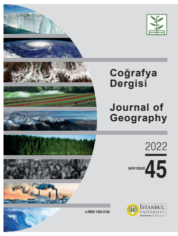

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Wetland Dynamics, Trends and Environmental Implications: Comparative Study in Bamenda II and III Municipalities, North West Region, Cameroon

Sulak Alan Dinamikleri, Eğilimleri ve Çevresel Etkileri: Kamerun'da Bamenda II ve III Belediyeleri için Karşılaştırmalı Bir Çalışma

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ABSTRACT
Despite the loss of wetlands at varying degrees around the world, there is insufficient empirical information to elucidate the trajectories in wetland dynamics, especially in developing countries. As such, this study examines the trends in wetlands dynamics in the Bamenda II and III municipalities of Cameroon, analyzes the environmental implications, and investigates some adaptation and mitigation strategies to wetlands mutation seen in these areas. Data was collected from institutions and online sources, and supported by interviews, field surveys, and the administration of a questionnaire to 164 respondents. Satellite images were downloaded from USGS for 1980, 2000 and 2020. These were corrected, and processed in ArcGIS 10.3 using the interactive supervised classification tool and converted from raster to vector, permitting the production of LULC maps and automatic calculation of changes in wetland areas. Frequency and descriptive analyses was done in SPSS version 20 and Microsoft Excel 2016. The results indicate that wetlands decreased from 33.91 km^2 to 28.58 km^2 in Bamenda II and from 13.58 km^2 to 9.09 km^2 in Bamenda III from 1980 to 2020. This retreat of wetlands is associated with biodiversity loss, pollution and flooding, which are the basis for engineering and non-engineering adaptation measures.
Keywords: Wetlands dynamics, degradation, Bamenda II and III municipalities

ÖZ
Sulak alanlar dünya çapında değişen oranlarda kaybedilmektedir. Ancak özellikle gelişmekte olan ülkelerde ise sulak alan dinamiklerinin durumunu açıklayan yetersiz ampirik bilgiler bulunmaktadır. Bu nedenle, bu çalışma Bamenda II ve III belediyelerinde sulak alan dinamiklerindeki eğilimi incelemiş, çevresel etkileri analiz etmiş ve sulak alan mutasyonuna uyum ve azaltma stratejilerini araştırmıştır. Veriler kurumlardan ve çevrimiçi kaynaklardan elde edilmiş, görüşmeler, saha araştırması ve 164 anketin yönetimi ile desteklenmiştir. Uydu görüntüleri 1980, 2000 ve 2020 için USGS'den indirildi. Bunlar düzeltildi ve etkileşimli denetimli sınıflandırma kullanılarak ArcGIS 10.3'te işlenmiş ve LULC haritalarının üretilmesine ve sulak alanlardaki değişikliklerin otomatik hesaplanmasına izin vermek için rasterden vektöre dönüştürülmüştür. Frekans ve tanımlayıcı analizler SPSS sürüm 20 ve Microsoft excel 2016'da yapılmıştır. Sonuçlar, 1980'den 2020'ye Sulak Alanların Bamenda II'de 33.91 km^2'den 28.58 km^2'ye ve Bamenda III'te 13.58 km^2'den 9.09 km^2'ye düştüğünü göstermektedir. Bu dinamikler, mühendislik ve mühendislik dışı uyum önlemlerinin temeli olan biyolojik çeşitlilik kaybı, kirlilik ve sel ile ilişkilendirilmiştir. Sulak alan dinamikleri aynı döngüyü takip etse de, sulak alan kaybı eğrisini kırmak için geliştirilen stratejiler bu değişimi farklı oranlarda yapabilmektedirler.
Anahtar kelimeler: Sulak alan dinamikleri, bozulma, Bamenda II ve III belediyeleri

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1. INTRODUCTION

Prioritizing action to reverse the curve of global loss of fresh water resources is pertinent (Tickner *et al*, 2020). Better conservation, restoration and management of wetland ecosystems will produce a carbon cycle that contributes to greater balance in the earth's climate (Mrema, 2020). Wetlands as ecosystems are especially vulnerable to change, which is expected to be more pronounced in the wake of climate change as an effect of wetland alteration (Kevin, 2009). Wetlands become sources of carbon dioxide emission into the atmosphere as a result of constant drainage, fire, and clearing. Carbon dioxide emissions from drained, burnt and degraded wetlands equate to about 10% of global annual fossil fuel emissions (Australian government, 2019). Thus, the relationship between humans and wetlands exacerbate climate change (United Nations Development Program, 2012).

Monitoring historical wetland dynamics and relating it to land use changes is essential to enhance our understanding of wetland evolution. Fengqin (2020) indicated that the marshy area in the Sanjiang plain decreased drastically at a rate of 53.17%. The quantification of long term wetland degradation by Tangao *et al*, (2019) in the Hangzhou Bay indicated that there was a statistically significant decreasing trend for natural wetlands of about 10km^2 a year on average from 1984 to 2016. Also, the continuous growth and expansion of urban areas led to significant degradation and loss of wetlands in the Tonghu area (Erqi and Yimeng, 2019). In Turkey, the total number of natural wetlands decreased from 1,299 in 1910 to 900 in 2014. This accrued to 21.2% loss of wetlands from 1,376,505 hectares to 1,085,936 (Ataol and Onmuş, 2021) as the Kizilirmak Delta was reshaped by state-led displacement, leading to environmental, infrastructural and demographic transformation of wetlands (Scaramelli, 2018). However, Siyavuş (2021) revealed that land use/land cover changes of the Duzce province of Turkey had no significant change between 1990 and 2000, while significant changes occurred between 2000 and 2018. As such, wetlands registered an 80% increase compared to 1990 owing to the effectiveness of the protection of Lake Efteni and its immediate surroundings in 1992, and the lake surface expansion works adopted in 2014 within the Efteni Lake Wetland Management Plan. On the other hand, 70% of marshes in the Donana region in Spain have been occupied by cultivated systems, leaving 29.5% untransformed or being restored, mainly within the Donana National Park (Zorrilla *et al*, 2013). In the arid and semi-arid regions of Africa, the pressure on wetlands is enormous due to demands for food production. Political instability and inefficient management methods in this area will continue to aggravate the situation for the survival of wetlands up to 2025 (Wolfgang, 2002).

Urban wetlands exhibited significant low taxonomic richness and diversity compared to those in the agricultural or grassland areas of the Front Range region of Colorado (Pieter *et al*, 2013). Consequently, the ecosystem services that are offered by urbanized wetlands are compromised (Lee *et al*, 2006). Urban wetlands are facing severe degradation, culminating in general pollution and a reduction in wetland area. The biodiversity of these wetlands are seriously damaged, with biological invasion leading to the disappearance of native species (Pengfei *et al*, 2018). Due to human activities, the wetlands of the city of Dakar in Senegal reduced rapidly at about 53.58% (Islam *et al*, 2010). The Niger Delta region in Nigeria has likewise suffered many episodes of perennial flooding because of wetland degradation, coupled with the fact that the value of the wetlands was overlooked. Here, wetland pollution was caused by local and illegal refinery, oil bunkering and spillage, and not leaving out non-sanitary disposal of sewage and plastics (Enwere, 2015). Asangwe (2009) noted that coastal wetland hazards are increasingly apparent in the localities of rapid urbanization of Limbe, Tiko and Douala in Cameroon, provoking environmental problems. Also, changes are seen in the peri-urban areas of Bamenda III municipality through the multiplication of land uses, with a significant reduction in agricultural land and a corresponding increase in the built-up area, with an annual change of 52.6%, triggering considerable wetlands invasion (Kimengsi *et al*, 2017).

2. AIMS AND METHODOLOGY

Empirical studies have not sufficiently focused on comparatively examining wetland dynamics, especially in developing countries, thus limiting our capacity to understand the trajectory in wetland degradation spatiotemporally. To this end, this study comparatively examines the trends in wetland dynamics in Bamenda II and III municipalities. It also analyzes the environmental implications of wetlands degradation, as well as investigates the adaptation and mitigation strategies to the repercussions of wetlands mutation in Bamenda II and III. All of this is anchored on the hypothesis that the rate of wetland loss is higher in Bamenda III than in the Bamenda II municipality. This substantiates current discourse as to whether wetland degradation follows the same trajectory or varies.

Secondary data was obtained from online sources, including published articles, books, dissertations and theses relevant to the theme of study. Secondary information from reports and town planning documents on the areas under examination were obtained from the Bamenda City Council. Data from primary sources were obtained from five interviews conducted with administrative officials from key ministerial delegations of Housing and Urban Development, Environment and Nature protection, the City Council and Bamenda II and III Councils. A field survey was also carried out in addition to the administration of a questionnaire to 164 people from the target population around wetlands, using both snowball and purposive sampling techniques. Equally, a base map was acquired from the Geo database of Cameroon, 2018, National Institute of Cartography (NIC) Yaoundé. Landsat 3, 7 and 8 images of the study areas respectively for 1980, 2000 and 2020 were downloaded from the United State Geological Survey (USGS) Earth Explorer as specified on **Table 1**. Cartographic data was also collected from the field using GPS unit to get waypoints of conspicuous wetland mutation sites, to enhance precision of significant wetland conversion hot spots and related features on maps.

To determine change amounts and maps of Land Use Land Cover (LULC), satellite images were preprocessed and processed in ArcGIS 10.3 and Erdas imagine 2014 as illustrated on **Figure 1**. The preprocessing stage was dedicated to radiometric correction of images to convert to reflectance values. Atmospheric effects were removed to determine surface reflectance values which were essential to avoid errors while geometric correction was done for orientation.

The processing stage began with image sub setting to delimit the study area, utilizing shape files, followed by the selection of training sites for supervised classification. This method was chosen in order to obtain more accurate results while still being able to classify the chosen samples. With this, an interactive supervised classification method was preferred as this tool uses the entire band from the selected image layer and accelerates the maximum likelihood classification process. This provided LULC in raster format which was converted into vector, permitting the automatic calculation of the surface area of different LULC classes for the study dates. The LULC in the raster format paved the way for classification accuracy analysis in ArcGIS. With this, where unfavorable analysis results were obtained, it led to the iterative process as seen on **Figure 1**.

To assess the level of success in classification of satellite images, accuracy analysis was done separately for the study years 1980, 2000 and 2020. This was done in ArcGIS 10.3 alongside Google Earth images as reference images, as ground control points could not be obtained due to the insecurity in the study area (sociopolitical crisis). As such, a point shape file was created in ArcGIS by selecting points for each land use class for all the years under observation. Points were selected spatially to cover the classified images to ensure representativeness. Each point was given a unique identifier in relation to its land use land cover class (user values) and saved. This was then opened to check if it matched the reality on the ground according to Google Earth images. This determined whether the user values were correct or wrong, thus providing the producer values. It should be noted that due to the unavailability of Google Earth images for 1980, the downloaded Landsat image was used to identify if its user values were correct or wrong, thus determining its producer values. The user and producer values then provided the necessary data that was used to build the confusion matrix for the study dates (**Table 2**).

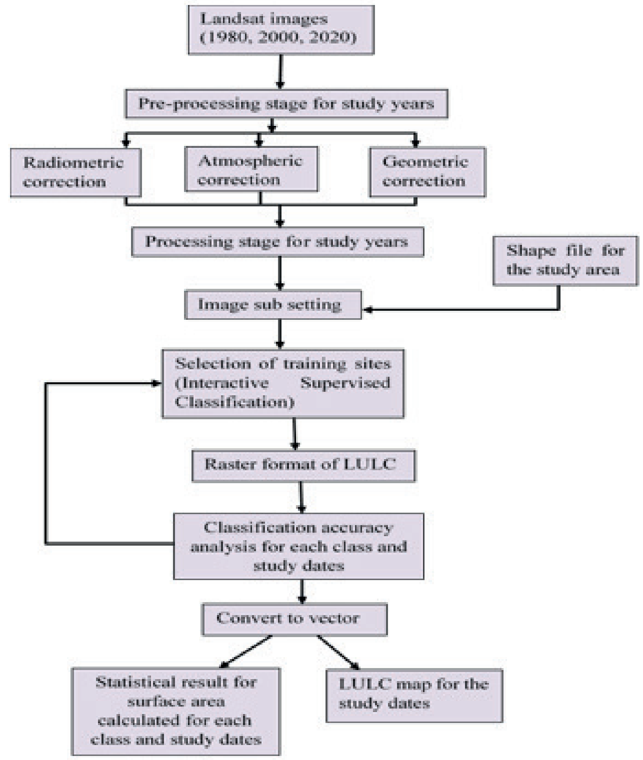

Figure 1: Work flow chart for LULC change determination (Field Survey, 2020).

Table 1: Satellite image data specificities.

S/N	Image date	Satellite sensor	Downloaded date	Spatial resolution (meters)	Band number	Path/row	Cloud cover (%)
1	14/01/1980	Landsat 3 MSS	11/05/2020	80	4	200/56	00
2	07/04/2000	Landsat 7 ETM	12/05/2020	30	7	186/56	12
3	01/01/2020	Landsat 8 OLI/TIRs	13/05/2020	30	11	186/56	6.91

Table 2: Confusion matrix.

	Built up	Farmlands	Other land uses	Wetlands	Total (Users)
1980					
Built up	7	0	0	0	7
farmland	0	7	1	1	9
Other land uses	0	1	4	0	5
Wetlands	0	0	1	8	9
Total (Producers)	7	8	6	9	30
2000					
Built up	9	1	0	0	10
farmland	0	8	1	0	9
Other land uses	0	1	4	0	5
Wetlands	0	1	0	5	6
Total (Producers)	9	11	5	5	30
2020					
Built up	9	1	0	0	10
farmland	0	7	1	0	8
Other land uses	0	1	4	0	5
Wetlands	0	0	1	6	7
Total (Producers)	9	9	6	6	30

With correctly classified pixels aligning diagonally, the overall accuracy and Kappa coefficients were calculated as they are the most robust means of ascertaining the level of accuracy in classification (Lucia *et al*, 2019). This was manually calculated thus;

$$\text{Overall accuracy} = \frac{\text{Total number of correctly classified pixels (diagonal)}}{\text{Total number of reference pixels}} \quad X \quad \frac{100}{1}$$

$$\text{Kappa coefficient} = \frac{(TS \text{ x } TC)-\sum(\text{column total x row total})}{TS^2-\sum(\text{column total - row total})} \quad X \quad \frac{100}{1}$$

Where TS= Total Sample and TC= Total Correct pixels.

Furthermore, the Statistical Package for Social Sciences (SPSS) software version 20 and Microsoft Excel 2016 were used for frequency and descriptive analyses. To elucidate the hypothesis, a mathematical equation was used to attain the rate of wetland change in percentage and in decimal given by the formula;

$$\text{Rate of change} = \frac{\Delta LULC}{\text{Initial surface area}} \text{ X } \frac{100}{1}$$

Where, Δ= change and LULC = Land Use and Land Cover. The change in the various categories of land use and land cover was calculated thus; ΔLULC (km^2) = New surface area (km^2) – old surface area (km^2). The change in LULC is therefore divided by the initial surface area to produce the rate of change in decimal. To attain the rate of change in percentage, the rate of Δ in decimal is multiplied by 100. All these made use of statistics from Landsat 3 and 8 images of the study areas for 1980 and 2020, computed in Excel.

Bamenda II and III Sub Divisions are located between latitude 5° 56'0" and 6° 4' 0" North, and longitude 10° 4' 0" and 10° 12' 0" East. They are bounded by Bafut in the north, Bamenda I and Santa to the south, Tubah to the east, and Bali Sub Division and Momo division to the west (**Figure 2**).

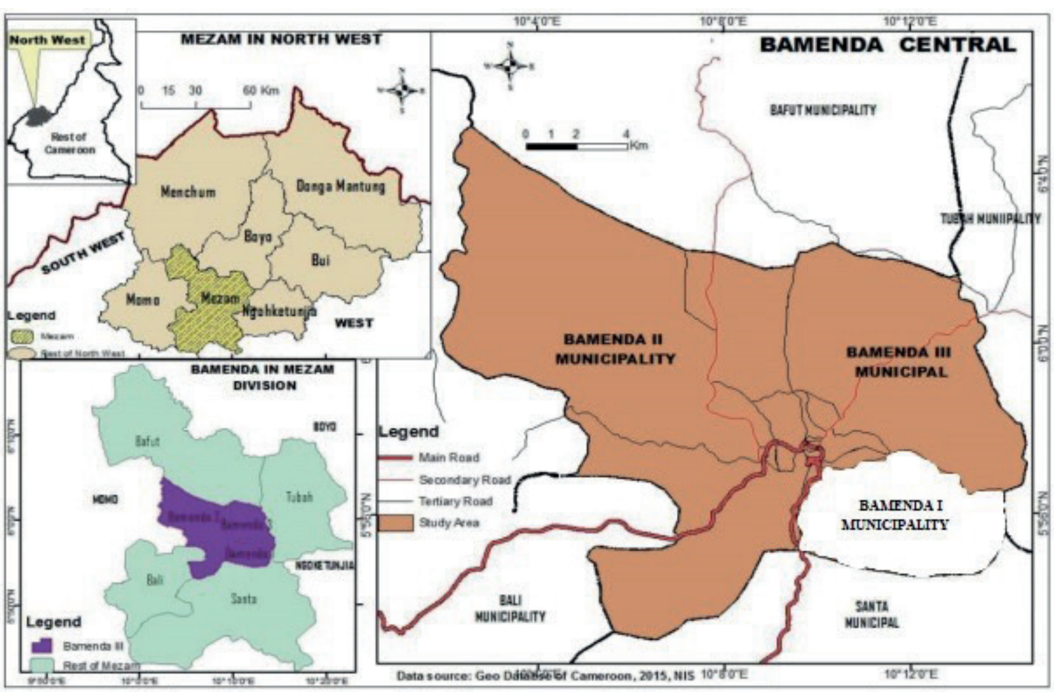

Figure 2: Location of Bamenda II and III Sub Divisions (Adapted from Fombe and Acha, 2020).

The Bamenda II municipality is made up of four villages including Mankon, Mbatu, Nsongwa and Chomba, while the Bamenda III municipality consists of the two villages of Nkwen and Ndzah. These sub divisions cover a greater proportion of the Bamenda urban space which lies largely at the foot of the Bamenda escarpment.

3. FINDINGS

A. Accuracy assessment

Accuracy analysis based on the confusion matrix (**Table 2**) demonstrates that images were processed and LULC maps were produced at an overall accuracy of above 86% for all the study dates. This indicates the images were classified correctly. The results of accuracy assessment are summarily presented in **Table 3**.

Table 3: Summary of accuracy analyses.

Study date	Overall accuracy (%)	Kappa coefficient
1980	86.67	0.87
2000	86.67	0.82
2020	90	0.86

As seen in **Table 3**, the images were classified as demonstrated by the Kappa coefficient for each study year as being 0.82 and above. This implies that, the classification performed well, providing a significantly reliable result. With this level of accuracy, the LULC changes detected are reliable to be employed in order to analyze the trends of wetland mutation in Bamenda II and III municipalities over the study period.

B. Trends in wetland dynamics in Bamenda II and III municipalities

a. Trend in wetland dynamics between 1980 and 2000

In 1980, the wetlands in the Bamenda II municipality had a surface area of 33.91km^2 amounting to 20.65% of the land surface, which was larger than that of built up area, while farmland had the largest surface area. On the other hand, wetlands covered an estimated surface of 13.58km^2 which made up 20.49% in Bamenda III. Therefore, by 1980, slightly more of Bamenda II was covered by wetland than Bamenda III. More farmlands existed in Bamenda II than in Bamenda III with a higher built up area in Bamenda II. Hence, in both municipalities, wetlands had a relatively higher coverage in 1980 than the area that was built up. In the same year, farming activities were high in both subdivisions. As such, wetlands were still intact in both subdivisions, with more of the landuse being agrarian. This is illustrated on **Table 4**.

By the year 2000, the total surface area of wetland reduced to 29.74km^2 (18.12%) and to 11km^2 (16.60%) in 2000, respectively for the Bamenda II and Bamenda III municipalities. By implication, wetlands witnessed enormous reduction in Bamenda III than in the Bamenda II municipality as the built up area increased greatly from 5.49% in 1980 to 9.22% in 2000 for Bamenda II and 7.51% in 1980 to 12.28% in 2000 for the Bamenda III municipalities. Farmland increased from 1980 to 2000 in Bamenda II and III. Hence wetlands in these subdivisions were lost to built up area and agriculture between 1980 and 2000, at different rates. This is also due to the reduction in area covered by "other uses" of the land in both areas, making other uses of land and land cover contribute to the rapid increase in built up area and farmland. This is illustrated by **Figure 3**.

In 1980, wetlands were very visible in both municipalities even in the area of tiny clustered settlements in the southern section and farming activities were substantial around the center of the municipalities. By implication, before 1980, wetlands dynamics could only be driven more by agriculture activities, which was not significant enough to trigger wetland loss giving way for a large area to be covered by wetlands. Other human activities were "at bay" in this period making wetlands visible and relatively stable. This pattern of land use and land cover changed subsequently.

Table 4: Trend in wetlands dynamics between 1980 and 2000.

	Bamenda II				Bamenda III			
	1980		2000		1980		2000	
Parameters	Surface area (km^2)	Percent	Surface area (km^2)	Percent	Surface area (km^2)	Percent	Surface area (km^2)	Percent
Wetland	33.91	20.65	29.74	18.12	13.58	20.49	11	16.6
Built up	9.02	5.49	15.15	9.22	4.98	7.51	8.14	12.28
Farmland	60.44	36.8	70.89	43.17	21.32	32.17	22.1	33.34
Others	60.86	37.06	48.45	29.5	26.4	39.83	25.04	37.78
Total	164.23	100	164.23	100	66.28	100	66.28	100

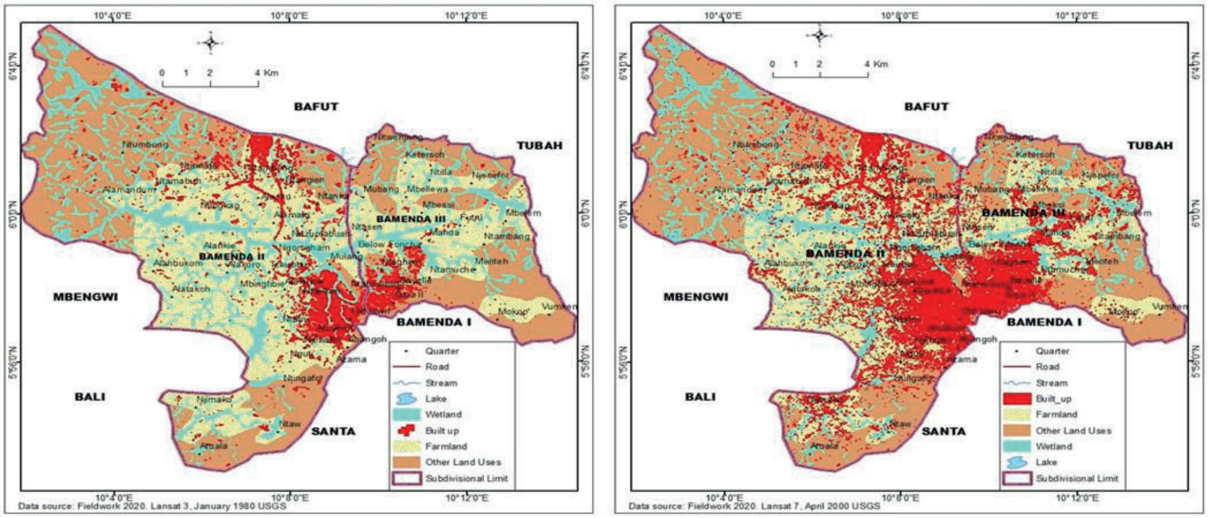

Figure 3: Wetlands situation for Bamenda II and III municipalities between 1980 and 2000.

Wetland encraochment is visible in 2000 as the built-up area expanded with the phenomenon of urban sprawl sparked in the eastern section in Bamenda III municipality towards Tubah, the northern section in Bamenda II towards Bafut and the south-western section towards Bali. Densification and agricultural activities within the urban space greatly triggered the encroachment on wetlands and led to their reduction. This is clearly demonstrated by the increases in the built up area in both municipalities. Farmland drove the degradation of wetland as its area increased, leading to the mutation of wetlands in Bamenda II and III council areas. Equally, urban sprawl contributed to the encroachment and degradation of wetlands in the Bamenda II and III municipalities, as it accompanied the increase in built up area. This is clearly observed in Bamenda II towards Bafut, Bali and Alahtakoh as well as in Tubah, Menteh and Mbellewa in the Bamenda III municipality.

b. Trend in wetlands dynamics between 2000 and 2020

In 2020, wetland area stood at 28.58km^2 (17.40%) and 9.09km^2 (13.71%) respectively in Bamenda II and III municipalities. This shows a reduction in both areas. Correspondingly, the built up area increased markedly from 9.23% in 2000 to 12.51% in 2020 for Bamenda II and from 12.28% in 2000 to 21.12% in 2020 for Bamenda III. On the other hand, farm land reduced markedly from 2000 to 2020 in both municipalities. However, constant reduction was observed in other land uses between 2000 and 2020 in the study areas (**Table 5**).

As a result, between 2000 and 2020, settlement expansion is the primary cause of wetland loss in both municipalities. Other land use and land cover types are also being degraded as a result of this. The reason for the sharp increase in built up area and the ironic drop in farming area within this period is the breakup of the Bamenda council into three council areas, putting in place a city council in 2007. This was when these two municipalities (the study areas) were created, which triggered the provision of a lot of administrative and municipal services and the consequent flow of people into this area. This increased development and expansion, exerting pressure on the wetlands (**Figure 4**).

Table 5: Trend in wetlands dynamics between 2000 and 2020.

	Bamenda II				Bamenda III			
	2000		2020		2000		2020	
Parameters	**Surface area (km^2)**	**Percent**	**Surface area (km^2)**	**Percent**	**Surface area (km^2)**	**Percent**	**Surface area (km^2)**	**Percent**
Wetland	29.74	18.12	28.58	17.4	11	16.6	9.09	13.71
Built up	15.15	9.22	20.54	12.51	8.14	12.28	13.99	21.11
Farmland	70.89	43.17	68.7	41.83	22.1	33.34	19.16	28.91
Others	48.45	29.5	46.41	28.26	25.04	37.78	24.04	36.27
Total	**164.23**	**100**	**164.23**	**100**	**66.28**	**100**	**66.28**	**100**

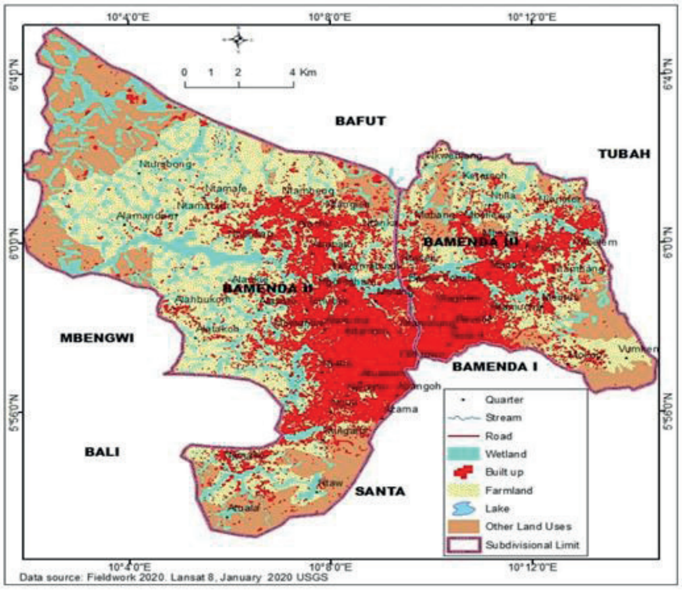

Figure 4: Wetlands situation for Bamenda II and III municipalities in 2020.

This shows a period of densification, and continuous sprawl and growth of the Bamenda II and III urban spaces. This led to encroachment on wetlands and other LULC especially, as it shows a cumulative dynamic on wetlands from 1980 to 2020 (a period of 40 years) as reflected by the changes in land use and land cover types. Alongside an increase in the built up area between 2000 and 2020, urban sprawl also continued to impact wetlands. As such, urban sprawl in both municipalities continued and intensified, especially towards the north-western, north-eastern and south-western areas. All of these considerably impacted the wetlands in these areas.

Therefore, wetlands witnessed enormous dynamics, leading to a loss of area in the regions studied from 1980 to 2020, especially due to the increase of built up land and urban sprawl. Wetlands evolved from a phase of tiny settlement concentrated in the south-eastern section with dominantly agricultural activities in 1980 to a more dense settlement in 2020 in both municipalities. Agricultural activities also significantly degraded wetlands, rendering their wise use and sustainability questionable. This illustrates that dynamics witnessed on wetlands were a result of several forces which cumulatively drove degradation. Hence, one particular driver cannot be isolated and used to unpack wetland degradation in the areas under study.

The hypothesis assumed that the rate of wetland loss is higher in Bamenda III than in Bamenda II municipality. This is based on the fact that Bamenda III generally has a relatively smaller surface area, with lesser wetland extent and here urbanization is relatively new and advancing rapidly. Thus, such attributes are assumed to be capable of conditioning more wetland loss in Bamenda III than in Bamenda II. The results are presented in **Table 6**.

Wetland has been lost at 15.72% in Bamenda II and 33.06% in Bamenda III municipality from 1980 to 2020. By implication, the rate of wetland degradation and loss was higher in Bamenda III than in Bamenda II municipality (33.06%>15.72%). This made it possible to accept the hypothesis. The negative signs in the statistics show a decrease in land use and land cover. Such a higher rate of loss is because of the fact that Bamenda III is the gateway for migrants from surrounding divisions, such as Ngoketunjia, Boyo, Bui and beyond (areas of rural exodus), into Bamenda town, who more often than not prefer to settle in this area. Also, after the 2007 decree which upgraded the status of this area into a full municipality, the improvement of administrative and municipal services triggered an inflow of people into this area. This has driven enormous encroachment, degradation and loss of wetlands. To shed more light on the trajectory of wetland loss in Bamenda II and III municipalities, **Figure 5** presents the trend and proportion of wetland loss that could be explained by changes in other land uses.

Table 6: Rate of wetland loss between 1980 and 2020.

	Land use	Wetland	Built up	Farmland	Others	Total
Bamenda II	1980 Surface area (km^2)	33.91	9.02	60.44	60.86	164.23
	2020 Surface area (km^2)	28.58	20.54	68.7	46.41	164.23
	Change in surface area (km^2)	-5.33	11.52	8.26	-14.45	-
	Rate of change (in decimal / percent)	-15.718%	1.27716	13.6664%	-23.743%	-
	Remark	Decreasing	Increasing	Increasing	Decreasing	Constant
Bamenda III	1980 Surface area (km^2)	13.58	4.98	21.32	26.4	66.28
	2020 Surface area (km^2)	9.09	13.99	19.16	24.04	66.28
	Change in surface area (km^2)	-4.49	9.01	-2.16	-2.36	-
	Rate of change (in decimal / percent)	-33.063%	1.80924	-10.131%	-8.9394%	-
	Remark	Decreasing	Increasing	Decreasing	Decreasing	Constant

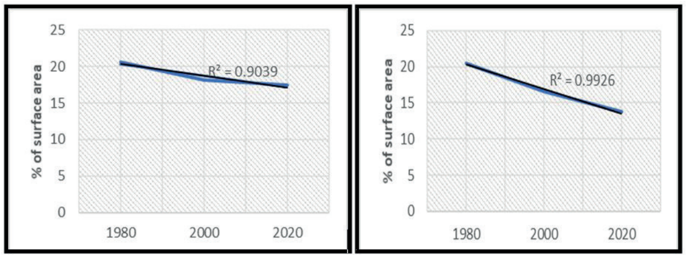

Figure 5: Trend of wetland loss in Bamenda II and III municipalities (January 1980, April 2000 and January 2020 Landsat images and Field Survey, 2020).

Though wetlands significantly decreased, following the same trajectory in both municipalities, they did so at different rates. The trend of wetland loss was relatively gentle for Bamenda II, while that of Bamenda III was steeper. This is explicitly displayed by the R^2 equation, which is expressed in percentage to indicate that, 90.39% and 99.26% of wetland loss for the Bamenda II and III municipalities, respectively, were as a result of land use change. This therefore explains the overall loss of wetlands, and the relatively higher rate of wetland loss in Bamenda III municipality. Though the trend of wetland loss follow the same trajectory in these areas, they do so at different rates (99.26%>90.39%).

C. Environmental implications of wetland dynamics in Bamenda II and III municipalities

a. Loss of habitats and biodiversity

The mutation of wetlands triggers loss of habitat for various species of amphibians and reptiles. Species such as birds, frogs, butterflies, snails, squirrels and other rodents, have continously lost their habitat to wetland degradation in Bamenda II and III municipalities. Even the *Banama Touraco* bird, which is unique in the entire Northwest Region was observed at the Nteilah wetland stretch, which is witnessing gradual encroachment and degradation. Thus, the mutation of wetlands is a serious driver of biodiversity loss in the Bamenda II and III municipalities given the rate of mutation witnessed in these areas. Wetland plants in Bamenda II and III municipalities have been rapidly lost as wetlands were mutated with non-native species introduced. This is glaring in Bamenda II and III municipalities as the intrinsic rapphia palm vegetation have been reclaimed for other land uses. Fresh water biodiversity is thus at the verge of collapse in the study areas given the unprecedented rate of conversion witnessed in Mulang, Musang, Nitop and Ngomgham in the Bamenda II municipality, and Bayelle, Namoh, Manda, Teken, Njengang and Ntefinki in the Bamenda III municipality. This renders the flora and fauna of these fresh water ecosystems vulnerable and threatened with extinction due to rampant encroachment into wetlands. This is especially the case as some wetland stretches have completely lost their biodiversity as they have been degraded entirely in structure and composition like the Ntakekah and Bayelle wetland stretches in Bamenda III municipality.

b. Pollution

Wetland degradation is associated with pollution in Bamenda II and III municipalities. This is observed through the dumping of household waste in and around wetlands in the study areas. The pollution problem experienced in these areas is associated with wetland degradation. This is exemplified by 24% of households who dump their waste into rivers, streams and drains with biodigradable food debris being the most dominant waste fraction. In the same light, the Mezam river was found to be slighty contaminated at the inlet into the Bamenda city, but highly contaminated at the outlet with values of coliform, bacteriological and physio-chemical parameters greater than the World Health Organisation's recommended standards, thus making the waters of river Mezam unsuitable for human consumption (Oben *et al*, 2018). This is shown in **Figure 6**.

Photo A: Deposition of waste at the Manda Stretch of wetland

Photo B: Deposition and accumulation of waste in the stream behind Food Market

Figure 6: Pollution of wetlands in Bamenda II and III municipalities (Field Survey, 2020).

Photo A depicts household waste at the *Manda* wetland stretch directly opposite Fokou Supply, whereas B captures waste deposited into the stream behind Food Market in Bamenda II municipality. All these conspicuously depict this phenomenon in the study areas. Therefore, the deposition of waste on wetlands and into streams significantly pollutes the environment and streams in Bamenda II and III municipalities. This was witnessed within the localities of the study areas especially, with the case of individual household waste deposition into streams and wetlands in Mankon and Nkwen.

c. Environmental degrdation and flooding

The encroachment and degradation of wetlands contributed to overall degradation of the environment. The wetland strech from upper Namoh, through Manda to lower Bayelle-Manda in Bamenda III municipality, and the Mulang and Ngomgham wetlands in Bamenda II municipality have witnessed great degradation, thus contributing to environmental degradation. Therefore, wetlands mutation is associated with environmental degradation as in itself contributes to degrading the environment. Also, Bamenda II and III municipalities are prone to flood hazards due to their location at the foot of the Bamenda escarpment which has relatively low relief, and is dissected by streams and valleys with their respective flood plains. The rapid growth of human settlement in these areas has transformed flood hazards into a recurring disaster. In recent decades, flooding in these areas have claimed many lives and caused significant property damage. Between 1995 and 2009, about 20 lives perished due to flooding, and enormous property damage in the Bamemda II and III municipalities aggravated by rainfall variability (Nyambod, 2010; Saha and Tchindjang, 2017). Wetlands in both sub-divisions are in high risk areas for flooding, but encroachment has transformed most of these areas to flood disaster hotspots (**Figure 9**). This is the case with the Mulang area in Bamenda II municipality and Lower Bayelle-Manda in Bamenda III municipality which experience severe inundation during the rainy season (peaking in August, September and October). **Photo 1** illustrates.

Photo 1: Flooding at Njengang, Bamenda III municipality (Field Survey, 2019).

The photo taken captures a flash flood event at the Futru-Njengang wetland stretch in the Bamenda III municipality in October 2019 with crops and road inundated. This wetland ecosystem has undergone severe transformation. Flooding has been a nomality in wetland areas, which is often experienced during the rainy season as an opportunity for wetlands to recharge and store more water to gradually release during the dry season. However, mutation has turned this into a recurrent disaster in these municipalities. Thus, the mutation of wetlands driven by housing construction and agricultural expansion exposed the population to floods in Bamenda II and III municipalities. This has been apparent with flash floods at Njengeng, Futru, Teken, Alahlie and Manda in Bamenda III municipality, and that of the Mulang in Bamenda II municipality, as well as prolonged floods at Lower Bayelle-Manda in Bamenda III municipality.

d. Other environmental implications of wetland degradation

In this case, environmental problems were not seen to have a direct relation to the encroachment into wetlands as they were secondary amplifications. Thus, these dominantly triggered and accelerated impacts of wetland dynamics. These indirect concerns are presented on **Table 7**.

A total of 89.50% of the population of Bamenda II municipality indentified climate variability as an environmental issue of wetland encroachment, while a corresponding 94.90% of the population of Bamenda III had a similar view. Thus, 92.10% of the population of both municipalities pointed to this. The phenomenon of climate variation is seen through climatic parameter of rainfall in Bamenda II and III municipalities. This variation is portrayed by changes in the rainfall amount received over these areas from 1971 to 2011. This demonstrates significant variability in the interannual rainfall anomaly percentage, from 1971 to 2011 (**Figure 7**).

Table 7: Other environmental issues of wetland encroachment (Field Survey, 2020)

Parameters	Identification of other environmental issues in Bamenda II municipality	Percent	Identification of other environmental issues in Bamenda III municipality	Percent	Identification of other environmental issues in Bamenda II and III municipalities	Percent
Climate variability	77	89.50	74	94.90	151	92.10
Water scarcity	47	54.70	59	75.60	106	64.60
Poor water quality	45	52.3	60	76.90	105	64.00
Total	86	100	78	100	164	100

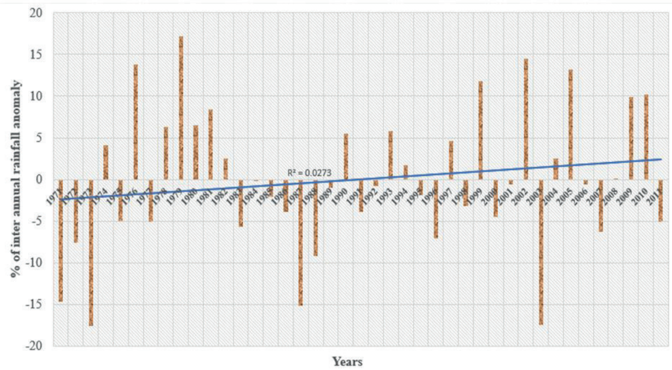

Figure 7: Percentage of interannual rainfall anomaly of Bamenda II and III municipalities (North-West Regional Delegation of Transport, and Field Survey, 2020).

The percentage of rainfall anomaly over Bamenda II and III municipalities from 1971 to 2011, as compared to the mean of interannual rainfall show that some of the years received a lower percentage of average precipitation with some negative, whereas others received higher rainfall. This indicates that rainfall has been highly variable in the Bamenda II and III municipalities as some years receive negative rainfall compared to the average inter-annual rainfall. This demonstrates the variability of climate in the Bamenda II and III municipalities. However, rainfall amounts slightly increased over these areas at a rate of 2.73% as displayed by the R square equation. Therefore, the climate varied over the decades with impacts felt in the localities of the study areas, which can not be dissociated from wetland degradation. This is due to wetland conversion directly leading to the release of stored carbon dioxide into the atmosphere, subsequently increasing temperatures as well as impeding carbon sequestration which fuels the variation in rainfall amounts. Thus, the degradation of wetlands directly contributes to global warming, whose impact is manifesting in varying precipitation patterns. By implication, as wetlands are continously encroached on and degraded, so too, unavoidably will climate variability worsen.

Futhermore, the degradation of wetland was found to be associated with water scarcity. This is assessed by the population at the rate of 54.70% in Bamenda II and 75.60% in Bamenda III, giving an overall rate of 64.60% of the entire population who linked water scarcity to wetland degradation. Associated to this was poor water quality reported at 64% in both subdivisions as seen on **Table 7**. This is because the wetlands' role of water filtration is undermined by degradation, making poor water quality unavoidable in the Bamenda II and III municipalities.

These environmental problems, however, are interwoven as each triggers and accelerates the other. In this case, the climate crisis contributes to fostering environmental problems such as water scarcity and food insecuricty as well as the deterioration of wetlands. For instance, the increase in carbon dioxide and climate variation, despite being trigerred and accelerated by wetland change, reciprocally impacts wetlands. **Figure 8** illustrates the relationship between the environmetal implications associated with wetland dynamics.

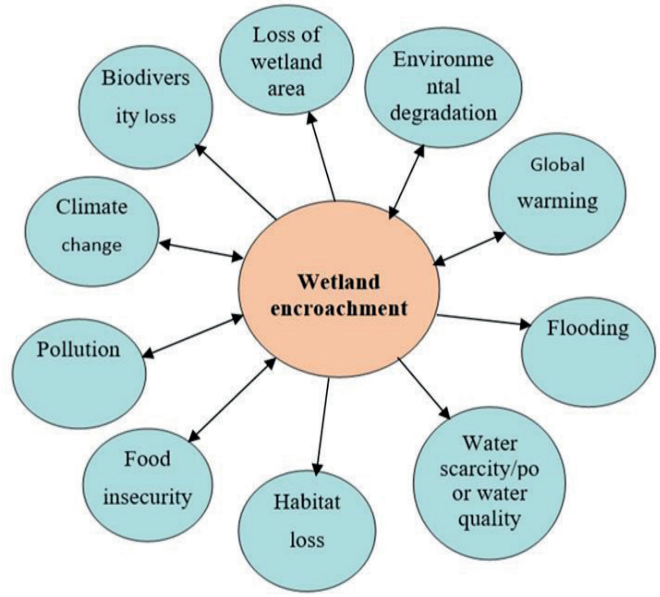

Figure 8: Environmental implications of wetland conversion (Authors' conception, 2020).

The relationship between wetland encroachment and environmental concerns are varied. Nonetheless, reciprocal relationships are visible between food insecurity, pollution, global warming and climate change. Non-reciprocal relationships are also highlighted between wetland encroachment and flooding, habitat and biodiversity loss. These environmental problems of wetland mutation were observed in communities of Bamenda II and III municipalities. The hotspots of some environmental problems associated with wetlands mutation in these municipalities are spatialized in **Figure 9**.

Pollution sites exist on wetlands in Bamenda II and III municipalities as indicated around the food market and the Manda areas, which were characterised by the dumping of household waste on wetland. Areas of biodiversity loss represent areas of very significant wetland habitat loss, such as the Ntakekah area which has lost its wetlands to human activities. Flood disaster zones denote the notable areas of flooding especially the Mulang-Lower Bayelle-Manda and the Manda wetland stretches.

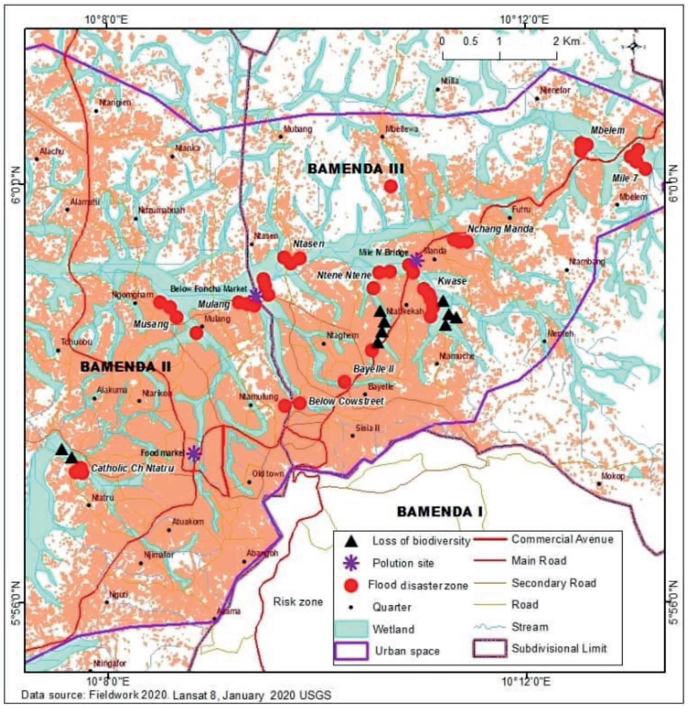

Figure 9: Hotspots of environmental implications of wetlands degradation (January 2020 image and Field Survey, 2020).

D. Adaptation and mitigation strategies to the environmental issues of wetland dynamics in Bamenda II and III Municipalities

a. Adaptation strategies to the problems of wetlands mutation

i. Engineering methods

A greater portion of the population in and around the wetlands raise their foundations during construction as a means of adopting to the impacts of wetland encroachnment, especially with regards to flooding (**Photo 2**).

Photo 2: Raised foundation on wetlands at Mulang (Field Survey, 2020).

This is a raised foundation within water on wetland at Mulang in Mankon Bamenda II municipality. This is a measure employed to adapt to the problems of wetland encroachment. This method was discovered to be rampant in wetland areas occupied by settlements and constructed business sites, which had their foundations raised to about 2 meters to guard against innundation. This is employed by wetland inhabitants in Bamenda II and III municipalities, and was observed more in the localities of Mankon and Nkwen where wetlands degradation is conspicuous. The population in the study areas also use rocks to construct foundations as a strategy to cope with the environmental implications of wetland degradation (**Photo 3**).

Photo 3: Rocks used for a foundation in the Mulang wetland (Field Survey, 2020).

Photo 3 shows a foundation made up of rocks at Mulang Street 7, behind house number 3 in the Bamenda II municipality. Construction in wetlands in Bamenda II and III municipalities often utilize these rocks due to their relative durability and resistance to weathering. This permits the foundations and other infrastructure on wetlands to have a degree of firmness, as acknowledged by the population in these municipalities. This mechanism is facilitated by the availability of these rocks in the study areas in Nteilah in Bamenda III and Mankon in Bamenda II municipalities. This is a central engineering method adopted on wetlands. Typically, lateritic soils were also brought into wetlands and allowed to be compacted naturally by rain before commencing construction activities. This completely changes the morphology and composition of wetlands in these areas. Most stream courses on wetlands in Bamenda II and III municipalities have also been mutated and straightened. The population in and around wetlands in Bamenda II and III municipalities also construct embankments as a coping mechanism to check water overflow and to prevent soil collapse as observed around infrastructure.

ii. Non-engineering measures

In Bamenda II and III municipalities, a unqiue agricultural calender especially for crop cultivation on wetlands was discovered. Wetland farmers adopt a unique calender for agricultural activities in order to cope with the environmental issues of wetland encroachment. In this calendar, wetland farmers begin cleaning activities as early as December and planting as early as February in advance of the normal rain-fed agricultural season. This permits harvesting to be done early enough (May and June) before the peak of rainfall when access to wetlands is made difficult due to inundation. As such, the entire population of wetland farmers in the study areas do not respect meteorological advice to maintain the regular agricultural season, especially pertaining to the planting season. Rather, the population carries out pre-emptive farming on wetlands to cope with the environmental implications of wetland encroachment. Equally, in some places within the study areas, the population placed bags and other materials as foot paths to cope in wetlands (**Figure 10**).

Photo A: Use of bags on walking path in *Ntefinki* Photo B: Locally adapted walking path to a fish pond in *Teken*

Figure 10: Adaptation strategies on wetlands in Bamenda II and III municipalities (Field Survey, 2020).

Photo A displays the use of bags as a foot path in Ntefinki in Bamenda III on wetland, and B is a locally adapted path to a fish pond in Teken, making use of tyres filled with soil, sticks and bamboo. Furthermore, non-native species of plants such as eucalyptus are used by the population of Bamenda II and III municipalities to absorb water and render the wetlands dry. This is especially as this plant has been noted for its high water demand and exotic nature in the environment. This is found from Mbelem to the east in Bamenda III, to Ntumbong to the west in Bamenda II municipality. These exotic species significantly absorb and release water to the atmosphere through transpiration. Thus, there exists varied local adaptation strategies to the environmental implications of wetland encroachment.

b. Mitigation Strategies to the Environmental issues of Wetland Degradation

Water-friendly trees have been planted on catchment areas within these municipalities in a bid to protect them and fight against climate variability and global warming. This was done by key institutions such as the Ministry of Environment and the North-West Development Authority as seen on **Figure 11**.

Photo A: Water friendly trees for *Atualah* Photo B: Water friendly trees for *Mbesi*

Figure 11: Water and environmental friendly trees for catchment areas in Bamenda II and III municipalities (Ministry of Environment, Protection of Nature and Sustainable Development).

Photo A and B are water and environmental friendly trees donated by the Ministry of Environment, Protection of Nature and Sustainable Development, and the North-west Development Authority, which were planted on water catchments in Atualah (Chomba) in Bamenda II municipality and Mbesi (Nkwen) in Bamenda III municipality respectively. This is in a bid to fight against the environmental problems associated with wetland deterioration, especially climate change. Also, in Bamenda II and III municipalities, some constructed structures have been abandoned due to the negative consequences of wetland encroachment. In this case, coping mechanisms proved futile, leaving abandonment as the only option to mitigate the environmental consequences of wetlands deterioration. This is shown on **Photo 4** as observed in the study area.

Photo 4: Abandoned structure on wetland at Mulang (**Field Su**rvey, 2020).

Thus, when the environmental impacts of wetland encroachment become overwhelming, the population resorts to abandonment. This happens when all adaptive measures have been exhausted, but the environmental impacts, especially flooding, keep aggravating. Local and regional authorities also resorted to prohibition of reclamation activities and non-provision of town planning acts to wetland inhabitants in the Bamenda II and III municipalities. Here, authorities displayed information prohibiting the reclamation of wetlands, carrying various ordinances and decrees and stating them out of bound for any encroachment as they are state public property. Added to this has been the non-provisions of town planning acts to the population on wetlands.

4. DISCUSSION AND CONCLUSION

Wetlands witnessed enormous dynamics in the Bamenda II and III municipalities. Though the trend of wetland loss follow the same decreasing trajectory in these areas (Fengqin, 2020; Tangao *et al*, 2019; Erqi and Yimeng, 2019; Islam *et al*, 2010; Fengqin, 2020; Tangao *et al*, 2019; Erqi and Yimeng, 2019; and Islam *et al*, 2010), they do so at different rates. Wetlands have been lost at a higher rate (33.06%) in the Bamenda III municipality than in the Bamenda II municipality (15.72%) from 1980 to 2020. The degradation of wetlands in these areas was found to be associated with a plethora of environmental challenges including biodiversity loss, pollution, flooding and environmental degradation (Pieter *et al*, 2013; Lee *et al*, 2006; Enwere, 2015; and Pengfei *et al*, 2018). The population of these areas employ adaption measures on wetlands amidst mitigation measures to cope with these challenges. However, the rate of wetland encroachment is a call for concern to ensure sustainable and wise use. This would save them from imminent extinction. **Figure 12** presents the overall situation of wetlands in Bamenda II and III municipalities.

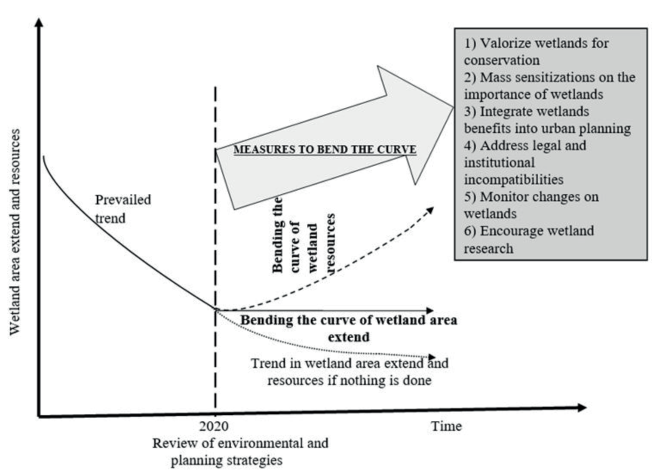

Figure 12: Trend in wetland loss and actions to bend the curve (adapted from Tickner et al, 2020).

Current measures undertaken to check wetland loss and the repercussions of wetlands change have proven fruitless and hence guarantee incessant decrease in wetland area in Bamenda II and III municipalities. This has rendered the curve of wetland area extent and wetland resources constantly falling with eminent decrease if nothing is done urgently. Halting the current trend of wetland loss will reverse the curve and save the integrity of wetlands for the harmonious existence of mankind and the environment. Environmental and planning strategies must be reviewed urgently to reverse the trend of wetland loss. Such trend of wetland loss prevails in other parts of the country as well as Sub-Saharan Africa and the world at varying degrees, waranting actions from key stakeholders.

Faced with the proliferating degradation of wetland in these sub divisions, the Bamenda City Council is urged to put in place a wetland management unit to integrate the benefits of wetlands into policy planning, monitor human activities on wetlands, and promote and encourage wetland research and sensitization. The city council should also implement a project to operationalise a green and recreational space along the Mulang-lower Bayelle-Manda stretch of wetlands, with the involvement of multiple stakeholders. The Bamenda III Council is recommended to adopt and expand the municipal deliberation on the raphia palms initiative into a wetland awareness and advocacy program, since raphia palms are naturally associated with wetlands. This should be standardized to bring on board multiple stakeholders, especially, academics, researchers, the administration, and the Council and traditional authorities. Also, the Bamenda III Council is recommended to design a long term project on the wetland stretch adjacent to the Council from Namoh/Menteh to Manda and the Mbelem wetland stretch to recreational areas, involving multiple stakeholders. Such projects would simultaneously lead to income generation and job creation, saving the intergrity of the wetlands. The Bamenda II council should design a project to sensitize the population of Bamenda II on the importance of wetlands to mankind and the environment, and the need to protect them.

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