*Journal of Arts and Humanities* (JAH):
*A Multidisciplinary Journal of the Faculty of Arts,*
The University of Bamenda
https://fajournaluba.com/index.php/jah/index

**Research Article**
This article is published by JAH, *Journal of Arts and Humanities*,
**Volume 7, N. 1, Feb., 2023**

ISSN: **2710-3013 (Print)**
ISSN: **2788-6360 (Online)**


**Article detail**
Received: **Nov. 10th, 2022**
Accepted: **April 12th 2023**
Published: **June 2023**

Conflict of Interest: *The author/s declared no conflict of interest.*

# Spatiotemporal Dynamics of Wetlands in Bamenda, Cameroon: Implications for Urban and Peri-urban Wetland Policy

By

**Dingha Chrispo Babila,**
**Mbanga Lawrence Akei, &**
**Kometa Sunday Shende**
Department of Geography and Planning,
University of Bamenda Cameroon
***Correspondingauthor:**
chrispodingha@gmail.com

## ABSTRACT

Wetlands are indispensable within the human settlement agenda. Recognising their evolution is vital for critical understanding and management of existing wetlands. Yet, the spatiotemporal variation of wetlands is less comprehensively understood between urban and peri-urban areas of developing countries. The study trust on this to analyse 1) the spatiotemporal dynamics of wetland between the urban and peri-urban areas of Bamenda, and 2) its implication to urban and peri-urban wetland policy. Landsat images of the study area for 1992, 2002, 2012 and 2022 were used and documentary review carried out to gain deeper understanding of urban and peri-urban wetland management policies. Images were processed using supervised classification with the help of ArcGIS 10.3 and Google Earth images. Findings reveal that, wetlands reduced from 5.31 $km^2$ (7.32%) and 6.29 $km^2$ (3.05%) in 1992 to 0.43 $km^2$ (0.59%) and 4.48 $km^2$ (2.17%) in 2022 respectively in urban and peri-urban areas. While built up area increased from 14.78 $km^2$ (20.37%) and 8.54 $km^2$ (4.14%) in 1992 to 36.89 $km^2$ (50.85%) and 16.83 km (8.15%) in 2022 for urban and peri-urban areas. This greatly triggered wetland loss coupled with urban sprawl and agricultural expansion. But, wetland management policy of the Bamenda City Council remains incomprehensive as degradation proliferates. Thus, urban and peri-urban wetland policy is not adequately regarded in Bamenda and the city is fast losing its privilege of a possible accreditation as a "Wetland City." This calls for urgent and accelerated awareness raising and implementation of policies for sustainable urban and peri-urban wetlands management.

**Keywords**: *Bamenda City Council, wetland city, Ramsar Convention, accreditation, LULC*

## 1. **INTRODUCTION**

Urban wetlands contribute greatly to the liveability of cities through values such as sustainability, biodiversity hosting, recreation, water quality improvement and mitigation of hazards (Somayeh *et al*., 2021). As such, they are important sites for conservation and environmental education (Panuccio *et al*., 2017). But increasing urbanization threatens wetlands through direct conversion to urban areas, as well as through watershed impacts of urban development (Ramsar Convention, 2015). Thus, growing urbanization impacts urban and peri-urban wetlands making their importance for biodiversity and quality of life more apparent. Urban wetlands lie within boundaries of cities while peri-urban wetlands are those adjacent to urban area (Ramsar Convention, 2008). And their ecosystem services have consistently been under-recognized in the face of rapid urbanization (McInnes, 2014) including the need to deliver high level societal wellbeing.

The Ramsar Convention and the United Nation Human Settlement Program (UN-Habitat) champion urban and peri-urban wetland policy. In 2011, the UN-Habitat adopted Resolution 23/17 providing a mandate to promote wetland biodiversity and ecosystem services within the human settlement agenda (McInnes, 2014). This recognised wetlands as an integral part of urban development, and encouraged cooperation with developing countries and their local authorities to strengthen their capacities in promoting sustainable management of urban and peri-urban wetlands. This orchestrated Ramsar Convention's Resolution X.27 that requested the convention's Scientific and Technical Review Panel to explore links with UN-Habitat regarding the promotion and preparation of guidelines for managing urban and peri-urban wetlands. In 2012, the Ramsar Convention's COP 11 adopted Resolution XI.11 on the principles for the sustainable planning and management of urban and per-urban wetlands (Ramsar Convention, 2012). This renewed commitment of contracting parties (Cameroon inclusive) to promote conservation and wise use of wetlands in urban and peri-urban environments by incorporating these principles into local sectorial policies. Building on this, Ramsar Resolution XII.10 approved a voluntary city accreditation system (Ramsar Convention, 2015) and invited contracting parties to propose cities in their territories with a significant wetland, or one or more Ramsar site lying fully or partly in its territory for accreditation. With pioneer city accreditation in 2018 (18 cities) and 2022 (25 cities), a total of 43 cities (Asia 28; Europe 9; Africa 5; North America 1) who value their wetlands have gained international recognition and positive support (Ramsar Convention, 2022; Ramsar Convention, 2018).

Notwithstanding, understanding land use dynamics is essential for tackling environmental and societal challenges such as ecosystems degradation. Land use change has affected 32% of global land area from 1960 to 2019. This magnitude is four times greater than previous estimate of long term dynamics characterised by varying trajectories with afforestation and cropland abandonment in the Global North, and deforestation and agricultural land expansion in the Global South (Winkler *et al*., 2021). Even though Fuente *et al*., (2021) found that wetlands located in the north of the tropic of Capricorn have more seasonal variability in size than those of the south, human activities trigger great and complex dynamics on wetlands (Yashuang *et al*., 2021). With varying patterns of degradation, the recognition of the evolution of wetlands is vital for critical understanding and meaningful analysis of existing wetlands anywhere (Greb *et al*., 2006).

In China, 2883 $km^2$ of wetland was lost to urban expansion in its north east, north, south east and southern parts from 1990 to 2010 (Dehua *et al*., 2018). Even 47 (75%) of its Ramsar Sites witnessed pressure from anthropogenic activities marked by expansion of aquaculture ponds and invasive species in the Yellow River Delta. The Chatra area of India lost 60% of its wetlands between 1991 and 2018 (Basu *et al*., 2021) with a projection of complete loss by 2045. Interestingly, wetlands encroachment varied in the Bengahera urban district of India as water bodies shrunk from 64 km$^2$ in 1965 to 55 km$^2$ in 2018 because of built up area increase. But, rural wetlands were lost to green space unlike to construction as the case of urban areas (Katja *et al*., 2020). In the same vein, the Ria Formosa area of Portugal lost 2000 ha of wetland converted into anthropic landscapes amounting to about 20% reduction in natural wetlands since the end of the 19$^{th}$ Century (Sousa, 2020). In the Mediterranean region, pressure on wetland resources is increasing with 48% of natural wetlands lost since 1970. This is due to 300% increase in urbanisation with increase in cultivated land by 42% from 1975 to 2005 (Perennou *et al*., 2020). Equally, from 1850 to 2000, Canton Zurich wetlands decreased severely from 13759 ha (8% of the total land area) to 1233 ha making only 1%. The largest loss was observed in the first half of the 20$^{th}$ Century in which 50% of total wetland loss occurred (Gimmi *et al*., 2011). However, Siyavuş (2021) rather revealed wetland registered 80% increase in the Duzce province of Turkey from 1990 to 2018 due to lake surface expansion works. Thus, wetlands have been transformed at varying degrees and rates within and between countries.

Wetlands in parts of Sub Saharan Africa have witnessed a significant decline which is triggered by land use change, population increase, poor management, urban and agricultural expansion (Kuusaanaa *et al*., 2021; Orimoloye *et al*., 2020; Workiyie *et al*., 2021; Obiefuna *et al*., 2021; Rebelo *et al*., 2010; Palela, 2000). Over 33 years for instance, the Kapkatet wetland in Kenya declined by 24.77% marked by vegetation decline as open ground increased owing to emerging land use pressures and weak environmental laws (Kibet *et al*., 2021). So too did the Rwampara wetland in Kigali received great pressure from urban expansion between 1987 and 2018 as built up area increased by 77% (Rwanyiziri *et al*., 2020), triggering the reduction of wetlands from 24 ha in 1987 to just 7.7 ha in 2018. Besides, urban sprawl in the Kampala City mounts enormous pressure on wetlands (Abebe, 2013), as built up area grew from 73 $km^2$ in 1989 to 325 $km^2$ in 2010 at an average growth rate of 10.14% per year. But, more often than not, these studies are comprehensively focused on the urban area leaving out concomitant dynamics in peri-urban spaces. This hinders comprehensive understanding of urban and peri-urban wetland policy.

With a total of seven wetlands of international importance (Secretariat of the Convention on Wetlands, 2021), Cameroon is a party to the Ramsar Convention pursuing the conservation and wise use of wetlands in its territorial jurisdiction since 2006 (Tazoacha, 2010). But, wetlands are greatly degraded by human activities and land use change (Tchindjang *et al.*, 2020). Wetlands of the Santa-Bamenda axis have witnessed massive human encroachment for agriculture and settlement with about 20% being colonized by eucalyptus plantations (Kometa, 2013). In Bamenda, wetlands reduced from 27% in 1984 to 6% in 2014 owing to anthropogenic activities (Balgah and Kimengsi, 2016). More so, Bamenda III have witnessed dramatic changes in its peri-urban zone leading to wetland encroachment (Kimengsi *et al.*, 2017). But, wetland reduction varied between Bamenda II and Bamenda III Sub Divisions from 20.65% in 1980 to 17.40% in 2020 and from 20.49% in 1980 to 13.71% in 2020 respectively (Mbanga and Dingha, 2022). This is amidst increase in settlement area from 5.49% in 1980 to 12.51% in 2020 and 7.51% in 1980 to 21.12% in 2020 respectively for Bamenda II and III Sub Divisions.

However, existing studies demonstrate that wetland have been on the path of degradation with varying trajectories. Yet, the spatiotemporal dynamics of wetlands is less comprehensively understood between urban and peri-urban areas especially in developing countries. This limits empirical understanding of the local uptake and implementation of policies of urban and peri-urban wetlands management. This is true for Bamenda with deficiency of studies explicitly focusing on urban and peri-urban wetlands. The study fills this gap by analysing 1) the spatiotemporal dynamics of wetland in the urban and peri-urban areas of Bamenda, and 2) its implication to urban and peri-urban wetland policy. This identifies where local wetland management policy stands in the phase of degradation. It also creates awareness and reinforces the need for local integration of applicable national and international policy initiatives aimed at improving urban and peri-urban wetlands management. At the same time, it demonstrates the importance urban and peri-urban wetlands have received following the synergy between UN-Habitat and the Ramsar Convention. This provides better understanding to recommend improvement in the uptake of urban and peri-urban wetlands policy in the context of the Global South.

## 2. STUDY AREA

Bamenda is located between latitude 5º 52′ 0″ and 6º 4′ 0″ North of the Equator, and longitude 10º 4′ 0″ and 10º 12′ 0″ East of the Greenwich Meridian. This is made up of Bamenda I, II and III municipalities. It is largely located at the foot of the Bamenda escapement which separates the area into two distinct segments of Up Station and Downtown (Ministry of Housing and Urban Development, 2012). Figure 1 shows the location of Bamenda and its municipalities.

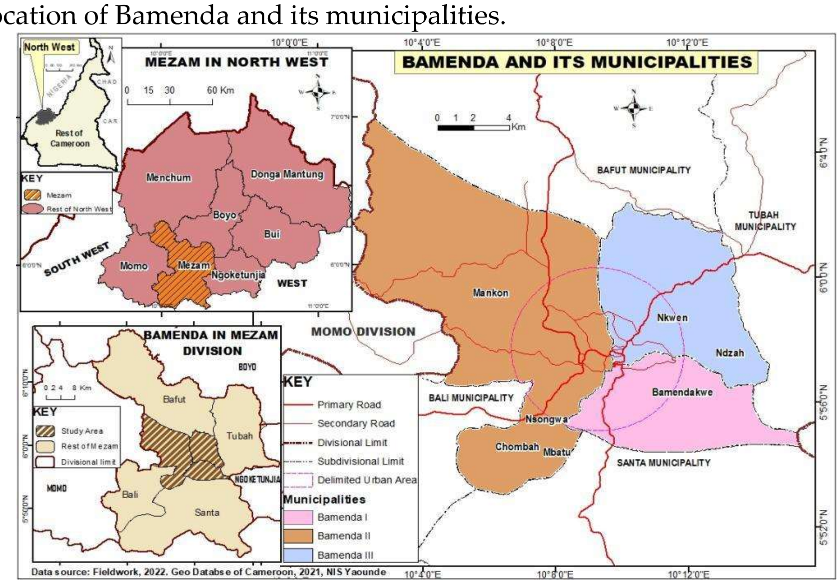


**Figure 1. Location of Bamenda**

In this study, the urban and peri-urban delimitation in Figure 1 adapted from the Ministry of Housing and Urban Development, (2012) is used as units for analysis. This is because, the study bases on remote sensing data to provide comprehensive understanding of the spatiotemporal dynamics of wetlands and policy implications. Bamenda has several wetland areas both in urban and peri-urban areas which are mostly riparian. This is the largest town in the North-West Region and the administrative and commercial hub of the region. It is the regional capital of the North-West Region, Divisional head quarter of Mezam Division and the sub divisional headquarter of Bamenda I, II and III municipalities in respect of the administrative set up of Cameroon. Bamenda is a planning and development area under the Bamenda City Council incorporating an urban space with a radius of about 5km from the Central Business District (CBD) (Ministry of Housing and Urban Development, (2012).

## 3. METHODOLOGY

Data collection instruments included mainly a laptop used to access the internet, and a book and pen used to write down important information. Base maps were acquired from geo database of Cameroon NIS Yaoundé. Landsat images were downloaded from USGS for 1992, 2002, 2012 and 2022. The choice of the base year (1992) was because, at this time Bamenda had not witnessed administrative reorganisation and large scale dynamics. Four different years of observation were chosen which coincides with periods when Google Earth images used for ground truthing are available. These also provided three distinct periods separated by a regular interval of 10 years to permit the detection of substantial changes on wetlands and other land uses. This was also to provide up to date information on wetland dynamics. Also, a 30 year cumulative period is relevant to reveal the trajectory of wetland dynamics in urban and peri-urban spaces of Bamenda. Table 1 illustrates details on satellite images.

**Table 1. Earth observation data specification**

| S/N | Image date | Satellite sensor | Downloaded date | Spatial resolution (meters) | Band number | Path/row | Cloud cover |
|---|---|---|---|---|---|---|---|
| 1 | 20/12/1992 | L.5 TM | 17/07/2022 | 30 | 6 | 186/056 | 20.00 |
| 2 | 09/12/2002 | L.7 ETM+ | 18/07/2022 | 30 | 7 | 186/056 | 11.00 |
| 3 | 20/12/2012 | L.7 ETM+ | 18/07/2022 | 30 | 7 | 186/056 | 2.00 |
| 4 | 27/03/2022 | L.8 OLI TIRS | 05/05/2022 | 30 | 9 | 187/056 | 4.35 |

**Source**: Field Survey, 2022

Another satellite image that was used for the study was Google Earth image of December 2021. This image was downloaded using the Universal Map downloader 9.30 and imported into ArcGIS (version 10.3) in which digitization of the wetlands was done. The image also permitted the digitization of the hydrographic and road networks, and other themes that were important for the study to enhance accuracy.

Documentary review was carried out to gain deeper understanding of urban and peri-urban wetland planning and management policies. Various sources of documents from the Bamenda City Council and the website of the Ramsar Convention (Ramsar.org) proofed very useful. Of great importance are the Master Plan of the Bamenda City Council (2011-2027) and the preliminary town planning of some earmarked projects within the Bamenda City Council (2012). With Cameroon being a party to the Ramsar Convention, other documents relating to Ramsar Resolution X.27 on Wetlands and urbanization; Resolution XI.11 on the principles for planning and management of urban and peri-urban wetlands; and Resolution XII.10 on the Wetland City Accreditation of the Ramsar Convention were equally reviewed to broaden understanding of urban and peri-urban wetland policy.

Images were imported into Erdas Imagine, 2014 where preprocessing was done. This saw layer stacking, image subset of the area of interest where urban and peri-urban delimitation in the Bamenda master plan was adapted to align with the study area and image enhancement through haze reduction. Interactive Supervised Classification was adopted for the processing of the images to generate a raster format depicting the designed Land Use/Land Cover (LULC) especially the wetlands. The raster format was imported into ArcGIS where it was converted from raster to vector format. Associated statistics of surface area of different LULC classes for the study dates were generated automatically before the extraction and symbolization of the different land uses to produce land use maps and the spatial distribution of the wetlands per study units. It is important to indicate that wetland dynamics is viewed from the spectrum of land use change as changes in other LULC are used to explain changes in wetlands between the urban and peri-urban areas of Bamenda. This is buttressed by the proportion of variation in wetlands that is explained by changes in other land uses (Figure 2).

Classified images were then subjected to accuracy analysis separately to ascertain the level of success in the classification process (Mbanga and Dingha, 2022). This was done using ArcGIS and Google Earth images for the various years of observation as reference, given that it was difficult to get substantial ground control points due to insecurity prevailing in the study area owing to the socio-political armed conflict. Thus, a point shape file was created in ArcGIS and points selected for each land use class for all the years of observation randomly over the classified images to ensure representativeness. Each point was given a unique identifier in relation to its LULC class (user values) and then ground truth according to Google Earth image, providing the producer values. The user and producer values were used to build a confusion matrix for the study dates (Table 2).

**Table 2: Confusion matrix of image classification**

| 1992 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Built up** | **Farmlands** | **Woodland** | **Gallery Woodland** | **Wetlands** | **Lake** | **Others Land use** | **Total (Users)** |
| Built up | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 15 |
| farmland | 0 | 10 | 0 | 0 | 0 | 0 | 2 | 12 |
| Woodland | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 4 |
| Gallery Woodland | 0 | 0 | 1 | 5 | 0 | 0 | 0 | 6 |
| Wetlands | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 |
| Lake | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Others | | 2 | 0 | 0 | 1 | | 5 | 8 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total (Producers) | 14 | 12 | 4 | 6 | 11 | 1 | 8 | 56 |
| **2002** | | | | | | | | |
| Built up | 12 | 0 | 0 | 0 | 0 | 0 | 1 | 13 |
| farmland | 0 | 9 | 0 | 0 | 0 | 0 | 2 | 11 |
| Woodland | 0 | 0 | 6 | 1 | 0 | 0 | 1 | 8 |
| Gallery Woodland | 0 | 0 | 1 | 4 | 1 | 0 | 0 | 6 |
| Wetlands | 0 | 1 | 0 | 0 | 9 | 0 | 0 | 10 |
| Lake | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Others | 1 | 0 | 0 | 0 | 0 | 0 | 6 | 7 |
| Total (Producers) | 13 | 10 | 7 | 5 | 10 | 1 | 10 | 56 |
| **2012** | | | | | | | | |
| Built up | 7 | 0 | 0 | 0 | 0 | 0 | 1 | 8 |
| farmland | 1 | 13 | 0 | 0 | 1 | 0 | 0 | 15 |
| Woodland | 0 | 0 | 6 | 1 | 0 | 0 | 0 | 7 |
| Gallery Woodland | 0 | 0 | 1 | 5 | 0 | 0 | 0 | 6 |
| Wetlands | 0 | 1 | 0 | 0 | 9 | 0 | 1 | 11 |
| Lake | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Others | 0 | 2 | 0 | 0 | 0 | 0 | 6 | 8 |
| Total (Producers) | 8 | 16 | 7 | 6 | 10 | 1 | 8 | 56 |
| **2022** | | | | | | | | |
| Built up | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| farmland | 0 | 9 | 0 | 0 | 1 | 0 | 1 | 11 |
| Woodland | 0 | 0 | 6 | 1 | 0 | 0 | 0 | 7 |
| Gallery Woodland | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 5 |
| Wetlands | 0 | 1 | 0 | 0 | 8 | 0 | 0 | 9 |
| Lake | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Others | 0 | 1 | 1 | 0 | 0 | 0 | 9 | 11 |
| Total (Producers) | 12 | 11 | 7 | 6 | 9 | 1 | 10 | 56 |

**Source**: Landsat 5, 7 and 8 images; Field Survey, 2022

With producer and users' values, correctly classified LULC classes align diagonally (Table 2) making it possible to determine the overall accuracy and Kappa coefficients thus;

Overall accuracy= Total number of correctly classified pixels (diagonal) X 100

Kappa coefficient= (TS x TC)-∑(column   Total number of reference pixels   1

Where TS= Total Sample and ´   $TS^2$-∑(column total - row total)   1

## 4. FINDINGS

Accuracy analysis of classified images of the various study dates indicate an overall accuracy of above 83% (Table 3). This demonstrates that image classification was successful with the Kappa coefficients for the observation years.

**Table 3: Summary of classification accuracy analysis**

| | Overall accuracy | Kappa coefficient |
|---|---|---|
| **1992** | 85.71 | 0.83 |
| **2002** | 83.93 | 0.81 |
| **2012** | 83.93 | 0.80 |
| **2022** | 89.29 | 0.87 |

**Source:** Landsat 5, 7 and 8 images

Table 3 indicates good performance of the image classification process (Kappa Coefficients greater than 80%) with significant and reliable results. As such, detected LULC changes are reliably used in analysing wetland dynamics in urban and peri-urban areas of Bamenda over the study periods.

## 4.1. Dynamics between urban and peri-urban wetlands in Bamenda (1992, 2002, 2012 and 2022)

Wetlands in urban and peri- urban areas of Bamenda have reduced tremendously over time. In 1992, urban wetland amounted to 5.31 km$^2$ making up 7.32% of the total land surface. While peri-urban wetland was 6.29 km$^2$ amounting to 3.05% of the land extent (Table 4). Built up area was 14.78 km$^2$ (20.37%) and 8.54 km$^2$ (4.14%) in urban and per-urban areas respectively, while farmland represented 52.44% and 41.07% of urban and per-urban land use. As such, farmland dominated the land use in both urban and per-urban areas of Bamenda in 1992 with wetlands being relatively high. Woodlands and other LULC types were also represented in both urban and peri-urban areas.

**Table 4: Urban and per-urban wetland dynamic between 1992 and 2002**

| | 1992 | | | | | | 2002 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | Peri-urban | | Total | | Urban | | Peri-urban | | Total | |
| LULC | Surface area | Percent | Surface area (Km$^2$) | Percent | Surface area (km$^2$) | Percent | Surface area | Percent | Surface area (km$^2$) | Percent | Surface area (km$^2$) | Percent |
| **Built up** | 14.78 | 20.37 | 8.54 | 4.14 | 23.32 | 8.36 | 20.46 | 28.21 | 10.17 | 4.93 | 30.63 | 10.98 |
| **Farmland** | 38.04 | 52.44 | 84.80 | 41.07 | 122.84 | 44.03 | 42.26 | 58.26 | 91.05 | 44.10 | 133.31 | 47.78 |
| **Woodland** | 1.16 | 1.60 | 23.40 | 11.33 | 24.56 | 8.80 | 0.71 | 0.98 | 14.60 | 7.07 | 15.31 | 5.49 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gallery woodland** | 4.96 | 6.84 | 28.00 | 13.56 | 32.96 | 11.81 | 2.81 | 3.87 | 28.21 | 13.66 | 31.02 | 11.12 |
| **Wetland** | 5.31 | 7.32 | 6.29 | 3.05 | 11.60 | 4.16 | 1.03 | 1.42 | 6.16 | 2.98 | 7.19 | 2.58 |
| **Others** | 8.29 | 11.43 | 55.28 | 26.77 | 63.57 | 22.78 | 5.27 | 7.26 | 56.12 | 27.18 | 61.39 | 22.00 |
| **Lake** | 0 | 0 | 0.17 | 0.08 | 0.17 | 0.06 | 0 | 0 | 0.17 | 0.08 | 0.17 | 0.06 |
| **Total** | 72.54 | 100 | 206.48 | 100 | 279.02 | 100 | 72.54 | 100 | 206.48 | 100 | 279.02 | 100 |

**Source:** Landsat 5 and 7 images; Field Survey, 2022

In 2002, wetlands demonstrated great changes as urban wetlands reduced to 1.03 km$^2$ (1.42%) while peri-urban wetland reduced to 6.16 km$^2$ (2.98%). Thus, wetlands witnessed a dramatic reduction in the last decade of the 21$^{st}$ Century especially in the urban area. This was accompanied by an increase to 28.21% and 58.26% of built up area and farmland respectively in the urban area. Therefore, urban wetland was lost to expanding urbanization and agriculture within this period. In the peri-urban area, wetlands reduced slightly during this decade as built up area and farmland increased slightly to 4.93% and 44.10% respectively. Other LULC types reduced considerably in the urban areas while peri-urban woodland equally reduced with slight increase in other LULC.

This continued to 2012 with urban wetland reducing further to 0.96 km$^2$ (1.32%) amidst built up area increase to 30.09 km$^2$ (41.48%) as seen in Table 5. Interestingly, farmland reduced markedly to 47.28% in the urban area as well as other LULC. In the peri-urban area, wetlands reduced to 4.79 km$^2$ (2.32%) while built up area increase to 6.86%. Farmland further increased to 46.15% as other peri-urban LULC types reduced. This indicates that, while wetlands were principally lost to build up area in the urban space of Bamenda within this decade, it was distinctively lost to build up area and agriculture in the peri-urban area. This is because, densification began in urban area at the beginning of the 21$^{st}$ Century while urban sprawl intensified in peri-urban areas contributing to increase infrastructure development and peri-urban agriculture as urban farmers resorted to this area. Equally, this period saw the administrative reorganisation of Bamenda in 2007 putting in place the Bamenda City Council.

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**Table 5: Urban and per-urban wetland dynamic between 2012 and 2022**

| | 2012 | | | | | | 2022 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | Peri-urban | | Total | | Urban | | Peri-urban | | Total | |
| LULC | Surface area | Percent | Surface area ($km^2$) | Percent | Surface area ($km^2$) | Percent | Surface area | Percent | Surface area ($km^2$) | Percent | Surface area ($km^2$) | Percent |
| **Built up** | 30.09 | 41.48 | 14.16 | 6.86 | 44.25 | 15.86 | 36.89 | 50.85 | 16.83 | 8.15 | 53.72 | 19.25 |
| **Farmland** | 34.30 | 47.28 | 95.29 | 46.15 | 129.59 | 46.44 | 29.69 | 40.93 | 92.30 | 44.70 | 121.99 | 43.72 |
| **Woodland** | 0.52 | 0.72 | 10.59 | 5.13 | 11.11 | 3.98 | 0.49 | 0.68 | 9.88 | 4.78 | 10.37 | 3.72 |
| **Gallery woodland** | 1.69 | 2.33 | 27.54 | 13.34 | 29.23 | 10.48 | 1.32 | 1.82 | 27.46 | 13.30 | 28.78 | 10.31 |
| **Wetland** | 0.96 | 1.32 | 4.79 | 2.32 | 5.75 | 2.06 | 0.43 | 0.59 | 4.48 | 2.17 | 4.91 | 1.76 |
| **Others** | 4.98 | 6.87 | 53.94 | 26.12 | 58.92 | 21.12 | 3.72 | 5.13 | 55.36 | 26.81 | 59.08 | 21.17 |
| **Lake** | 0 | 0 | 0.17 | 0.08 | 0.17 | 0.06 | 0 | 00 | 0.17 | 0.08 | 0.17 | 0.06 |
| **Total** | 72.54 | 100 | 206.48 | 100 | 279.02 | 100 | 72.54 | 100 | 206.48 | 100 | 279.02 | 100 |

**Source:** Landsat 7 and 8 images; Field Survey, 2022

Wetlands still demonstrated degradation in 2022. While urban wetland reduced to 0.43 $km^2$ (0.59%), peri-urban wetland stands at 4.48 $km^2$ (2.17%). Thus, wetland in the Bamenda urban space is at the verge of collapse. This is given the continuous increase observed in built up area which now occupies more than half (50.85%) of the land surface in Bamenda urban space. Farmland further reduced to 40.93%. By implication, urbanisation is responsible for urban wetlands loss in Bamenda. Peri-urban wetlands reduced as built up area increased to 8.15% demonstrating intensification and densification of urban sprawl into peri-urban areas as farmland also reduced to 44.70%. This makes urban sprawl responsible for peri-urban wetland degradation.

### 4.1.1 Trends in urban and peri-urban wetlands dynamics in Bamenda

The trend in wetland decrease in the urban and peri-urban areas show varying patterns as seen in Figure 2. Between 1992 and 2002, urban wetlands rapidly declined continuing relatively gentle between 2002 and 2012, continuing to 2022. On the other hand, decrease in per-urban wetlands in Bamenda between 1992 and 2002 was relatively gentle. This accelerated slightly from 2012 to 2022. This is accounted for by the stabilisation of the City Council and three sub divisional councils of Bamenda I, II and III put in place in 2007, which increased the provision of administrative services in peripheral zones attracting a considerable number of the population leading to encroachment and degradation of peri-urban wetlands.

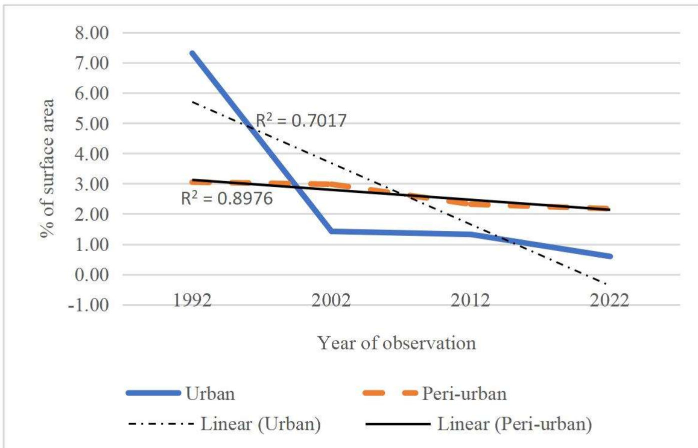
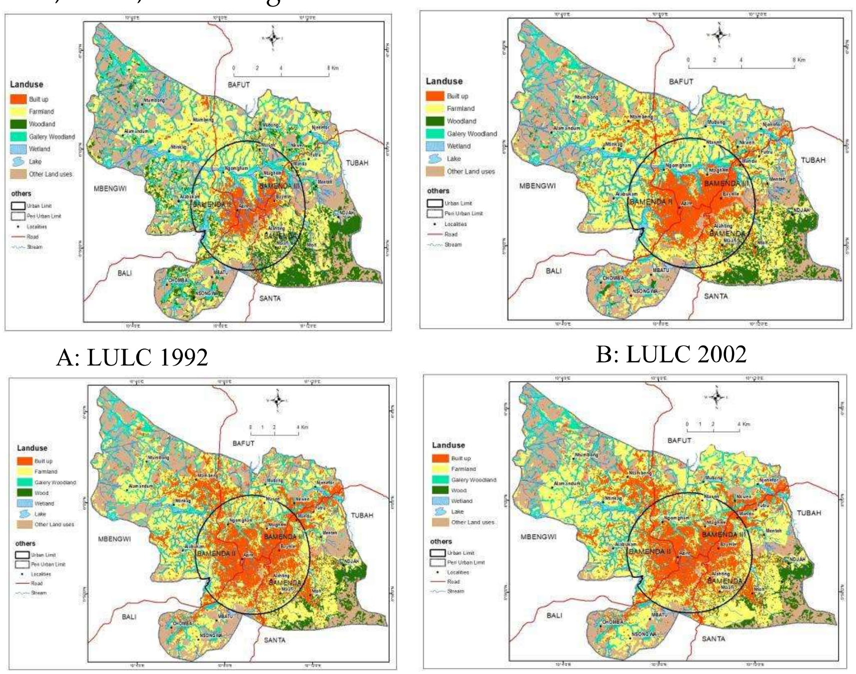



**Figure 2: Trends in urban and peri-urban wetland dynamics**
**Source**: Landsat 5, 7 and 8 images; Field Survey, 2022

Figure 2 depicts a steep constant decrease of wetland surface area in the urban space of Bamenda falling from 1992 to 2022 reaffirming its degradation and loss. The proportion of wetland loss that can be explained by variation in other LULC is indicated by the $R^2$ equation. This show that, urban wetland loss is accounted for by variation in built up area and urban agriculture at 70.17%. Alternatively, the trend of wetland degradation in the peri-urban area is relatively gentle, and accounted for by built up area increase and agriculture at 89.76%.

### 4.1.2 Evolution of urban and peri-urban wetlands in Bamenda

The LULC changes observed in urban and peri-urban areas of Bamenda indicates that wetland have evolved tremendously. As shown in Figure 3, wetlands evolved from a visible state in Manda, Ngomgham, Ntaghem and Ntakeka in the urban area, and Meteh, Mbelem and Ntoh in the peri-urban zone in 1992 when settlement in both areas were less dense. But in 2002, urban and peri-urban wetlands witnessed conspicuous encroachment from agriculture in both urban and peri-urban areas and built up area increase. The urban area sprawled to the north, north east and the southern parts of Bamenda. Urban sprawl thus, became very visible in this phase of evolution especially in the peri-urban zones of Menteh, Futru, Ntambeng and Ntoh.




A: LULC 1992 B: LULC 2002

C: LULC 2012 D: LULC 2022

**Figure 3: Evolution of LULC in Bamenda**

**Source:** Landsat 5, 7 and 8 images; Field Survey, 2022

In 2012, wetlands became less visible in urban and peri-urban areas as the urban area densified with intensification of urban sprawl. Major axes of urban sprawl into peripheral areas included those towards Njenefor, Ntambeng, Chombah and Ntoh while minor axes included Menteh, Mubang, Ndzah and Alamandum all in the per-urban zone. The increase in built up area and the reduction in farmland in the urban area is visible while, expansion of farmland into peri-urban areas became enormous triggering wetland loss. Such trend continued to 2022 with the densification of urban area making wetland loss visible along the Ntaghem-Ntakeka area. This is also true with the densification in urban expansion axes in Ntoh, Futru and Ntambeng encroaching into peri-urban wetlands.

Cumulatively, wetland and LULC dynamics between urban and peri-urban areas from 1992 to 2022 of the study area provides the results in Table 6.

**Table 6: Rate of urban and per-urban LULC change between 1992 and 2022**

| | Urban | | | | | Peri-urban | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Surface area 1992 ($km^2$) | Surface area 2022 ($km^2$) | Change in Surface area (km2) | Rate of change (percent) | Remark | Surface area 1992 ($km^2$) | Surface area 2022 ($km^2$) | Change in Surface area (km2) | Rate of change (percent) | Remark |
| **Built up** | 14.78 | 36.89 | 22.11 | 149.59 | Increasing | 8.54 | 16.83 | 8.29 | 97.07 | Increasing |
| **Farmland** | 38.04 | 38.04 | 0 | 0 | Constant | 84.80 | 92.30 | 7.50 | 87.82 | Increasing |
| **Woodland** | 1.16 | 0.49 | -0.67 | -4.53 | Decreasing | 23.40 | 9.88 | -13.52 | - 158.33 | Decreasing |
| **Gallery woodland** | 4.96 | 1.32 | -3.64 | -24.63 | Decreasing | 28.00 | 27.46 | -0.54 | -6.32 | Decreasing |
| **Wetland** | 5.31 | 0.43 | -4.88 | -33.02 | Decreasing | 6.29 | 4.48 | -1.81 | -21.19 | Decreasing |
| **Others** | 8.29 | 3.72 | -4.57 | -30.92 | Decreasing | 55.28 | 55.36 | 0.08 | 0.94 | Decreasing |

**Source**: Landsat 5 and 8 images; Field Survey, 2022

Between 1992 and 2022, urban wetland was lost at the highest rate (33.02%), compared to 21.19% loss rate in the peri-urban area. This is because of the high rate of urbanisation and infrastructure construction that characterised the urban area coupled with urban agriculture expansion into wetlands. Therefore, though wetlands have decreased throughout the study period in both urban and peri-urban areas in Bamenda, the former degraded at a faster rate.

## 4.2. Policy implications of urban and peri-urban wetland loss

Urban and peri-urban wetlands in Bamenda have been lost from 5.31 $km^2$ (7.32%) and 6.29 $km^2$ (3.05%) in 1992 to 0.43 $km^2$ (0.59%) and 4.48

km$^2$ (2.17%) in 2022 respectively. This is because of constant encroachment especially by build-up area, which increased from 14.78 km$^2$ (20.37%) and 8.54 km$^2$ (4.14%) in 1992 to 36.89 km$^2$ (50.85%) and 16.83 km (8.15%) in 2022 respectively for urban and peri-urban areas. But, wetland management policy of the Bamenda City Council remains confusing and unclear in stemming degradation. At the same time as the conversion of wetlands due to urban development is seen as unsustainable in the Master Plan of the Bamenda City, the City Council appears to paradoxically promote conversion. This is exemplified by the indication that:

> "Large portions of the city are swampy. These swampy areas have constituted breeding spot for mosquitos, refuse dump and urban encroachment. Many private developers do not respect minimum setbacks of streams during building construction. The consequences have far reaching especially lost urban ecology and general destruction of urban ecosystem. In order to cope with the environmental issues and also meet up land demand for building, all marshy areas have been design for reclamation." (Ministry of Housing and Urban Development, 2012; P. 68)

This clearly demonstrates the incomprehensiveness in wetland management policy as degradation proliferates in Bamenda. While wetlands conversion is regarded as unsustainable with "far reaching" consequences especially on "urban ecosystems", the city council rather opt for reclamation of all wetlands to cope with "environmental issues" in Bamenda. Yet, "most people have built along and in swampy areas", "consequently increasing flooding" (Ministry of Housing and Urban Development, 2012; P. 14). This is further compounded by the study on preliminary town planning of some earmarked projects within the Bamenda City Council identifying several wetland stretches for reclamation amidst acknowledgement of its importance in urban centres (Bamenda City Council, 2012). Such incomprehensiveness and unsupportiveness of wetland management policy sacrifices them to increasing degradation in urban and peri-urban areas of Bamenda.

Also, as wetlands deteriorate in Bamenda, Cameroon is a party to the Ramsar Convention whose promised wetland policy is yet to bare out.

However, with observed degradation, the unique Ramsar resolution on the principles for planning and management of urban and per-urban wetlands which urged contracting parties (Cameroon inclusive) to act upon these principles to ensure their take up by responsible sectors is disregarded in Bamenda. So too is the Resolution X.27 urging contracting parties to pay due attention to the importance of wetlands in urban and peri-urban areas (Ramsar Convention, 2008) not taken up into local policy in Bamenda. This is as urban development is greatly impacting wetlands in urban and peri-urban areas marked by incomprehensive wetland management policy of the Bamenda City Council. By implication, Resolution XII.10 of the Ramsar Convention on voluntary city accreditation inviting contracting parties to propose cities in their territories (such as Bamenda in Cameroon) for wetland city accreditation (Ramsar Convention, 2015) is not envision. This is as there exist incomprehensive locally adapted policy for sustainable wetland management in this area. Thus, as Bamenda-a primate city in the North West Region of Cameroon-*par excellence* is rapidly losing its wetland in urban and peri-urban areas to urban development, it is increasingly losing its privilege for a possible accreditation as a "Wetland City" of the Ramsar Convention. This is despite the fact that the process of accreditation is free with benefits of management support for the implementation of sustainable urban designs. Therefore, Bamenda is not on track for achieving Sustainable Development Goal 11 of building a sustainable city as its wetlands are at the verge of collapse.

## 5. DISCUSSION AND CONCLUSION

From 1992 to 2022, wetlands have drastically reduced to just 0.59% in the urban and 2.17% in the peri-urban areas of Bamenda. This is because of constant pressure especially from built up area, which occupies 50.85% of the urban space and 8.15% of the peri-urban area in 2022. As such, urban wetlands are degraded at a faster rate (33.02%) than those in the peri-urban areas (21.19%). This implies that, wetlands are at the verge of collapse especially in the urban area of Bamenda. Yet, local wetland management policy of the Bamenda City Council have remained unsupportive and incomprehensive (Ministry of Housing and Urban

Development, 2012; Bamenda City Council, 2012) favouring continuous degradation. Even applicable national and international wetland management policies (Ramsar Convention, 2012; Ramsar Convention, 2008) are neglected and not reflected in local management policy in Bamenda sacrificing wetlands for incessant conversion and degradation. As it stands therefore, Bamenda is fast losing its privilege of a possible accreditation as a wetland city (Ramsar Convention, 2015).

Though such wetland reduction trend have been reported by Mbanga and Dingha (2022); Balgah and Kimengsi (2016); Orimoloye *et al*., (2020); Sousa (2020); and Dehua *et al*., (2018), this study elucidates reduction trajectory in urban and peri-urban areas in Bamenda. In the urban area, wetland is greatly lost to build up area expansion just like the case of Katja *et al*., (2020) but, this takes a different twist in the peri-urban area of Bamenda as wetland is lost to urban sprawl (Abebe, 2013) and agriculture unlike to green space (Katja *et al*., 2020). Therefore, wetland degradation is triggered by urbanisation (Rwanyiziri *et al*., 2020) and agricultural expansion (Yashuang *et al*., 2021). As built up area expands, wetlands have become a safety net for urban and peri-urban agriculture in Bamenda whose future is threatened by reclamation and lost. This has great implications for the principles of sustainable planning and management of urban and peri-urban wetlands orchestrated by the Ramsar Convention and UN-Habitat which is not adequately integrated into local policy just like elsewhere (McInnes, 2014). As such, Bamenda is not on track to contribute to achieving Sustainable Development Goals 11 on sustainable city and it is fast losing the privilege of a possible accreditation as a wetland city, despite the benefits that accrue. This is true for other cities in Cameroon and Sub Saharan Africa.

Wetlands have witnessed enormous dynamics in the urban and peri-urban areas of Bamenda due to anthropogenic land use change. Built up area occupies 50.85% of the urban area of Bamenda reducing wetlands to barely 0.59% of the total urban land cover in 2022. This puts wetlands at the verge of collapse in Bamenda especially in the urban space. In the face of this, the Bamenda City Council paradoxically provides incomprehensive and unsupportive wetland management policy. As such, the synergistically developed principles for the planning and management of urban and peri-urban wetlands of the UN-Habitat and the Ramsar Convention is not regarded and taken up in sectorial policies in Bamenda. The city is hence, fast losing its privilege of being accredited as a "Wetland City" despite positive international support that accrue. This calls for urgent and accelerated awareness raising and implementation of policies for sustainable urban and peri-urban wetland management in Cameroon and other cities in developing countries.

## FUNDING

This research paper received no internal or external funding.

## ORCID

***Dingha Chrispo Babila: https://orcid.org/0000-0003-1266-1829***

***Mbanga Lawrence Akei: https://orcid.org/0000-0001-8986-3424***

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