**Road network connectivity implications on urban wetlands accessibility in the city of Douala, Cameroon**

**ABSTRACT**

Urban wetlands have an established record to provide essential services such as flood mitigation, water purification, and biodiversity conservation, but the uncoordinated growth of third world cities have triggered an influx into these wetlands. The Douala urban peripheral mangrove wetlands that were none constructible areas have succumbed to this human pressure which compromises their accessibility and functionality. This study investigates the implications of road network connectivity on urban wetland accessibility in Douala, Cameroon. Field survey of the road transport network was carried out and analyzed for road network connectivity using the Beta index in addition to a survey through targeted questionnaires to 500 households in three wetlands that epitomize the road accessibility trait. Results of the study revealed that the road network of Mambanda and Makepe Missoke is high with 7.1 km/km2 and of 8.1km/km2 while that of Bois des Singes is low with just of 3.5 km/km2. The connectivity of the road network in the wetlands from the beta indices gives a connected road network with Mambanda, Makepe Missoke and Bois des Singes having beta indices of 1.17, 1.11 and 1.02 respectively. The implication is that the urban wetland road connectivity gives a false impression of accessibility for the flux of good and human services that are constraint by the natural hydro geomorphological conditions. There is need to rethink the mobility plight of the urban wetland duellers once left to colonize such *inedificandi* areas.

**KEY WORDS**: urban wetland, rood network connectivity, accessibility, Douala, Cameroon

1. **INTRODUCTION**

The number of people living in coastal cities around the world remains high as a consequence of the world population increase. The bulk of humanity is clustered on coasts that are 10% of the earth’s land surface. In Africa, some 52 cities are home to more than one million inhabitants and most are coastal cities with a great influx of the population from the hinterland. Human expansion of these cities on hydro-geomorphological traits of urban wetlands is on the rise. The Douala city has emerged as the economic capital of Cameroon where development is anarchical and uncontrolled over the years resulting in the occupation of the wetlands. The human colonization of wetland space has spread from the centers to the urban peripheral mangrove wetlands that *a priori* are none constructible areas. This condition has made the wetland, over the years, to become domains of municipal social facility neglect while at the same time become a domain of under privileged population territory for makeshift infrastructural implantation. This has grown with an indescribable anarchy especially for the road network that is key determinant of wetland accessibility. The access roads are in an adequacy to the flux of population and goods and even with the few access roads that exist, the high level of degradation only go to inhibit the accessibility of the wetlands.

Wetland within the Douala urbanscape are important mindful of its dominantly low-lying topography of the River Wouri estuary characterized by coastal and mangrove wetlands with muddy soils (Fogwe and Tchotsoua, 2006). Douala city has hydromorphic and ferralitic soils. The hydromorphic soils which are gley or pseudo gley soils are on the low-lying areas along the coast while ferralitic soils are found on the relatively higher altitude areas. Mambanda and Bois des Singes are located on estuarine hydromorphic soils while Makepe Misspoke has hydromorphic soils in the low-lying flooded basins while ferralitic soils are on the elevated sites with an altitude that goes up to 60 m above sea level. This geologic setting coupled with heavy rainfall averaging 4000 mm per year makes it difficult for roads to implant in these wetlands.

The Ramsar 2018 delineation of wetlands included areas of marine water, the depth of which at low tide does not exceed six meters, and the World Wildlife Fund (2024) further ruminates a wetland as land that is covered by water-salt, fresh, or somewhere in between-either seasonally or permanently. Fathomably, these conditions restraint the construction of roads as it unswervingly influences the cost and appropriateness of the site technology deployed. Both are mutual deterrents to the development of good road network in the Douala wetlands, the few access roads are not properly constructed, often degraded and inundated resulting in difficulties for people to access and circulate within the wetlands.

In Douala, more than 80 percent of the degradation is shown by potholes on roads (Ngatcha and Ekodeck, 2003). Road surface water retention results from the shallow water table, low-lying topography and rainfall. This distorts and destabilizes the schedules and activities of the inhabitants, and the rhythm of evacuation of goods. Tonye et *al*, 2013 considers that the degradation of infrastructure in Douala is caused by flooding that between 2000 and 2010 have caused over 100 deaths and destruction of houses and roads. During such periods, human activities in the city swamps are forestalled and traffic jams occur. The ttransportation component of the urban system is critical to the metropolitan life and economic vitality considering that modes of transport can work interdependently or independently as a system. Well-developed and efficient transportation systems offer high levels of accessibility, while less-developed ones have lower levels of accessibility (Rodrigue, J.P. *et al*, 2009). This study considers this as the core of the research problem to probe as for the Douala wetlands. This paper posits that all Douala wetlands are not equal because some are more accessible than others thereby amplifying local imbalances.

1. **STUDY AREA AND METHODOLOGY**

The Atlantic coast of Cameroon has some town like Limbe and Kiribi but the digest and fasted growing is Douala on the Wouri Estuary, extending 30km from the Atlantic Ocean. Located between latitudes 4° 05’ and 4° 57’ North and longitudes 9° 35’ to 9° 80’ East of the Greenwich Meridian. Within this geographical space three wetlands that epitomize the road accessibility trait evaluation were considered. At the west of the city is the Mambanda wetland, to the South is Bois des Singes wetland and in the heart of the city towards the northeast is the wetland of Makepe Missoke (Fig. 1).

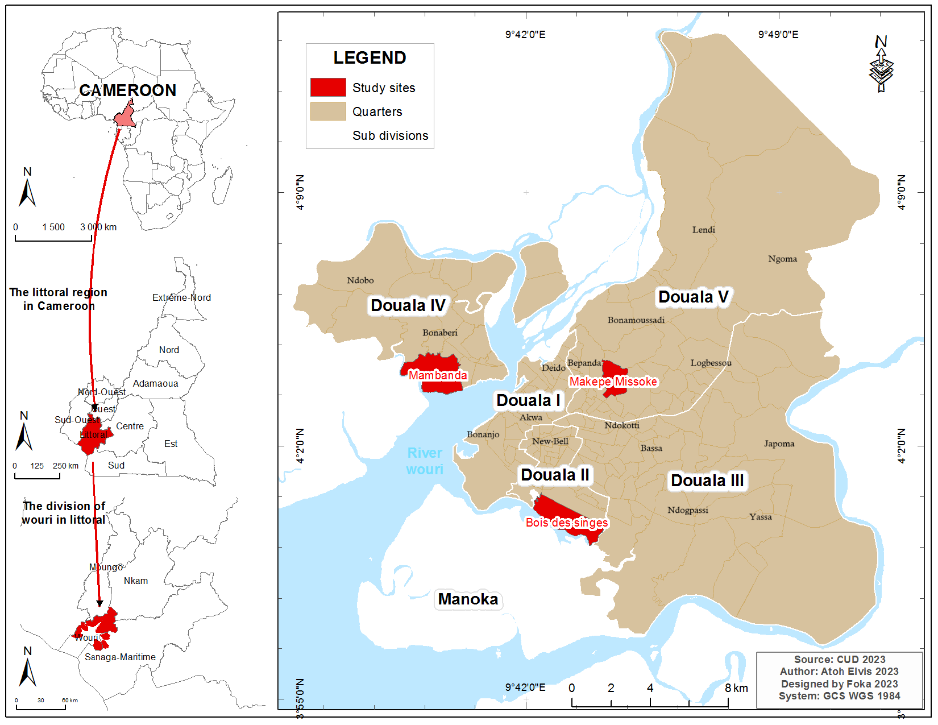


Figure 1: Map of the wetlands studied in Douala, Cameroon

These sites in Douala are located within the inter-tropical zone in the Gulf of Guinea, within a tropical humid climate whose mean annual rainfall is 4000 mm and temperatures ranging between 24 and 27˚C. The dry season is barely three months while the wet season runs nine months thus providing ample atmospheric input for urban wetlands. The chosen wetlands thus have appreciable areas estimated as follows: Bois des Singes (385 hectares with a population of about 20,000), Mambanda (470 hectares with of about 100.000) while Makepe Missoke (188 hectares with an estimated population of about 50.000). Stakeholder perception on road accessibility were surveyed through questionnaire technique of simple random sampling variably according to the wetland (Table 1)

Table 1: Sample point characteritics

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Name of wetland | Population | | | Wetland unit | Number selected per zone | Total questionnaires administered | % |
| Population | % | |
| Mambanda | 100.000 | 58.8 | | Centre | 126 | 200 | 40 |
| peripheral | 74 |
| Makepe Missoke | 50.000 | 29.4 | | Centre | 104 | 160 | 22 |
| peripheral | 56 |
| Bois des Singes | 20.000 | 11.8 | | Centre | 88 | 140 | 38 |
| Peripheral | 52 |
| Totals | 170.000 | | 100 |  | 500 | 500 | 100 |

Source: Researcher’s Construct, February 2025

Study data were collected through questionnaire surveys and informal interviews in the Mambanda, Makepe Missoke and Bois des Singes quarters (Table 1) about the state of the road and means of transport used, indigenous adaptations to the roads and accessibility of each area. The questionnaires were treated using the Statistical Package for Social Sciences (SPSS) Version 20 to generate tables and graphs. Secondary data were from the road network topological maps and the Beta index computed to determine the connectivity and accessibility indicators.

1. **PRESENTATION OF RESULTS**
   1. **The emergence of urban wetlands in the sprawl of Douala from 1960**

Douala that was part of French Cameroon, at independence in the 1960 comprised essentially Deido, Akwa, New Bell, Bonapriso, Bonanjo and Bonaberi. The Landsat satellite images for 1975 for Douala were treated to obtain the initial relative distribution between the urban area and the non-urbanised wetland areas. Urban sprawl initially avoided but in the long term swallowed up natural obstacles as swamps, flood plains and the mangrove vegetation that were the Douala wetlands. Initially, some 80% of the present-day Douala as of 1975, was covered by natural vegetation. This implies that only 4,322 ha was urbanised while 36.000 ha was a dense primary vegetation and 5,000 ha made up of secondary vegetation, being a total of 41.000 ha of vegetated area dominated by mangrove swamps. In 2024, the urbanised area of Douala had increased to 20.000 ha and the total vegetation decreased to 21.000 with primary vegetation of just 13.800 ha (Fig. 2)

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| --- | --- | --- |
|  |  |  |
| **Land uses in 1975** | **Land use in 1986** | **Land use in 2024** |
| Source: Landsat 4 TM (1975), INC 2024 | Source: Landsat 4 TM (1975), INC 2023 | Source: Sentinel 2 (2024), INC 2024 |

**Figure 2: The evolution of relative land uses of Douala in 1975-2024**

The spatial distribution reveals that by 1975, wetlands in Douala were still occupied by the natural mangrove vegetation at Mambanda, Makepe Missoke and Bois des Singes with little or no urban population expansion and construction (Fig. 3)

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| --- | --- |
|  |  |
| The 1975 location of the Mambanda, Makepe Missoke and Bois des Singes wetlands | The 1986 situation of Mambanda, Makepe Missoke and Bois des Singes wetlands |
|  | |
| The 2024 situation of Mambanda, Makepe Missoke and Bois des Singes wetlands | |

**Figure 3: The evolution of urban sprawl unto the wetlands from 1975 to 2024**

The increase in urbanised area more than doubled in size and urban front extended into the Douala wetlands in the 1980s. This period marked the beginning of the occupation of the wetlands in the city of Douala. In 1986, more than 90% of Makepe Missoke was urbanised compared to just about 30% of Mambanda and 5% of Bois des Singes and this trend continued to 2024 in an anarchy and spontaneity that did not permit an appropriate road development for wetland accessibility.

**3.2 Road network in the Douala wetlands**

Urbanization of the Douala wetlands necessitate the extension of access ways into the area through roads with diverse modes of mobility. The road network in these Douala wetlands is largely untarred, degraded, poorly drained and muddy. These traits are either indicative of the long history of municipal neglect of social service provision through roads or a mirror of the misery that marks the bulk of its colonizing in-migrants. The few access ways have therefore a strong limitation by technology and financial input worthy of its population

In the wetland of Mambanda, there are differences in the road conditions at the interior and the peripheral areas resulting in the use of different modes of transport. In Mambanda, just over 2.5 km of roads are paved or tarred. These are the Mambanda main road which is paved from Cemetiere to ALPICAM and the tarred secondary road passing through Quartier administrative to Foret Bar. There are untarred secondary roads that are degraded and poorly drained during the rainy season and partially graded during the dry season as the one passing through John White to Bloc 23, the road to Ecole Communale, the GBHS Mambanda roads and the roads behind ALPICAM. These roads that are tarred, paved and untarred but seasonally graded are found in the interior (centre) part of the wetland. At the peripheral areas, the road network is made up of untarred secondary roads and footpaths that are degraded and often inundated. The transport modes range from clandestine buses (clando) to taxis, motorbikes (benskin) and trekking. The choice of the transport modes depends on the level of individual and the place of resident. In Mambanda, only the main road is accessible with the constant circulation of buses, taxis and motorbikes. People who live along and around the main road have the choice of choosing amongst different transport means while those who live at the peripheral areas where motor vehicles cannot reach their neighborhood either take a motorbike or walk on foot.

In the wetland of Makepe Missoke, the road network characteristics are similar to that of Mambanda but with the difference that the roads at the interior are more drained because of its location which is on a plateau. The road network of Makepe Missoke is also made up of main roads, secondary roads and footpaths having different characteristics at different parts in terms of road conditions and transport modes. In this wetland, about 2 out of about 15.3 km of roads are tarred with some secondary roads that are not tarred but often maintained during the dry season. The tarred roads are the main road from Bepanda through Makepe Missoke to Ndogbong and Makepe Petit Pays. The transport modes here include clandestine vehicles (clandos), transport buses, taxis and motorcycles (benskin). The inhabitants of this area choose the transport mode that suits their activities. Those secondary roads that are not tarred but often graded during the dry season are the secondary road from Entrée Chefférie towards Pont-Cassé, the secondary roads at Desert and those around Hotel Doville. Unlike the tarred roads, the secondary roads do not have permanent circulation of any transport mode but the inhabitants can use any modes of transport in this zone if hired. At the peripheral zones (the low-lying areas of the drainage basin), there are untarred secondary roads and footpath which are sometimes degraded and poorly drained especially during the rainy season thereby limiting transport modes with only motorcycles and walking being the main transport mode.

Bois des Singes possesses similar characteristics of road network with only about 720 m of tarred road from the entrance of Bonapriso to the crematorium at Entrée Chefférie. The rest of the road is not tarred, poorly drained, degraded and muddy during the rainy season but maintained during the dry season. The inhabitants of this zone use trucks, taxis, private cars, and motorcycles (benskin) for mobility. In the peripheral zones, the secondary roads and footpaths are poorly drained, muddy and inundated especially during the rainy season causing the use of only motorcycles and trekking.

**3.3 Indigenous structural responses to road accessibility challenges into the wetlands**

Douala wetland inhabitants have resorted to indigenous adaptations to the road accessibility challenges as some inhabitants group themselves into association and jointly work on maintaining community roads while others work individually on private roads in order to make their locality or homes accessible. Such Development Associations involved in Mambanda include the Development Association of Block 23, Development Association of Block 25, The Youth Association of Bloc 7 and the Association of Young entrepreneurs of Mambanda John White. The ones in Makepe Missoke include Dynamic Youth of Makepe Missoke, Development Association of Block 1, and Youth Association of Makepe Chefferie. Those of Bois des Singes include Development Association of Chefferie Bois de Singes I, Dynamic Youth of Kuweit Bois de Singes, Development Association of Bois des Singes III, Association for the Development of Sahel Bois des Singes, les Jeunes Fulbé de Bloc 8, Les Jeunes Dynamique de Kuweit Bois des Singes and others.

These Local Development Associations work for the positive enhancement of their localities through amending the degraded secondary roads, improving on the drainage system of the area by digging and widening drains to reduce flood impacts. The communities raise funds for the purchase of gravel and other materials used in the filling of roads on their local transport system. Some inhabitants of the peripheral areas of the wetlands carry out indigenous adaptations on the roads using local materials such as planks, poles, sawdust, stones, car tyres and solid waste (Table 2).

**Table 2: Common adaptation materials used in the Douala wetlands**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Douala wetland** | **Locality** | **Type of material used** | **Dimension** | | **State of material** | **Wetland characteristics** |
| **Length (m)** | **Width (m)** |
| **Mambanda** | Passerelle | Saw dust | 20 | 3 | Good | Poorly drained |
| CES | Car tyres | 15 | 0.5 | Bad | Muddy and flooded |
| Rambo | Wood | 5 | 0.4 | Deteriorating | Flooded |
| Block 7 | Gravel | 10 | 3 | Degraded | Poorly drained |
| **Makepe Missoke** | Pont Casse | Wood | 8 | 0.4 | Good | Flooded |
| Depot de planche | Saw dust | 7 | 2 | Bad | Poorly drained |
| Carrefour Tete | Car tyres | 13 | 0.5 | Bad | Poorly drained |
| **Bois des Singes** | Quartier Boule | Black earth | 5 | 0.3 | Bad | Flooded |
| Quartier Bamenda | Gravel | 10 | 3 | Good | Poorly drained |
| Cite de Dieu | Wood | 7 | 0.4 | Good | Flooded |

Source: Field surveys, 2024

In Mambanda, saw dust from the wood processing industry (ALPICAM) where the inhabitants then transport to their various localities. Inhabitants of Makepe Missoke get their own from sawmills at Depot de Planche. In localities like Passerelle Mambanda and Depot de planche Makepe Missoke, there exist roads and footpaths of 0.5 to 3 m wide and about 15m to 20 m long that have been adapted with saw dust as a means of reclaiming the roads. However, field survey permitted us to establish some four-adaptation strategies by the population within the Douala wetlands (Figure 4)

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| Filling with saw dust | Filling with gravel and laterite | Aligned waste tyres | Passages with suspended plank bridges |

**Figure 4: Access way strategies adapted on roads in the Douala wetlands**

The strategies adapted are fair the same in the three wetlands. Specific variation could only be indicative of the availability of the raw material that can be dumped on access ways as immediate palliatives for human and goods mobility.

**3.4. The degree of accessibility of the wetlands**

In evaluating the road network and accessibility of the wetlands of Douala, it was important to take into consideration the state of roads, the road network density and the road network connectivity. The road network density is a measure of the length of roads per kilometre square (Table 3).

**Table 3: Road network density of the Douala Wetlands**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Locality | Road length (km) | | | Wetland area (km2) | Road density(km/km2) |
| Tarred | Untarred | Total |
| Mambanda | 2.4 | 31.3 | 33.7 | 4.7 | 7.1 |
| Makepe Missoke | 1.97 | 13.4 | 15.3 | 1.88 | 8.1 |
| Bois des Singes | 0.72 | 12.7 | 13.4 | 3.84 | 3.5 |

Source: Extracted from road network of the city of Douala, CUD 2024

In Mambanda, 1.9 of the 4.1 km of the main roads are paved and 0.5 of 29 km of secondary roads is tarred making a total of 2.4 out of 33.7 km. The total length of roads of 33.7 km on a total surface area gives a road network density of 7.1 km/km2. In Makepe Missoke, 1.97 km of roads are tarred out of 15.3 km on a total surface area of 1.88 km2, giving a road network density of 8.1 km/km2. In Bois des Singes only 0.72 km of road is tarred out of 13.4 km. with a total surface area of 3.84 km, its road network density is 3.5 km/km2.

The connectivity of the road network in the Douala wetlands was calculated using the Beta Index. The Beta Index is obtained from the topological maps of Mambanda, Makepe Missoke and Bois des Singes (Fig. 5).

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| --- | --- | --- |
|  |  |  |
| Mambanda | Makepe Missoke | Bois des Singes |

**Figure 5: Topological maps of the sampled wetlands of Douala**

The Beta index is mathematically calculated using the formula *B*=e/v, where e stands for the edges or links and v for the vertices or nodes. A road network with a Beta Index of one is connected, less than one is not connected and more than one is highly connected (Table 4).

**Table 4: Road network connectivity of the Douala wetlands**

|  |  |  |  |
| --- | --- | --- | --- |
| Locality | Number of edges or links | Number of vertices or nodes | Road network connectivity (Beta index) |
| Mambanda | 498 | 427 | 1.17 |
| Makepe Missoke | 307 | 277 | 1.11 |
| Bois des Singes | 185 | 180 | 1.02 |

Source: Extracted from map of road network in the city of Douala, CUD, 2024

The road network of Mambanda is made up of 498 links (edges) and 427 nodes (vertices) which gives a beta index of 1.117. The wetland of Makepe Missoke is made up of 307 links and 277 nodes for a beta index of 1.11 while in Bois des Singes, there are 185 links to 180 nodes which gives a beta index of 1.02 (Table 4).

1. **DISCUSSIONS OF RESULTS**

The city of Douala rapidly expanded towards the North and then East and South-East avoiding major obstacles which were River Wouri and seaport in the west, the mangrove swamps and the airport in the South (Nsegbe, *et al*, 2014) including wetlands till about 1980. The urban space of Douala was limited to Deido, Akwa, New Bell, Bonapriso, Bonanjo and Bonaberi before the population started occupying and inhabiting the wetlands, that of Makepe Missoke first that was close to the city centre, then to Mambanda at the south western and Bois des Singes in the south of the city after 1990. The untarrerd secondary roads and footpaths become degraded, muddy or inundated especially during the rainy season making them at times impassable. No form of public transport mode is regularly used on secondary roads and on footpaths in the wetlands except motorbikes. The inhabitants of the wetlands undertake indigenous adaptation on roads to access such areas through road filling with the use of gravel, black earth, saw dust, stones, garbage and car tyres and construct walk overs. The assessed road network of Mambanda and Makepe Missoke is high with 7.1 km/km2 and of 8.1km/km2 while that of Bois des Singes is low with just 3.5 km/km2. The connectivity of the road network in the wetlands from the beta indices gives a connected road network with Mambanda, Makepe Missoke and Bois des Singes having beta indices of 1.17, 1.11 and 1.02 respectively. The hydrogeological traits that determine the state of the roads makes them unstable for use as 80% of the road network in the peripheral areas of the wetlands are footpaths that are constantly flooded, 60% of them are degraded, muddy and poorly drained especially during the rainy season. This study corresponds with that of Yiran *et al* (2024) whom in the study of Spatial Analysis of Exposure of Roads to Flooding and Its Implications for Mobility in Urban/Peri-Urban Accra found that peri-urban Accra are experiencing uncontrolled urbanization resulting in haphazard and unplanned developments resulting to road flooding that make residents to be unable to access their homes or carry out their daily activities depending on the depth and duration of the floodwater on roads. And that it is not enough to rely solely on road network indices like centrality measures, link importance indices, and site exposure indices to address the challenges faced by road exposure to flooding, especially in peri-urban areas of Africa. Zhang, K. *et al* (2025) in studying impact assessment of urban waterlogging on roads trafficability and emergency sites accessibility under extreme rainfall events in Zhengzhou, China, affirms that urban waterlogging washes out or floods roads and other traffic facilities, severely affecting the trafficability of road and the accessibility of emergency sites. When waterlogging occurs, urban road systems and infrastructure are the most severely damaged and the social and economic development and normal life of urban residents are inextricably linked to the road networks which therefore means that degraded, damaged and flooded roads impacts negatively to the road network connectivity and reduces the accessibility of such areas.

**CONCLUSION**

Despite the efforts made by the inhabitants in trying to access the inaccessible wetlands, most parts of the wetland become inaccessible during the rainy season especially the peripheral parts of the wetlands. The accessibility of the Douala wetlands generally low, Mambanda is the most accessible with the highest road network density and connectivity while Bois des singes is the least accessible of the three wetlands. The stakeholders involved in the management of the wetlands make very little efforts in extending good roads in the wetlands partly due to inadequate finances given the high cost of constructing roads on hydro geomorphic areas and most of the wetlands not planned for urban habitation. This explains why only 2.4 kms of road out of about 34 km of existing roads are tarred in Mambanda, about 2 km tarred in Makepe Missoke out of about 16 km and less than 1 km tarred in Bois des Singes out of about 13 km. These stakeholders only participate in grading of parts of the roads using gravel during the dry seasons which are often wiped away during the raining resetting the roads to their original state and some times worse necessitating indigenous adaptations on roads by inhabitants in order to access their localities. The results of this study conformed with the hypothesis which shows that less developed and inefficient transport system in the Douala wetlands results in low accessibility. This study recommends that stakeholders managing these wetlands should engage in the planning of the wetlands in a sustainable, resilient and inclusive way that may facilitate the extension and improvements of the road network in these wetlands. This study on road network connectivity implications on urban wetland accessibility therefore contributes significantly in urban planning and sustainable development, ecosystem services and biodiversity conservation, economic implications and policy and governance. Understanding how road network affects access to urban wetlands helps planners design cities and balance development with environmental conservation. Insight into connectivity can promote sustainable transportation options, reducing ecological impacts on urban sprawl. This study may help researchers identify areas where wetlands are at risk due to road construction or urban expansion aiding conservation efforts. Ensuring accessibility and functionality of wetlands through thoughtful road designs enhances urban resilience to climate-related disaster while boosting eco-tourism and recreational activities in the wetlands that benefit the local population. This study therefore bridges environmental science, urban planning and social equity. It provides actionable insights for creating sustainable, resilient and inclusive cities while preserving critical ecosystems thereby addressing global challenges like urbanization, biodiversity loss and climate change.

**COMPETING INTERESTS DISCLAIMER**:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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