists a spillover effect of the nearby cities.

However, urban growth is a complex phenomenon and a non-linear process [5]. Though, various factors have generally affected to impact urban expansion and spatial patterns of town. Classical theories such as urban economic

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base [6][7]; threshold and range of goods [8]; and basic and non-basic components of urban function [9] are one and or other ways have discussed the urban expansion and spatial pattern of growth of the town. Similarly, Von Thunen's model (1826), Burgress concentric zone model (1925), acknowledged that urban areas expand outwards from their Central Business District (CBD), while Hoyt's sector model (1939), and Harris, and Ullman's Multiple Nuclei Model (1945) developed ideas further by theorizing that urban expansion happens along with existing transportation network, in a suitable topography, in the vicinity of similar land uses and outwards from multiple market centres [4].

By examining in the Nepalese context, urban settlements are more dynamic and constantly changing over time. The changes have been found both in spatial and temporal dynamics. One of the most changes found in the urban area is in the farmland and farming system that is shrinking due to the expansion of the urban built-up area. Increasing urban services and facilities in the municipalities has attracted more people from surrounding areas, particularly from the rural regions. In the municipality, changes can be analyzed in terms of the land use and spatial expansion as well as functional characteristics of the town. Such changes collectively affect the process of planning and policy formulation, which is related to the social, economic, environmental change patterns and trends of urban expansion. In Nepal, most of the urban areas/municipalities have rural characters and have agriculture as the main sources of income and employment. However, with the increasing investments in infrastructure development and as the consequence of population migration in the municipalities, the unregulated built-up areas are increasing day by day. Increasing informal sectors and informal settlements are the consequences of rural to urban migration in Nepal [10]. This leads to haphazard urban growth causing irregular, substandard, and inaccessible housing patterns and significantly increased vulnerability to disaster [11] which again causes the growth of squatter settlements in the urban areas [12]. In this context, the main objective of this paper is to analyze urban expansion and spatial patterns of growth of Barahathawa municipality.

2. Materials and Methods

This study is based on the primary and secondary data collected through fieldwork in 2018 during detailed consultation meetings at the municipal and ward level. A land-use map has been prepared based on 0.5 m spatial resolution satellite imagery. Land use data of the past was collected from the ICIMOD Geo-data portal [13] and processed using the ARC GIS10.4. It has also analyzed the land-use changes in the last ten years by overlaying on the GIS environment.

2.1 The Study Area

Barahathawa is a small market and has declared the municipality status in 2015 by incorporating seven small villages (previously known as Village Development Committee (VDC) [14]. From the very beginning, it has been developed as a rural market center. It is located in Sarlahi District in province no Two (Figure 1). The total area of the municipality is 107.04 Square Km.

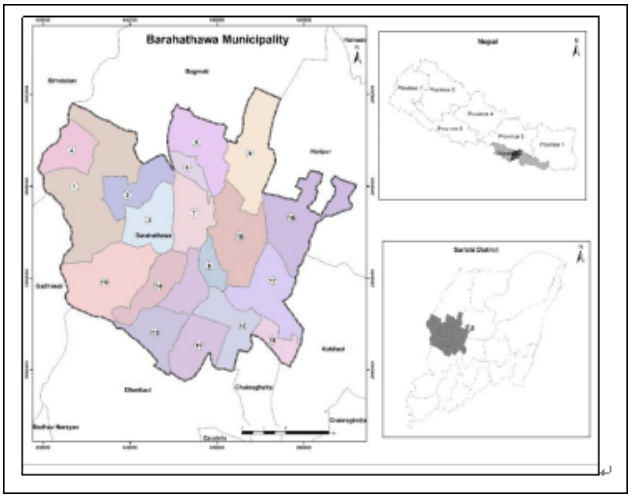

Figure 1. Location of the Study Area, Barahathawa Municipality

2.2 Topography, Climate, and Rivers

The municipality falls in the Tarai physiographic region, which covers the northern rim of the Gangetic plain. The land is most flats with minor relief. Elevation of Barahathwa Municipality ranges from 86 to 110 meters, and the climatic condition is sub-tropical monsoon type. The rainfall distribution is irregular but the trend is higher in July and lowers in Nov and Dec. Bagmati and Lakhandei are the main rivers and Ekadasi Nala, Pathailaiya Nala, and Manusmara river are also drained in the municipality originated from the northern Siwalik and hill region and flow down to the south with a flash flood during the rainy season.

2.3 Roads and Accessibility

Barahathawa municipality is connected by blacktopped and graveled roads which link to the east-west highway (to the north) to Malangawa (to the south-east). Roads connected from Barahathawa to surrounding municipalities and market centers such as Hajariya, Murtiya, Laukath, Sundarpur Choharwa, and Bagmati (Soltee Bazar) are

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earthen roads. Nayaroad-Barahathawa (10 km), Kaudena-Janakinagar (15 km), Hariwon-Janakinagar (5 km), and Janakinagar-Baraudharan (20 km) are major roads in the municipality (Figure 2).

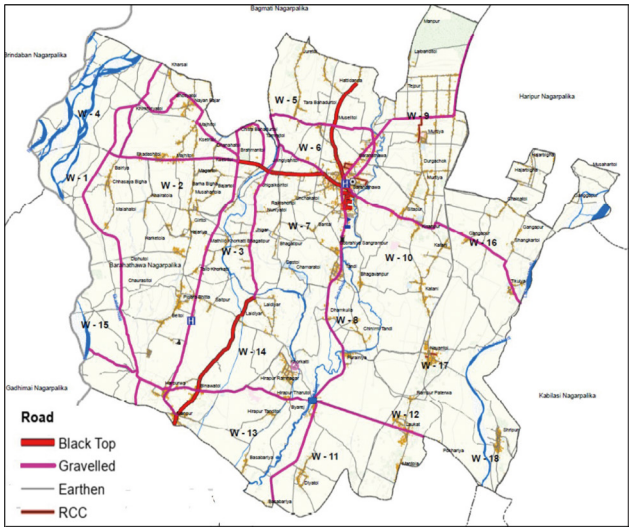

Figure 2. Road Network (Surface types) in Barahathawa municipality

The total road network in the municipality is 191.5 km, of which 71 percent are gravel, and 15 percent are earthen. Except few, many parts of the study area do not have proper drainage and sewerage facilities. Open drainage at Bazzar areas has been observed.

2.4 Socioeconomic Characteristics of Municipality

Barahathawa Municipality has 84,522 populations of which 50.68 percent are male and 49.32 percent female [13]. The municipality has 13,863 households and an average household size is 6.1. The population density of the municipality is 790 people per sq. km, and the sex ratio 103. In the past, the municipality had a 69,822 population with 11,853 households [15]. The average annual population growth rate in the period 2011-2018 has been calculated as 3.5 percent. Among others, wards no 18, 10, 6 and 7 have the highest population growth rate (more than 6 percent) and ward no 2, 14, and 12 have the lowest population growth rate (below 0.3 percent). There is an uneven distribution of the population in the municipality. Among others, ward no 7, 5, and 1 have the highest population density. Population density ranges from 422 to 2356 per square Km with highest in ward no 6 to lowest in ward no 17 (Figure 3).

People have been migrated from one place to another for better livelihood. Youngsters are going abroad for income, employment, and higher education as well. However, as the municipality has a direct link with the district headquarters, Malangawa, and easy access to the east-west highway, and hills districts, municipalities, and rural municipalities of Province No 2 and Bagmati province; there is a high possibility for increasing population in the municipality. Focus Group Discussion (FGD) at Barahathawa revealed that the municipality is the best destination due to its good connectivity, relatively cheap land value, and suitable location. Therefore, people from the northern hill districts and the municipalities/rural municipalities have selected Barahathawa as the best place for lives and livelihood (FGD, 2018 at Barahathawa). It has also been found that 1527 population from 303 households were migrated in the Barahathawa municipality from nearby villages of Sarlahi and Rautahat districts; whereas, 671 population from 179 households were migrated to the nearby towns, villages of Rautahat, Sarlahi and Kathmandu districts in 2018 [14].

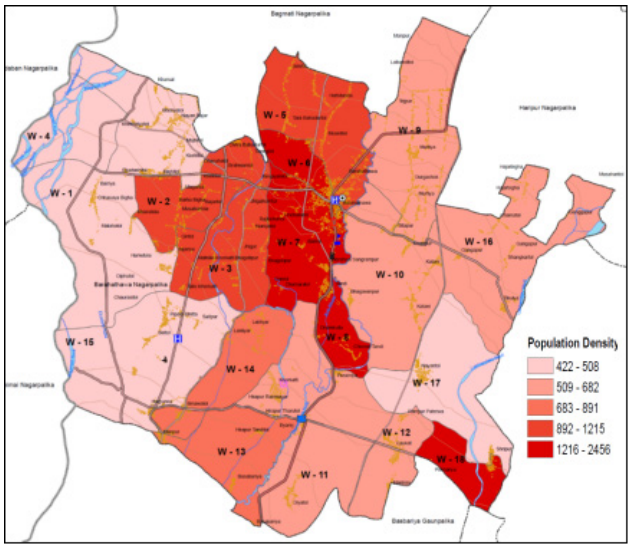

Figure 3. Population Density, Barahathawa Municipality 2018

However, as the municipality has a direct link with the district headquarters Malangawa and other urban centers developed along the east-west highway and easy access to the Indian markets, and hills districts, municipalities, and rural municipalities of Province 2 (Center Tarai); there is a high possibility of increasing population in the municipality. Well-road connectivity, increasing urban services and facilities, increasing trade and local business will collectively attract people, goods, and services to the municipality in the coming years. As of municipal profile, Barahathawa has 84,522 population in 2018 with an annual growth rate of 3.5 percent, which is very highly compared to the national population growth rate (1.35 percent) [15]. If the population growth rate remains the same, the population of Barahathawa municipality in the next five-year would be 97,985 (e.g., 2023), and will reach 131,686 in the next 15 years (e.g., 2033) [15] (Figure 4).

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Agriculture is the main occupation of the people in Barahathawa municipality characterized by the Tarai lowland cultivation. This municipality has taken off towards commercialization from its state of subsistence agriculture. The present level of farming in this municipality is in the semi-commercial stage farming system of this municipality is agriculture-based with a specialization of few selected crops in larger areas/blocks. Paddy, maize, and wheat are the main cereal crops, whereas, sugarcane, turmeric, potato are the main cash crops grown in the municipality. There are three distinct seasons: monsoon, winter, and spring. The crop grown in different seasons overlaps each other. Hybrid maize, sugarcane, turmeric, rapeseed, and potato are considered major high-value crops of this municipality. There is a large market of agricultural production at this place that supplies cereal grains to Kathmandu and other urban cities of the country, as well as exporting to nearby Indian markets.

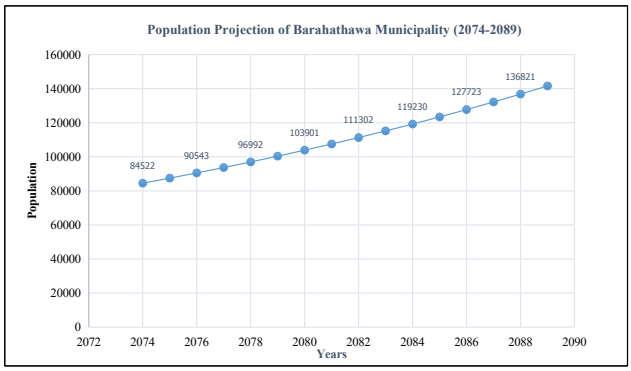

Figure 4. Population projection in Barahathawa municipality (2018-2033)

3. Urban Expansion and Spatial Growth

Expect few, many areas of the municipality have rural characters and have dispersed, and compact settlements. Dispersed settlements are ones where the houses are spread out over a wide area. They are often the homes of farmers and can be found in rural areas. Settlements like Barahathawa, Sundarpur Choharwa, Laukath, Sreepur, Hajariya are developed in a compact form, and in a leaner pattern (Figure 5). These are small market centers as well, where most of the urbanization seem to be concentrated in the future. These markets are providing services to surrounding settlements and villages. The municipality is well-connected by graveled roads which connect Malagawa in the south-east (the district headquarters) Nayaroad, Harion (east-west highway) in the north. Roads connected to Barahathawa- Malangawa, and Barahathawa-Nayaroad are also all-weather roads. Other urban roads in the municipality connected different settlements.

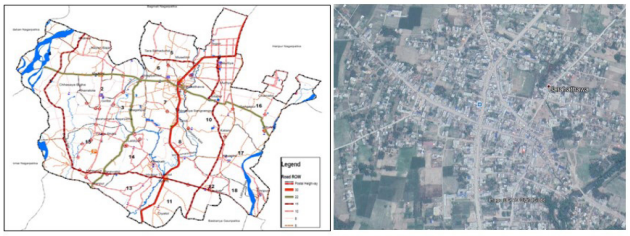

Figure 5. Overview of Urban Structure around Barahathawa

Source: Google Earth Achieve Image, 2018. Bazar

Nayaroad-Barahathawa, Barahathawa-Laukhat, Barahathawa-Hajariya, Barahathawa-Murtiya, and Barahathawa-Soltee Bazar road corridor's area will grow significantly in the future. Among others, Barahathawa and Murtiya are the most urbanized market centers in the municipality; and it has also been observed that urbanization seems to be high in and around these areas. It has also expected that the population of Barahathawa Municipality in the next 15 years (2033) would be 131,686; the populations will concentrate mainly in and around Barahathawa and Murtiya sides. If we look at the past, urban expansion had concentrated in and around the Barahathawa and Murtiya (Figure 6).

Barahathawa & Murtiya; April 2018

Barahathawa & Murtiya; November 2002

Figure 6. Spatial Growth Trend, Barahathawa (2002-2018)

Source: Google Earth Achieve Images of different time interval

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Barahathawa municipality has also posed diverse spatial characteristics. Covering dominant plain (Tarai) topography and river channels have fertile land. Based on the topographic diversity, it has different potentialities of agricultural production, settlement development and urban expansion in different areas.

In terms of the settlement system and its spatial distribution, settlements are mostly dispersed and some are agglomerated. However, some settlements along the Barahathawa-Hajariya, Murtiya to the south roads have developed as a linear pattern. Barahathawa is moving towards agglomerate while other settlements, for example, Murtiya and Hajariya, are developing mostly in the compact linear pattern. Urban expansion seems to be developed along the Barahathawa-Hajariya, Murtiya to the south roads. Settlements hierarchy have been identified based on their size, functions, strategic location, and services they provide. Based on this, Barahathawa Bazar remains in the first order settlement while Hajaiya, Murtiya, Laukath, Hirapur, Nayatol, SundarpurChaurwa has identified in the second-order settlements. Many settlements in the municipality have been identified in the third, and fourth order settlements (Figure 7).

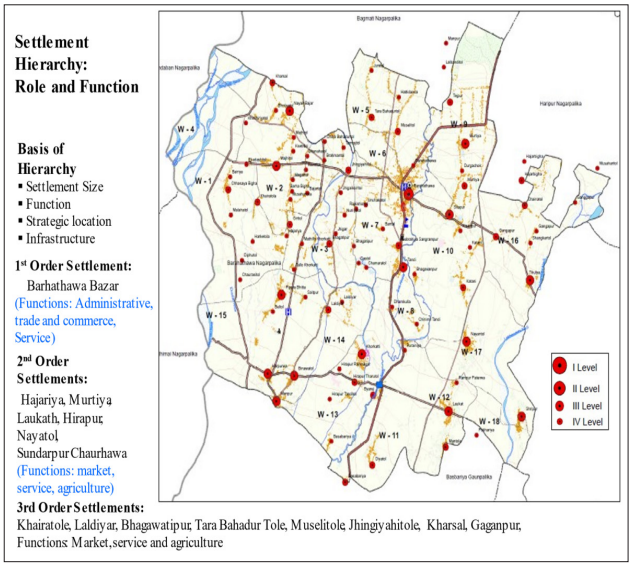

Figure 7. Settlement system and Hierarchy of Barahathawa Municipality

Spatial analysis has also been done through the road accessibility to households. The municipality has good access of roads serving more than 74 percent of households within 500m distance (about 6 minute motorable road access), and more than 19 perecent households have road accessed within 1 km (12minute) (Figure 8). Most of the urban roads are gravel in condition.

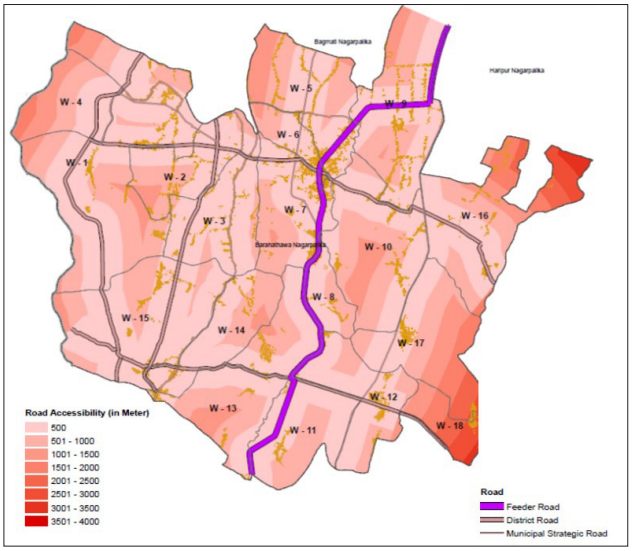

Figure 8. Road accessibility

4. Land Use and Built-up Area

Agriculture and forest are dominant land use, which has covered about 91 percent of the municipal area (Figure 9).

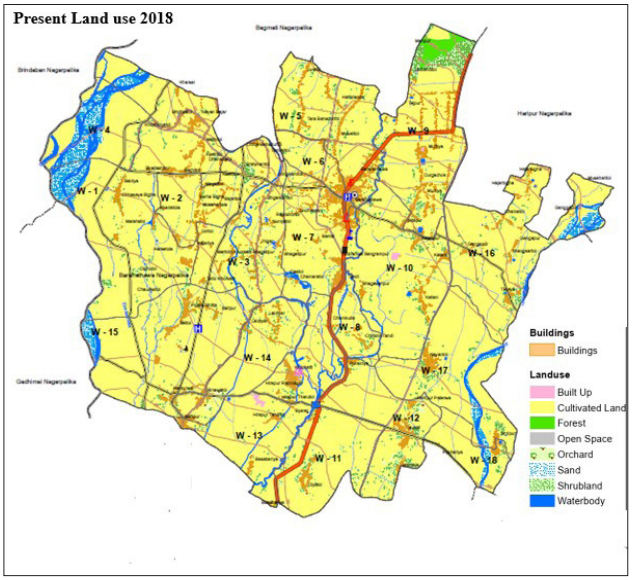

Figure 9. Present Land use Barahathawa 2018

The built-up area is covered only 2.04 percent. The agricultural land use pattern of the Barahathawa municipality has been categorized as Tarai Cultivation with paddy domination. Agriculture, built-up and barren land (along the Bagmati and Lokhandei riverside) are dominant land use categories in the municipality. Except few, most of the area have irrigation facilities through Bagmati Irrigation System (east canal) and local irrigation canals, particularly from the Lokhandei. Agriculture in Baraha-

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thawa has highly commercialized dominated by maize, turmeric, sugarcane, mustard, and wheat. Winter agriculture in the southern Laukath and Sundarpur Choharwa has mostly dominated by cereal crops (e.g., wheat, maize, and mustard). However, small patches of bamboo and mango orchards have also been observed. A significant number of people are also engaged in commercial farming. Sugarcane, turmeric, and mustard are noted high-value crops; particularly at Rajghat, Shankarpur, Murtiya, and Barahathawa sides. Both traditional and modern farming practices have been observed.

Agriculture practices have been found slowly decreasing due to increasing human encroachment and expansion of the market center, particularly at the main road sides (i.e. east-west highway, Nawalpur-Malangawa, and Naya Road-Barahathawa). Rapid conversion of agricultural land into residential use has been observed at Barahathawa and Soltee Bazar sides. The rate of conversion of agricultural land into residential or commercial/industrial is reported high. Barahathawa is one of the oldest market centers of Sarlahi and has known for its agriculture production and marketing. At the beginning was a small collection of centers of agriculture production. Table 1, shows the change in land use in Barathawa municipality in the period between 2010-2018.

Table 1. Land Use Changes in Barahatawa (2010-2018)

Land Use Category	Land Use, 2010		Land Use, 2018		Percentage Changes
	Area (sq km)	Percent	Area (sq km)	Percent	
Built-up	1.98	1.85	5.61	5.24	183.2432
Cultivation	92.63	86.54	91.03	85.04	-1.7333
Forest	1.01	0.94	0.72	0.67	-28.7234
Pond	0.59	0.55	0.29	0.27	-50.9091
Orchard/Nursery	1.56	1.46	0.25	0.23	-84.2466
Sand	5.3	4.95	1.33	1.24	-74.9495
Shrub	1.51	1.41	5.32	4.97	252.4823
River	2.46	2.3	2.49	2.33	1.304348
Total	107.04	100	107.04	100	0

Sources: ICIMOD 2010 and DUDBC 2018.

Erosion/river cutting, and flooding have brought a significant change a land use around the riverside. Similarly, the cultivation area has converted into a built-up area (i.e., expansion of the market area, construction of the new residential building, roads, etc.). Linear and cluster settlements have been observed in many areas of the municipality. Brick factories at Laukath, Sundarpur Choharwa, Hajariya, and Barahathawa sides have also been noted, and small-scale processing industries are also increasing, which have also brought significant changes in land use in the municipality. Three major factors have been identified so far regarding the land-use changes:

Agriculture land has converted into a built-up area: It is because of the increasing residential building/commercial units around the market centers and factories. These scenarios have been observed in and around Murtiya, Barahathawa, Laukath, and Hajariya. Changes have also been observed along the Naya Road-Barahathawa-Malangawa road corridors. Mostly, traditional wooden pillar houses are also observed in municipality areas. Houses having cemented bonded bricks/stone foundation RCC houses are recorded only about 10 percent. However, in the recent years, multi-story commercial and residential building using modern construction materials are gradually increasing by number in Barahathawa, Murtiya and other small market centers like Hirapur and Hajariya.

Photo 1. Traditional vs Modern buildings, September 7, 2018.

River and Waste Land: Bagmati and Lakhandehi Rivers are flowing by making a wide channel. Flooding on the rivers has lost people and amounts of properties every summer season. Marginal areas of Hajariya, Janakinagar, Sreepur, and Sundarpur Choharwa areas are prone to flood and inundation. The western part is

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prone to flood from the Bagmati river, whereas eastern parts are prone to flash floods and inundation of Lakhandei river generating from the northern hill region in Monsoon time (Figure 10).

Photo 2. Lakhandehi river and wastelands, September 7, 2018.

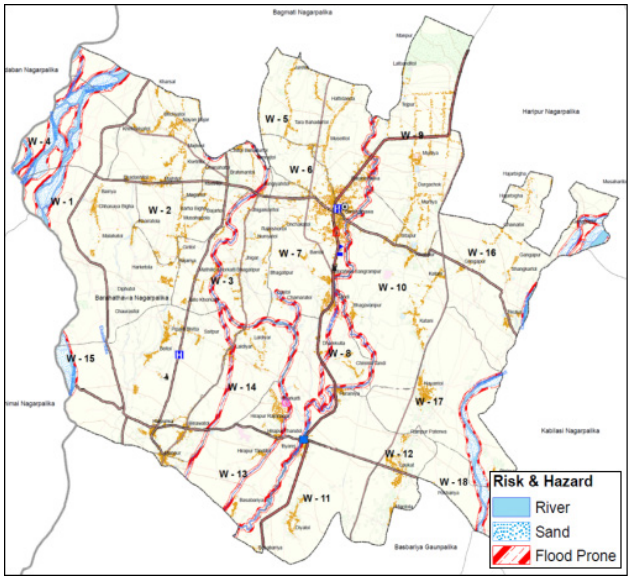

Figure 10. Environmental Sensitive Areas of Barahathawa

Market Center: Particularly Barahathawa market is expanding rapidly in terms of functional range and magnitudes. The gravity of the market is increasing recently; therefore, in-migration has also been increased over the last five years from surrounding municipalities and rural municipalities.

Photo 3. Periodic Haatbazar and Barahathawa Bazar, September 7, 2018.

Agriculture practices, in general, are found slowly decreasing due to increasing human settlements and emerging new market centers at the main roads side i.e. east-west highway, Nawalpur-Malangawa, and Naya Road-Barahathawa. Conversion of agricultural land into residential use has been observed along both sides of roads particularly at Barahathawa and Soltee Bazar side. Barahathawa is a designated municipality in 2014 incorporating other VDCs of the surrounding areas. Therefore, the rate of conversion of agricultural land into residential or commercial/industrial is reported high. Barahathawa is one of the oldest market center of Sarlahi and has known for its agriculture production and marketing. In the beginning, it was a small collection centers of agriculture production. Figure 11 shows the change in land use in Barathawa municipality in the period between 2010-2018.

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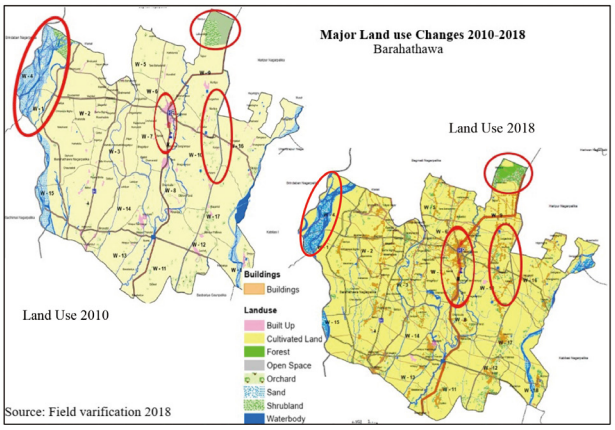

Figure 11. Changed in major land use sites2010-2018

5. Conclusions

Newly declared municipalities like Barahathawa are rapidly growing and becoming a center of attraction for the people living in the surrounding areas. The conversion of agricultural land into the built-up area has been found significantly high in the municipality. Urban expansion has been found in and around the markets, strategic roads, and junctions. Looking at the planning issues, it has to expand haphazardly, and, therefore, proper planning with a long-term development vision is needed to regulate urban growth. One of the best tools to regulate municipality is zoning. The government of Nepal has promulgated the Land use Act [17] and Land use Policy [18], emphasizing the safe and secure settlement along with environmental protection and food security, and has mandated for designation of ten land use zones/classes. The local government needs to focus on the planned urban development of Barahathawa by considering the Land use Act, the existing growth scenario, and local needs. As a newly emerging and rapidly growing municipality, it requires delineating such zones for the long-term development of the municipality. Based on the existing growth pattern and considering the increasing trend of land-use changes which was quite visible during the field visit, growing urbanization and industrialization trend, increasing population, and demand of land for non-agricultural uses, land use zones are needed to be prepared.

Acknowledgment

This article is based on primary and secondary data, which was collected during the process of preparation of the Integrated Urban Development Plan (IUDP) for the Department of Urban Development and Building Construction (DUDBC). Therefore, we would like to thank DUDBC for providing the opportunity. We also thank Bhushan Prakash Bhadari and Raju Chapagai for their field supports and map works.

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ARTICLE

Floodplain Mapping and Risks Assessment of the Orashi River Using Remote Sensing and GIS in the Niger Delta Region, Nigeria

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ABSTRACT

Residents along the shoreline of the Orashi River have yearly been displaced and recorded loss of lives, farmland, and infrastructures. The Government's approach has been the provision of relief materials to the victims instead of implementing adequate control measures. This research employs Shuttle Radar Topographic Mission and Google Earth imagery in developing a 3D floodplain map using ArcGIS software. The result indicates the drainage system in the study area is dendritic with catchment of 79 subbasins and 76 pour point implying the area is floodplain .Incorporating the 3D slope which reveals that> 8 and <8 makes up 1.15% and 98.85% of the study area respectively confirms the area is a floodplain. Aspect indicate west-facing slope are dark blue, 3D hillshade indicate yellow is very low area and the high area is pink and also the buffer analysis result reveals waterbodies reflecting blue with an estimated area of 1.88 km^2, yellow indicate 0.79 km^2 of the shoreline, red indicate 0.81 km^2 of the minor floodplain and pink contain 0.82 km^2 with the length of 32.82 km. The result from google earth image in 2007 indicate absent of settlement, 2013 indicate minimal settlement and 2020 indicate major settlement in the study area when correlated with 3D Floodplain mapping before and during the flood in other to analyze and manage flooding for further purpose and the majority of the area are under seize with flood like in 2020. Therefore, Remote Sensing and GIS techniques are useful for Floodplain mapping, risk analysis for control measures for better flood management.

1. Introduction

Floodplain mapping is a critical land area that constitutes most landform in the Niger Delta region at large. These areas are majorly used for farming and settlement. The need for development and growth within the Niger Delta has also led to the increase of human settlements on river floodplains and low-lying regions effectively blocking drainage pathways [2]. Geographic Information System (GIS) and Remote sensing have also been applied extensively to flood studies [3] as it reflects all kinds of spatial data in the real world. Three sources of primary sorts of flooding are usually associated with the area such as Coastal, Fluvial, and Pluvial flooding but in this case, our main focus is Fluvial Flooding is caused by overflowing of rainwater from the river to the surrounding environment and filling up smaller streams, rivers, and Lakes [5]. The resultant effect is the breakage of dams, dikes and thereafter making the surrounding environments swampy this type of flood can be classified into two. Overbank and Flash flooding. The degree of fluvial

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flooding is resolute by the quantity of rainfall, the absorption capacity of the soil, and the undulation. [1]. Changes in climatic conditions have led to frequent torrential rainfall heightening the risk of flooding. The high rate of human population growth globally; 1.1% per annum [8], and rural migration has led to the inhabitation of areas predisposed to flooding. By its destructive nature, man is seeking ways to mitigate and where possible, avert these associated hazards, giving rise to the need for floodplain mapping and risk analysis. Therefore, the integration of Remote Sensing and GIS techniques on Floodplain mapping and assessment calls for consigning by applying GIS and remote sensing tools to monitor floods.

2. Study Area

The area under investigation is the lower Orsahi River that falls within Ahoada West LGA in Rivers State in Akinima. The area is a rapidly growing urban area in the South-South geopolitical region of Nigeria. The major communities surrounding it are Biseni and Zarama in Bayelsa State and Jorkarima 1,2,3,4, Akinima, Oruama, Mbiama, Ushie, etc The area is accessible by road and river. This zone is located in longitudes 006^0 20'0" and 006^0 40'0" east of the first meridian and latitudes 04^0 50'0" and 05^0 10'0" north of the equator in the coastal zone of Niger Delta (Figure 1). Its topography is generally low-lying with elevations ranging from below sea level in the southwestern flank of the region to about 39 m further inland [2]. The area is drained by tributaries linked to the Orashi River. Various communities in the area are close to hydrocarbon flow stations owned by the SPDC and Agip Oil Company and the Niger delta basin contains a landmass area of about 105,000 km^2 [6]. These structures are facies of the pro-delta Akata Formation. Facies of the Agbada Formation constitutes a paralic delta front. The Benin Formation constitutes a continental delta top facies [7].

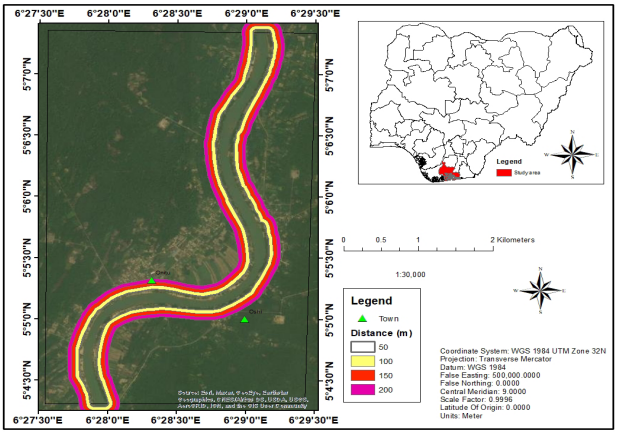

Figure 1. Location map of Orashi River

3. Materials and Method

3.1 Data Acquisition

Shuttle Radar Topography Mission (SRTM) was obtained from United States Geological Survey (USGS) earth explorer [10] while both the High Resolution Google Earth image and the administrative shape file were derived from Google Earth Pro.

3.2 Data Processing

The area of interest was delineated in Google earth, saved as kml file and imported into the ArcGIS software which retains the Projected Coordinate System using WGS UTM Zone N32 which fall within the Niger Delta Region and then converting it to shape file on ArcGIS.

Sub setting of SRTM and Google Earth imagery was done using clipping tools on Arc Toolbox in the following steps: Arc Toolbox → Data Management → Raster → Raster Processing → import Shape file of Area of Interest → import SRTM and Google Earth imagery Create Output Folder → Clip.

3.3 Data Analysis

Multiple Buffer assessment was carried out to outline areas affected by flooding on the floodplain at intervals of 50 m starting from 50 m to 200 m. Spatial Analyst tools were then used to analyze for hydrology and surface, Hydrological tools include Digital Elevation model, Drainage network, Drainage point (pour point), and Catchment. And for Surfaces; Hillshade, Aspect, and slope were evaluated before using the reclassify tool, which is also a spatial analyst tool to classify the digital elevation model into four classes in other to map out floodplain in the region. Furthermore, Arc Scene was used to create a 3D model before the flooding and during the flooding. Incorporating 3D slope and 3D Hillshade, to understand the risk factor of the area such as farming and settlement for floodplain studies. Finally, composite maps were created by overlaying the 3D models with the buffer analysis.

4. Result and Discussion

The understanding of 3D surface in viewing the Earth offers an excellent means of knowing its shape and characteristics, as ridges, peaks or valleys can be seen in greater detail with more information about a place. The following display using a 3D Slope ,3D Hillshade, and Aspect of the surfaces, Drainage network, Drainage point, Catchment, Flood Risk, floodplain mapping and flood mapping during and after the flood including historical google earth

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image in viewing the risk assessment in 2020.

4.1 The Drainage Network, Drainage Point and Catchment

Since drainage network is the area upon which water-falls and the channel through which it travels to an outlet as seen in Figure 2a. The drainage channel within the study area reveals to be dendritic [4]. The catchment in the study area contains 79 subbasins with a total area of 0.22 km^2 and the total area flowing to a given outlet or pour point is 76 in Figure 2b, indicating the area is a floodplain and that during the rainy season water will flow through the pour point, creating a flash flood.

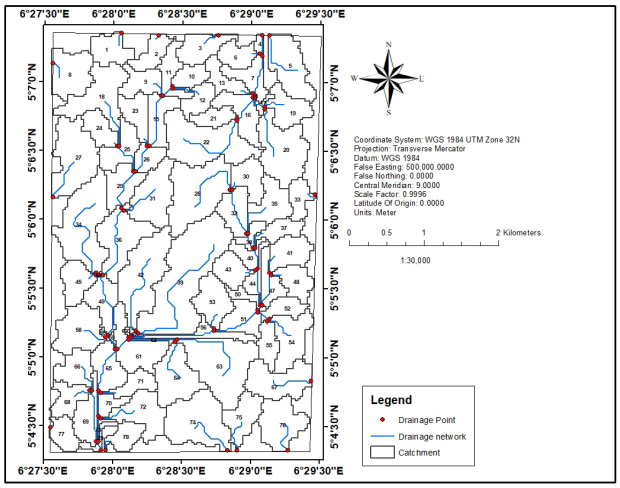

Figure 2a. Drainage network, Drainage point and Catchment Map of the study area

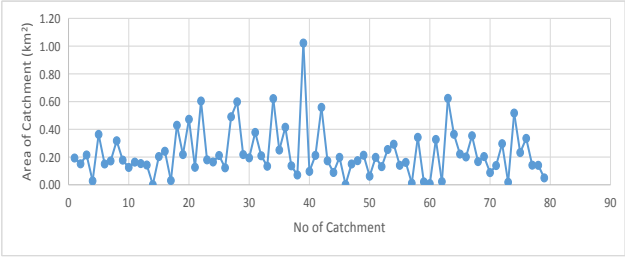

Figure 2b. Chat of area of each catchment against no. of catchment

4.2 The Slope

The following result in Figure 3 shows the slope has darker shades of red indicating steeper slopes with degree greater than 8 has 0.22 km^2 and is the highest in the area in term of slope and the lowest in terms of land area (Table 1) while other ranges from 0 to 2 contain 7.52 km^2 indicate Dark green in the area,2 to 4 has 8.09 km^2 reflecting light green,4 to 6 contain 3.24 km^2 indicate light yellow and 6 to 8 has 0.79 km^2 contain dark yellow and is the second highest slope and second lowest mass land area. In general, the area which slope is >8 contain 1.15% is the high area, and <8 is 98.85% indicating low land area with a low degree of slope.

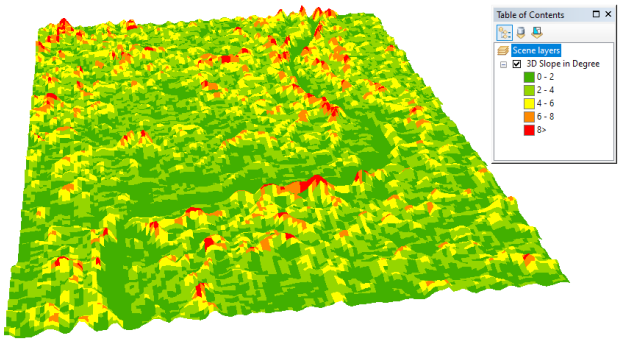

Figure 3. 3D Slope map of the study area

Table 1. Estimated land area of slope in the study area

S/N	Degree (°)	Area (km^2)
1	0-2	7.52
2	2-4	8.09
3	4-6	3.24
4	6-8	0.79
	8>	0.22

4.3 The Aspect

The result in Figure 4 indicates west-facing slopes are dark blue. North facing slope is red and southeast-facing slopes are green etc. with various estimated land area in Table 2. The flat (-1) area in Figure 4 also indicates the Orashi river

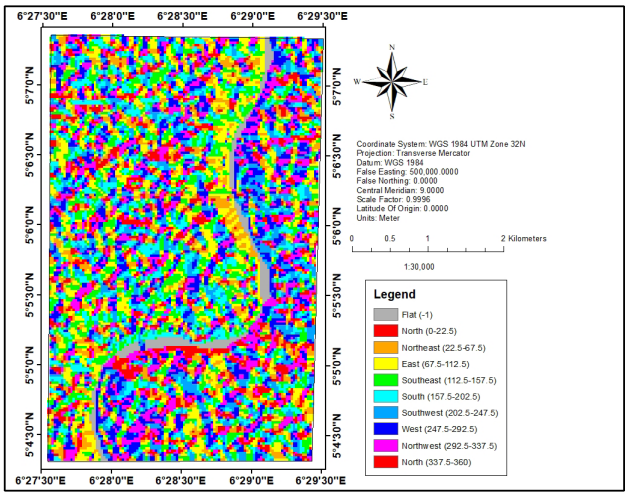

Figure 4. Aspect map of the Study area.

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Table 2. Estimated land area of Aspect in the study area

S/N	Aspect	Area (km^2)
1	Flat(-1)	0.54
2	North (0-22.5)	1.21
3	Northeast (22.5-67.5)	2.06
4	East (67.5-112.5)	2.76
5	Southeast (112.5-157.5)	2.64
6	South (157.5-202.5)	2.33
7	Southeast (202.5-247.5)	2.56
8	West (247.5-292.5)	2.57
9	Northwest (292.5-337.5)	2.44
10	North (337.5-360)	0.95
11		

4.4 The Hillshade

The result in Figure 6 indicates the distribution of light along a surface when illuminated by the light of the sun as defined by a locational bearing expressed in terms of azimuth and vertical angle. Hillshade will increase the perception of depth in a 3D surface for better visualization of the terrain for floodplain mapping and risk analysis of the area i.e. very low area in the terrain are denoted in a yellow, low area in red, and pink for the high areas.

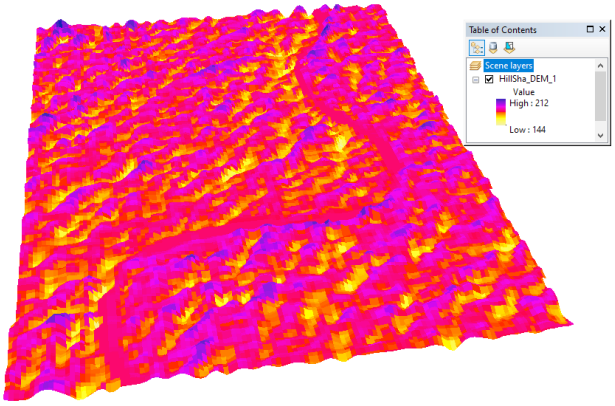

Figure 5. 3D Hillshade map of the Study area

4.5 Buffering Analysis

Buffering analysis used in delineating floodplain area in Orashi River was buffered using multiple buffers with a range of 50 meters to 200 meters away from the river. The result is shown in Figure 6, which reveals that is waterbodies reflecting blue with an estimated area of 1.88 km^2, yellow indicate o.79 km^2 of the shoreline, red indicate 0.81 km^2 of the flood plain, and pink contain 0.82 km^2 with a length of 32.82 km in Table 3

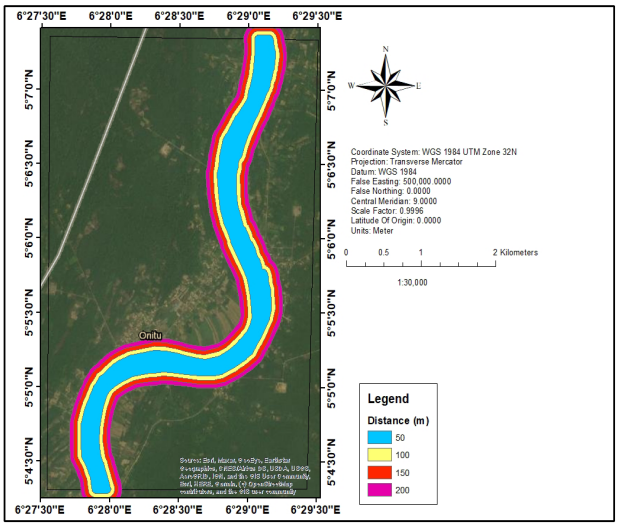

Figure 6. Buffer analysis map of the study area

Table 3. Estimated land area of buffer analysis away from the river in the study area

S/N	Distance Away from river (m)	Area (km^2)	Length (km^2)
1	50	1.88	15.65
2	100	0.79	31.6
3	150	0.81	32.21
4	200	0.82	32.82
Total		4.3	112.28

4.6 Digital Terrain Modeling for Flood Risk Mapping and Terrain Classification

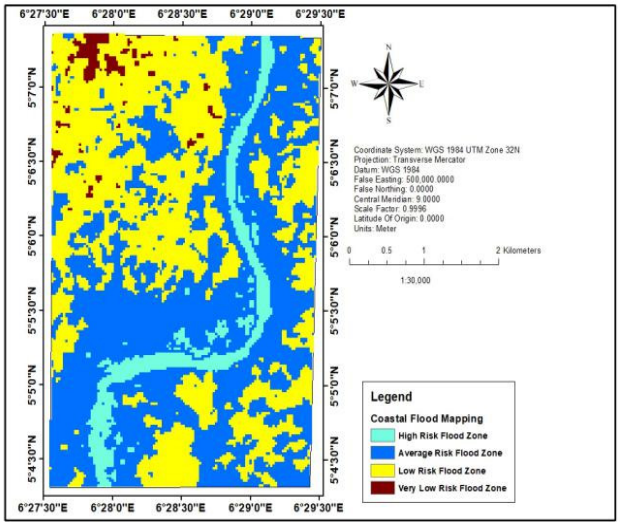

Figure 7a. Flood risk mapping of the study area

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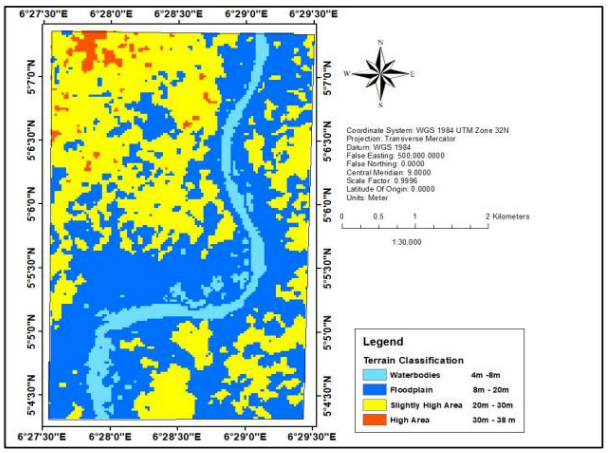

Figure 7b. Terrain classification mapping

Table 4. Estimated land area of flood risk and terrain classification mapping in the study area

S/N	Flood Risk Mapping	Terrain classification mapping	Elevation (m)	Area (km^2)
1	High Risk Flood Zone	Waterbodies	4-8	1.49
2	Average Risk Flood Zone	Floodplain	8-20	9.88
3	Low Risk Flood Zone	Slightly High Area	20-30	8.14
4	Very Low Risk Flood Zone	High Area	30-38	0.35
Total				19.86

From Figure 7a and 7b, it is observed waterbodies indicating high risk flood zone with elevation ranging from 4 m to 8 m with an estimated land area of 1.49 km^2 indicating light blue (Table 4), floodplain contain elevation ranging from 8 m to 20 m indicating average risk flood zone with 9.88 km^2 which constituted the large area, low risk flood zone is map as the slightly high area with 20 m to 30 m indicating yellow with 8.14 km^2 and the high area is map as a very low risk flood zone with elevation ranging from 30 m to 38 m indicate the area is suitable for flood relief center with estimated land area of 0.35 km^2.

4.7 3D Floodplain Mapping and Risks Assessment

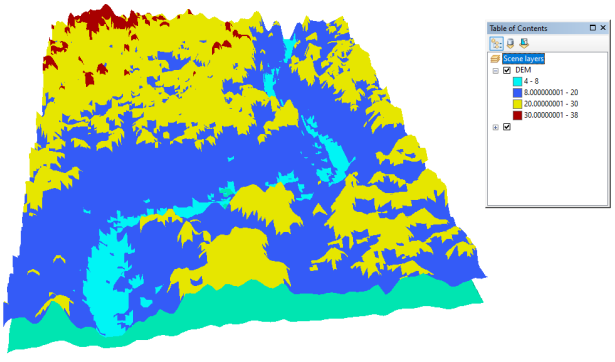

Figure 8a. 3D Floodplain mapping before the flood in 2020

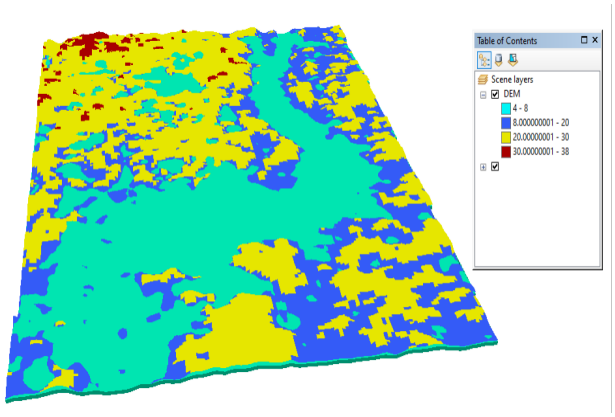

Figure 8b. 3D Floodplain mapping during the flood in 2020

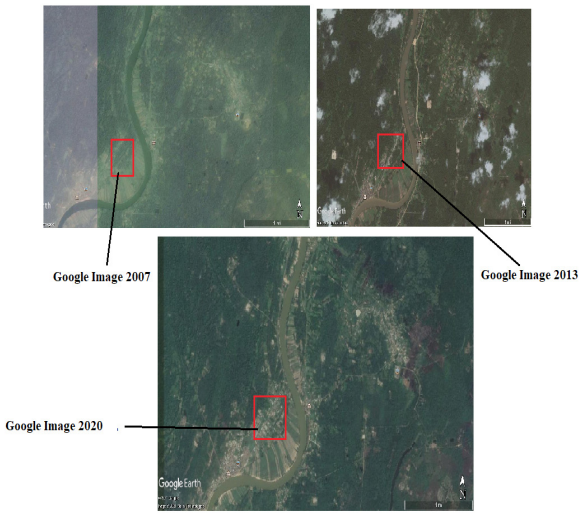

Figure 9. Google Earth historical imagery of 2007, 2013 and 2020

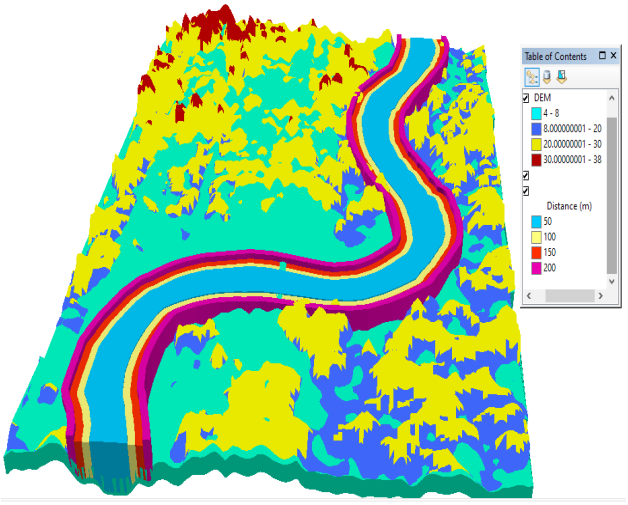

Figure 10. Overlap of buffer analysis on 3D Floodplain mapping during the flood in 2020

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Figure 11. Flood in Akinima Ahaoda West LGA Rivers State [9]

Risk assessment is important in analyzing flooding for proper planning and managing situation to avoid major effect on flooding during flood season in the Niger Delta and other parts of the world in deciding for the building of the structure and site suitability including settlements, farming, road, and railway construction and it is also critical to understand the terrain of the area by carrying out hydrological and surface analysis to investigate the statue of the area, majorly in terms of the drainage system, due to most area in terrain has poor drainage system resulting from lack of planning thereby building structure and road on drainage channels resulting to flooding during the rainy season. From Figure 9 the google earth image in 2007 indicate the absence of settlement in the area, 2013 indicate minimal settlement in the area and 2020 indicate major settlement in the area when correlated with Figure 8a and 8b 3D Floodplain mapping in other to analyze and manage flooding for the further purpose it indicates the majority of the area is under seize with the flood in Figure 8a,8b, also from Figure 10 the overlap of buffer analysis indicate the majority of the area is floodplain from 100 m to 200 m away from the shoreline which can be used for shoreline design for pilling purpose. If the government plan early during 2007 by earmarking on sand filling and piling of the shoreline in the study area they could have minimized the flooding in 2020 and loss of life, properties including farmland resulting in food scarcity in Figure 11. Therefore, the need for government and other agencies to plan and manage for is vital due to flood has come to stay with us but we need to manage our waterways and ensure the people and the government do their part by obeying law and regulation.

5. Conclusions and Recommendation

GIS and remote sensing have proven that using Shuttle Radar Topographic Mission and Google Earth imagery to assess flood risk and map out floodplain is vital for flood management. The result indicates the drainage system in the study area to be dendritic with a catchment of 79 sub-basins and 76 pour points typifying a floodplain. Integrating the 3D slope which highlights that 1.15% of the area is greater than 8^{o} and 98.85% less than 8^{o} also confirms the area is a floodplain. Aspect highlights west-facing slope. In the 3D Hillshade yellow very low area and pink, high areas. The buffer analysis result reveals the waterbodies reflected as blue with an estimated area of 1.88 km^2, the shoreline of 0.79 km^2 as yellow, red indicate 0.81 km^2 of the minor flood plain, and pink contain 0.82 km^2 with a length of 32.82 km. Settlement in the area when correlated with 3D Floodplain mapping before and during the flood in other to analyze and manage flooding for further purpose and the majority of the area are under seize with flood like in 2020. Therefore, the need for government and other agencies to plan and manage flooding is vital due to flood has come to stay with us but we need to manage our waterways by ensuring the people and the government do their part by obeying law and regulation.

The State Government should embark on a massive in-depth floodplain mapping for better flood management. Relocation of people inhabiting the floodplain or immediately sand fills the land. Finally, a floodplain can be used for large scale agricultural purposes such as rice farming.

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ARTICLE

Impact of Land Reclamation on the Vegetal Cover of Bayelsa State, Nigeria

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ABSTRACT

The study examined the impact of land reclamation on vegetal cover in Bayelsa State. For the purpose of this study, both quantitative and qualitative research methods were adopted. Field observations, questionnaire survey and landsat imagery of land cover changes in the year 1986 and 2018 were generated from the global ground cover facility stream. The time series study design and supervised classification of the image processing were adopted to determine the impact of land reclamation on vegetal cover of the study area. It was therefore recommended that recovery of land will make strategic urban planning initiatives sustainable in overcrowded areas and institutions should also put in place laws and strategies to regulate reclamation activities across the region and also geo-spatial skills should be put in place to help quantify the dynamics, trends and rate of reclamation induced land cover change in the environment. Educational institute should inculcate environmental knowledge in the local environment.

1. Introduction

Due to the challenge of finding space in geographically restricted and densely populated areas, Bayelsa State in the Niger Delta have in time past and recently struggled to accommodate development [6]. Technologies of dredging implemented in recent decades have allowed land to be retrieved under favorable capital outflows [7]. Bayelsa State has a great deal to benefit from the more competitive recovery costs in response to pressing urbanization patterns. Recovery of land will make strategic urban planning initiatives sustainable in overcrowded areas in order to satisfy the need for new homes, transport and infrastructure. To 'reclaim land' means to recover the land for a particular purpose and use. Land reclamation can be classified as a process of acquiring land from wetlands coast or sea [9]. In other words, the reconstruction of distressed land into an improved condition may be called land reclamation [10]. Another concept of this could be termed as an additional trait base on the conversion of desert fields into fertile land and rural settlements [1]. Furthermore, different freshwater water sources, such as channels, canals and dams, are being rebuilt. The technologies utilized are the principal distinctions between the several processes for reclamation. For instance, land reclamation in some mainland uses substantially different methods from coastal land reclamation and vice versa [11], however the detrimental effects of extensive land reclamation are stronger from the environmental standpoint than the beneficial effects [12]. Although there's not a single unanimous uniform definition, but the notion of land conservation has been around for decades. The definitions of land reclamation are not just general. The terminology for suggesting these meanings often differs in connection with the region in the country. In addition to the western definition for land reclamation, there is a vast variety of literature

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on coastal development and sea containment from the east of the country. Reclamation in many regions of the world has been an integral part of the urban planning process, including in Nigeria, China, Great Britain, Japan, the Netherlands, Korea and the United States of America [5]. Lagos State has benefited from reclaiming land for infrastructural and industrial development. Banana Island in Lagos, Nigeria is one good example and it was reclaimed from the seashore. We are also faced with Eko Atlantic, a new coastal town on 10 million meters inland on Victoria Island, which is covered by an 8.5 km long. There are still sites in Lagos Island under recycling operations, one being the Dangote oil refinery, and more than half of Lagos Island has been restored. The place is bigger than the Victoria Island. It is 2,135 hectares of land, and dredgers recovered 30 million cubic meters of land in Lagos between November 2016 and 2018. The punch newspaper 11th Oct. 2012 claimed that local residents living nearby blamed Eko Atlantic for persistent building practices that contributed to coastal destruction and ocean surge as ocean waters washed through residential areas that overwhelmed access highways pushed down power poles and forced people to evacuate. The influence of land reclaiming activities on north coasts of Bantam was investigated by [2]. He found that land recovery induces flooding and degradation, decreased seawater content, caused fish and marine biota death. In general, there are environmental, physical and chemical consequences on the remediation and dredging site [8].

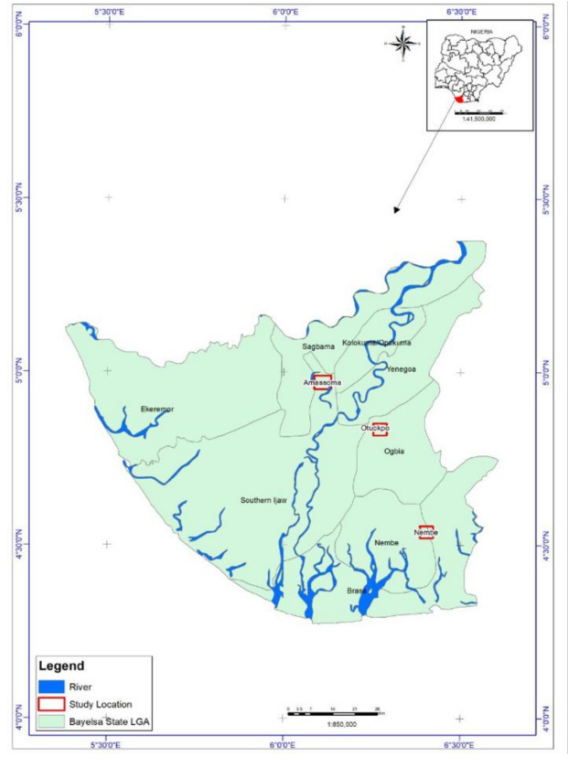

Figure 1. MAP OF BAYELSA STATE

The study area is located in Niger Delta region, Southern Nigeria. The area is located geographically within latitude 4^0 12' 30.892" N and 4^0 50' 10,7" N and longitude 4^0 56' 15' E and 9^0 40' 2.654" E. [4] Described the region of southern Nigeria which is bordered on the south by the Atlantic, East by the Republic of Cameroon and other Federal States of Nigeria which includes Abia State, Edo State, Imo State, Anambra State and Ondo State on the north and west. The Niger Delta encompasses the areas from Benin River to Imo East and covers oil-producing regions in Nigeria. This oil producing area is basically in total deprivations, for example, housing, environmental deterioration and pollution problems. Therefore, encouraging land reclamation with a view to creating more land for urbanization. Thus, such efforts to commensurate land reclamation developments with quality environment and no impact in oil producing regions is most desirable.

2. Methodology

The research design adopted for this study is time – series design of the study sequence as adapted by [3, 13]. Time-series sample design is retrospective and participants do not interact with their subjects/variables by encouraging the researcher to analyse changes in the dependent variable over time. Observations have been performed on individuals over a period of time, often lasting several years, to track trends or improvements in the characteristics of the target population at both the group and individual levels. Time-series analysis is more likely to show the degree of transition and pattern due to its scale. 1986 and 2018 Landsat imagery of land cover changes for the study area, complemented by data from the Federal and State Departments of the Environment respectively. Landsat imagery of land covers change was taken from the U.S. Shuttle radar imagery, National Geospatial-Intelligence Agency (NGA) and multinational ground cover installations owned by the United States (Administration of National Aeronautics and Space, NASA). Several studies/observations of Bayelsa State ecosystems on the subject have been carried out in this study over a period of time spanning years. As a result, the time-series for the study design adopted allowed the researcher to consider the changes that have taken place in these phenomena between 1986 and 2018. It was necessary because the measurement of the phenomenon in question (i.e. the lack of plant cover over the sample field) goes beyond a single moment in time. This is quite fitting as the time-series observation of land cover changes over time made it possible to carry out a proper evaluation of the effect of urbanisa-

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tion on land over time in the research field. In the case of this study, the ground cover picture of the study area was imported into the GIS environment where the data was evaluated to analyze land reclaimed and its impact on vegetal cover.

The sampling technique utilised for this research is the supervised classification of the image processing. This approach helped the researcher to gather data from the sampling region within the imagery in a polygon format and the device using GIS software on the highest chance platform or extension, and has been instructed to recognise features in the imagery that have identical reflections to those sampled using the guidance order method. Features with identical reflections as sampled have been identified and added to the attribute outlined for this phenomenon. After that all functional groups with the same reflection were classified as the same and labelled under the same context. The data were processed and the bands 1, 3, 5 and 7 collapsed in the composite band in the GIS environment, which were processed and categorised using the supervised classification to distinguish the region covered by the vegetation and reclaimed land in the study field, this process was also applied to analyze objective one and two. Under the supervised classification polygons for features have been glued together and labelled to reflect the different features. Polygon was analysed in order to gather data for characteristics groups of identical reflection in the research field using the highest probability analysis.

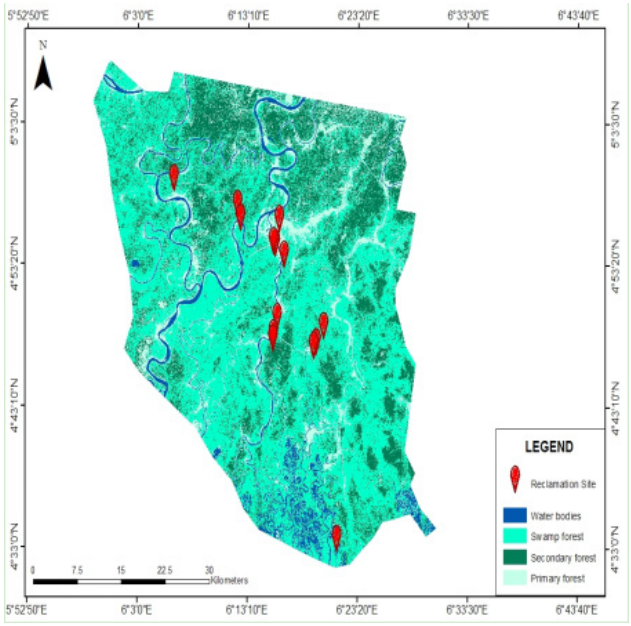

Figure 2. 1986 Landsat Band for Bayelsa

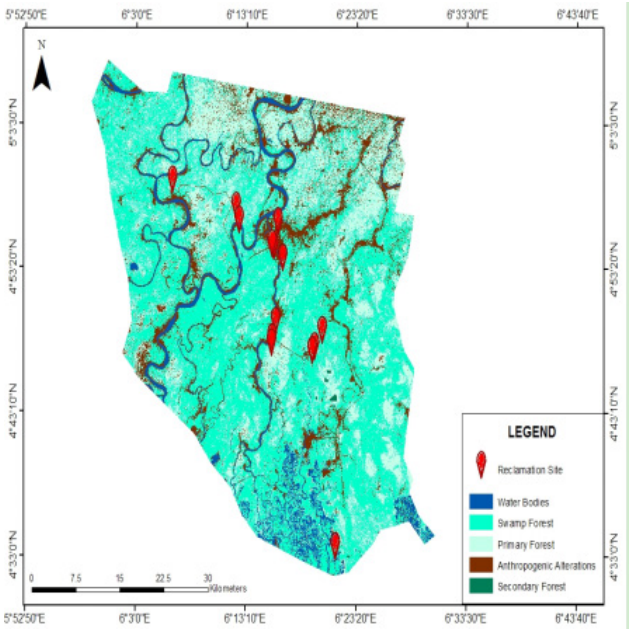

Figure 3. 2018 Landsat Band for Bayelsa

The analysis as shown in Figure 2 revealed that as at 1986 the level of anthropogenic alteration within the study area is not very visible. Swamp forest lies across most parts of the study area while secondary forest occupies the northern part of the study area. As at 2018 the level of anthropogenic alteration represented by the brown color is spatially distributed in the study area with low level of secondary forest cover as shown by the dark green color. Swamp forest lies in the southern part of the study area with pockets of primary forest across the study area.

Table 1. the dimension of different Land cover types in parts of Bayelsa State

Land cover type	1986 area in sq.m	2018 area in sq.m
Swamp Forest	58,734,753	37,691,068
Water Bodies	4,875,915	1,258,626
Primary Forest	5,316,648	39,103,234
New land created	1,876,242	47,436,846
Secondary Forest	80,678,627	25,992,411

Analysis as shown in Table 2 revealed that there is a reduction in the area covered by swamp forest, primary forest, and secondary forest with an increase in area of anthropogenic alterations, and water bodies across the study area. From the analysis it is noticed that there is very little noticeable area affected by anthropogenic activities on the surface coverage of the study area which could be tied to the very little activity in the region before the creation of Bayelsa State.

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Table 2. Extent of land reclamation in Bayelsa State

STATE	EXTENT OF LAND RECLAIMED
Bayelsa	5,816,309sq.m

The total area of reclaimed land in Bayelsa state is 5,816,309 sq. m.

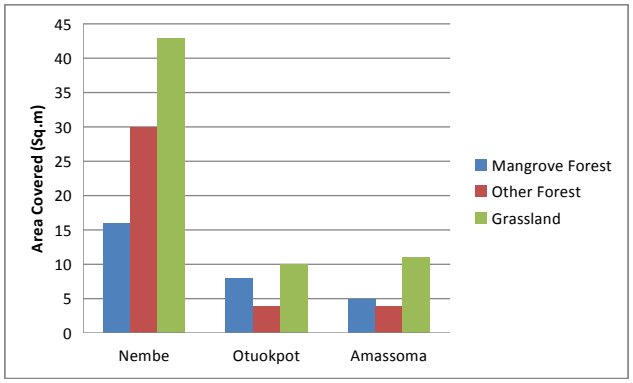

Figure 4. Nature of forest covers before reclamation

Source: Fieldwork, 2018

Before the reclamation was begun Figure 4 demonstrated the nature of the timber cover. The research revealed that mangrove forests and secondary (grazed) forests dominate the entire study region, with Nembe leading in all levels.

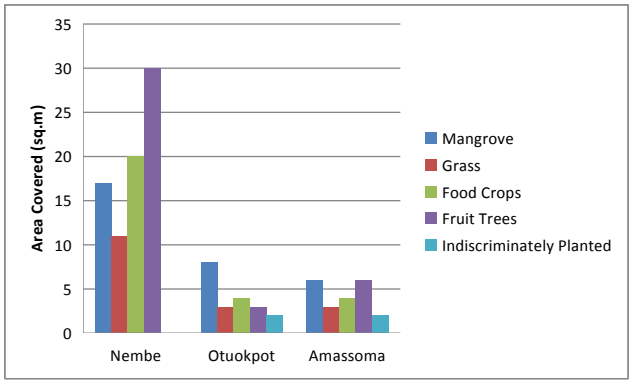

Figure 5. Re-vegetation of surface after reclamation

Source: Fieldwork, 2018

After remedial operation, Figure 5 showed the degree of vegetation in the field of research. The analyses showed that the speed of re-vegetation was sluggish to follow the surface, recovering from the river bed. The study found that people do not even see the growth rate of vegetation across space. The response is thus a win-win because some agreed to while some negated re-vegetation.

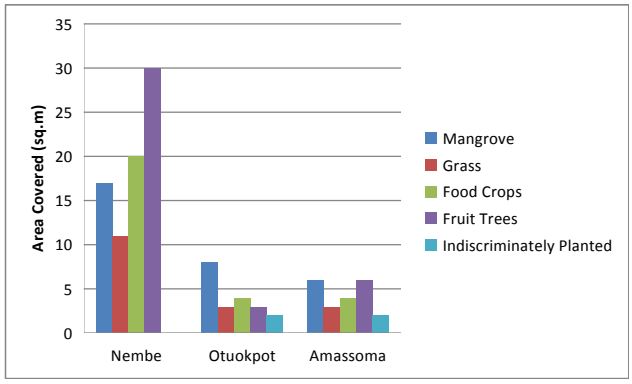

Figure 6. Composition of forest after re-vegetation

Source: Fieldwork, 2018

Figure 6 showed that in most reclaimed sites where re-vegetation is taking place, vegetal covers are indiscriminately growing, making the vegetal cover across space diverse in species and buttressed by the deliberate cultivation of food and fruit crops which resulted in anthropogenic induced greenness across the study area.

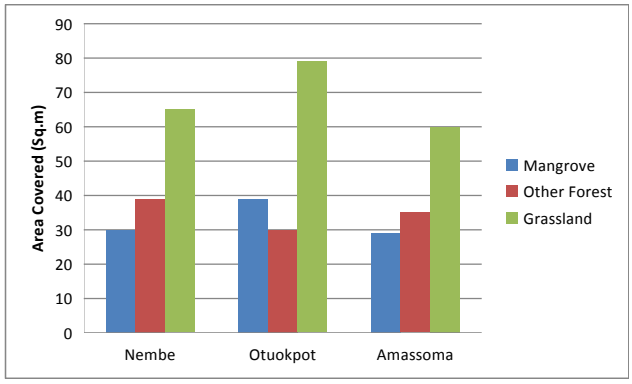

Figure 7. Types of forest resources impacted by reclamation activities in Bayelsa State

Source: Fieldwork, 2018

Until reclamation was started, the respondents' answers to the natural environment suggest that some forest properties were impacted or most affected by the regeneration of the soil.

3. Conclusions

The Niger Delta is the largest in Africa and the third largest in the world, one of the most essential wetlands in Nigeria, and Bayelsa is one of the states in the Niger Delta. As a result of land reclamation in Bayelsa State, green areas were destroyed. Habitat for different species and organisms were impacted on and the organisms were displaced. The study therefore recommends that the institutions such as Bayelsa State ministry of lands, housing and urban development should put in place laws, strategies and geo-spatial capacities to lead and quantify changes in the study area in terms of

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the dynamics, patterns and pace of reclamation. Educational organizations should consider environmental awareness and perception of the environment, part of their duty.

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ARTICLE

Deforestation and Habitat Loss: Human Causes, Consequences and Possible Solutions

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ABSTRACT

Deforestation leads to habitat loss while preservation and conservation of the natural forest increase biological diversity. Multiple factors have been reported to be responsible for deforestation and habitat loss, which could either be of human or natural origin. Natural causes of deforestation could be as a result of forest fires, droughts, exotic animals, floods, overpopulation of foreign animals and climate change. That notwithstanding, human activities are among the principal causes of global deforestation and habitat loss with agricultural expansion, cattle breeding, timber extraction, mining, oil extraction, dam construction and infrastructure development as some examples of these human influences. This study identifies agricultural activities and urbanization as the chief causes of human induced deforestation and habitat loss on a large scale. The simple and more practicable approach to curb the already alarming effects of deforestation and habitat loss is through *environmental education* of everyone still surviving on our planet. Environmental education is the key to reversing continuous and deliberate human actions through the protection of every natural forest and afforestation where necessary.

1. Introduction

Deforestation leads to habitat loss while preservation and conservation of the natural forest increase biological diversity. Through the biological diversity of the natural forest the basis for life on earth and it is a *sure means* of securing the abundance of the earth for people of the future. In essence, by conserving the forest, we do not just guarantee the survival of several other habitats but also the survival of the human environment. In the long run, we can have food security, improved agriculture, recreational pursuits and other derive benefits through different the varieties of life that the forest houses by conserving the different characteristic elements and the biological diversity of the forest [23]. Biological diversity is the assurance we need for healthy living presently and in the future as the entire scope of the uncommonly rich and assorted biological legacy of the tropical areas is presently in danger. The reasons why the issue of deforestation and habitat loss should be seen as global concern and given urgent attention are so many; some of which are the exploding human population, the continuous scientific advancement of new uses for biological diversity and currently the extinction or the gradual disappearance of some rare plants and

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animals. Despite this alarming circumstances, some countries of the world are still destroying the forest in their surroundings, especially the ones with high income. The poor countries of the world have relatively low rates of deforestation because their available income is limited in carrying out large scale exploitation in their environment; and as the incomes of these countries rises, more lands are being deforested for the purposes of development [23].

Mankind in a journey to build up the Earth's surface and change the common environment has annihilated the majority of the world's defensive cover from the outside hurtful gases. This cycle isn't new—it has been continuous for centuries—however it has quickened forcefully in the course of the last two centuries, and particularly over the most recent few years [20]. The forest system of the world has been destroyed, demolished, and felled by cutting tools, until just little pieces of their unique degree endure. Forested areas have been hit particularly hard in a way that the forested areas of the world have been diminished by generally half in the course of recent hundreds of years. Clearing land for farming and development is a significant reason for environment destruction. Within the last 100 years, the measure of land utilized for farming has nearly multiplied [20]. Land utilized for cattle grazing has dramatically increased. Agribusiness alone has cost the United States half of its wetlands and practically the entirety of its tall grass grasslands.

Scholars have concentrated on tropical jungles, for two basic reasons. To start with, despite the fact that these habitats cover just 7% of the Earth's territory surface, they contain the greater percentage of the species in the whole world biota. Secondly, most of the forested areas are will likely vanish inside the following century, taking with them a huge number of animal categories into eradication. Many have assumed that the speed of extinction currently may even be faster than it did in the 1800. How sad will the world be, to observe the passing of the last member of a particular species? With the current rate of deforestation, that possibility is now happening. The forests need protection as well as the lives in it, to promote our own survival on earth. This study focuses on the influences on human actions on our forest; the impact deforestation has on our environment, and the possible solutions to avert deforestation and habitat loss using secondary data such as scholastic publications, newsletters, documentaries and other related articles.

2. Conceptual Clarifications

2.1 Deforestation

Deforestation can be defined comprehensively to incorporate the change or conversion of a natural forest to a non-forest for purposes of agricultural services and development [28]. In a nutshell, we can conclude that deforestation simply means the permanent transition from forest to all other land uses.

About half (47 percent) of Earth's forest front of over 8,000 years have gone into extinction as a result of human action [1]. Despite the above unfortunate incident, above 25 percent of the earth surface is still covered with forest or 3.5 million hectares (ha). 55 percent are situated in developing nations, fundamentally in the tropical world. According to Angelsen [1], from 1980 to 1995, the developing nations lost around 200 million ha (10%) of their forested areas, while developed nations extended their forested areas to around 20 million ha.

2.1.1 Forest Degradation

Forest degradation is a process which negatively affects the structural and functional characteristics of a forest. Forest degradation usually results from human activities, which are greatly influenced by the variety of macroeconomic, demographic, technological, institutional and political factors. The degradation of the forest do not happen suddenly (like an earthquake) but a gradual process, that may take a long period before it is visibly ascertained, implying that the forest degrades over time [27]. The gradual degradation of the forest can also occur due to increased disturbance resulting in loss of forest products or the reduction of forest quality - the thickness and structure of the trees, the biological administrations that provided the biomass of plants and animals, the species variety and the hereditary variety. When the quality of the forest drops, the forest's biotic components may also be affected leading to reduction of the quality of the soil and water, and interactions between the individual components, ultimately affecting forest functioning and diminishing the provision of ecosystem goods and services. Man is solely responsible for forest degradation because of his unsustainable exploitation through excessive harvesting of forest products, overgrazing, wildfires, and the spread of invasive species or pests.

Figure 1. Massive clearing of the forest for developmental purposes.

Source: Derouin [19].

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2.1.2 Forest Fragmentation

Forest fragmentation is the breaking of enormous, adjoining, forested regions into more modest bits of forest; ordinarily these pieces are isolated by streets, farming activities, utility passageways, regions, or other human developmental projects. It ordinarily happens steadily, starting with clearing few portions of the forested lands for temporary or permanent human activity. After some time, those non-forested patches gradually extend into deeper part of the forest and continue to grow until most parts of the forest are affected, leading to the reduction in the quality, function and value of the remaining forest [10].

2.1.3 Afforestation

Afforestation is the transformation from other land uses into forest, or the expansion of the shelter cover over the 10% threshold. Afforestation is the converse of deforestation and incorporates territories that are effectively changed over from other land uses into forest through conscious human effort. For instance, consciously planting trees in an abandoned agricultural field will over time, transform such area to a forest. Afforestation also entails the natural transitions of non-forest areas into forest [10].

2.1.4 Reforestation

Reforestation is the re-enforcement of forest formations especially with a noticeable reduction in the number of individual trees, quality and value of the forest below 10% canopy cover due to the activities of the humans or natural disturbances[25]. According to Tejaswi [25], "*the definition of forest clearly states that forests under regeneration are considered as forests even if the canopy cover is temporarily below 10 per cent*". Thus, reforestation can be said to be planting more trees in places in the forest where the richness of the forest is seen to be depreciating or generally restoring a dying forest.

2.1.5 Forest Improvement

Forest improvement is simply increasing the richness (number of trees) or stocking within a forest to restore the forest to its full or former capacity and increase sustainable usage. Forest improvement can also be defined as the increase of canopy cover and/or stocking of the forest through growth [25]. Generally, forest improvement is the long-term increase of the overall potential supply of benefits from the forest, which incorporates biodiversity and every other product or services [25].

2.2 Habitat Loss

Habitat loss is the process by which a natural habitat becomes incapable of supporting its native species thereby leading to total or partial loss of the richness or biodiversity. Basically, three major types of habitat loss can be identified: habitat destruction, habitat degradation, and habitat fragmentation.

2.2.1 Habitat Destruction

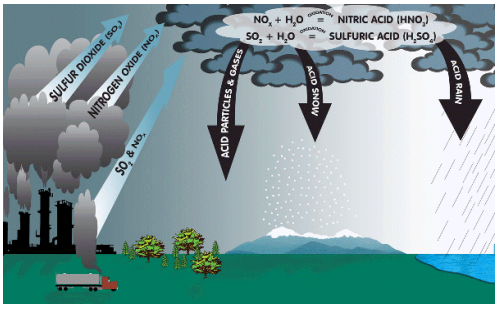
Figure 2. Jungle burned for agriculture in Southern Mexico. Source: Jami Dwyer [29].

Habitat destruction is the cycle in which natural habitat is harmed or wrecked so much that it is no longer capable of supporting the species and biological networks that normally happen there. This scenario brings about the elimination of species and, subsequently, the deficiency of biodiversity [28].

Most habitats are greatly destroyed directly by the numerous human activities, where a large portion land is usually cleared for farming, mining, logging, hydroelectric dams, and developmental structures [10,11]. Very unfortunately, it is reported that humans are currently destroying natural habitats at a rate and spatial extent that exceed the level of at which most species and communities can survive [28]. Aside from the human induced factors, habitat destruction can also be caused by natural circumstances like floods, volcanic eruptions, seismic tremors, and atmosphere variances [28].

Despite the fact that habitat destruction fundamentally causes species eradications, it can likewise open up new living space that may give a climate wherein new species can develop, in this manner exhibiting the versatility of life on Earth [11].

2.2.2 Habitat Degradation



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Habitat degradation is another outcome of human activities. The continual quest of humans to develop the environment has led to habitat degradation. The resultant effects of this human developmental agenda are environmental contamination, climate change, and the introduction of obtrusive species, and general reduction in the quality of the environment, making it hard for local plants and creatures to flourish [28].

Of the factors that are aiding habitat degradation is urbanisation. On the rise, small villages are the turned into towns and cities; leading to an increase in human population and also the demand for land [6]. This scenario will lead to a *bigger reality* where habitat degradation not only affects native species and communities but human populations as well. Human's survival depends on healthy lands, because degraded lands are frequently lost to erosion, desertification, and nutrient depletion [10].

2.2.3 Habitat Fragmentation

Habitat fragmentation is often defined as a process during which a large expanse of habitat is transformed into a number of patches of a smaller total area, separated from each other and different from the original pattern.

Figure 3. Aerial view of sections of rainforest felled for small-scale oil palm in Sumatra, Indonesia. Source: Butler [14].

In simple term, forest fragmentation is the breaking of large, contiguous, forested areas into smaller pieces of forest; typically these pieces are separated by roads, agriculture, utility corridors, subdivisions, or other human development. It usually occurs incrementally, beginning with cleared patches scattered within the area. Over time, those non-forest patches tend to multiply and expand until eventually the forest is reduced to scattered, disconnected forest islands. Fragmentation is caused by both natural and anthropogenic processes in terrestrial and aquatic systems.

3. Causes of Deforestation and Habitat Loss

Multiple factors are responsible for deforestation and habitat loss, which could either be of human or natural origin. Natural causes of deforestation could be as a result of forest fires, droughts, exotic animals, floods, overpopulation of foreign animals and climate change. That notwithstanding, human activities are reported to be among the main causes of global deforestation with agricultural expansion, cattle breeding, timber extraction, mining, oil extraction, dam construction and infrastructure development reported as the primary causes[8]. The focus of this section shall be to identify the core human induced factors of deforestation; thus, agricultural activities and urbanization is drawn out as the main primary human causes.

3.1 Agricultural Activities

According FAO, nearly 80% of global deforestation are said to be caused by expansions in agriculture [28]. Forested lands of more than 50,000 acres are cleared by farmers and loggers everyday worldwide, and the equivalent of over 10,000 football fields are destroyed daily in the Amazon Basin alone [21]. The constant destruction of our forests threatens biodiversity, decreases carbon absorption, magnifies natural disaster damage, and disrupts water cycles.

Agricultural practices especially the type practised in the developing countries increases deforestation and habitat loss [10]. Bush burning is usually employed as a method of clearing natural forest in Nigeria for the purposes of agriculture [28]. Forests are set ablaze to clear space for agriculture, taking vegetation and wildlife with them. This process kills most of the nutrient available in the soil that makes it fertile. Subsequently, with the availability of the poor soil for agriculture, the level of yield depreciate also, leading to more quest to deforest more areas for agriculture to meet up to the needs of the growing population. The bad agricultural practice makes even the available lands barren, leading to reduction in food production and scarcity.

Figure 4. The aftermath of slash - and - burn farming in central Amazonia. Source: Laurence [20].

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Most of the deforested areas are in the rainforests, which are home to over 50 percent of plants and animals on the earth [28]. If humans were to continue to burn and destroy rainforest at the current space, thousands of species will be lost every year, and probably crops like wheat, chocolate, and coffee will disappear and the effects of climate change will likely double [10].

Animal agriculture is also a leading cause of deforestation in our forests today. On a daily basis, large portions of land are being cut or burned to make room for cattle grazing and feed crop production as a result of the global demand for meat. These animals require more space and nourishment, so millions of acres of untouched land are cleared every year to make room for feed crops and grazing pastures. As human population increases and more houses are being built, logging is becoming a top deforestation driver. The constant destruction of our forests threatens biodiversity, decreases carbon absorption, magnifies natural disaster damage, and disrupts water cycle.

3.2 Urbanisation

Usually in cities, people use more unprocessed or processed materials from the forest especially with the availability of more income for their expenditures [8]. Firewood, timbers, and herbs are highly needed in bakeries, construction and pharmaceutical industries. There are always greater demands for animal products and processed foods, which in turn drives the quest for more lands for livestock grazing and cultivation of crops. In most developing countries, the forested areas in the cities are being cleared to give way to developmental projects like the construction of markets, schools, parks, bridges, roads and industries. The governments of the developing countries focus more on developing and modernizing their environment than the preservation of the forest.

Figure 5. Deforestation of the tropical rainforests in Southeast Asia by this timber operation in Indonesian Borneo. Source: Laurance [10].

It is against this backdrop that some researchers have observed that urbanisation do not always lead to positive changes in the environment [6,7,8]. A typical example is the scenario of the city of Port Harcourt in Rivers State of Nigeria, which was popularly known and referred to as a Garden City in the 90s, because of the freshness and cleanliness of the total environment [6]. It was a city of few spaced structures with a lot of gardens, flowers and tall trees in every direction you turn. The then beautiful city was enclosed with beautiful forests in the neighbouring communities like Rumuigbo, Rumuokoro, Orazi and others, that is still evidenced by the single ancestral trees in some of the junctions of these communities today [6].

The once beautiful surrounding forests and vegetation of the city of Port Harcourt have disappeared into the "*so called development*" of the city [7,11,28]. Currently, airborne diseases and air pollution are normal occurrences as black soot has taken over the entire state [16,17,18]. In environmental sense, the city of Port Harcourt was truly developed in the 80s and 90s. However, in term of congestion, population and physical structures; it could be assumed by the citizens that Port Harcourt is now an ungraded city with many developmental structures. Speaking environmentally, urbanisation is one of the contributory factors to deforestation, thus, true development can only come through proper urban planning that encourages planting of trees and proper spacing between structures or buildings to avoid future congestion.

4. Consequences of Deforestation and Habitat Loss

4.1 Loss of Biodiversity

The most pronounced consequence of deforestation is the destruction of biodiversity. The forests house some of the most veritable hubs of biodiversity, covering mammals, birds, insects, amphibians or plants, the forest shelters many rare and fragile species. When humans engage in deforestation, they put the entire ecosystems in danger, creating natural imbalances, and putting their own lives at risk. The forest is a huge *support system* or a *web of connectivity*. For instance, the trees provide shade and colder temperatures for animals and smaller trees or vegetation which may not survive with the heat of direct sunlight. Besides, trees also feeding animals with their fruits while providing them with food and shelter they need to survive.

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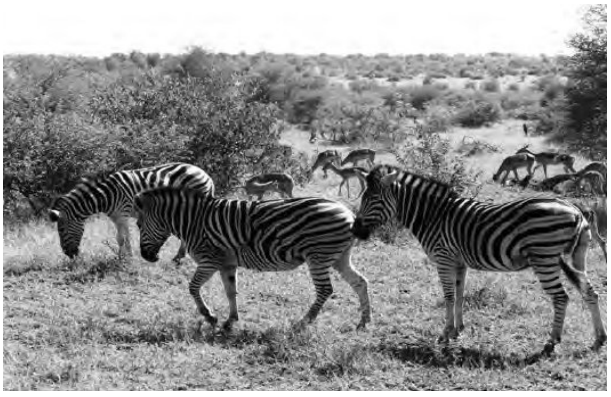

Figure 6. African savannas are threatened by livestock overgrazing and conversion to farmland. Source: Laurance [20].

The ecosystem is a web of dependence for survival. For instance, if a particular species of herbivores were to become extinct, it would affect populations of some carnivorous animals that depended on them for food. Each piece of an ecosystem relies upon other pieces; one species loss can have far-reaching consequences for other species. Deforestation is very disastrous for plants and animals, as many may not survive the effect. Deforestation that is accompanied by bush burning, can wipe out an entire species.

4.2 Soil Erosion

Deforestation usually reduces the quality of the soil. The soil in the forest is very rich in organic matter and also very resistant to erosion, bad weather, and extreme weather events. On the other hand, deforestation simply exposes the soil making it increasingly fragile, leaving it more vulnerable to natural disasters such as landslides and floods. Deforestation will also pose a serious erosion problem to the environment. These eroded soils can lead to disastrous mudslides. Large amounts of soil can wash into local streams and rivers, clogging waterways and causing damage to hydroelectric structures and irrigation infrastructure. In certain areas, soil erosion issues caused by deforestation lead to farming problems and loss of reliable electric power [15].

The truth is that, deforestation causes the soil erodes and washes away, causing farmers to keep moving to another land by deforesting more areas in quest of searching for a fertile land for agriculture. When a soil is eroded, it leaves the land barren and more susceptible to flooding, specifically in coastal regions.

4.3 Climate Change

Deforestation is a big contributor to climate change. Trees, on a daily basis specialises in trapping and absorbing excess carbon dioxide (CO_2) from the atmosphere which could have been harmful to man. The fact remains that when we cut down trees, we are releasing the already trapped CO_2 back into the atmosphere. Very unfortunately, these trees are cut down for the purposes of agriculture; as records show that *food and agriculture* account for 24% of greenhouse gas emissions, while deforestation is estimated to be responsible for 10-15% of all anthropogenic CO_2 emissions [15].

Global climate changes are as a result of greenhouse gases such as methane and carbon dioxide are gases that trap heat in Earth's atmosphere. Trees provide human with what they need most to survive which through the release of oxygen and water into the atmosphere, aside from eliminating the excess carbon dioxide through absorption. Global climate change can alter survival of wild animals, plants and humans through drastic weather changes and increased possibilities of natural disasters. Every year deforestation is contributing to the excess greenhouse gases in the atmosphere, leading to several habitat loss on earth because of the continuous cutting down of trees that acted as valuable carbon sinks [28].

4.4 Water Cycle Disruption

The trees also aid in the distribution of water on the earth. Water from Earth's oceans as well as from the surface of trees evaporates and condenses into clouds. Trees extract water from under the ground and release the same water into the atmosphere through a process called *photosynthesis*. Subsequently, this water in the atmosphere forms clouds that produce rain, which falls back on the earth forming run-offs on the surface, with some percolating downwards to produce groundwater and eventually ocean water again.

Deforestation simply implies that there will be no tree to extract, store and release into the atmosphere. This means that cleared forests, which once had moist, fertile soil and plenty of rain become barren and dry [15]. Unfortunately, when this natural sequence of water cycle is altered, it leads to what is desertification in the deforested area due to the change in climate. The trees help in controlling the level of water in the atmosphere through the regulation of the water cycle. When the natural forest is cleared, there is usually less water in the air to be returned to the soil. This causes the causes the soil to become dryer, reducing the ability of the crops to grow.

4.5 Environmental Refugees

The long term effects of deforestation are *environmen-*

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tal deterioration. People live around forested areas and depend on the forest resources for their survival. Deforestation of such forest can have adverse consequence on the people living around the forest. Most often people may be forced to migrate leaving them as "*environmental refugees*"—people who are forced to move away from their ancestral homes due to environmental degradation, which could be deforestation, sea-level rise, expanding deserts, and drastic changes in weather [3,7,12,14]. It has been reported that in recent time, people are more displaced by environmental disasters than by war [8].

4.6 Outbreak of New Diseases

The invasion of the forest by human for food or for games has led to the emergence of tropical diseases and outbreaks of new diseases, including deadly hemorrhagic fevers like ebola and lassa fever, which are consequences of deforestation [14,17]. These exploiters, who are pushing deeper into the thick forest, usually encounter dangerous microorganisms that they can transmit to those outside the forest on their return. Unfortunately, this bad practise of forest invasion and destruction could lead to a massive epidemic that could kill many innocents on our planet [14].

A scientific report reveals that land alterations especially the invasion of thick forests, brings humans in contact with pathogens (such as malaria and snailborne schistosomiasis). Most of these invasions are mainly for the purposes of development, leaving behind breeding grounds for mosquitoes because of the proliferation of artificial pools of water like dams, rice paddies, drainage ditches, irrigation canals, and puddles created by tractor treads [14, 17]. Malaria has become a common problem in deforested and degraded areas, and far less is experienced in the forested zones [14].

4.7 Destruction of Renewable Resources

Valuable renewable resources are destroyed yearly through deforestation leaving behind barren lands. The forests are the source of renewable resources that can significantly contribute to the economic growth of a country on a continuing basis.

When practised properly, logging can be a sustainable activity, generating huge source of revenue without diminishing the resource base. According to World Bank, an estimate of about US$5 billion in revenues is being lost annually as a result of illegal logging. Ecotourism of a nation also suffers from deforestation as no tourists, will want to travel in order to see polluted rivers, stumps of former forests, barren wasteland, animal carcasses, and abandoned settlement of former inhibiters [28].

4.8 Human-Wildlife Conflict

Most animals are forced out their natural habitat by hunters and other forest invaders. In the quest to escape from their hunters or in search for safer accommodation, some of these animals move into areas populated by humans which often resulted into fatal encounters with wild animals like tigers, lions and venomous snakes.

When the conflict between humans and forest animals is beyond bearable limits, many farmers simply kill the offending animals.

5. Environmental Education as the Solution to the Problem of Deforestation And Habitat Loss

Environmental Education is a process of learning that increases people's knowledge and awareness about their immediate environment and the challenges within. It helps in identifying environmental problems, developing the necessary skills and expertise. Environmental Education equip individuals with the ability to address their challenges, foster attitudes, build the necessary motivations, and commitment to make informed decisions and take responsible action that will benefit them and their future generation. The whole essence of environmental education is to bring the citizens to full knowledge of their environment, creating abilities that help them solve or mediate current environmental problems and avert new ones.

5.1 Basic of Goals of Environmental Education

Environmental Education enhances the acquisition of knowledge, skills, desirable attitude by an individual, towards a better interaction with the natural world (Igbinokpogie, 1990). According to Sola [24], the objectives listed in UNESCO-UNEP [26] for environmental education are as follows:

a. Awareness

In most situations, people lack knowledge of the happenings in their environment and the possible problems they might encounter in the process of interaction with their immediate surroundings. This is where environmental education comes in to sensitize the public by creating awareness about the total environment and its associated problems. Environmental education in this sense, help people have a clear understanding of the environmental problems being faced and possible alternatives to take.

b. Knowledge

Most times, awareness of the problem may not be enough in combating the possible consequences; having deep knowledge of the occurrence in the environment is the key to resolving any possible challenges. Knowledge

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of the environment and its associated problems can also come from cumulative one's experiences or through activism.

c. Attitude

Man's reaction to the environment reveals his understanding of the environment. Environmental education helps in the acquisition of social values, strong feeling of concern and the needed motivation that builds in us an attitude that encourages the protection and improvement.

d. Skills

Environmental education helps in the acquisition of the necessary skills needed in identifying and solving environmental problems and also help individual seek a balance between short and long range implications when taking environmental decisions.

e. Participation

When the aim of environmental education is achieved, participation of the citizens in identifying and solving their environmental challenges is usually expected. Environmental education uses participatory objective to ensure that everyone is carried along in the process of solving environmental problems.

Understanding our ecosystem and its beneficial function helps in the conservation and preservation of the environment. Most human influenced destruction of the environment is carried out in gross ignorance of the consequences of such actions [2,3]. A clear example is the people of the Niger Delta people in Nigeria who lived happily for several decades with the consequences of petroleum pollution until environmental activism and education exposes to them the dangers they are living in, and the calamities that awaits their future generation if they continue to stay in a polluted environment or permit petroleum pollution and gas flaring in their communities [2]. It was environmental education of the people of Ogoniland that lead to the stoppage of the operation of Shell Petroleum Development Company of Nigeria (SPDC) and the invitation of United Nations Environmental Programme (UNEP) to do the assessment of the environmental damage, and subsequently recommendation for a comprehensive cleanup of impacted areas in Ogoniland by the Nigerian government and SPDC [7,12].

Most unfortunately, petroleum pollution of the environment can be done deliberately because of the financial gains accruing to the state and the exploration companies [7,12,13]. This same practise is being carried out during deforestation where the governments of these defaulting countries who are the custodians of the laws of the environment, are the ones leading the mission of *eliminating the forests*. Environmental campaigns and activism on forestry protection and conservation in every country of the world will definitely go a long way to safeguarding the diminishing and already disappearing species in the forests, and also help to maintain balance in nature. Environmental education is therefore a useful tool in curbing human excesses in the environment through proper awareness and sensitization.

6. Conclusions

Deforestation and habitat loss is not about losing a few plants and animals, but also the survival of man hangs on it (Butler, 2019). Deforestation aids the mechanism of altering the already endangered planet earth; making it dangerous for plants and animals to survive it. The quest for more lands for agricultural activities and human expansions is further reducing the forested areas on the surface on the earth. Environmental education is the key to reversing continuous and deliberate human action through the protection of every natural forest and afforestation where necessary.

6.1 Research Prospects

Deforestation problem cannot be exhausted by a single article; thus every research in this area has prospected. For instance, deforestation and habitat loss in this study is viewed to be the consequences of negative human actions. Some other schools of thought have asserted that deforestation is actually a profitable activity, that is, socially, economically and even environmental wise. The questions that may need answers are:

1. Can human-induced deforestation be said to be beneficial in all sense?

2. Can the current rate of deforestation ever reduce or will it continue to increase with advancement of technology?

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ARTICLE

Mapping Seasonal Variation in the Distribution and Concentration of Heavy Metals Using Water Quality Index and Geographic Information System Based Applications

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ABSTRACT

Incessant monitoring of water is essential in terms of heavy metals and toxic substances as it provides detailed information on aquatic resources. Majority of lagoons receive freshwater from their catchment areas containing industrial and domestic waste. The paper analysed seasonal variations in the distribution and concentrations of Lead (Pb), Copper (Cu), Cadmium (Cd), and Manganese (Mn) in the Fosu lagoon in Ghana to ascertain the quality of the lagoon. Water was sampled from eighteen (18) different points on the lagoon and was analysed at the Water Research Institute (WRI) of the Center for Scientific and Industrial Research (CSIR) using Atomic Absorption Spectrometry (AAS) and the results were interpolated using kriging. The results obtained were compared with the World Health Organisation water quality index. Statistical analysis of heavy metal concentrations using Pearson's two-tailed significance correlation showed positive correlations for both seasons; between Pb and Cu (0.297; sig. = 0.232, and 0.196; sig. = 0.436), and Cd and Mn (0.119; sig. = 0.643 and 0.191; sig. = 0.447) for the wet and dry seasons respectively. A paired sample t-test on concentrations also showed statistical differences between wet and dry seasons' concentrations for Pb (t = 1.324; sig. = 0.203), Cu (t = 2.759; sig. = 0.013), and Cd (t = 3.056; sig. = 0.007), and Mn (t = -4.014; sig. = 0.001). Pb and Cd showed higher concentrations above the World Health Organisation's permissible limits. Heavy metal concentrations of water samples analysed varied widely in terms of seasons and sampling points.

1. Introduction

Coastal lagoons are critically valuable habitats. They are home to a variety of endangered species and are extremely competitive [37]. They serve as breeding grounds for marine fish and invertebrates, and as a resting place for many migratory bird species. Residents have long exploited coastal lagoons for their natural resources, particularly for fishing and aquaculture; coastal populations are depen-

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dent on lagoons for subsistence and small-scale economic enterprise [7]. More than 70% of Ghana's population live along the coastal strip with maximum population densities occurring at the coast [7]. Although coastal lagoons play important roles, they are unambiguously delicate because they are naturally rich, spatio-temporarily disturbed, and susceptible to human and natural stresses [5]. To ensure stability and resilience, these ecosystems need to be protected. Many anthropogenic activities in third world nations, especially in Sub-Saharan Africa (SSA), have prompted environmental issues and strategic monitoring [3]. According to [16], due to their potential long-term implications for public health in both developed and developing countries, there is substantial environmental concern regarding the presence of heavy metals in water sediments and other environmental media.

Quality of water is one of the main concerns of the many, which is directly linked to human health and welfare [27,29,26]. Heavy metals are classified as compounds with a specific magnitude that is at least five times the prescribed gravity of water. Heavy metals are not eco-friendly and thus at some rates of introduction, they are toxic to plants, marine life and human health [20]. [10] is of the view that heavy metal concentrations may rise to a toxic level that has the potential to hamper human health. Water contaminated with heavy metals, anion and cations such as Cd, Pb, Cr, As, Hg, Ni, Zn, So42C, No3¡, No2¡, Cl¡, F¡, Ca2 C, NaC, Mg2 C, and KC can have harmful effects on human health due to excessive intake of contaminated water by human beings [26]. The continuous discharge of manufacturing and built-up wastewater into the Fosu Lagoon is a potential supply of contaminants in the lagoon. The Fosu lagoon is known as the third most polluted lagoon in Ghana, [9]. Because of the contaminated state of the lagoon, UNEP classified the lagoon with the designation "Dead Zones," which defines lagoons where pollution threatens fish and other aquatic life and the health of people who rely on it for their livelihood [34]. Again, it is on record that most of the research works on the Fosu Lagoon that focus on the quality of water considered the presence of heavy metals in only sediment samples of the lagoon [23,10]. These emphasize the need for thorough heavy metal analysis of the Fosu lagoon, taking cognisance of the water sample and how they are distributed across time and space. Despite [35] presents an assessment of the state of the coastal and marine waters of the West and Central African Regions from the Atlantic Ocean to the Sahara Desert, spanning across from the shores of Lake Chad to Senegal, this study bridges the gap in literature as it susses and addresses two of the principal constraints identified by [35]. As such, the study provides detailed scientific data on four heavy metals and provides a quantitative and statistical assessment of their concentrations as well as their sources to the Fosu Lagoon.

According to [6], there are several factors responsible for the prevalence of heavy metals in the environment; in their Northern Ghana report, [6] reported that mining even at a smaller scale was the amplified source of heavy metals. More to that, through principal component analysis, their findings revealed that heavy metals such as Hg came from other sources (maybe anthropogenic) compared to other heavy metals like Zn, Pb, Cd, and As in both mining regions. In their study, higher heavy metal concentrations were recorded in rainy season for both water and sediment than in dry season, except for Pb and Cd, which had higher sediment concentrations in the dry season. Also, [31] in their research, which detected concentrations of heavy metals in water and sediments from the El Guájaro Reservoir, it was found that Pb and Hg were not detected in the surface waters of El Guájaro reservoir during the dry season, nor was zinc detected during the wet season; however, the highest concentrations of heavy metals were observed during the wet season. [31] and [22] avers that the concentration of heavy metals varies with seasons. These studies suggest that heavy metals are high in the rainy season, although smaller concentrations were reported in the dry season with a few exceptions. [18] and [22] suggest that more rainfall mineralization helps to understand why heavy metals are strong in the wet season and vice versa. [38] supports this view in their research on the supply of heavy metals in soil, sediments and fish from the Damodar river basin in the Steel City. They concluded therefore that heavy metal concentrations in all the physical and chemical parameters analysed were high in the pre-monsoon period compared to post-monsoon. Spatially, the river's source was uncontaminated with the metals studied in the two seasons except for Hg, As, and Cd which has extensively contaminated the midstream and downstream ends of the river [22]. These findings point out that heavy metals are widely found in the midstream and downstream of heavy metal-polluted rivers. [12] recorded industrial activities as the main causal factor-affecting heavy metals spatial disparities. [15] also reported the distribution and concentration of heavy metals in their study. They found that Cd, Ag, and Cr have considerably elevated in oysters from the Pearl River Estuary of China in the western part, and Cu, Zn, and Ni in the easternmost section during 2011–2018. Trace metals are concentrated in industrial and downwind bloom areas in the surface sediments [42]. The above references reveal the high concentration of some heavy metals and their spatial distribution and concentrations in the environment. This paper, therefore,

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analyses the seasonal variation in the distribution and concentrations of Lead (Pb), Copper (Cu), Cadmium (Cd), and Manganese (Mn) in the Fosu Lagoon. It also evaluates the spatial distribution of heavy metals in the collected samples. As indicated above, it is very important to examine and analyse the lagoon to determine the distribution and levels of heavy metals' accumulation in it. Lead (Pb), Copper (Cu), Cadmium (Cd), and Manganese (Mn) were considered in this study because of the presence of potential sources of these heavy metals in proximity to the lagoon and these are established in literature. According to the [32], leaded gasoline has been a major historic source of Lead contamination, and Loranger et al. (1994) found manganese concentrations to be significantly correlated with traffic density. According to them, areas of intermediate and high traffic densities had Manganese concentrations above the natural background level of 40 ng/m^3 [14,13]. The garages and the roads close to the lagoon pose as potential sources of Lead (Pb) and Manganese (Mn). [11] adds that Cadmium accumulates in aquatic organisms such as shellfish and crustaceans and in the liver and kidneys of mammals. [40] expresses that levels of copper in running or fully flushed water tend to be low, whereas those of standing or partially flushed water samples are more variable and can be substantially higher. The study considered Cadmium for its potential accumulation in aquatic life in the lagoon, and Copper for the state of the lagoon as a standing water body that seasonally interact with the Atlantic Ocean. The paper will contribute to understanding the mechanisms that regulate heavy metals' spatial differentiation from a global perspective.

2. Materials and Methods

2.1 Site Description

Ghana's coastal zone which is 540 km^2 has been categorised into three based on [10,1,4] reflecting their geomorphological distinctiveness. They are situated on the East, Central and West coasts of Ghana. The east coast, approximately 149 km west of Prampram, stretches from Aflao (Togo Border) in the east to Laloi Lagoon in the west. The central coast stretches from the Prampram area to the Ankobra River, while the western coast stretches from Ankobra River to Elubo, the Ghana-Ivory Coast border. The current study took place in the central coastal plains of Ghana where the Fosu lagoon was studied. The Fosu Lagoon is situated in Cape Coast, the Central Region's capital city, Ghana. The geographical coordinates of the lagoon are 5°6'8.98"N, 1°15'8.58"W; 5°6'38.71"N, 1°15'49.11"W; 5°6'21.81"N, 1°15'45.34"W; and 5° 6'33.60"N, 1°15'24.98"W, as shown in Figure 1. The lagoon is a small, closed lagoon isolated from the sea by a barrier that is normally breached by heavy rain or manually as part of the typical Fetu festival activities witnessed by the people of Cape Coast [4]. The average water depth of the lagoon is 1.6 metres. The region receives two wet seasons in a year, the major one from April to July and a minor season from September to November. Cape Coast is a humid area with mean monthly relative humidity varying between 85% and 99%. The sea breeze has a moderating effect on the local climate.The lagoon is surrounded by numerous sites that serve as point sources for contaminant emission. Domestic waste discharges from a highly polluted area, a metropolis transport garage on the lagoon's northern side, and an industrial waste discharge from mechanical workshops on the lagoon's north eastern side are all included. The lagoon's surroundings include drains from an educational institution and a nearby hospital, as well as household dumping and sewage. Human activity in the study area is extensive, and nutrient enrichment has resulted in massive sediment deposition, particularly in the more populated northern sector, where one can walk for many meters on waterweeds as the lagoon has been metamorphosed into refuse and swamp land. The geological composition of the coastal zone is composed of strong granites, granodiorites, metamorphosed lava and pyroclastic rocks. Sandstones dominate sections of these coastal areas and shales from Ordovician, Silurian, and Devonian times [4]. The hilly nature of the place has greatly affected building and road construction. It also promotes erosion, especially along slopes, and sedimentation/siltation and flooding at low-lying areas. It is bounded by the sea to the south and surrounded by different vegetation cover. The land cover in the Fosu lagoon catchment is dominated by introduced vegetation with little remnant areas of mangrove vegetation. It is found in the dry semi-deciduous.

Figure 1. Map showing study areas in a regional and national context

Source: Department of Geography and Regional Planning, UCC, (2019)

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2.2 Sampling Procedure

The Fosu lagoon was sampled for the study for various authors including [33] have reported pollution and contamination in the lagoon. Water samples from the lagoon were obtained at various points between May and September, and January and March. Eighteen (18) samples of water were collected during each of the seasons. In all thirty-six (36) sampling points were analysed for respective heavy metal concentrations. In Ghana, these periods are regarded as wet and dry seasons respectively. The sampling points are shown in Figure 2. Sampling sites were carefully selected to optimally and evenly cover all drains emptying into the lagoon. Location of entry channels and water sampling sites were also mapped directly from field surveys. A Global Positioning Systems (GPS) receiver, Trimble Juno SD hand-held was used for the mapping activity. The lagoon was demarcated into three sections as upstream, midstream and downstream to conform to the structure and morphology of the lagoon. The upstream consisted of the upper reaches of the lagoon, where the Siwdu sports stadium and garage area, the entry points of the various drains, and the social and economic activities around the lagoon are found. The midstream is around where the Bakano community is located, with their sewage and gutters directed into the lagoon, while the downstream is where the sand bar that ensures the intermittent mixing of the lagoon, and the main bridge that connects the Cape Coast township and enjoining communities are located.

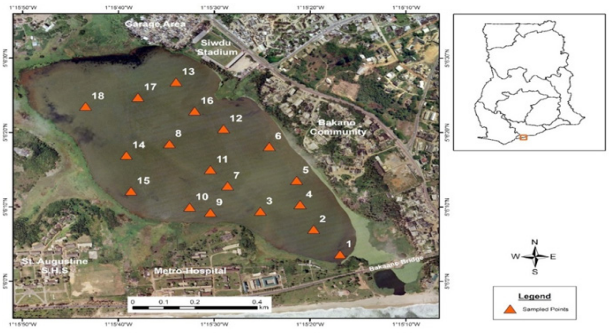

Figure 2. Sampling points of heavy metals

Source: Field Data, (2018 and 2019)

2.3 Sample Collection

Polyethene gloves were used on the hand to obtain water samples from the lagoons. High-density polypropylene bottles were rinsed with lagoon water three times at each sampling point before the water sample was collected. The rinsed bottles were submerged about 8 cm beneath the water surface [10]. Water samples collected were stored capped in the high-density polypropylene bottles and soaked with 10% nitric acid [25,24]. Until being shipped for examination at the laboratory, the obtained water samples were acidified.

2.4 Sample Preparation and Analysis

Analyst 400 Perkin-Elmer Atomic Absorption Spectrophotometer (AAS) was employed in evaluating the heavy metal constituents and concentrations. The water sample was first filtered with Whatman No. 0.45 filter paper, after which 50 ml of the filtrate was acidified with 50% nitric acid to give a pH of 1. The AAS was calibrated with regular solutions and de-ionized with water before calculating the absorption of sampled traces. The collected water samples were analysed at Center for Scientific and Industrial Research (CSIR) of the Water Research Institute (WRI) in Accra, Ghana, for interpretation and study, to establish the heavy metal content in the samples, following the procedures given by [10].

The concentrations of heavy metals were mapped using ArcGIS 10.1 to provide a spatial view of the data from samples from the lagoon. Ordinary kriging was adopted to interpolate and map the values derived for the heavy metal concentrations for the various sampling points. Ordinary kriging was adopted for this study as it has been justified by [41]; according to them, ordinary kriging is more accurate than other methods, with smaller mean relative error (MRE) which is known to be a good variable for estimating the accuracy of predictions. Kriging is based on the assumption that the parameter being interpolated can be treated as a regionalized variable. The kriging estimator is given by a linear combination of the observed values with weights [41]. The weight of ordinary kriging is derived from the kriging equation using a semi variance function. The parameters of the semi variance function and the nugget effect can be estimated by an empirical semi variance function [39]. An unbiased estimator of the semi variance function is half the average squared difference between paired data values:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2$$

where γ (h) is the semi variance value at distance interval h; and N(h) is the number of sample pairs within the distance interval h; $z(x_i + h)$ and $z(x_i)$ are sample values at two points separated by the distance interval h.

2.5 Quality Control and Assurance

Sampling procedures were strictly followed to reduce

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mistakes, avoid contamination of samples and ensure the accuracy of tests. Again, laboratory regulations such as proper cleaning of equipment, and equipment calibration were observed to ensure the results were scientifically applicable. Standard reference materials (SRMs) used were regarded as samples themselves for measuring the performance of the equipment used and further validating the procedure.

2.6 Water Quality Index

The heavy metal concentrations of the water samples were compared to the WHO water quality index shown in the Table 1. The Water Quality Index is known to be the most effective tool for assessing water quality. The index offers a standardized variable that calculates the average water quality at a certain place and time, depending on a variety of water quality parameters. The index makes it possible to compare the different extraction positions.

Table 1. WHO Water Quality Index

Heavy metal	WHO Water Quality Index (mg/L)	
	≤	>
Lead	0.01	0.01
Manganese	0.4	0.4
Copper	2	2
Cadmium	0.003	0.003

Source: UNEP (2006)

2.7 Statistical Analysis

Heavy metal concentrations report from the Atomic Absorption Spectrophotometer (AAS) was coded into Statistical Package for Social Science (SPSS) V. 20. Descriptive statistics were run and the mean heavy metal concentrations, with their standard deviations, were established. Pegging confidence level at 0.95 (95%), Pearson's two-tailed significance correlation was run on the concentrations for the seasons. Finally, a paired sample t-test was run to establish the differences in seasons' concentrations of heavy metals. The results are presented in tables.

3. Results and Discussion

3.1 Concentrations of Heavy Metals and Implications

Lead (Pb)

The results indicated a minimum Pb concentration of 1.3 mg/L and 1.7 mg/L and a maximum of 2.6 mg/L and 3.2 mg/L for the wet and dry seasons respectively. These are high above the WHO standard for drinking water and the result is shown in Figure 3 and 4. The concentration of Pb found in the current study is higher when also compared with the findings of [22], who found that Pb concentrations in the Tano River ranged from below detection limits (BDL) to 0.929 mg/L. According to [43], lead-bearing fuel deposited on roads by automobiles can be transported by runoffs into water bodies and cause an increase in Pb concentrations in water. This explains why the highest Pb concentrations in the lagoon water occurred at points very close to the road and the garages around the lagoon. This confirms that the road close to these points is a source of Pb to the lagoon.

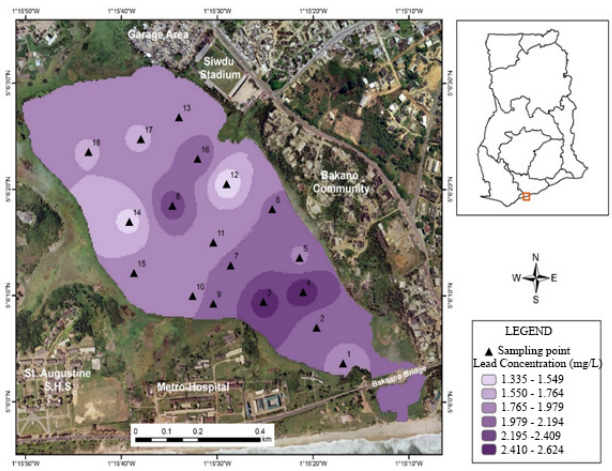

Figure 3. Pb concentration (mg/L) in the Fosu lagoon during the wet season

Source: Field Data, (2018)

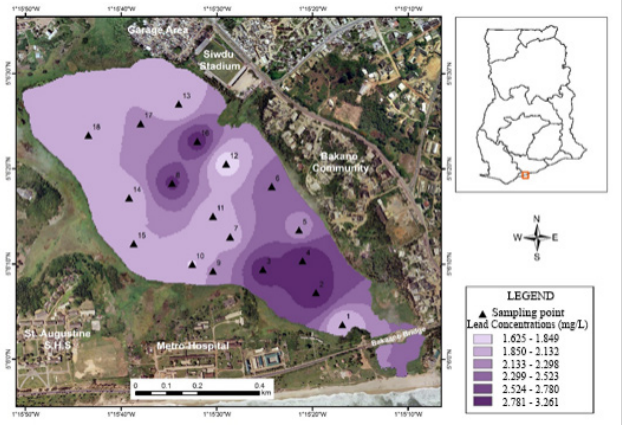

Figure 4. Pb concentration (mg/L) in the Fosu lagoon during the dry season

Source: Field Data (2019)

Copper (Cu)

Generally, Cu recorded the lowest concentrations in all samples as shown in Figure 5 and 6 respectively for the wet

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and dry seasons. A Cu concentration range of 0.13 mg/L - 0.40 mg/L was found for the wet season. Cu concentrations appreciably increased slightly above the levels of the wet season in the dry season's samples; ranging from of 0.13 mg/L - 0.46 mg/L. The concentrations of Cu are very low when compared with the WHO standard of 2 mg/L of Cu for drinking water, and may pose little or no threat to the health of consumers. As well, these low concentrations have little or no harmful effects on the lagoon's ecosystem. Despite this, the current study found concentrations, which are higher than [22] found, as they found Cu concentrations as below detection limits (BDL). The concentrations were mostly found at the mouth of the lagoon and this could be due to the seasonal interaction between the lagoon and the sea. The [36] suggests that geological weathering and corrosion of plumbing products and structures are the main sources of Cu in aquatic environments.

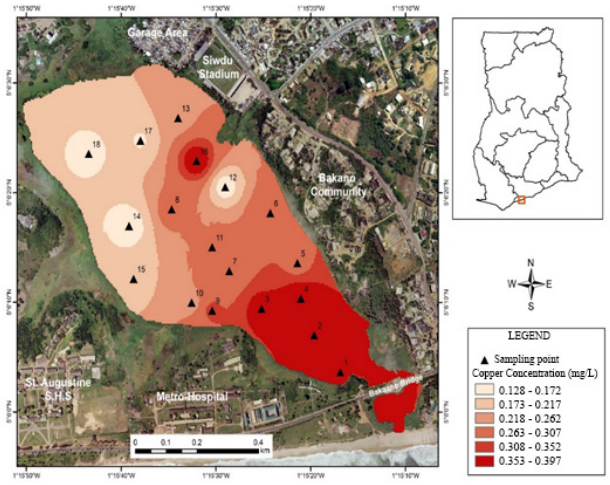

Figure 5. Cu concentration (mg/L) in the wet season Fosu lagoon

Source: Field Data (2018)

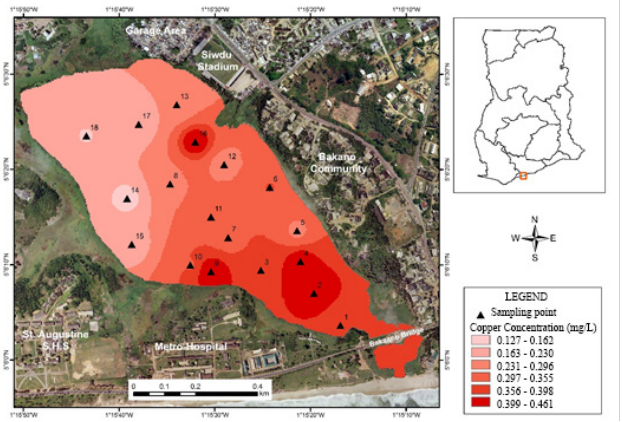

Figure 6. Cu concentration (mg/L) in the Fosu lagoon in the dry season

Source: Field Data (2019)

Cadmium (Cd)

The study found the concentration of Cd in the lagoon as ranging between 0.09 mg/L and 1.33 mg/L during the wet season. In somewhat conformity, recordings for the dry season's concentrations of Cd did not vary much from the recordings for the wet season. The presentation is shown in Figure 7 and 8 respectively. The values for Cd concentrations found for the dry season ranged from 0.09 mg/L to 1.82 mg/L. These are high above the WHO permissible limit of 0.003 mg/L. In a similar study, the range of Cd concentration levels found by [22] shows that Cd concentrations in the Tano River ranged from BDL to 0.11 mg/L. Cd is identified to be harmful to fish and other marine species in marine studies [1]. Cd is a toxic and nonessential trace element to all other organisms [17]. Cd is considered as a major hazardous environmental contaminant, especially due to its environmental persistence and ability to cumulate throughout almost the whole life span of humans [25]. Prolonged exposure to cadmium through contaminated drinking water can also cause anaemia and cancer [21,25]. In addition to natural sources, overspills from farms where phosphate is used as manure are a significant source of Cd contamination. Therefore, by dumping metal, as well as organic and other inorganic wastes around the lagoon's banks poses a potential danger to the lagoon and its resources by increasing metal toxicity in the lagoon. The industrial activities around the Fosu lagoon are gradually adding to the toxics in the lagoon. Higher concentrations of Cd were observed behind the Siwdu stadium's end of the lagoon. Here, there is a massive deposition of industrial waste. It can, therefore, be inferred that the corrosion of galvanized pipes on canoes, erosion of natural and other deposits, runoffs from waste batteries and paints from the town and nearby surroundings are the main sources of Cd contamination to the Fosu lagoon.

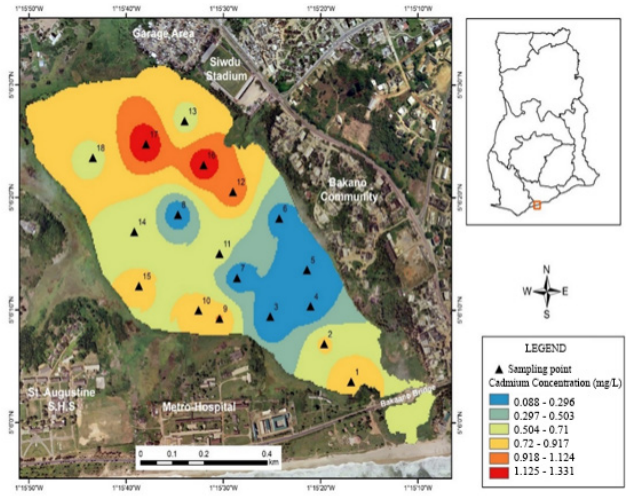

Figure 7. Cd concentration (mg/L) in the Fosu Lagoon in the wet season

Source: Field Data, (2018)

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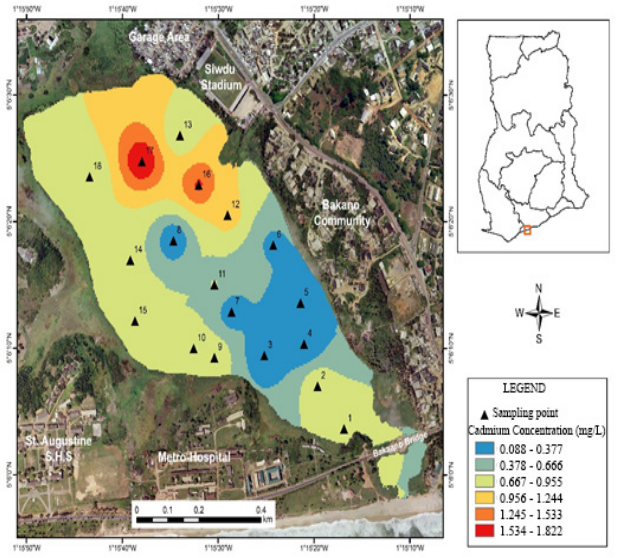

Figure 8. Cd concentration (mg/L) in the Fosu Lagoon at the dry season

Source: Field Data, (2019)

Manganese (Mn)

The concentration of Mn recorded for the wet season ranged between 0.32 mg/L - 0.57 mg/L. Seeming different from the sequence recorded for Pb, Cu, and Cd, the concentration of Mn concentration in the dry season recorded an appreciable decrease in the recordings for the wet season, this is shown in Figure 9 and 10. The findings showed a range of 0.27 mg/L - 0.46 mg/L. The concentration values observed at areas around the upstream of the lagoon for both seasons could mean that the garages close to the lagoon are releasing some metal pollutants into the lagoon of which Mn is one of them. This confirms [2] that many commercial and industrial discharges originating from the urban settlement threaten the coast's environmental quality. These toxics degrade water resources thereby increasing heavy metals in them. The relatively lower concentrations recorded along the mouth of the lagoon could largely be due to the interaction with the sea at the point of breaching. The abundance of Mn in the earth can also contribute to the high levels in the samples. The findings for Mn in the lagoon for the dry season are below the tolerance level given by the WHO and thus poses a low or no risk to the environment. However, the wet season's concentrations are slightly above the WHO's limit and may pose a danger to the environment during the wet season.

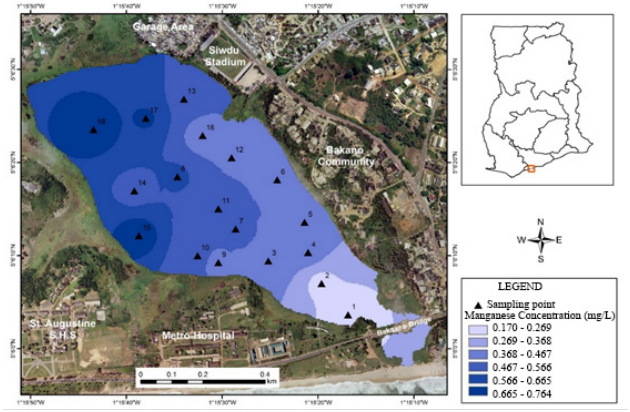

Figure 9. Mn concentration (mg/L) in the Fosu lagoon at the wet season

Source: Field Data (2018)

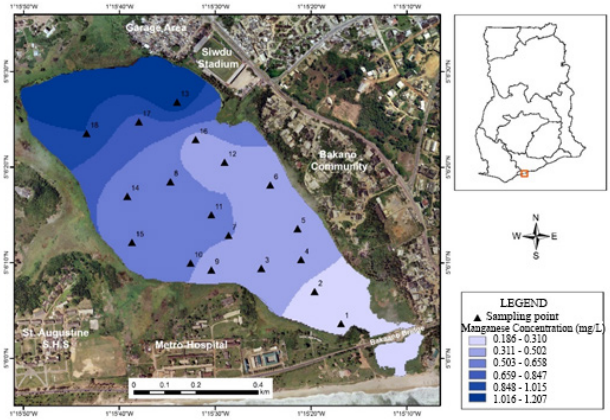

Figure 10. Mn concentration (mg/L) in the Fosu lagoon in the dry

Source: Field Data (2019)

3.2 Spatial and Seasonal Concentrations of Pb, Cu, Cd, and Mn in the Fosu Lagoon

Pb was spatially distributed with the highest average concentration of 2.71 mg/L occurring in the waters at the upstream level of the lagoon and a lowest of 2.14 mg/L concentration at downstream for both the wet and dry seasons' samples. For all two seasons, Cu had a maximum mean concentration of 0.40 mg/L at upstream and a lower concentration of 0.22 mg/L at the downstream level and this is presented in Table 2. The case of Cd was in disparity from those discussed earlier as it recorded its highest mean concentration at the downstream with a concentration value of 0.91 mg/L and a lowest of 0.44 mg/L at the midstream. Mn showed similar characteristics as the concentration pattern observed for Cd, as the highest mean concentration was recorded downstream with the value of 0.57 mg/L and lowest of 0.27 mg/L, at the upstream. [6]

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suggest that heavy metal concentrations can be traced to different sources and do not tend to be at the same concentrations. Spatially there are differences in heavy metal concentrations. It should be emphasized that the presence of a potential heavy metal source at various locations and varying intensity of the occurrence answers the question of how are heavy metals spatially distributed and varied across the globe. The above assertion is consistent with the results, as spatial differences in the concentration of heavy metals have been observed.

The mean Pb concentration in the Fosu lagoon is 2.28 mg/L for the wet season and 2.32 mg/L for the dry season. This connotes a higher concentration of Pb in the dry season than in the wet season. In either season, the concentrations are higher than the WHO recommended standard for drinking water. The study found 0.27 mg/L mean Cu concentration for the wet season and the dry season, a mean concentration of 0.31 mg/L was found. This indicates higher Cu concentration in the dry season than in the wet season, all below the WHO standard of 2 mg/L for drinking water. For Cd, wet season concentration level was 0.61 mg/L, and 0.70 mg/L was found for the dry season. In this case, Cd concentrations are high above the threshold concentration for drinking water according to the WHO. This as well indicates that there are higher concentrations of Cd in Fosu lagoon during the dry season than during the wet season. Exhibiting higher wet season concentrations than the dry season, the mean Mn concentrations were 0.4835 mg/L and 0.39 mg/L for wet and dry seasons respectively. Despite Mn concentrations are higher in the wet season than the dry season, the figures are at the threshold of 0.4 mg/L according to the WHO.

Table 2. Mean seasonal concentrations and variations

Heavy metal	Wet season		Dry season		WHO standards (mg/L)
	Mean concentration (mg/L)	Std. Deviation	Mean concentration (mg/L)	Std. Deviation	
Pb	2.2757	0.4483399	2.3230	0.4873270	0.01
Cu	0.2722	0.0860047	0.3081	0.1058332	2
Cd	0.6076	0.3560361	0.6984	0.4223708	0.003
Mn	0.4835	0.1440662	0.3900	0.1261690	0.4

Source: Fieldwork, (2019)

In agreement with this study, a study on the seasonal variation of heavy metal concentrations around Tejgaon Industrial Area of Bangladesh, by [19] found that the concentrations of studied pollutants were higher during the dry season particularly in January when rainfall is comparatively low and this adjustment might have occurred because of rainfall and dilution. In their study, it was only in the case of Pb where concentration level was high during the wet season and they attributed it to the high percentage of Pb in Dhaka's air in recent time, which mixed up with rainwater during the monsoon season. With the months for the seasons for sample collection coinciding with the months in which water samples were collected for this study, [22] found the opposite to what this study found for Pb and Cd. According to them, Pb and Cd concentration in River Tano were high in the wet season than in the dry season. Generally, all heavy metals they studied in River Tano showed higher concentration in the wet season than in the dry season. Except for Mn, the current study found higher concentrations for all heavy metals (Pb, Cu, and Cd) in the dry season than in the wet season. [8] in their assessment of the Sakumo II, Chemu and Kpeshie Lagoons of Ghana, reported substantial variations in Mn concentrations in water samples collected in the wet and dry seasons. This indicates that the sources and discharge of Pb, Cu and, Cd to the Fosu lagoon are not much influenced by precipitation and the accompanied runoff, despite it may be for Mn concentration. Recording higher concentrations for Pb, Cu, and Cd and the lower concentration of Mn in the dry season does not necessarily mean there is a limit in the discharge of Pb, Cu, and Cd in the wet season. However, it can be inferred that the sources may be active and these heavy metals are released into the lagoon all year round, unlike the case with River Tano where the discharge of heavy metals limits in the dry season. Higher evaporation of the surface waters of the lagoon in the dry season may be the reason for higher concentrations of Pb, Cu, and Cd in the dry season than the wet season. This is because the more there is freshwater in the lagoon, the lesser the concentration levels will be for all solubles.

3.3 Correlations between Heavy Metal Concentration Levels

Heavy metals available in the water samples exhibit different levels of correlation with one another. Pegging the analysis at a significant level of $p < 0.05$, the Pearson two-tailed correlations were run on pairs of heavy metals uniquely for the wet and dry seasons. This analysis is shown in Table 3 below. For the wet season, Pb-Cu and Cd-Mn were the only pair that exhibited positive correlations while all other pairs of heavy metals showed negative associations. The same observation is mirrored into the results for the dry season. However, Pb-Cu showed a moderate correlation coefficient for the wet season and a weak correlation coefficient for the dry season.

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Table 3. Correlation matrix of heavy metal concentrations in the wet and dry seasons

		Wet season				Dry season			
		Pb_W	Cu_W	Cd_W	Mn_W	Pb_D	Cu_D	Cd_D	Mn_D
Pb	Pearson Correlation	1				1			
	Sig. (2-tailed)								
	N	18				18			
Cu	Pearson Correlation	.297	1			.196	1		
	Sig. (2-tailed)	.232				.436			
	N	18	18			18	18		
Cd	Pearson Correlation	-.469*	-.306	1		-.430	-.185	1	
	Sig. (2-tailed)	.050	.216			.075	.463		
	N	18	18	18		18	18	18	
Mn	Pearson Correlation	-.033	-.714**	.117	1	-.050	-.516*	.191	1
	Sig. (2-tailed)	.897	.001	.643		.845	.028	.447	
	N	18	18	18	18	18	18	18	18

Source: Fieldwork, (2018)

According to [30,28], if the correlation coefficient between the studied heavy metals is higher, metals have a common source of origin with mutual dependence and similar behaviour during transport. Weak correlation among metals suggests that metals are not controlled by any single element but rather, they are controlled by a combination of geochemical support and associations. This hints that a common pollution source that discharges Pb and Cu to the Fosu Lagoon stops discharging either one of Pb or Cu with the switch from wet to dry seasons. The negative correlation coefficients express the varying dependence on pollution sources, and the interplay of processes or a combination of processes that influence the concentration and distribution of respective heavy metals in the Fosu Lagoon.

3.4 Seasonal Variations in Heavy Metal Concentrations

A paired sample t-test was conducted to evaluate the differences in heavy metal concentrations for wet and dry seasons. The analysis from Table 4 revealed a significant difference between Cu, Cd, and Mn concentrations for wet and dry seasons. However, Mn showed a very significant decrease in concentrations from the wet season to the dry season while Cu and Cd exhibited an increase in concentration levels. Pb concentrations, however, revealed no significant difference. With this, there is a statistically enough reason to conclude that Pb concentrations in the Fosu Lagoon do not vary with seasons. This confirms the results for the Pb-Cu correlation analysis; that the discharge of Cu to the Fosu lagoon declined in the wet season since the mean concentration of Cu for the dry season is higher than the mean concentration for the wet season. The higher heavy metal concentration values observed during the dry season may be the result of varying levels of evaporation and precipitation. It can therefore, be said that with the exception of Pb, seasonal disparity exists between the studied heavy metals in terms of distribution and concentration.

4. Conclusions

The levels of concentration of heavy metals (Cu, Cd, and Mn) in the lagoon were analyzed and their spatial distribution was estimated. The results show elevated Pb levels in the lagoon from the wet to dry seasons, resulting from vehicles depositing Pb on the road near the lagoon. Seasonal changes were found in the accumulation and distribution of heavy metals from samples of water analysed. While Pb and Cd concentrations in the Fosu lagoon were high during the dry season, the concentrations of Mn and Cu were close to and low respectively in comparison to the WHO standard limit and thus pose no or little danger to the lagoon's flora and fauna, as well as other users of the lagoon. Contrary, the contamination of the lagoon with Pb and Cd pose hazard to human and aquatic health, through bioaccumulation as residence may consume resources from the lagoon. This is indicated by the level of contamination in water samples collected from the lagoon as they contained relatively significant levels of the various metals. There is also increased industrial, municipal and domestic wastes emptying into these lagoons with fewer environmental guidelines. The increased heavy

Table 4. Seasonal differences in heavy metal concentrations

	Mean	Paired Differences					T	df	Sig. (2-tailed)
		Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper				
Pair 1	Pb^W - Pb^D	.0472778	.1514533	.0356979	-.1225937	.0280382	1.324	17	.203
Pair 2	Cu^W - Cu^D	.0358611	.0551460	.0129980	-.0632846	-.0084376	2.759	17	.013
Pair 3	Cd^W - Cd^D	.0907778	.1260454	.0297092	-.1534587	-.0280969	3.056	17	.007
Pair 4	Mn^W - Mn^D	-.0935000	.0988381	.0232964	.0443490	.1426510	-4.014	17	.001

Source: Fieldwork, (2019)

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metal values observed during the dry season could be in response to the difference in evaporation rate and precipitation. Heavy metal concentrations of water samples varied widely in terms of seasons and sampling points within the study area.

Recommendations

The Wildlife Commission must track the lagoon on all water quality parameters or requirements as specified by law in 'surveillance' monitoring, at least one surveillance per year. Surveillance is intended to provide a general summary of the state of the lagoon and acts as a framework for an organisational management system. Operational monitoring becomes important when the water body is at risk of failing to meet the required status or standard and monitors the quality parameters that indicate the stress causing the loss of water quality. Subsequently, investigative monitoring should be carried out if the reasons for the fall in standards cannot be identified. This means that the lagoon should be monitored constantly to provide accurate information that will assist in making decisions. City authorities (Cape Coast Metropolitan Assembly) should put up measures such as sanction of perpetrators to prevent the deposition of heavy metals, industrial waste and domestic waste into the lagoons. The numerous garages at Siwdu and the palm kernel extractors at Adisadel village should be relocated. Due to the presence of low concentrations of trace metals, periodic monitoring campaigns of the lagoon is required, in order to highlight any possible increase in contamination event and to reduce any harmful effects, employing the best environmental management practices available. The role of government is to create awareness on habitats and biodiversity values and the need to safeguard the Fosu lagoon for sustainable utilisation. This could be done by strengthening relevant governmental and nongovernmental institutions through capacity building and provision of appropriate logistics. It is worthy to note that fishing, public health, and recreation are multifaceted activities requiring cooperative management and intersectoral coordination. To accomplish the coordination requires the full involvement of all the various stakeholders and government is encouraged to spearhead this agenda of bringing the stakeholders together to ensure consensus building.

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