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Assessing Landcover Change for the Management of Floral and Aquatic Ecosystem in Kalikiliki Area of Lusaka, Zambia

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Abstract: *Human activities have adversely changed landcover in most residential areas thereby negatively impacting the ecosystems. Therefore, understanding dynamics of landcover is important for efficient ecosystem management and sustainability. The aim of this study was to assess floral and aquatic ecosystem change in Kalikiliki area of Lusaka, Zambia for a period 2004 to 2020 in order to suggest appropriate sustainability measures. Geographical Information Science was used to detect land cover based on google earth engine imageries. Questionnaires were used to collect data on ecosystem management and sustainability practices. Results of the study indicated a significant change in ecosystem composition in Kalikiliki area, which was greatly influenced by socioeconomic and political activities in the area. Generally, vegetation was lost to build up human settlements and other socioeconomic amenities. It was also established that environmental clubs played a role in ecosystem management and sustainability, but only yielded average results in ecosystem management and sustainability because their use was below average. The analysis and findings of the study highlight important policy implications for ecosystem sustainability in Kalikiliki Area and how that, urban planners and ecosystem managers must consider mainstreaming effective informal environmental education. It was suggested that environmental education be expeditiously implemented in the area for optimum results on ecosystem sustainability. The study also suggests that government entities in charge of ecosystem management should also adopt collaborative activities in the area for improved ecosystem sustainability.*

Keywords: *Ecosystem management, sustainability, landcover change, GIS, Floral and Aquatic Systems*

1. BACKGROUND

Floral and aquatic ecosystems are important for survival of both human and non-human forms of life because of the diverse ecosystem services and goods they provide. [1] Affirm that ecosystems have great contributions to quality of human and non-human life. These contributions derived from ecosystems can be categorised as; provisioning of services such as water, food and timber; regulating services such as climate regulation, erosion control, air quality; supporting services such as soil formation, oxygen production and; cultural services, which include recreational and health benefits [2]. Additionally, ecosystems play an important role in sustainably reducing the risks of disasters [3] such as urban flooding and environmental diseases [4]. As a result, over exploitation of these resources harms the health of the ecosystems and health of the people [5]. [6] also affirms that, despite nature making human life possible, the relentless demand for earth's resources is accelerating extinction rates and devastating the earth's ecosystems. Therefore, protection and management of ecosystems has become an urgent and imperative venture.

Ecosystem protection has since the last decade been a popular phrase among various stakeholders such as environmental educators, conservationists and other interdisciplinary communities of scientists [7] and [8]. For example, by the time this study was being conducted, the United Nations launched the United Nations Decade on Ecosystem Restoration 2021-2030 in order to expedite the process of restoring degraded and degrading ecosystem and protect those that were still intact [9]. A study by [10] revealed that all ecosystems irrespective of their geographic location are under some form of stress. However, urban ecosystems are more threatened than those in many rural setups.

11] conducted a study to assess Landuse and Landcover change detection using remote sensing in the Lake Tana Basin, Northwestern of Ethiopia. In their study, the results showed that significant change detection was observed during the study period. The change detection indicated that there was change of Landcover from bush land and grazing land to settlements. The results further showed an increasing trend in residential and urban areas while the grasslands and bush lands showed a decreasing trend. This resonates with the findings by [12] in their analysis of Spatiotemporal Dynamics of Land use/cover Changes in Jubek State, South Sudan. [12] established that built up areas accounted for the most significant Landcover change in their study area. Meanwhile, the study by [11] further observed that these changes could have implications on resource management and the general livelihood of the local people. They therefore recommended improved land management practices; integrated watershed management and active participation of local community to prevent any undesirable Landcover dynamics in the basin. This argument was also advanced by [13]. On a good note, [13] acknowledges the intervention strategies, which barely underscore the importance of EE strategies for sustainable ecosystem management. The current study takes a position that, without effective environmental education for local community, whatever is purported to be local community participation remains superficial as local people barely understand why they are participating. So if environmental education is informally mainstreamed in their daily narrative, they shall make informed decision around preservation of ecosystems.

Studies on landcover change and ecosystem management have been under taken by a number of scholars. Scholars such as [14] and [15] have acknowledged that Landcover change is an essential component in understanding and solving environmental problems. Additionally, [16] explain that knowledge of Landuse and Landcover change and its consequences on the environment is essential to developmental plans and policies necessary for changing current trends in Landuse and Landcover especially under anthropogenically-induced climate change. With the recent global advances with higher precision in landsat archiving, activities of data processing, mapping, Landuse and Landcover temporal frequency and thematic details have been advanced [17]. Notwithstanding such unprecedented development in technology towards improved ecosystem management in general, these studies lack a focus on what Environmental Education can actually do to complement such technicist approaches. This gap is also noted in studies by [18] at national level, [19] in Southern Zambia, [20] in North-western Zambia, [21] on the Copperbelt Province

This study focused on landcover change in the peri urban area of Kalikiliki in Lusaka District because of the notable loss in aquatic and floral ecosystem that the area had undergone by fieldwork time. Depreciation of natural landcover in Lusaka's peri urban areas has drastically led to the loss of aquatic and flora ecosystems with their respective goods and services. As the population keeps on increasing, the aquatic and floral ecosystems are highly under threat because of high demand for land for infrastructure development and settlements. According to [22] Lusaka is one of the cities that have experienced notable urbanization and urban development. With population of over 3 Million as of 2022, urbanization is rapidly on the rise to a point where human settlements are now encroaching into protected floral and aquatic ecosystems resulting in environmental degradation and, consequently, loss of selected ecosystem goods and services.

Contextually speaking, changes in the structure and function of natural ecosystems in Kalikiliki are likely to punctuate health hazard to human population. [4] posit that, these changes are significant drivers in the emergence, distribution, and transmission of numerous infectious diseases. This implies that, if the problem of ecosystem change remains unaddressed in Kalikiliki, it may punctuate several environmental challenges such as permanent loss of ecosystem goods and services, increased environmental hazards and disasters among others. Several technical approaches have been adopted to address changes in landcover and eventually ecosystems, but these have widely failed given that, human settlements have indiscreetly encroached beyond free range ecosystem into those which are protected by law such as the Forest 27 [23]. Therefore, this study endeavored to detect changes in ecosystem in Kalikiliki area of Lusaka district so as to suggest educational approaches that promote ecosystem sustainability. The aim of this study was to assess the dynamics of landcover and landuse change in Kalikiliki area of Lusaka, Zambia for a period beginning from 2004 to 2020 in order to suggest appropriate measures for ecosystem management. This aim was attained through three

objectives. These were; to assess changes in ecosystems between 2004 and 2020 for kalikiliki area, to examine ecosystem management activities in the area, to suggest environmental education (EE) activities that could be used to enhance ecosystem sustainability in the area.

2. METHODS AND TOOLS

The study was conducted in the peri urban area of Kalikiliki in Lusaka District of Zambia. The area is located approximately 11.5km from the Central Business District (CBD) [24] Kalikiliki has a total area of about 740,000 m^2 inhabited by 77,614 spread among 6570 housing units. It is geographically surrounded by Mtendere Settlement area on the North Eastern side, on the South is a formal settlement known as Kabulonga, and Ibex Hill on the east. The area has a high water table with generally clay soils resulting into poor drainage prone to flooding [25]. Figure 1 shows location for Kalikiliki in Lusaka District.

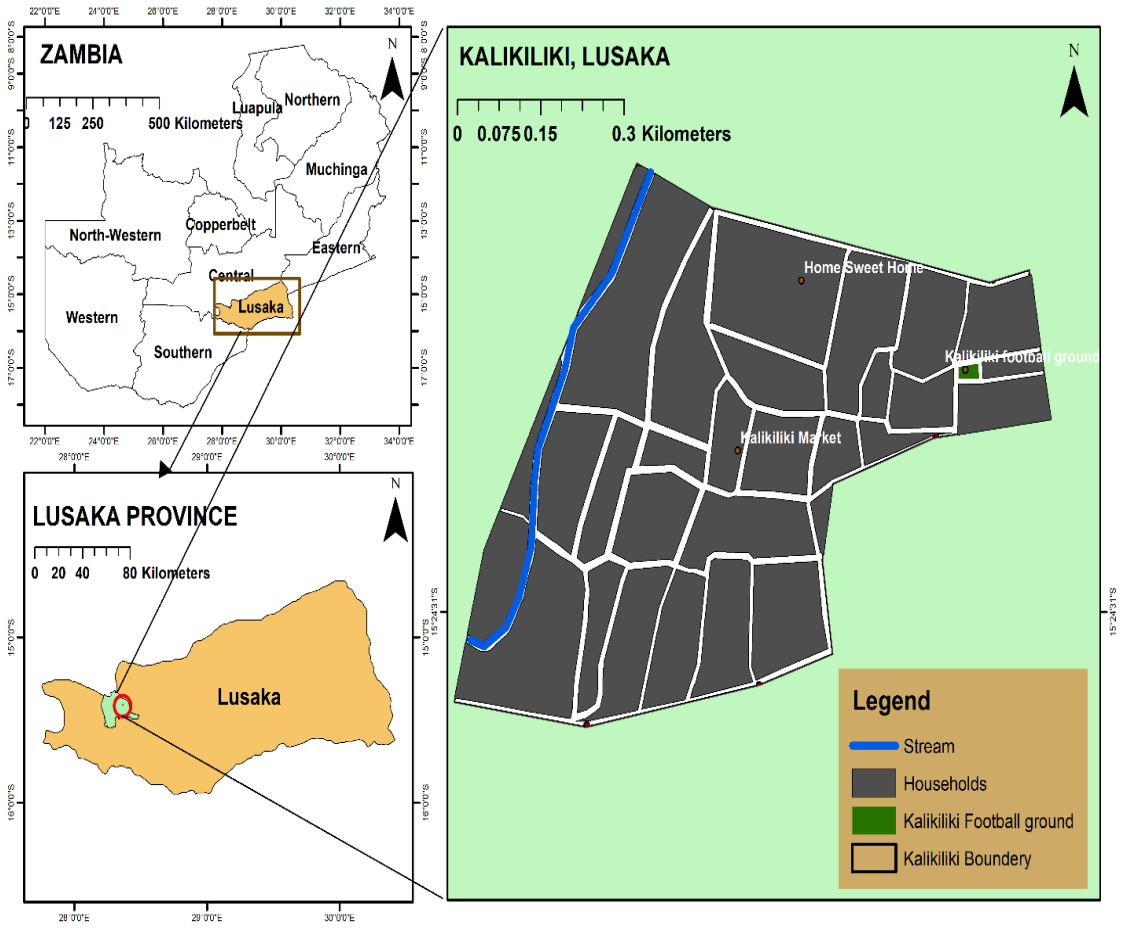

Figure1. *Location of the study Area in Zambia*

A quantitative approach was adopted in this study. Data was collected using Geographical Information Science and structured questionnaires that were administered to 217 residents of Kalikiliki area. Due to the prevailing situation of COVID-19 by then, movements in the country were limited. This necessitated the use of purposive sampling to select the 217 respondents. Data collected through questionnaires was analysed using descriptive statistics, and coefficients of variation using excel spreadsheet. Landcover imagery was collected from Google Earth Engine (GEE) and it underwent multistage analysis process that included; image processing and ground truthing, image classification and the final stage involved the creation of multi-temporal Choropleths, which visualised spatial-temporal variations of coverage of aquatic and floral ecosystems over 16-year period. Figure 2 shows a summary of the data analysis process.

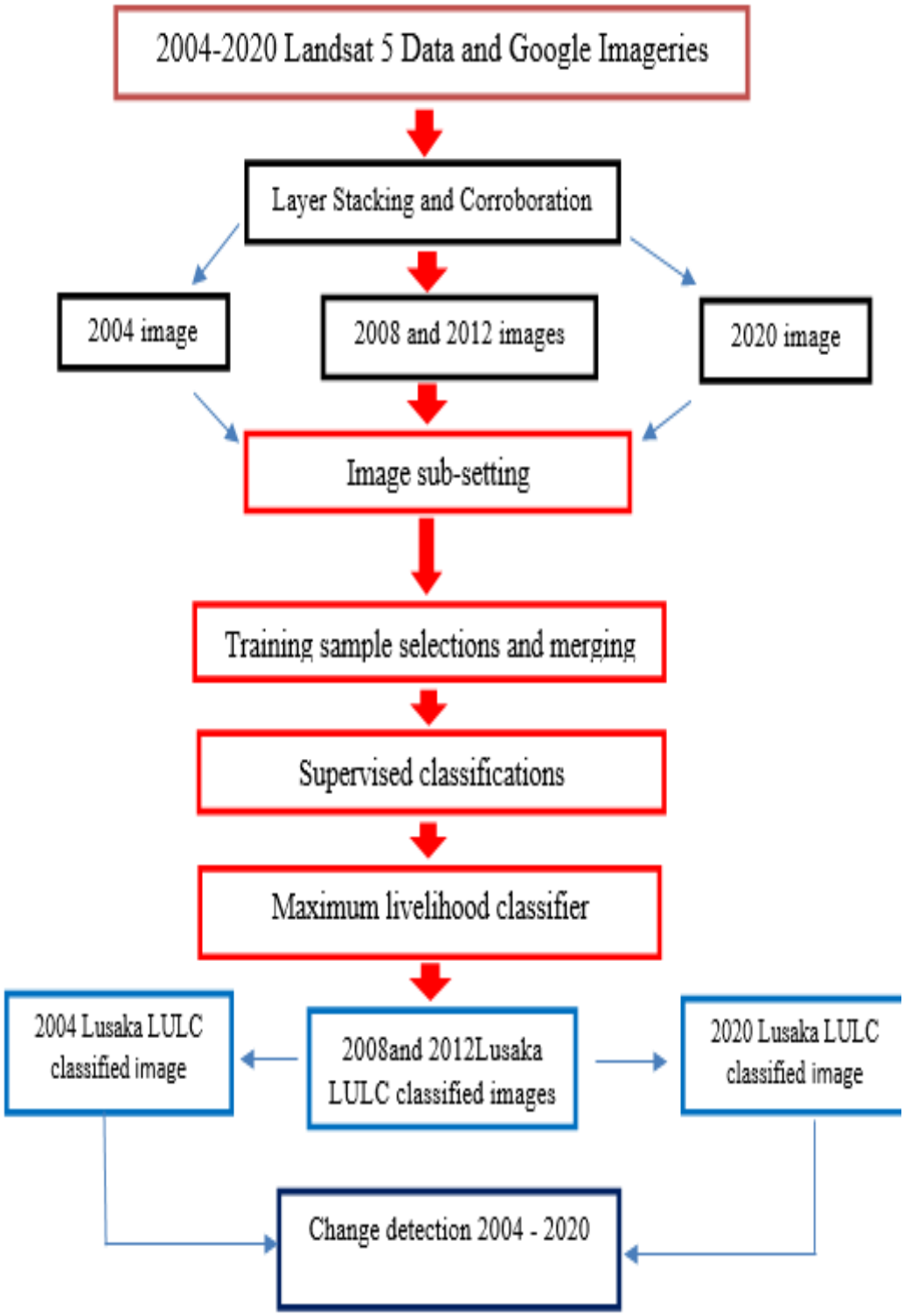

Figure2. *Analytic framework for ecosystem change detection and analysis*

3. RESULTS

Landcover change

With Kappa Coefficient of 89%, the results showed a notable change in land use and landcover. There was a 19% loss of vegetation cover in the area between 2004 and 2020. Vegetation was generally being replaced by built infrastructure and other social amenities. The increase in infrastructure spread from northwest to south east of the study area, which shows the urban sprawl direction. Infrastructure increased from 43% in 2004 to 90% in 2020. Bare land and aquatic components of the ecosystems reduced significantly from 18% to 2% and 12 % to almost a point of extinction, respectively (Figure 3).

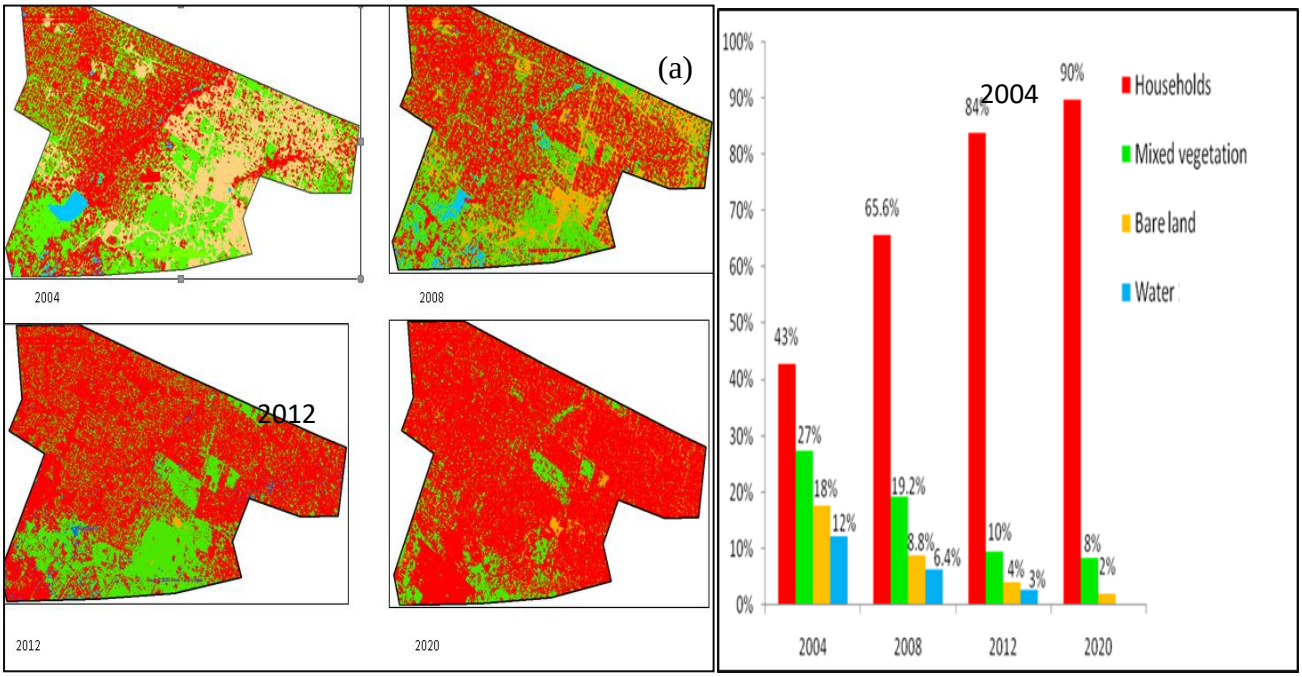

Figure3. *(a) Geospatial and (b) quantitative landcover change in Kalikiliki Area*

Source: Fied Data 2020

The findings further revealed a significant change in all landcover parameters that were assessed. The built infrastructure showed an upward significant change while other variables such as water, vegetation and bare land showed significant downward changes. Change in household and built infrastructure had the highest upward significant change during the period under study (Table 1).

Table1. *Land cover change Variations for the period between 2004 and 2020 for selected Residential Areas in Lusaka District.*

LANDCOVER	COEFFICIENTS OF VARIATIONS (CV*) BETWEEN INITIAL YEAR (2004) AND THE FINAL YEAR (2020) KALIKILIKI
Built Infrastructure	0.50
Vegetation	0.77
Water	1.13

** Any CV value above 0.05 shows that there was a significant change*

Aquatic and Floral ecosystem change

Respondents were asked to indicate whether they had noted change in ecosystems or not. More than 90% of the respondents indicated that they had noted change in aquatic and floral ecosystems of Kalikiliki. *"Kudala Mitengo yenze yambiri, manje apa bantu ba ndalama bajuba chabe mitengo pomangila manyumba" Benangu ba manga na mumanzi,penze manzi apa yambiri, but apa kulibiletu, kaya mwandi"* This field narrative literary described the ruthless cutting of trees for construction of houses and that, some people also went as far as constructing in watery environment such that, water bodies have since disappeared. This implies that, they had been observant of the ongoing changes although they could potentially not attribute them to their own course of action, but rather pushed the blame outwards (Table 2).

Table2. *Participants' responses on Changes in Aquatic and Floral Ecosystems*

Residential Area	Respondents' observations of changes in Aquatic and floral Ecosystem			
	Observed change		Observed no change	
	Frequency	%	Frequency	%
Kalikiliki	197	91	20	9

Source: Field Data 2020

Drivers of Ecosystem Change in Kalikiliki Area

The drivers of ecosystem change were multifaceted and classified into two main categories namely, economic and social drivers with high demand for settlement, 55%, being the leading cause under the social dimension. Generally, residential development and social amenities constructions were principally the most cited drivers of change in the ecosystems.

Table3. *Drivers of Ecosystem Change*

	Frequency of responses	
	Kalikiliki	**Total**
Drivers of change in ecosystems	**Frequency**	**%**
Road construction	28	13
Residential households	118	55
Social and business amenities	71	32
TOTAL	**217**	**100**

Source: Field Data 2020

Ecosystems Governance

The study explored governance issue around the management of ecosystem and found that it was highly leaning on the government institutions (59%). This inherently points to lack of effective participation on the part of the community possibly due to lack of understanding of how they could be part of general environmental governance process. Some NGOs also played a role in ecosystem sustainability although these were also potentially doing it because of some funding they initially received and, not out of environmental consciousness. Responses also indicated that participation in environmental governance by individuals was low 15% while participation by collective actions of community members was the lowest with 5%. The scenario shows that, it was none of the community's business to engage in ecosystem governance, but the government (Figure 4).

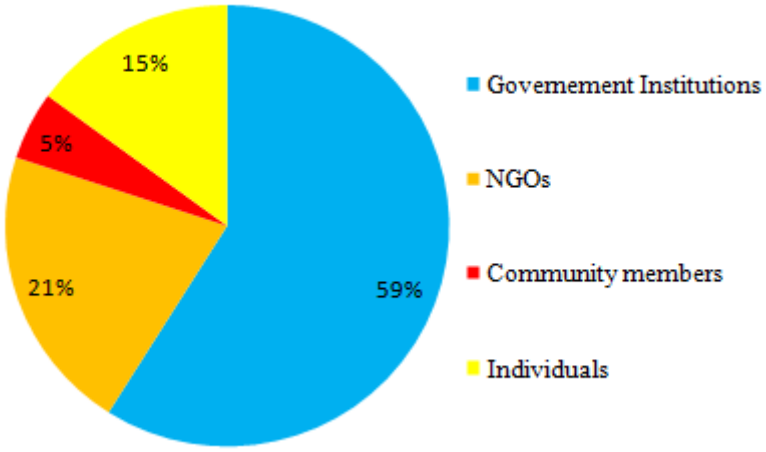

Figure4. *Entities involved in ecosystem governance*

Source: Field data 2020

Existing Environmental Education Activities for ecosystem management

Some Environmental Education activities such as environmental clubs, tree planting and water conserving activities were rated according to their performance on ecosystem management. Although these could have been useful tools, Table 4 shows that they were not effectively used as their use was predominantly average or below average. Environmental clubs and water conservation activities were rated at average in terms of achieving ecosystem sustainability of floral and aquatic while tree planting exercises were rated low and average for floral and aquatic sustainability, respectively. With

such a scenario as shown in Table 4, behavioural change for environmental sustainability as well as ecosystem management could not be attained.

Table4. *Ranking of Environmental Education Activities for ecosystem management*

Activities	Ecosystem	Ranking of the impact of different Environmental Education related Practices for ecosystems conservation				Standard Deviation (Smallest values=most influential)			Interpretation of standard deviation
		Low (1)	Average (2)	High (3)	Mean Rank	Low	Average	High	
Environmental clubs	Vegetation	9	4	21	2.35	0.95	**0.25**	0.46	Average
	Aquatic	9	13	0	1.6	0.42	**0.28**	0.46	Average
Promotion of tree planting	Vegetation	26	4	0	1.13	**0.09**	0.62	1.32	Low
	Aquatic	17	4	9	1.73	0.52	**0.19**	0.90	Average
Water conservation activities	Vegetation	0	4	0	2	0.71	**0.00**	0.71	Average
	Aquatic	0	34	0	2	0.71	**0.00**	0.71	Average

Source: Field Data 2020

4. DISCUSSION

The study noted with great concern on the rate at which settlements were increasing to the detriment of equilibrium of ecosystems in the areas. This was evidenced by tremendous increase in spatial coverage of households from 43% in 2004 to 90% in 2020. Conversely, land covered by vegetation, bare land and water bodies reduced tremendously as they were being taken up by the ever-increasing human settlements. Increase in households implied demand on water resources as well as land for settlements. Therefore, it can be argued that vegetative landcover change in Kalikiliki was as a result of demand for construction of households and other built infrastructure. This phenomenon was also noted in a study conducted by [26] who observed that urbanization was one of the reasons of dwindling total water availability in China's well-urbanized places. They further noted that as more and more houses were being built, water bodies reduce due to urbanization generating the increase of urban water demand for expansion of urban water users and the growth of water consumption per urban resident. In their study on landuse-landcover change of Lusaka District [27]also noted that the water bodies that occupied 174.42 Ha in 1995 had decreased to 64.62 Ha in 2005 and a further decrease to 24.72 Ha in 2015. According to [24], the decrease of the water bodies was attributed mainly to land reclamation due to high demand for residential and commercial space in the district of Lusaka. The current study shows that vegetative and aquatic landcover had continued undergoing change due to built infrastructure. [28] reports that, changes in floral ecosystem had significantly contributed to loss of water accessibility thereby depriving the local communities in southern Zambia of the most desired aquatic goods and services. This scenario is worse off when it happens in peri-urban areas where people are densely clustered together forcing them into ecological traps that they can neither reverse nor escape. Synthesizing together all emerging perspectives, the study held the perspective that, such unsustainable loss of floral and aquatic landcover were a product of under-utilization of environmental education activities.

According to [29 p.56], "Environmental Education developed from the concern that human development was having profoundly damaging effects on the natural environment and its primary aim is the protection and conservation of the environment including natural habitats and ecosystems." The current study suggests that promoting environmental education activities could drastically improve ecosystem sustainability in the area. Moreover, environmental education would also enhance community participation in ecosystem governance unlike the scenario where only the government was driving the processes. This is in agreement with [30] who stated that education is an essential tool for achieving sustainability and plays an important role to solve those problems. Environmental education and climate training is a crucial tool in preserving the environment. Training increases one's ability to acquire, decode and comprehend information and the effects on learning and changes in behaviour.

5. Conclusion and Recommendations

The study concluded that there was a significant change in Floral and aquatic ecosystems as exemplified in the landcover change and these changes were mainly due to unprecedented increase in human settlements. All areas were found to only have had less than 10% of floral and aquatic ecosystems cover with much of the original natural ecosystems taken up by human settlements and infrastructure construction. The unprecedented depletion of floral and aquatic natural covers signified loss in anticipated ecosystem goods and services and also signals how poorly educated residents were about the wellbeing of the environment. The current study suggests an effective promotion of environmental education activities in order to drastically improve ecosystem sustainability in the area. With government being the major entity in charge of ecosystem management, this study recommends that government entities in charge of ecosystem management should increase environmentally educated officers so that EE activities that promote ecosystem sustainability are enhanced. As it stands, government is a major stakeholder in ecosystem management yet, ecosystem loss is very high in the area with no notable activities to improve the situation. This could be attributed to negligence for implementation of environmental education as people were not able to link their actions to the changes they observed. Moreover, the study recommends progressive transformation of residential areas into eco-peri-urban areas to offset some of the irreversible damages caused by the ever expanding residential areas.

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