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MAPPING THE EVOLUTION OF URBAN WETLAND SERVICES IN NKOLBISSON, CAMEROON, A REMOTE SENSING-GIS APPROACH.

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ABSTRACT

Urban wetlands management has been challenging due to the impact of rapid urbanisation, obliging low-income urban dwellers to settle in low-cost areas such as wetlands, leading to its loss and degradation thus difficult to identify its boundaries. This study has as objectives to determine the spatial distribution and the evolution of urban wetlands within the Nkolbisson zone from 2007-2017, using a remote sensing and GIS based approach. An Advanced Space borne Thermal Emission and Reflection DEM was reclassified and associated with the red edge criteria on a 2010 Spot image, followed by an object based digitising on the images obtained from Google earth to demarcate the wetland. A diachronic study was done on the images and the following results obtained. Wetlands covered a total surface area of 1200 hectares out of the 3500 hectares of the study area making 34.5%. A total of 8 wetland types were identified notably: riparian vegetation, dense vegetation, herbaceous wetland, open water, woody wetland, degraded wetland, farmland and build up the area. A total of 5 classes were identified notably farmland, built-up area, bare soils, water body and vegetation. This gave a spatial variation of 18.94 % built-up area, water body -0.13 farmland 27.43 vegetation -29.94 and bare soil -15.73 from 2007 to 2017

Keywords: *Urban wetland, services, Remote sensing, GIS, Nkolbisson, Yaounde, Cameroon.*

I. INTRODUCTION

Wetlands, once known as wasteland (Kota, 2016), are now one of the most solicited natural resources as far as human subsistence biodiversity conservation and climate change mitigation, are concerned (Dinsa et al, 2019). They are amongst one of the numerous ecosystems which are transition zone between aquatic and terrestrial organisms. Wetland resources are one of those resources facing challenges from climatic variation, (Kelvin, 2009) as well as anthropogenic activities due to the rapid urbanisation in urban area giving rise to urban wetlands. These wetlands have become difficult to delimit due to the encroachment of urban areas into the wetlands be it for agriculture or settlement. There is, therefore, the need for its delimitation and the effective monitoring of the evolution of these urban wetlands. This research paper has as objectives; to determine the spatial distribution and evolution of urban wetlands within Nkolbisson and its environs using high resolution satellite images.

Urban wetlands have been described by resolution X. 27 Nº 3 as those wetlands that fall within the limits of urban area (Ramsar Chengwon, 2008) and went ahead to express concern on the loss and degradation of urban wetlands due to population encroachment. Urban wetlands have faced a lot of challenges as far as their management and sustainable use is concerned. More emphasises was made on the 2018 Wetland day celebrated on February 2 under the team wetland *for a sustainable urban future*. This is the thematic problem of this study as is the case of all urban wetlands in Cameroon which we seek to assess in the case example of Nkolbisson Zone of Yaounde. This study was aimed at raising awareness on Importance of urban wetlands ecosystem to the natural environment and to its rapidly growing urban population while taking in to consideration the need for a sustainable cities. The importance of these wetlands were elaborated as follows

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The importance of urban wetlands

Urban wetlands are generally known for their multiple function. This is one of the major reasons why a lot of importance have been attributed to the management conservation and monitoring of wetlands, especially in urban areas. Wetlands functions has been classified under ecological social and economic functions according to by Zedler, 2003, Swanepoel et al, 2007, the Ramsar briefing notes of 2015, Stockholm Environment Institute working Paper 2012/08 as follows;

Wetlands serve in nutrient and toxin retention. The input of excess nutrients such chemical fertilizers and pesticides used in agriculture, to water bodies, stimulates excessive algae and plants, this lead to a high-level decomposition of organic matter in the water causing oxygen shortages and death bottom (Mfopou, et al., 2017). This state is known as eutrophication.

Wetlands play a very important role in flood mitigation and erosion control (Tiafack et al 2017). This is realised by the retention of rainwater during heavy storms and releases it gradually at a slower rate. This is generally known as the sponging effects of wetlands.

Wetlands are well known for the major role they play in water recharge as they mostly serve as the catchment area for most watercourses. This is because water stays long enough in the vegetation to maximise infiltration. This retained water if in excess will be discharged in the form of springs streams and rivers. Thus serving as a source of water for most of the population living around during dry periods (Garth et al. 1998).

Wetlands just like forest ecosystem are very important for climate change mitigation and adaptation (IUCN, 2007). Wetlands are considered as carbon sink as its vegetation converts atmospheric carbon to plant biomass through the process of photosynthesis. Due to the low rate of decomposition of biomass, lots of carbon is stored in them thus reducing the quantity of atmospheric carbon. In terms of adaptation, they provide opportunities for adaptation to extreme conditions and source of livelihood. Wetlands are a transition zone between terrestrial and aquatic organisms, this makes the rich in biodiversity as they serves as habitat for most organisms especially at a critical stage of their life. They also serves as habitat for endangered species and are generally referred to as genetic banks for biodiversity (IUCN 2003, RIS, 2008).

Nowadays, wetlands have been considered one of the most important sites as far as ecological research and education is concerned. They are often used to study long term global environmental status and trends. Research areas within wetlands include ecology, fisheries, hydro-geology, pollution control, medicine, agriculture, climate change, Entomology Natural disasters, (Tiafack et al 2017), (Kamdem et al 2012), (Mfopou, et al., 2017).

With all these functions, wetlands serve as a point of attraction to the population thus too much pressure on its services. The rapid rate of urbanisation around this wetlands leads to the intensification of activities such as agriculture and construction. This serious effects on the wetlands, such as siltation, eutrophication and reduction, at the same time there is the increasing need for land thus serious land reclamation going at an alarming rate on the wetland (Nkwemo et al, 2018).

An insight into urban wetlands in Yaounde

Yaounde often described as the town of Seven Hills is blessed with a large number of wetlands which corresponds to valleys often occupied by rivers, streams or stagnant waters (Ngala et al, 2015). These wetlands include the Mfoundi basin area, olezoa, Simbock and the Nkolbisson among others. The rapid rate of urbanisation in Yaounde has led to the indiscriminate occupation of these wetlands generally known as "*elobies*". This is as a result of rural exodus and natural population growth. The unplanned occupation of these wetlands has had devastating effects on the ecosystem as well as the wellbeing of its occupants, leading to the phenomenon of urban wetlands. Urban wetlands have been described by resolution 27, N° 3 of the 10th meeting of the conference of the parties to the convention of wetlands as those wetlands that fall within the limits of an urban area (Chengwon, 2008). They went ahead to express concern on the loss and degradation of urban wetlands due to population encroachment. This rapid and uncontrolled urbanisation has made it difficult of identifying the limits of these urban wetlands.

Yaounde in recent times have witnessed a rapid rate of urbanisation resulting from population growth and rural-urban migration. The population of Yaounde increased from 458 426 in 1976 to 19,07479 in 2005, with most of its population living in urban areas (BUCREP, 2005) This phenomenon has caused shortage of land within the city centre leading to the occupation of wetlands generally known as "*elobis"* be it for construction, fishing or agricultural purposes. The unplanned occupation of these wetlands has had devastating effects on the ecosystem as well as the wellbeing of its occupants. The case of Yaounde VII was chosen as it is known to have a diverse array of wetlands which serves as habitat, especially to the low income earners for construction and other activities. This action has led to a huge number of consequences notably, siltation, eutrophication, encroachment and flooding. There is also an advance rate of biodiversity loss thus the urgent need for the identification of these wetlands for its sustainable management.

The birth of the Ramsar convention in 1971 which came in to force in 1975, made stakeholders develop more interest in wetlands and hence the need for its identification. Before 1986, none of the agencies notably the U.S. Army Corps of Engineers, the Environmental Protection Agency (William & Jr, 1995), the Natural Resources Conservation Service, had adopted a standard technical manual for the delineation of wetlands; They rather used local national aids, proposed manuals and guidance documents as working documents. This trend changed in the 80^s when each agency formulated its manual which was later harmonised in 1986. This manual was aimed at applying the definition of wetlands and their respective characteristics for delineation. A review made by Meng et al (2017) on the evolution wetland studies from 1964-2015 shows the rapid increase in the use of remote sensing technologies from 1991. In this study, the authors identified the effectiveness of Landsat TM and Modis in the mapping and monitoring of wetlands which are coarse and medium-resolution images respectively. This was found to have a lot of limitations as it generalises a lot of wetland classes thus the need for a high-resolution image that will permit the delineation of these wetlands at a low cost. This study will seek to answer the question of; can the use of a high-resolution satellite image, ensure the effective delimitation, its state and the evolution of urban wetland within Nkolbisson and its environs.

The case of Nkolbisson and its environs was chosen as it is known to have a diverse array of wetlands which serves as habitat, especially to the low class income earners for construction and other activities. This is because of its hilly nature with its corresponding valleys that are mostly humid. Yaounde VII has been rapidly and indiscriminately urbanised, leading to the occupation of river beds with or without reclamation for construction purposes and agriculture. This action has led to a huge number of consequences notably, siltation, eutrophication, encroachment and flooding consequently the loss and degradation of these wetlands. There is also an advance rate of biodiversity loss hence the urgent need for the identification and monitoring of these wetlands for sustainability.

II. METHOD AND MATERIAL

Situated south of the Centre Region and in the Mfoundi Division, Yaounde VII covers a total surface area of 35.34Km^2 (INC, 2018) with a population estimate of 97,997 inhabitants giving a population density of 2,775inhab/km^2 (BUCREP, 2005). About 95% of the surface area is urbanised (fig 1). This figure must have increased since the 2005 census. Yaounde experiences an Equatorial Guinean climate with regular and abundant precipitations of 1,600 mm/year (Ngala et al, 2015), an average annual temperature of 23°C. It is characterised by four seasons, notably two dry seasons from July to August, December to February and two rainy seasons from March to June, September to November.

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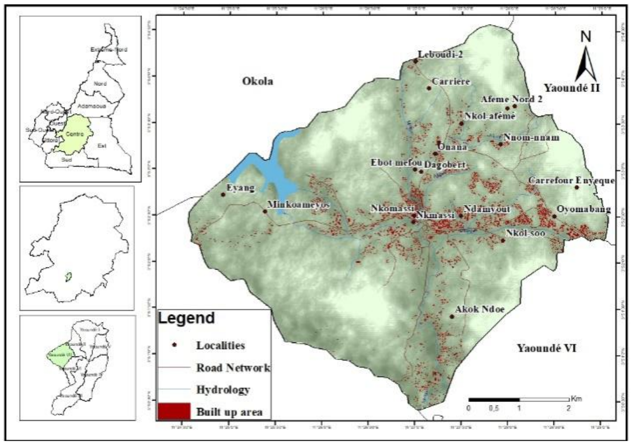

Figure1 Location map of Nkolbisson and its environs in the Yaounde VII subdivision of the Centre Region Cameroon

Material

For this study, both open source and commercialised data sets were used (Tab 2)

Table 2: Characteristics of data used

Image	Year	Resolution	Source
Quick Bird	2007	2.5m	Google Earth
Quick Bird	2017	2.5m	Google Earth
Spot	2010	10m	Commercial
ASTER DEM	2009	30m	Open-source
Administrative boundaries	2016		National Institute of Cartography
Localities	2016		National Institute of Cartography
Road network	2017		Quick bird 2017 Image
Hydrology	2017		Satellite image and the National Institute of Cartography

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Methods

To realise this study, data processing was done using the hydrogeomorphic characteristics of Yaounde VII and remote sensing, to determine the state of evolution of wetlands within the study area between 2007 and 2017, remote sensing, cartographic realisations and statistical interpretation were also carried out.

An ASTER (Advanced Spaceborne Thermal Emission and Reflection) Image was used to delineate the drainage basin, the flow direction as well as calculated to define the accumulation flow and creating a stream network for the wetland. These ASTER Digital Elevation Model (DEM) was later reclassified into four different classes as follows 621m-721m, 722m-765m, 766m-829m, 830m-978m above sea level with 621m-721m above sea level, corresponding to low-lying area conforming with the wetlands. This classification was associated with the red edge analyses (Mahdavi et al 2017) from the spot 2010 image to delimit the urban wetlands of Yaounde VII by the bright red nature of wetland vegetation on the false colour composite which uses the red (0.79-0.89 mm) and near-infrared (0.79-0.89mm) bands. These bands are very effective for vegetation data extraction. A 2.5m resolution satellite image was obtained from Google Earth for 2007 and 2017 and the images georeferenced using the geographic coordinate system and the world geodetic system 1984 (GCS_WGS_1984). The 2017 image was used to identify the different types of wetlands in the study area using an onscreen digitising method by identifying objects, its state and limits of the different wetland classes. A supervised image classification using the Mahalanobis algorithm on Erdas imagine were carried out on the 2007 and 2017, 2.5m resolution Google Earth image to determine the Land use /the Land cover of Yaounde VII. The results obtained from the diachronic study of the two images were compared and the evolution of the wetland from 2007 and 2017 determined. The interpretation was done based on onscreen analyses, literature review, field verification and results represented in the form of maps graphs and charts.

III. RESULT & DISCUSSION.

Results

This study revealed that wetlands occupy about 35% of the total surface area of Yaounde VII with 8 wetlands classes and 5 different land uses on the wetlands (fig 2)

a) The State of Urban Wetland in Nkolbisson and its environs

The results obtained from the analyses and field verification, identified wetlands to fall between altitudes 621m-721m above sea level with bright red edge vegetation. The wetlands within Nkolbisson and its environs cover a total surface area of 1200 hectares out of the 3500 hectares (fig 2) covered by the Yaounde VII urban area which is very significant consequently raising a need for its proper management and monitoring.

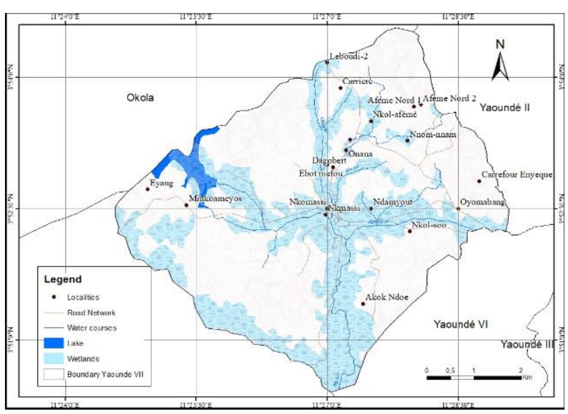

Figure 2 Show the spatial distribution of Urban Wetland within Nkolbisson and its environs obtained from a high resolution google earth image of 2017 and SPOT 2010

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A total of 8 wetland classes were identified notably; Build up area, riparian vegetation, dense vegetation, herbaceous wetland, woody wetland open water, degraded wetland and farmland(fig.3), which corresponds to the wetland areas drained by eucalyptus trees to reduce soil moisture.

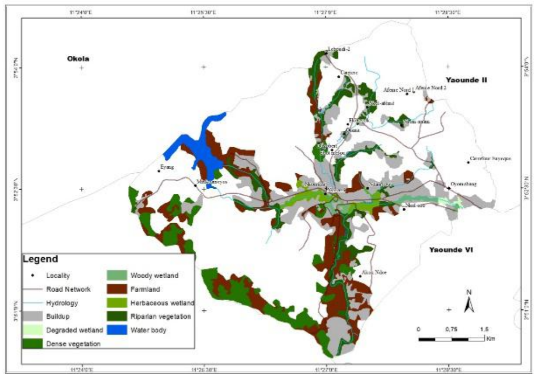

Figure 3 Showing the present state of urban wetlands within Nkolbisson and its environs with a total of 8 wetland classes identified

These different classes of wetland occupied varying percentage of the wetlands with built-up area and farmland occupying the highest percentages of 33% and 26% respectively (fig 4.) This strongly indicates the presence of human activities on the wetlands of Yaounde VII. This is followed by dense vegetation which is at 16 % value of 0.5% of the wetland completely degraded. Given the high rate of human activity (fig 5.) On the wetland, there is a need for the monitoring of these wetlands for a sustainable urban wetland future.

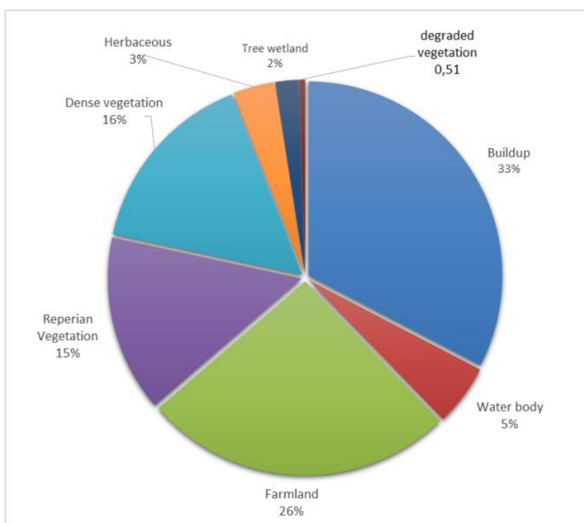

Figure 4: Percentage occupied by wetland classes with farmland and build-up area occupying the greater percentage of the wetland.

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Figure 5: The Different classes of wetlands within Nkolbission and its environ, photo 1 showing woody wetlands, 2 build-up area, 3 and Herbaceous wetland, 5 degraded wetland and 6 farmland. This shows the influence of anthropogenic actions on the wetland.

b) Evolution of urban Wetlands in Nkolbisson.

The rapid rate of urbanisation of Yaounde VII has led to the indiscriminate occupation of its wetland, leading to visible changes over time. A diachronic study was carried out on the two images, with an interval of 10 years within Nkolbisson area to get the evolution of wetlands. The land-use land cover map was obtained, with and the following classes identified; bare soils, build up area, farmland, vegetation and water body (fig 6). This revealed a variation in the different classes from 2007-2017 where there was an increase in farmland from 2007 to 2017, from 15.72% to 29.83%. This trend shows a rapid increase in urban agriculture as urbanisation increases which can be seen to have increased from 12.72% to 29.94%. Following this rapid rate of urbanisation and the expansion of urban agriculture, the total vegetation surface decreased from 67% in 2007 to 8.51% in 2017. Also, the total area of bare soil which included the rock outcrop increased from 2.90% to 29.51% in 2017 while the water bodies decreased from 3.61% to 2.03% (fig 7). This shows some dynamics in the uses of urban space and thus urban wetlands with the natural environment giving way to settlement and agriculture. This phenomenon has an impact on the natural environment consequently there is a need for the sustainable management of the environment as most of the wetlands have been used for agricultural space and settlement.

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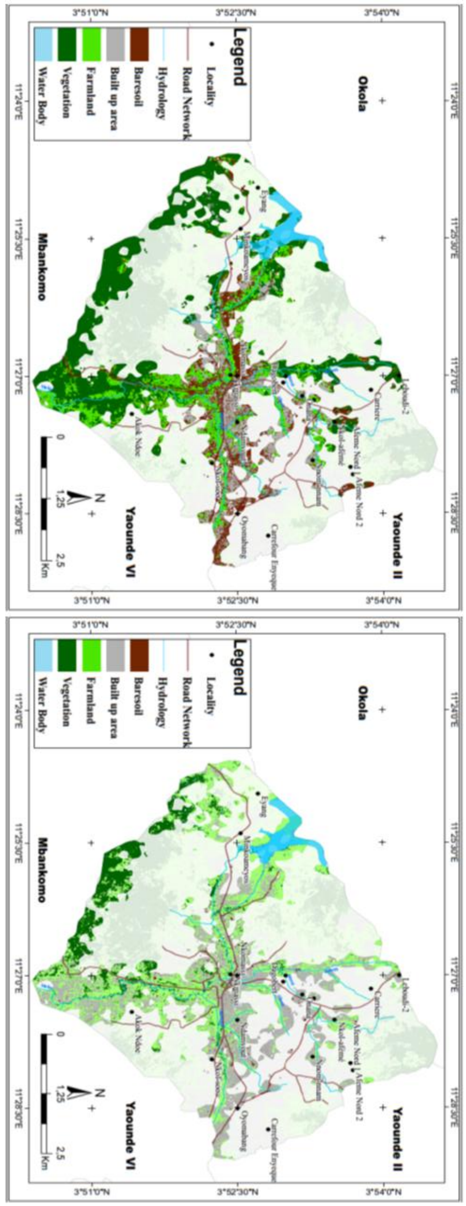

Figure 6 Evolution of urban wetlands within Nkolbisson and its environs

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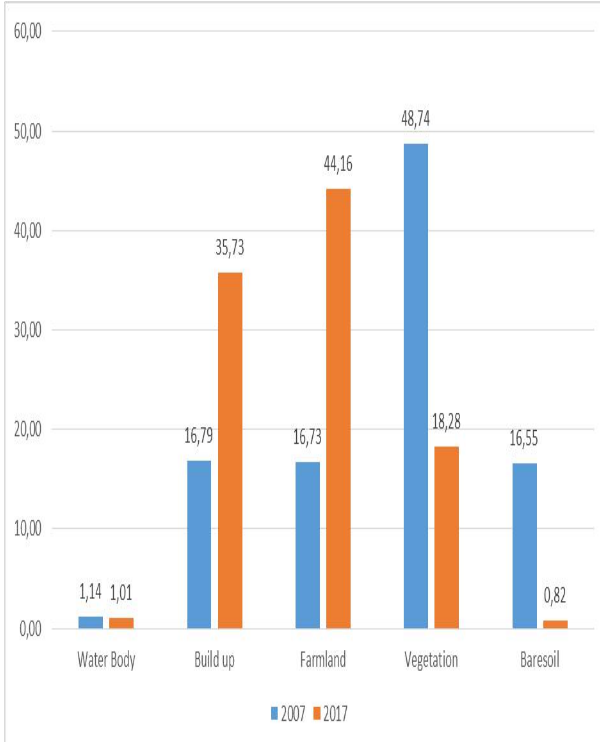

Figure 7: Land use land cover variation from 2007-2017

IV. DISCUSSION

Urban wetland management has been a major challenge to climate change, natural resource management and environmental protection. This was seen to be important as it figured as the theme for the 2017 wetland day which was *«wetlands for a sustainable urban future*". This has been as a result of the rapid rate of urbanisation in urban areas leading to its loss and degradation.

Urban wetland identification and monitoring have been a problem due to the serious encroachment of urbanisation and human activities into these wetlands. This study use of free and high-resolution satellite images obtained from google earth to demarcate urban wetlands with the using remote sensing technics and the hydrogeomorphic characteristics of Nkolbisson and its environs. The application of remote sensing on wetlands studies has been seen to have increased from 1991 to 2015 as reviewed by (Meng et al 2017). This method was found to be very effective as it does not necessarily take into consideration only the surface features like vegetation which has been greatly affected by anthropogenic activities which came as a result of the rapid and uncontrolled urbanisation around the Nkolbisson area. This method was also used by Ozesmi et al, 2002 where they used multispectral remote sensing alongside relief and hydrology, where the difference is the cost of obtaining high satellite images which are generally very expensive. They also went ahead to include the soil factor for more precision which was not considered in this study. This method was confirmed to be very effective contrary to that used by the US army corps of Engineers which was also found to be very effective but without the application of Remote Sensing. For this study, a high-resolution satellite image was used to identify wetland. We identified wetlands to cover a total surface area of 1200 hectares out of the 3500 hectares of Yaounde VII. A total of classes where 8 classes were identified and a diachronic study carried out to get the state and evolution of these urban wetlands as used by Munyatti 2007 and Dzeidze 2008, from the above results. We also observe that the major cause of wetland degradation and loss around Nkolbisson and its environs is centred on agriculture and settlement which has indiscriminately occupied about 59% of the wetlands. Which is also observed by (Balgah et al, 2016)and by (Bopda et al, 2010) in Bamenda and Yaounde respectively where they observed an increase in urban farming and land use dynamics on wetlands.

This continues conversion of wetlands confirmed by Swanepoel et al, 2007 Ndeidze 2010. This phenomenon needs to be properly handled to ensure the sustainable management of wetlands to meet up with the objectives of the Ramsar convention of identifying and managing urban wetlands for a sustainable urban future with the help of remote sensing. A significant variation was observed from the diachronic study carried out between 2007 and 2017 with a great reduction in the vegetation by -29.94% giving way to built-up area and farmland for agriculture which increased by 18.94% and 27.43% respectively this clearly show some loss and degradation as observed by (Dzeidze et al 2010, Yaw and Merem, 2006, Huang et al 2018). The effects of the rapidly increasing population of Nkolbisson and its environs on the wetland if not checked will lead to serious damage to the natural ecology thus drastic effects on the genetic bank of the wetlands. This study had as challenge obtaining high resolution satellite images as well as soil data as a parameter for wetland identification. This could be done while including this criterial.

V. CONCLUSION

Urban wetlands are one of the most sensitive ecosystems which are easily affected by human action. They serve as habitats to many living organisms, especially at the early stage of their life cycles. These wetlands have been said to store twice as much carbon as stored in the forest ecosystem thus very crucial for climate change. With the rapid rate of urbanisation, there is the encroachment of human activities into these sensitive sites leading to its loss and degradation thus the need to identify and monitor these urban wetlands. This study has as objectives to determine the spatial distribution and the evolution of urban wetlands within Nkolbisson zone and its environs using remote sensing. Wetlands were found to cover a total surface area of 12.11 Km^2 out of the 35.34Km^2 of Yaounde VII sub-division making up 34.5% of the total surface area. A total of 8 wetland types were identified notably: riparian vegetation, dense vegetation, herbaceous wetland, open water, woody wetland, degraded wetland, farmland and built up the area. A Diachronic study was carried out on the two images notably 2007 and 2017. A total of 5 classes were identified notably farmland, build-up area, bare soils, water body and vegetation with the maximum variation recorded on vegetation with a decrease of -29.94 and a drastic increase on farmland as the rate of agriculture intensified to feed the rapidly increasing population. This has led to the drastic loose of these urban wetlands to built-up area and farmland with 0.5% showing degraded vegetation, due to siltation and household waste disposal. This shows some weaknesses in the laws, management policies and methodology put in place. With this serious impact of urbanisation on this wetland, there is the need for effective use of remote sensing and geographical information systems for the management and monitoring of these wetlands. This has been seen to be very effective, as it is cost and time effective especially with the existence of open-sourced data, even though with some degree of expertise required.

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