

Vulnerability Studies of Sensitive Watershed Areas of Owerri South East Nigeria Using Digital Elevation Models

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Abstract: The impact of human activities on sensitive watershed terrains is a critical consideration in the management of urban ecosystems. Degradation of sensitive ecosystem features such as watershed land areas is often irreversible due to the extent and intensity. The vulnerability of 150 m watershed management zone of Otamiri river Owerri Imo State, Nigeria was studied by topographic analysis using 1977 Digital Elevation Model (DEM), 1977 aerial photos, shuttle radar topographic mission DEM of 2000, 2006 satellite imagery and the master plan of the study area. The impact of human activities in elevation change was observed in the parts of substantial human activities while topographical stability was recorded for areas of very low human activities. At the East banks of Otamiri and Nworie rivers where heavy human activities take place, average changes in elevation were -7.138 and -4.454 m, respectively, indicating eroded banks. While the West banks of Otamiri and Nworie rivers with sparse human activities measured +0.048 and +0.000 m in average changes in elevation. Along Otamiri and Nworie water courses from source to confluence, an average elevation increase of +3.616 and +5.159 m, respectively were recorded, indicating sedimentation and siltation. And a reduction (-7.028 m) in average elevation change, suggestive of erosive action was measured from Otamiri/Nworie confluence to the South, an area of intensive sand excavation. The study recommends enforcement of the watershed management edict that seeks to create a buffer zone around the river banks, so, as to protect the valuable ecosystem.

Key words: Vulnerability, watershed, ecosystem, impacts, activities, consideration

INTRODUCTION

Urban ecosystem is a dynamic complex ecosystem with physical, biological and social components that interact and behave as a functional unit in any environment. Like natural ecosystem, urban ecosystems are important because they provide services such as provisioning, regulating, supporting and cultural at various scales and forms. These services are easily recognized in any given watershed area. The services such as water supply, ground water recharge, natural flood control, biodiversity conservation and micro climate regulation make watershed an environmental “sensitive area” that demands close monitoring for sustainable use. (Reventa *et al.*, 1998).

The increasing population growth in urban ecosystem entails increase in demand for and consumption of biological and physical resources, thus, causing escalating impacts on ecosystems and the services they provide (Millennium Ecosystem Assessment, 2005). The problem posed by the growing demand for ecosystem services is compounded by the increasingly serious degradation in the capability of ecosystems to provide these services. Some of these impacts of these degradations may be irreversible as the case of biodiversity loss and soil degradation (Lambin and Geist, 2010). This ever-growing demands being placed on increasingly degraded ecosystems seriously diminishes the prospects for sustainable development.

Urban ecosystem management is important because of the increasing population growth and its attendant resource depletion and degradation (Shen *et al.*, 2016). The degradation of the ecosystem is critical if it is in the watershed land area.

The study area, Otamiri watershed is an urban watershed situated in a high density area, Owerri in Imo State, Southeastern Nigeria. Imo State is one of the densely populated states in Nigeria with Owerri having a high population density of 813.54 persons/km² in the study area (USGPO., 2009). Otamiri river is significant because it serves as the only surface water for domestic and agricultural purposes. The watershed resources such as coarse red sands in form of laterites are used for construction purposes.

In seeking to protect the surface water in the state from ecological hazards, the 1995 Imo State Government Watershed Management Regulation provides a clause that states that 150 m wide on both sides of the river bank, termed watershed management area should be protected and not encroached upon. Analysis on the changes in the pattern and distribution of land uses and land covers in the study area, showed that the designated 150 m wide watershed management zone is disturbed. Sand excavation and builtup land classes occupied 13.95 and 9.07% of the buffer zone. And 16.59% of the riparian vegetation that make up the buffer zone as converted to sand excavation site between 1977 and 2012 (Chukwuocha and Igbokwe, 2014). The high dynamicity index values of 25.78 and 11.51% (2006) from sand excavation sites and builtup classes, respectively have implications for changes in the topography of the protected zone (AC-Chukwuocha, 2015).

These inappropriate activities such as infrastructural developments, farming and sand excavation activities practiced within and around the protected watershed area, make the fragile ecosystem vulnerable to stream bank erosion, gully erosion sites at the downstream of the study area, siltation of Otamiri tributary and at the head source upstream. This study attempts to measure changes in elevation due to human activities within the watershed management zone and along the water courses.

The study area: Owerri capital territory is located between latitudes 05°25' and 05°32' North and longitudes 06°57' and 07°07'. Rainfall is the greatest climatic variable with annual total mean of 2190 mm (Anonymous, 1977). The

mean monthly temperature for dry season is 34 and 30°C for rainy season. The river has average flow of 10.7 m³/sec in the rainy season (September-October) and a minimum average flow of about 3.4 m³/sec in the dry season (November- February). The total annual discharge of the Otamiri is about 1.7×10⁸ m³ and 22% of this (3.4×10⁷ m³) comes from direct runoff from rainwater and constitutes the safe yield of the river (Uma and Egboka, 1986).

According to Anonymous (1977), Owerri was originally an agricultural settlement of 5 villages with a central market linking the villages. The story of the modern Owerri may begin with the year 1901 when the British administration reached Owerri and by 1918 Owerri had become the headquarters of the Eastern Protectorate. In 1953 the Shell DIArcy Exploration Company began to build up its headquarters known as "Shell Camp", bringing some economic growth resulting in residential expansion, market reconstruction and a new motor park. The early plan of the town was prepared in 1948 by Tetlow, a British town planning adviser to West Africa.

On February 3, 1976, Imo State was carved out of the old East Central State and Owerri was made the capital of the new state". Owerri has since, then expanded into neighbouring towns and villages of Orji, Egbu, Mbieri, Uratta, Amakohia, Irete, Egbeada, Avu, Obinze, Nekede, Ihiagwa, Naze, etc. Many layouts have been planned and developed.

From the creation of Imo State, the philosophy of the development of modern Owerri is built on the principle of a Twin city. The two water bodies that transverse the present day Owerri formed the boundaries of the old Owerri city. Otamiri River, the major water body runs approximately East-West from its source at Egbu until its confluence with the Nwaorie stream, a tributary of Otamiri River. Nwaorie runs approximately North-South down to the confluence with Otamiri River. After the Confluence, Otamiri River continues Southwards to Nekede. In those early days people inhabited Owerri North of Otamiri River and East of Nwaorie Stream. There was a natural safe distance between the settlements and the water bodies. However, with the creation of Imo State came a very fast expansion of the town and human activities along the riparian forest area on the sides where humans inhabited increased tremendously also. Figure 1 shows the Owerri Master Plan, comprising of the Old Owerri and the New Owerri Twin city.

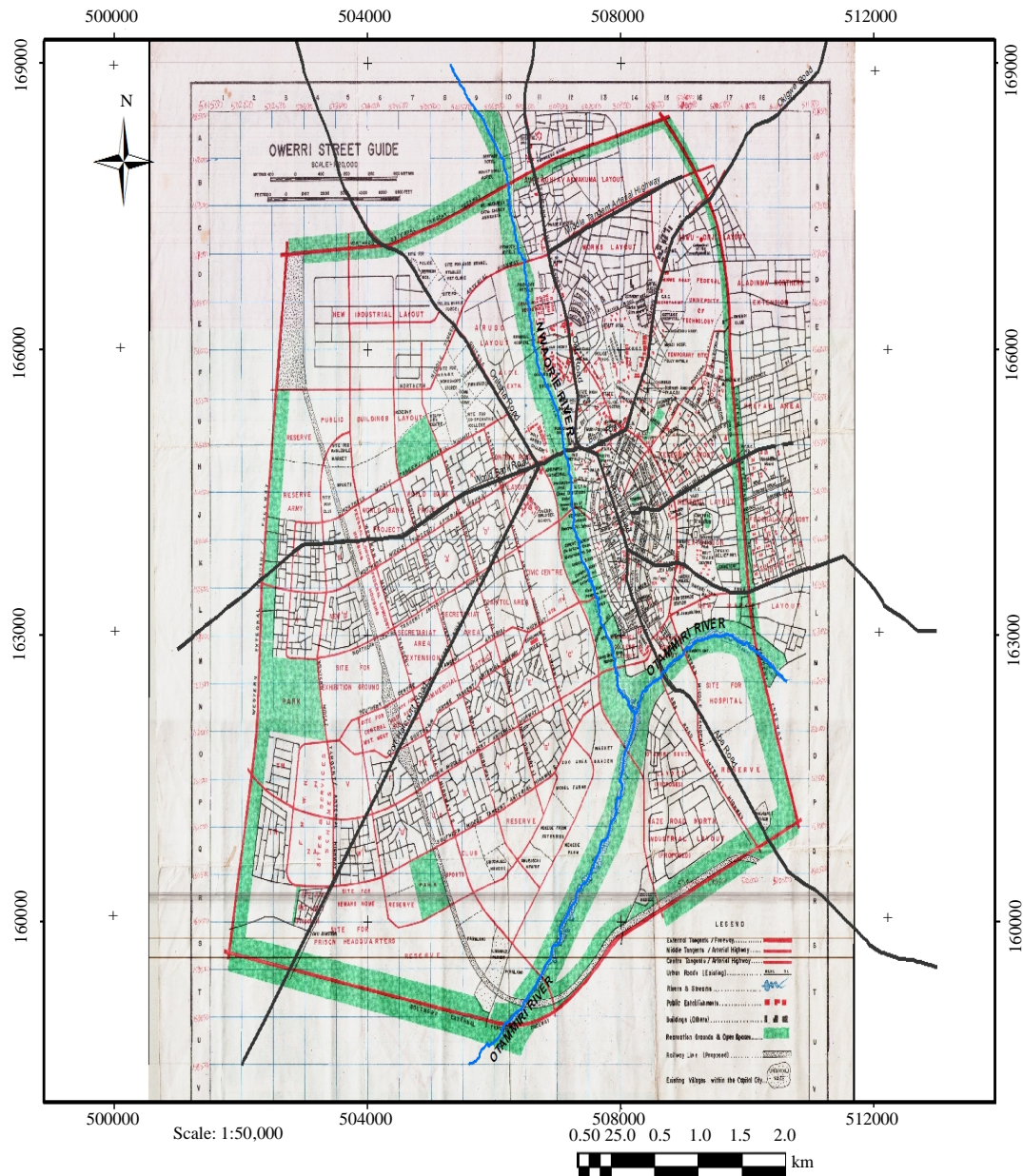


Fig. 1: Owerri master plan showing the old and new Owerri Twin City

MATERIALS AND METHODS

Data source and acquisition process: The study employed the datasets of 1977 topographical maps (created from the same 1977 aerial photogrammetry survey of Owerri). Shuttle Radar Topographic Model DEM, tile 38-11 of the year 2000 series and master plan of Owerri. The 1977 topographic maps were scanned and georeferenced to create a map mosaic of the project area. Contours and spot heights that were digitized were used to create the Digital Elevation Model of the study area.

The DEM of 1977 topographic map sheets was overlaid with 2000 SRTM DEM. The result was a Digital Elevation Change Model which was sampled at fourteen points at 1 km interval to determine an average value of change in parts of the water courses. In order to delineate the designated watershed management area, the Master Plan of Owerri was overlaid on the change DEM of the study area.

Figure 2 shows the points along the water bodies at which elevation change data with which the analyses presented in Table 1 were collected. The elevation sample

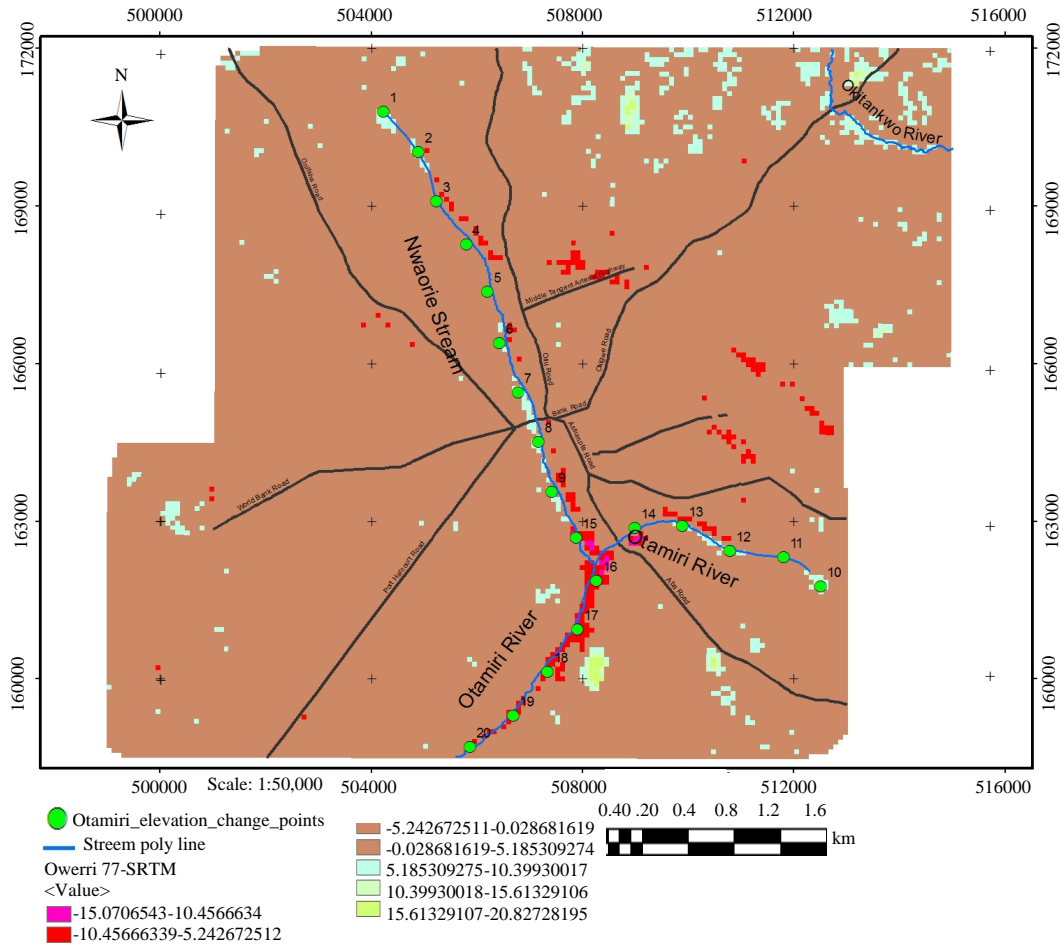


Fig. 2: Sample elevation change data points along Nwaorie Stream and Otamiri

Table 1: Sample Points of elevation changes along Otamiri water courses

Sample	Easting (m)	Northing (m)	Elevation	Average/Elevation
1	504,226.15	170,806.08	9.702	Along Nwaorie stream course, from source, North West to confluence = +5.159 m
2	504,888.23	170,034.03	6.860	
3	505,231.83	169,101.37	2.876	
4	505,795.96	168,280.64	1.955	
5	506,200.27	167,374.84	2.427	
6	506,420.16	166,398.11	4.924	Along Otamiri River course from source, East to confluence = +3.616 m
7	506,772.45	165,454.01	7.202	
8	507,160.21	164,526.22	5.323	
9	507,415.57	163,571.01	7.158	
10	512,513.20	161,769.34	9.876	
11	511,813.34	162,317.88	3.976	Along Otamiri River course, from confluence central area going South = -7.028 m
12	510,791.92	162,440.83	4.002	
13	509,893.45	162,913.71	1.003	
14	508,985.52	162,875.88	5.232	
15	507,878.99	162,700.91	-2.393	
16	508,266.75	161,873.38	-12.248	
17	507,907.36	160,946.53	-6.705	
18	507,339.91	160,142.64	-6.695	
19	506,687.34	159,310.38	-5.124	
20	505,864.53	158,714.55	-4.367	

Researcher's work 2015

data points are shown as green points. Average values of elevation changes along Nwaorie stream, Eastern Otamiri

river and South of the confluence were determined to be +5.159, +3.616 m and -7.028, respectively, between 1977-2000. The average change values of +5.159, +3.616 m imply raised elevations along the courses of Nwaorie stream and Eastern Otamiri River. These positive values are indicative of the sedimentation and siltation taking place along the water courses of Nwaorie stream and certain sections of Otamiri River as may be observed physically.

About -7.028 m average change value of Otamiri South of the confluence implies a deeper elevation in year 2000 than in year 1977. The reduction in elevation is suggestive of erosive action taking place along Otamiri water courses South of the confluence. These areas are found within the Nekede community where gully and stream bank erosion has ravaged the land. Intensive and extensive sand and gravel excavation take place in this area. Arable farmlands were cleared and access roads built for the commercial sand excavation activities.

RESULTS AND DISCUSSION

Measures of elevation changes along the water courses:

Table 1 presents the result of average measure in the change of elevation along the water courses at average interval of 1 km.. Sample points 1-9 depict values of elevation changes along the course of Nwaorie stream. While sample points 10-14 are the values of elevation changes along the Eastern Otamiri river before the confluence. And sample points 15-20 are values of the elevation changes South of the confluence.

Figure 3 is the elevation change map overlaid with the master plan of Owerri. The master plan of Owerri is dated 1977. It shows areas that were inhabited by that year of its production and also shows planned use of other parts of the capital city. It is observed that the areas within the sensitive water body banks that were inhabited as at 1977 suffered worse washing away of the banks while such sensitive areas that remained uninhabited had their elevations unchanged over the period. Of course apart from the Nwaorie stream which parts of it are silting up possibly due to sand filling by government to create bridges, the other parts of the water bodies where they are silting up are the parts where the banks are washing away. These point to the harsh impact of anthropogenic activities within the sensitive watershed area.

Elevation changes in the watershed management area:

The analysis of the elevation changes as in Table 2 for old Owerri and Table 3 for New Owerri show marked erosion of the banks of the water bodies in the old Owerri areas which have been heavily populated over the years. The water courses along those areas, specifically along the Nwaorie stream from the source at the North of the project area going South towards the confluence showed marked siltation up between 1977 and 2000 the border dates of the elevation data. The same is the case for Otamiri river running from East side of the project area to the confluence which has recorded remarked erosion of the bank North of the river in the old Owerri side and a marked elevation of the water bed, suggesting siltation.

Two clear behaviours were observed in the watershed management areas (river banks). The Nworie stream runs approximately in the North South direction from its source, to the confluence with Otamiri river. On the other hand Otamiri River runs approximately East to West from its source, to the confluence. The Northern river bank of Otamiri through the confluence to the eastern bank of Nworie stream fall in the old Owerri capital city. This river bank which has been under heavy activities, since, the 1970 sec was observed to have been eroded leading to

Table 2: Elevation changes at sample points in the watershed management area of old Owerri with high human habitation density

Easting (m)	Northing (m)	Elevation (m)	Remarks
512,814.54	161,763.54	-2.446	North of Otamiri River old Owerri.
512,170.34	162,299.17	-3.458	Densely populated area. Average elevation change = -4.109
511,960.43	162,393.27	-2.842	
511,330.71	162,494.60	-3.283	
510,614.13	162,733.46	-4.918	
509,956.46	163,048.69	-6.383	
509,593.55	163,182.23	-5.431	
504,396.47	170,807.79	-1.124	East of Nwaorie stream old Owerri.
505,058.97	170,048.99	-5.837	Densely populated area. Average elevation change = -4.454
505,335.07	169,136.86	-3.696	
506,031.51	168,359.55	-6.124	
506,414.22	167,363.15	-3.906	
506,680.52	166,439.42	-4.631	
507,055.64	165,491.85	-1.152	
507,328.00	164,544.75	-4.018	
507,630.01	163,624.49	-3.778	
508,045.03	162,756.39	-10.272	
509,104.60	162,689.14	-14.667	East of Otamiri River, South of the confluence, old Owerri. Heavy white sand excavation site and erosion area, abutted by Nekede Mechanic village.
508,455.62	161,840.47	-6.593	
508,074.97	160,823.32	-5.818	
507,625.67	160,030.82	-5.249	
506,858.13	159,175.91	-3.361	Average elevation change = -7.138

Table 3: Elevation changes at sample points in the watershed management area of new Owerri with low density human activities

Easting (m)	Northing (m)	Elevation (m)	Remarks
504,052.11	170,791.67	0.414	West of Nwaorie stream, new Owerri.
504,690.95	169,895.24	-0.124	Very sparsely populated area. Average elevation change = -0.000
504,948.54	169,055.49	-0.289	
505,479.18	168,200.28	-0.186	
504,964.00	169,034.88	-0.288	
506,081.95	166,299.23	-0.004	
506,349.85	165,356.44	0.022	
506,787.76	164,449.71	0.624	
507,081.42	163,594.50	-0.171	
511,769.16	162,208.64	0.146	South of Otamiri stream. New Owerri.
510,677.13	162,227.36	0.216	Very sparsely populated area. Average elevation change = -0.022
510,764.49	162,214.88	-0.216	
509,734.86	162,776.50	-0.235	
507,715.10	162,033.48	-0.196	West of Otamiri River. New Owerri.
507,349.32	161,028.86	-0.067	Very sparse human activities in this area. Average elevation change = 0.048
506,880.50	160,307.60	0.155	
506,221.06	159,565.73	0.270	
505,489.49	158,901.14	0.077	

Researcher's work 2015

reduction in elevation of the river banks by an average 4.454 m for East of Nworie and 4.108 m for North of Otamiri.

The Southern bank of Otamiri from its source to the confluence has been largely uninhabited and untampered. The water bank West of Nworie stream down to the confluence and further down South along the Western bank of Otamiri river from the confluence going towards Nekede, a village close to the capital city fall in the New Owerri capital territory an area largely uninhabited over the years. These water banks were observed not to have been eroded in some cases recording average elevation change ranging from 0.000-0.048 m indicating no change in elevation.

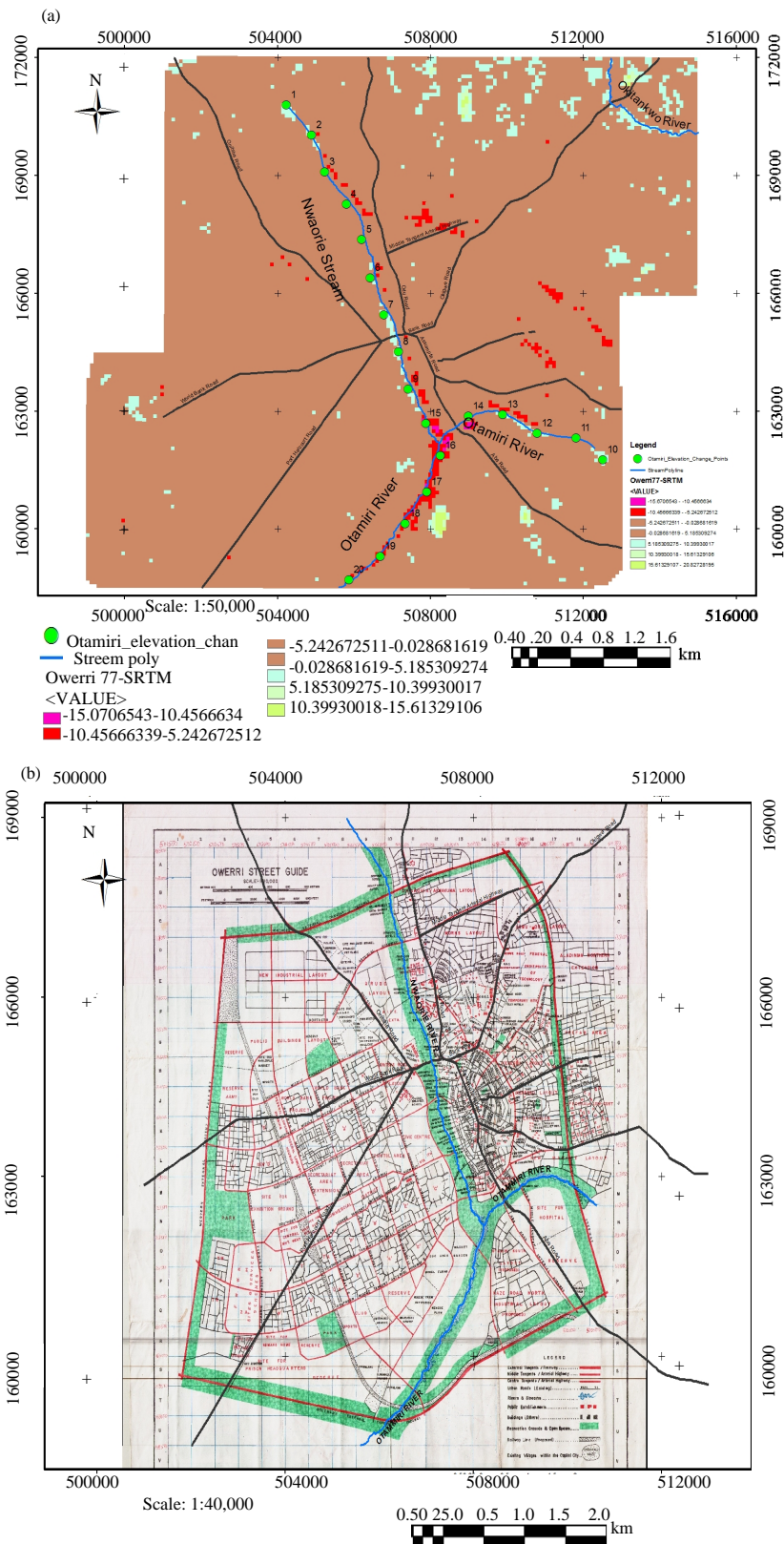


Fig. 3: Otamiri watershed elevation change map overlaid with the master plan of Owerri

These average changes in elevation reported along the water courses and within the designated buffer zone have strong implications for the ecosystem and its resources. The ecosystem is vulnerable to severe decline in abundance of specie along the riparian vegetation corridors of the river banks. And with the current spate of city development, encroaching into the buffer zone, there may be a near loss of biodiversity from the watershed ecosystem. Loss of biodiversity has been noted as one of irreversible human impact on the ecosystem (Lambin and Geist, 2010). The ecosystem is prone to greater risk of climate change because of their weak capacity for resilience.

CONCLUSION

This study has effectively demonstrated the feasibility of the “Vulnerability Studies of Sensitive Watershed Areas by human activities in Owerri South East Nigeria Using Digital Elevation Models (DEM)”. Digital Elevation Models (DEM) of 1977 and 2000 epochs were processed on a Geographic Information Systems (GSI) platform to create the digital elevation change matrix which is a Raster data type showing recorded changes in elevation over the period of study.

These studies derived foundational scaled quantities of the impact of human activities on the sensitive parts of the watershed. Based on the above findings, the study concludes that the 150 m wide on both sides of the river banks designated as watershed management zone is threatened with degradation due to intensive human impacts. The loss in ecosystem services is loss of biodiversity and arable land, increase in impervious surfaces with its attendant overland flow, loss of properties and human settlements and increase in the treatment of the water for domestic and industrial needs.

RECOMMENDATIONS

Based on the findings, it is recommended that these digital elevation change matrix method be employed in the scaled studies of the vulnerability of the sensitive watershed areas. These studies can actually lead to the determination of what volume of sand that has been washed away and through that ultimately the population

of Earth inhabiting faunas that have been washed away with the sand. A number of other impacts could be studied using this method.

By the conclusion of these vulnerability studies, it is obvious that the Otamiri River and the attendant ecosystem are threatened and may silt up. Government is called upon for immediate intervention to stop further constructions within the 150 m protected area and to also reduce human activities that would impact the Otamiri watershed and ecosystem negatively.

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