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Man Invades Nature: Tracing the Dynamics and Trends of Anthropogenic Stressors Within a Coastal Wetland Environment

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Abstract: Coastal areas contain some of the most valuable resources on earth that are constantly under threat due to human development. Notable among these resources are wetlands, a delicate but beneficial asset to coastal dwellers. This study studied the growth of Winneba City into the Muni Lagoon catchment as well as its associated effects on the Ramsar Site. The study used satellites images for the years 1990, 2000, and 2019 to model encroachment within the catchment over the 30-year period. Stakeholders were purposively selected and interviewed to gain insight into the subject under discussion. The study revealed that there is a high rate of encroachment occurring within the lagoon catchment, evidenced in the form of residential structures and agricultural practices. The rate of encroachment has almost tripled within the period under study. These activities are likely to affect flora and fauna within the catchment. The encroachment has been successful as a result of a lack of clearly defined boundaries showing the extent of the wetland. The study recommends all the stakeholders come together and work with the Wildlife Division of the Forestry Commission to establish the boundaries of the wetland beyond which anthropogenic activities should not be allowed.

Keywords: Muni Lagoon, Encroachment, Urban Growth, Land Cover Change, Wetland

Introduction

One of the preferred areas people want to settle currently is those surrounding wetlands, since, in their minds, these places seem to be idle and underutilized. Wetlands are a unique ecosystem on Earth that lies in transition zones between land and aquatic systems (Ghosh and Das, 2020). Wetlands, in many instances, are regarded as wasteland and humans try to put them to potential use (Danso *et al*., 2021). The benefits humans obtain from wetlands cannot be necessarily quantified; they are immeasurable and form a substantial part of the ecosystem services. However, most of the wetlands across the globe are being lost to rapid urban growth (Mao *et al*., 2018). Various human activities occurring in urban centers are social, economic, or cultural, contributing to changing the homeostasis of urban wetlands (Mensah, 2016; Kuusaana *et al*., 2021). Information from numerous studies, such as that of the Environmental Protection Agency, Cobbinah *et al*. (2020); Korah and Cobbinah (2017), indicates that, within urban centers, planners hardly perceive the importance of wetlands and the need to include them in planning but rather tag them as idle lands and hence they are subjected to harsh treatment (Kuusaana *et al*., 2021). The decline in coastal wetlands is often overlooked in international policy agendas Brown *et al*., 2021) and hence has given rise to the unsavory conditions of global wetlands now.

It is easy to count most African countries as signatories to the Ramsar Convention. However, their utilization of urban wetlands is not sustainable (Adu-Boahen *et al*., 2018). There is growing concern and awareness both at the national and international level that many forms of development activities are causing environmental and natural resource degradation. The ability of wetlands to sustainably provide essential ecosystem services has come under serious threat due to both adverse natural effects and growing debilitating human activities (Kuusaana *et al*., 2021). Within the last 50 years, ecosystems have been altered more rapidly and extensively than in any other period of history. This has led to an unprecedented transformation of freshwater

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ecosystems and, consequently, biodiversity loss, with over half of the world's population living in river basins. Most urban wetlands in African cities are deteriorating in terms of hydrology and water quality. Urban wetlands continue to undergo immense changes due to the changing socioeconomic conditions and human activities within urban areas (Kuusaana *et al*., 2021). The world's wetlands continue to be lost and degraded at an alarming rate as a result of human activities. Consequently, the essential benefits provided by wetlands to people continue to be seriously eroded (Kopeć and Sławik, 2020). Removing pressures on the ecological character of wetlands is the best practice for preventing further loss and degradation when this is not feasible (Kopeć and Sławik, 2020).

The Muni-Pomadze Ramsar Site can be described as an important coastal lagoon that serves as a nesting site for marine turtles on the sandy shore, houses over 23,000 water birds of different kinds (terns, waders, herons, and egrets) where they feed and breed and contains diverse butterflies, with about 75 species currently known. The human activities occurring within this Ramsar site include grazing, farming, and hunting (Eze *et al*., 2023). However, the major threat facing the Ramsar site is urbanization and encroachment (RSIS, 2015). According to RSIS (2015), the Muni Lagoon is under threat of encroachment due to rapid urbanization occurring in the Winneba township. As Adu-Boahen *et al*. (2018) put it, the main human impact that is impinging on the Muni Lagoon and its environment is encroachment. According to Rocha Ghana (2021), the disturbing reports revealed by the local people indicate that there is biodiversity decline occurring in the Muni Lagoon catchment as a result of encroachment. The Muni-Pomadze wetland site manageress on one occasion put it this way: "Encroachment is a major issue troubling and threatening the survival of the site. Farming activities along the banks of the feeder streams, grazing, as well as infrastructural development are evident in the catchment "(Rocha Ghana, 2021).

The problem of urban growth and encroachment is not only affecting the Muni Lagoon but other important wetlands such as that of the Sakumo Ramsar site. When the Centre for Remote Sensing and Geographic Information Services (CERSGIS) collaborated with the Forestry Commission to create a documentary on the state of the wetland in June 2021, they lamented the rate of encroachment in the Sakumo site. They reported the serious brink of extinction of the lagoon due to the threat of encroachment that has beaten the area for the past three decades (CERSGIS, 2021). This is a clear indication of how wetlands in Ghana are suffering from urban growth and encroachment. According to Gordon *et al*. (2000), the Muni Ramsar site and the four other internationally recognized Ramsar sites in the country are constantly threatened by urban development and site encroachment. The World Population Review (2019) stated that there is a constant growth rate of more than 2% per annum in Ghana and the pressure on these delicate systems is bound to grow in the future. In 2000, 53% of the Muni-Pomadze wetland site was classified as natural vegetation, 32.5% as agricultural lands and the 11 communities that reside on the site accounted for the 12.6% that is residential development (Gordon *et al*., 2000). However, in 2010, Atampure reported 31.9% forest cover, 20% agricultural land, and a built-up area of 40.5%, a clear indication of anthropogenic pressure on the wetland. Attention is given to the Muni Ramsar site because the area where this site is found (Winneba) is still a peri-urban zone where urban growth is gradually taking off, implying that if measures are put in place on time, a lot can be done to save the situation. Again, studies are done within the Muni Ramsar site such as Adu-Boahen *et al*. (2018); Biney (1995); Gordon *et al*. (2000); Wuver (2006); Ryan and Attuquayefio (2000); Tumbulto and Bannerman (1995); Tay *et al*. (2010); Oteng-Yeboah (1994); Amatekpor (1994); Atampugre (2010), among others, were all concerned about the sustainability of the zone, as some even mentioned the problem of encroachment. However, it appears little attention has been given to studies that examined the pattern of urban growth in the area over the years, the activities described as encroachment, as well as indigenes' perspectives on the problem of encroachment. Several wetlands, particularly those in urban areas, have been harmed by human activity. Often dangerous amounts of fertilizers, heavy metals, pesticides, and toxins from sewage treatment plants, chemical manufacturers, and urban agriculture are carried by waterways (Boanu *et al*., 2022; Okyere *et al*., 2023). The removal of vegetation, grading, filling in open spaces, building development, and adjustments to water levels and drainage patterns are some additional frequent direct effects of human activity that have an impact on ecosystem functioning (Breuste *et al*., 2013). This study will help highlight the impact of anthropogenic disturbances on urban ecosystems and suggest solutions for mitigating these dangers. Addressing the dearth of knowledge concerning the problem, this study modeled the rate of urban growth within the Ramsar site, presented the growth dynamics, and engaged the Wildlife Division of the Forestry Commission and other stakeholders responsible for sustaining the site in order to ascertain their notion of the issue of urban growth and encroachment occurring in the lagoon. A robust risk management plan and environmental protection programs are shown to be effective in reducing the environmental impact of anthropogenic activities on wetlands (Norton *et al*., 1992). Estimating possible risks or threats posed by stressors to biotic and/or abiotic components of the wetland is necessary for determining the degrees of

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environmental risk that exist for wetlands. The ecological, structural, and functional aspects of wetlands, rivers, and lakes have been the focus of previous studies. Unfortunately, little research has been done on the viewpoint of citizen science about environmental risks to wetlands (Malekmohammadi *et al*., 2023). Based on the discussions that have already taken place, the following major goals have been established: To analyze potential changes in land use and land cover within the lagoon catchment, to examine stakeholder perspectives on the ecological and economic benefits of wetlands, and to determine the potential long-term effects of encroachment on the study area.

Theoretical Perspective

The 'Wetland Risk Assessment (WRA) Framework' by the Ramsar Convention emphasizes the need to regularly monitor the status and changing biophysical and ecological character of wetlands globally (Ghosh and Das, 2020). In assessing a suitable framework and method that are necessary for predicting changes in the ecological atmosphere of wetlands, the main focus should particularly be on changes that are anthropogenically induced. Anthropogenic activities continue to stress and alter the ecological makeup of wetlands, especially those that are found in urban areas (Brown *et al*., 2021). An evaluation of the environmental risk levels for the dynamic ecosystem of wetlands can help us comprehend the state of the ecosystem and its existing functions. The types of threats and the likelihood and severity of each in the environment are considered when defining the various degrees of environmental risks. According to Van Dam *et al*. (1999), a thorough list of factors and variables that affect the environmental risk for wetlands was compiled after consulting with experts and reviewing the literature. Due to stress-inducing environmental and ecological changes brought on by operations like dredging and filling, hydrologic changes, pollution runoffs, eutrophication, impoundment, and fragmentation by roads and ditches, wetlands are fast disappearing. Thus, wetland conservation has recently attracted a lot of academic attention as well as political interest in order to safeguard these crucial natural resources and promote wetland ecosystem sustainability. The framework for assessing wetland risk is broken down into six components that function together (Van Dam *et al*., 1998). These processes include problem identification, which deals with the process of figuring out the problem's nature and coming up with a solution. It establishes the goals and parameters as well as the framework for risk evaluation. The identification of the negative impacts is the second stage. At this step, the wetland's potential for negative change or impact is assessed. It is derived from field research because field data are more suited for assessing the many effects that could have an impact on a wetland. Identification of the problem's scope is the next step. Using data acquired regarding the problem's behavior and the amount to which it has occurred elsewhere, this calculates the expected scope of the issue on the wetland under consideration. Information on transport, dilution, partitioning, degradation, transformation, and other behavioral aspects is included. In order to determine the level of harmful ecological change on the wetland, the fourth stage, known as the identification of the risk, entails integrating the findings from the assessments of the likely consequences and the problem's likely scope. The adoption of a GIS-based framework is a potentially helpful method for quantifying risk in wetland areas (Van Dam *et al*., 1999). Risk management and reduction is a crucial stage that affects the decision-making process. It makes use of the data gathered during the assessment process mentioned above and seeks to reduce the risk without sacrificing other societal, community, or environmental benefits (wise use). The monitoring phase (last stage), which is related to the risk assessment process, should be carried out to confirm the success of the risk management choices. It includes elements like early warning systems, which can identify when risk management strategies have failed or performed poorly before a major environmental impact occurs (Bayliss *et al*., 2012). This framework served as the basis by which the study was anchored.

Materials and Methods

Study Area

The Muni-Pomadze Ramsar site, also called Muni Lagoon, is a closed coastal lagoon found in Winneba in the central region of Ghana. The site was designated as a Ramsar site on August 14th, 1992. The lagoon has a total area of 9,461.1 hectares. However, the size of the wet area of the lagoon varies depending on the season, from 100 ha in the dry season to over 1000 ha in the wet season. The geomorphic characters that can be found on the Muni-Pomadze Ramsar Site include a sand dune. The dune serves as a barrier, separating the lagoon from the ocean. An integral part of its ecosystem is the large variety of flora and fauna. There is the presence of the Yenku Forest reserves A and B, which serve as the hunting grounds for ‘bush buck’ during the annual Aboakyir festival of the Effutu people (Gordon *et al*., 2000). There is also the presence of scrub, farmland, and marsh areas subject to tidal and seasonal inundation. The sandy shore of the lagoon serves as a nesting ground for marine turtles as well as a feeding and breeding site for over 23,000 water birds, including terns, waders, herons, and egrets. Furthermore, the Ramsar site is home to approximately 75 different species of butterflies. The site has a thick mangrove cover to the east, which is harvested by the surrounding communities for fuel wood for fish smoking. In the narrow strip of sand dunes which separates the lagoon from the sea, stands a coconut plantation that attracts birdwatchers and tourists. Among the human activities occurring on the site are cattle grazing, farming, hunting, and fishing (Gordon *et al*., 2000). The catchment is also bordered by the Yenku Hills and the Egyasimanku Hills. In 2000, 53% of the site was classified as natural vegetation, 32.5% as agricultural lands and the 11 communities that reside on the site accounted for the 12.6% that is residential development (Gordon *et al*., 2000). However, in 2010, Atampugre reported 31.9% forest cover, 20% agricultural land, and a built-up area of 40.5%. The major economic activities in the municipality are fishing, wholesale and retail services, manufacturing, salt mining (white gold), crop farming, and agro-processing. Fishing and farming (particularly maize and cassava) are the leading economic activities in the municipality, but there are other minor activities like hunting (often done by the Effutu people), cattle grazing, sand, clay and gravel mining, salt winning and charcoal production (Eze *et al*., 2023; Wuver, 2006). Figure 1 presents the map of the study area.

Land Cover Classification

Satellite images acquired from the USGS website were used to estimate the rate of urbanization (encroachment), other land use patterns, and the changes occurring within the catchment of the wetland between 1990 and 2019. The satellite images used for the study had at most 10% clouds so as to give a real reflection of objects and phenomena in the area as they occur. Enhanced Landsat 8 Thematic Mapper plus (ETM +) images of dry seasons for 2000 and 2019 were used. The 1990 image used was the Landsat Thematic Mapper (TM). These images were taken in the dry season due to the absence of cloud cover. Specifically, the 2019 image used was sensed in December and those for 1990 and 2000 were sensed in January. This was observed on the premise of the availability of desired levels of clouds on images.

Remote Sensing Image Processing and Classification

In processing the images for the analysis, Erdas Imagine remote sensing software was used for layer stacking of individual bands in individual images for various years and this was followed by sub-setting to carve out the area of interest from the composited bands. A 2 km riparian buffer for the lagoon was created and used for subsetting. The images were processed and an unsupervised classification of 250 land cover classes was generated from the images for the various years. Supervised classification was then employed to generate clusters of various land cover classes in the area using ground-truthing approaches for the 2019 classes and google earth historical images for the 1990 and 2000 classes. This helped in establishing how urbanization (human activities) has affected the catchment of the lagoon.

Land Cover Classes

Six land use classes based on USGS (2010) shown in Table 1 were generated from the analysis. These were areas that have built up; forest cover; areas with grass cover (grassland and scrub); areas with water bodies; bare surfaces and farmland.

Purposive sampling was used to select traditional leaders who are well-versed in traditional knowledge and management systems used to protect the lagoon. Other experts, two (2) each from the Wildlife Division of the Forestry Commission, Effutu Municipal Assembly, community leaders (assemblyman and chief fisherman), and Rocha Ghana (a non-governmental organization), were purposively selected and interviewed in relation to the approaches to conserving the lagoon. These experts were selected because the Wildlife Division of the Forestry Commission is responsible for managing the flora and fauna within the catchment; the Municipal Assembly is responsible for planning the communities; and the NGOs provide alternative livelihoods and contribute to ecosystem restoration exercises. Data from interviews were analyzed thematically using the inductive approach. The interview responses were manually transcribed and discussed in relation to the themes of the objectives of the study. Data from the satellite imagery was analyzed in frequency and percentages and presented on maps for easy visualization.

Table 1: Land cover descriptions

Land cover classes	Description
Barren land	Barren Land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. It is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the shrub and brush category of rangeland. Categories of barren land are Dry salt flats, sandy areas; transitional areas; and mixed barren land
Built-up	land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns and villages, and institutions that may, in some instances, be isolated from urban areas
Open forest	Open forest has a tree-crown aerial density (crown closure percentage) of less than 10 percent but more than 5%
Waterbodies	Water includes all areas within the landmass that persistently are water covered. The delineation of water areas depends on the scale of the presentation and resolution of the remote sensor data used; Categories include stream, lakes, reservoirs, lagoons, and estuaries
Grassland	is comprised of areas where the potential natural vegetation is predominantly grasses, grass-like plants, forbs, or shrubs and where natural herbivores were an important influence in its pre-civilization state. Some rangelands may have been or may be seeded in introduced or domesticated plant species. Categories include herbaceous range, shrub and brush rangeland, and mixed rangeland
Farmland	may be defined broadly as land used primarily for the production of food and fiber

Source: USGS (2010)

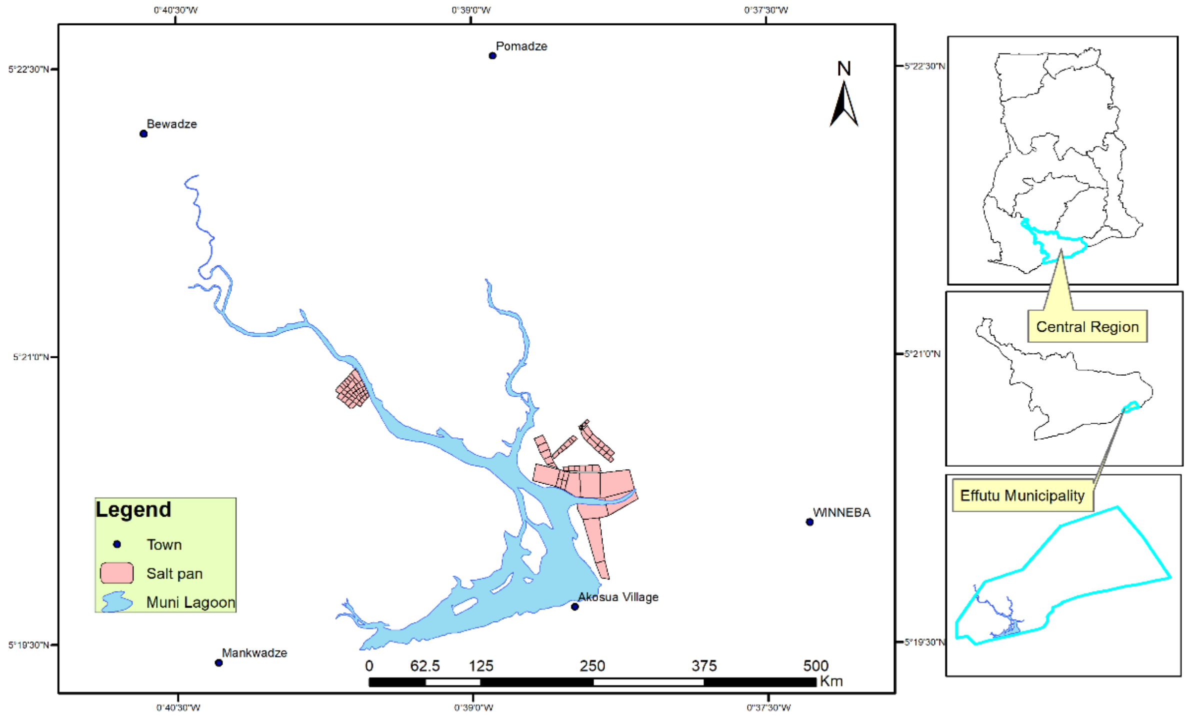

Fig. 1: Map of the study area

Results and Discussion

This section is a synthesis of data collected from the field and their related discussions.

Modeling Encroachment on the Muni Lagoon Catchment

The growth in the human population and the necessity to provide for humans' basic needs has led to the use of any available space for building, farming, and other developments. This notwithstanding, it has multiple effects on resources, especially those that are delicate, such as wetlands. Wetlands have reserved space that needs to be kept untouched. However, these areas are now becoming the preferred zones for all kinds of activities. This study employed remotely sensed images to model how human developments are extending from Winneba town towards the lagoon. The community and the Wildlife Commission have set the extent to which human activities such as the construction of buildings and agricultural activities should occur. However, due to limited space and the continuous increase in population resulting from the increase in students' enrolment (presence of the University of Education, Winneba), workers' intrusion, and the scarcity of land for residential purposes, the reserved areas within the catchment have become the preferred development sites. Again, most areas closer to the lagoon are being used for vegetable farming, where most of the farmers use the rivers feeding the lagoon (Pratu and Ntakofa) as a source of irrigation to promote their agricultural activities.

The Water Resource Commission of Ghana has instituted a buffer of 30m for water bodies such as lagoons, within which no activity should be carried out Ghana Water Resource Commission (WRC, 2013). However, during the inundation, the lagoon can flood to a greater extent beyond the established buffer. Therefore, with consultation from the Wildlife Division of the Forestry Commission, the study looked at activities carried out within the two-kilometer buffer from the lagoon over the years. The Wetland Risk Assessment (WRA) framework promotes the use of GIS in environmental risk analysis (Van Dam *et al*., 1999) hence the study resorted to the use of satellite imagery using 1990 as the base year to assess how human activities have extended to the lagoon from that time to the current year 2019. It would have been best to use an older map than that of 1990, but a 1990s map was used for the study because that is the oldest map you can ever chance on. The Effutu Municipal Assembly lacks older maps that can be used as the basis for comparison. Hence, 1990 was used to give an idea of the land use and land cover change that is occurring within the 2 km buffer of the Muni catchment that has been set for the study.

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Surface Areas of Land Cover Units in 1990

In 1990, which forms the base year for the study, the level of anthropogenic activity within the catchment was very minimal. Built-up covered 23.5 ha, which was just 9.1% of the total 1029ha area under study as shown in the table. Farming activities were high in the year 1990, covering an area of 52.7 ha (20.3%) of the catchment. Within this period, water bodies had an area extent of 11.9 ha. That is 4.6% of the total area under study. Forest and grassland within the area in 1990 covered 45.6 ha, making up 17.6% and 701.8 ha, covering 27.4% of the catchment respectively. The barren land, consisting of the beach, abandoned or dried salt pans, and the bare land, covered 4.5 km^2 (17.2%) of the area. Though a substantial section of the catchment was bare land (540.5 ha), it can be inferred that, during the year 1990, within the 1029 ha of the wetland catchment, most areas were covered up with vegetation, which is the forest and grassland as shown in Fig. 4. The presence of open forests and grassland encouraged ranching and farming activities during the period. Human interference within the Muni catchment was minimal.

Within this year, the city was extending towards the lagoon area; encroachment evidenced in built-up and farming activities was low, covering 31.1% of the total catchment. It could be seen from Fig. 4 that the built-up area was far from the lagoon, growing from the eastern side of the catchment. This confirms Gordon *et al*. (2000) assertion that in Winneba town, many new houses are being built on the eastern parts of the wetland, up to areas that had been used for the winning of salt in the 1970s.

With forest and grassland covering the majority of the catchment, they served as protection for the lagoon against excess evaporation. This helped to prevent excess evaporation, regulate and maintain the temperature of the lagoon and go a long way to preventing the lagoon from drying up. Table 2 shows the area coverage of the land use units.

Surface Area of Land Cover Units in 2000

In 2000, which was 10 years from the base year, changes were recorded in the land cover within the catchment. The built-up area this year covered 107.9 ha, which was 10.5% of the catchment. The waterbodies this year also covered 48.0 ha, which is 4.7% of the assessed area. Forest and grassland covered 192.6 ha and 265.3 ha, or 18 and 25.8% respectively. The barren areas covered 203.5 ha or 19.8%. By comparing the land cover mages for the years 1990 and 2000 shown in Fig. 4, it could be inferred that there was an increase in built-up and anthropogenic activities, signifying an increase in encroachment.

Built-up and farmland have tripled in the catchment over the last decade, with these two major activities constituting encroachment in the 2 km buffer of the wetland catchment under assessment. Notwithstanding, this had no effect on the lagoon, as area coverage of waterbodies increased from 11.9 ha (4.6%) in 1990-48.0 ha (4.7%) in 2000. This could be due to the fact that forest cover in the area also increased, that is, from 45.6 ha in 1990-192.6 ha in 2000. This indicates that an increase in vegetation cover serves to protect waterbodies from direct sunlight and subsequent evaporation. This is affirmed by Gryczkowski (2015) who stated that riparian vegetation safeguards the watershed, regulates its temperature, and slows water evaporation. Figure 4 shows the increase in encroachment within the catchment in 2000 accompanied by an increase in the coverage extent of waterbodies and forests, comparing it with that of 1990. The land use unit coverage for the year 2000 is captured in Table 3.

Surface Area of Land Cover Units in 2019

With 2019 remotely sensed image analysis, it was revealed that built-up (Fig. 2) and farming activities (Fig. 3) within the area of assessment covered 125.7 ha with 12.2% and 212.8 ha with a percentage of 20.7, respectively. Interestingly, waterbodies covered 86.8 ha (8.4%) this year, the highest coverage in the 30-year study period. However, forest cover has decreased dramatically this year, from 192.6 ha in 2000-176.3 ha in 2019. Considering Fig. 4, it could be seen that most of the area under study was now being turned into farmland, increasing from 52.7 ha in 1990, 212.0 ha in 2000, and 212.8 ha in 2019.

Table 2: 1990 land use unit coverage

Land use unit	Surface area (ha)	Percentage (%)
Built up	23.50	9.10
Forest	45.60	17.60
Grassland and scrub	701.80	27.40
Waterbodies	11.90	4.60
Bare land	540.50	21.00
Farmland	52.70	20.30
Total	1029	100

Source: Fieldwork (2021)

Table 3: 2000 land use unit coverage

Land use unit	Surface area (ha)	Percentage (%)
Built up	107.90	10.50
Forest	192.60	18.70
Grassland	265.30	25.80
Waterbodies	48.00	4.70
Bare land	203.50	19.80
Farmland	212.00	20.60
Total	1029	100

Source: Fieldwork (2021)

Bare land areas decreased comparing results for 2019 with those of 1990 and 2000, which is likely to have been lost to built-up areas and possibly other land use systems. The surface area covered by each of the land use units and their percentages in 2019 are shown in Table 4.

Table 4: 2019 land use unit coverage

Land use unit	Surface area (Km^2)	Percentage (%)
Built-Up/Anthropogenic activities	125.7	12.20
Forest	176.3	17.10
Grassland	237.9	23.10
Waterbodies	86.8	8.40
Bare land	190.0	18.50
Farmland	212.8	20.70
Total	26.0	100

Source: Fieldwork (2021)

Fig. 2: A recent encroachment in the catchment that the Wildlife Division has halted. This is located at the northern part of the Muni lagoon close to the Ntakofa River. Source: Authors construct (2021)

Fig. 3: An area found at the central portion of the catchment close to Gerald international school cleared for agricultural activity

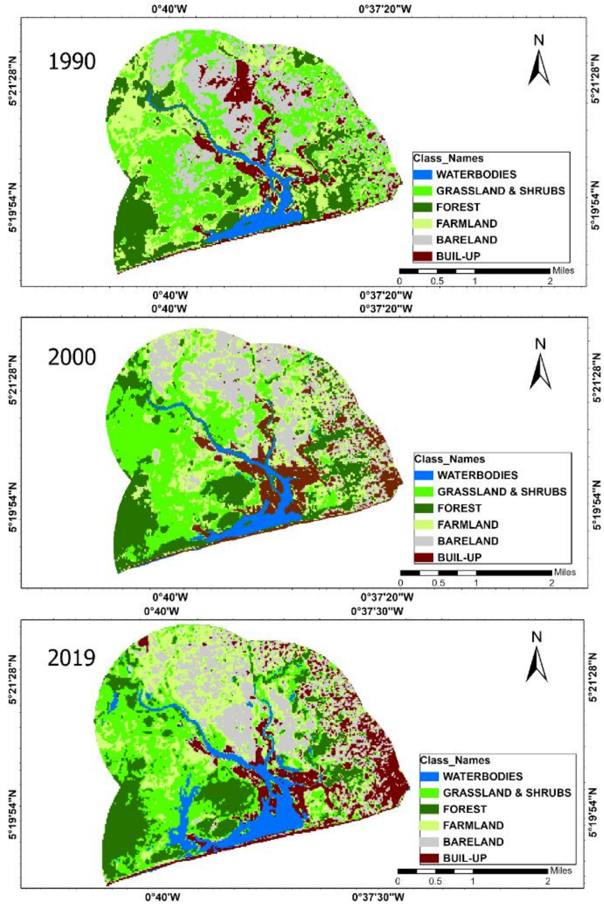

Fig. 4: A land cover map for 1990, 2000 and 2019

Encroachment Dynamics from 1990-2019

A lot of changes have occurred within the 30 years of assessment (Table 5), that is, from 1990-2019. The rate of encroachment evidenced in built-up and agricultural activities has almost quadrupled. The change in land cover within the Muni Lagoon catchment can be attributed to the fact that vegetation has been replaced by built-up (settlement) and agricultural activities. There have also been a lot of deforestation activities within the area, as evidenced by a forest reduction of 16.3 ha (-8.46%) during the period from 2000-2019. Within the period from 1990-2000, the study revealed that built-up which covered 23.5 ha (9.1%) of the assessed area in 1990 increased to 107ha (10.5%) in 2000. In comparison to 1990 and 2000, the area's built-up area increased by 102.2 ha (434.9%) between 2000 and 2019. Considering waterbodies within the catchment, it could be seen that it increased in area extent from 4.6% in 1990 to 4.7% in 2000. This increment could be attributed to the regular afforestation projects embarked on regularly by the wildlife division of the forestry commission, where mangroves and tree species were planted around the lagoon and in the Yenku Forest (Osman *et al*., 2022).

Table 5: Summary of land use unit coverage for the 30-year period

Land cover categories	Total land area ha	1990 area (ha)	Percentage %	2000 area (ha)	Percentage %	2019 area (ha)	Percentage %
Waterbodies	1029	11.9	4.6	48.0	4.7	86.8	8.4
Grassland & shrubs	1029	701.8	27.4	265.3	25.8	237.9	23.1
Forest	1029	45.6	17.6	192.6	18.7	176.3	17.1
Farmland	1029	52.7	20.3	212.0	20.6	212.8	20.7
Bareland	1029	540.5	21.0	203.5	19.8	190.0	18.5
Built-up	1029	23.5	9.1	107.9	10.5	125.7	12.2
Total		1029		1029	100	1029	100

Source: Fieldwork (2021)

That period saw the loss of grassland and bare land to forest and farming activities. The effort of reforestation probably might have helped improve the fertility of the soil, encouraging agricultural activities within the catchment. This is in line with Basiago (1998), who asserts that in achieving sustainability of the resources (lagoon), biodiversity within an area should not be exploited above their rate of regeneration, thereby ensuring the integrity of our ecosystem. From 2000 to 2019, waterbodies again increased within the catchment, from 4.7-8.1%, respectively. This huge gain corresponds to the breaching (opening) of the sandbar that separates the lagoon and the ocean, allowing an inflow of ocean water to and fro to the lagoon. This rapid fluvial inflow forced the lagoon to erode new areas, leading to an increase in water bodies as revealed by the satellite imagery analysis. Again, it could be attributed to the activities of the Wildlife Department of the Forestry Commission, including embarking on a series of demolition exercises and stopping most construction activities within the site (Okyere *et al*., 2023). The Department further engaged in the planting of mangroves and other tree species along the banks of the lagoon, leading to the reduction of pressure on the lagoon (Osman *et al*., 2022).

Considering the area and percentage changes over the 30-year period, it could be seen from Table 6 that built-up areas within the catchment increased by about 434.9%. That is 359.1% from 1990-2000, 16.5% from 2000-2019, and 434.9% from 1990-2019. This gives a clear indication of the speed of encroachment within the catchment. According to Table 6, the increase in built-up area over time has an inverse effect on forest cover in the sense that forest cover increased from 1990-2000 by 147 ha but fell rapidly between 2000 and 2019 by 16.3 ha. This implies that, as built-up increases, vegetation cover decreases. What this means is that most of the vegetation within the catchment is being lost to settlement, agriculture, and other anthropogenic activities. It is also known that a decrease in vegetation in an area and an increase in built-up areas lead to an increase in surface temperature (Mukherjee and Singh, 2020).

According to the discussion, if the encroachment is not controlled within the catchment, temperatures will rise, causing high evaporation on the lagoon, potentially leading to its dwindling over time. In a study they conducted in Beijing, Jiang *et al*. (2014) affirm this by putting forth that this type of temperature change is consistent with the process of land use change and urbanization. The table shows that most of the bare areas and grassland within the catchment are being used for other activities, of which building up is one. Other areas close to the lagoon are also being used for agriculture, as shown in Fig. 3 below, where agricultural effluent may easily get into contact with the waterbody and affect aquatic organisms. A study conducted by Al-Kodmany (2018) revealed that excess fertilizer washes into rivers, lagoons, and oceans as a result of their proximity to these water bodies. The high concentration of these nutrients may create eutrophication which has the propensity to disturb ecological equilibrium such as promoting algae bloom. With this condition, microbes may consume the algae and suck all the dissolved oxygen in the water resulting in a dead aquatic zone. Fertilizers and pesticides used in farming along water courses end up in waterbodies increasing the risk for humans and other organisms (Keraita *et al*., 2008; Okyere *et al*., 2023).

When comparing the rate of built-up and farming activities (what constitutes encroachment) within a catchment against the size of the lagoon, it can be said that encroachment keeps increasing while the waterbodies (lagoon) also keep eroding new areas. Therefore, it can be said that the increase in encroachment has not necessarily had a depleting effect on the lagoon as evidenced by the area coverage increase of the two land cover types. In general, it can be said that over the years, the lagoon has been expanding due to the periodic breaching of the sandbar and the activities of the Wildlife Division. These findings are in consonance with (Atampugre, 2010) findings that land cover changes (encroachment) were a result of construction, urban expansion, and agricultural activities in the Muni catchment.

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Table 6: Land cover changes from 1990-2019

Land cover categories	Change (1990-2000) area (ha)	Percentage change (ha) %	Change (2000-2019) area (ha)	Percentage change (ha) %	Change (1990-2019) Area (ha)	Percentage change (ha) %
Waterbodies	36.1	303.36	38.8	80.83	74.9	629.41
Grassland and shrubs	-436.5	-62.27	-27.4	-10.30	-463.9	-66.01
Forest	147.0	322.37	-16.3	-8.46	130.7	286.62
Farmland	159.3	302.30	0.8	0.38	160.1	303.80
Bareland	-337.0	-62.30	-13.5	-6.63	-350.5	-64.85
Built-up	84.4	359.10	17.8	16.50	102.2	434.90

Source: Fieldwork (2021)

The reasons for encroachment could be attributed to rapid urban growth, where land is becoming a scarce resource in Winneba and coupled with the rise in student population and intrusion of workers. This has led to high prices of land and rent, forcing people to move towards the lagoon catchment to get land at relatively cheaper prices to put up structures to serve the rising population. Again, due to urban development, there are limited open spaces for agricultural activities and for construction, making the open space within the catchment area of the lagoon the alternate area for such developments. Moreover, it appears there is a lack of a policy framework clearly defining the extent to which land should be given out for anthropogenic activities in relation to the lagoon catchment. This confirms the work of Shrestha (2015), who worked on encroachment within the Bagmati River catchment in India, where she found that encroachment within the river catchment is a result of a lack of clear demarcations, lack of space, and urbanization.

Stakeholder Perspectives on Benefits of the Lagoon and Encroachment Impacts

The Wetland Risk Assessment (WRA) framework which formed the basis of this study recommends the need to include the community and society in analyzing threats posed to wetlands (Van Dam *et al*., 1999). Based on the citizen science perspective, the stakeholders elaborated on the delicate role of the Muni Lagoon in the life of the locals and community in general. They commented on both the ecological and economic role of the lagoon. In the case of the ecological benefits, the study showed that the Muni lagoon ecosystem regulates the local systems, it also contributes to carbon sequestration, maintaining freshwater quality through sedimentation, nutrient conservation, and providing habitats for several wildlife species. They also serve as natural sponges when high rainfall events occur thereby reducing flooding etc. This corroborates the work of (Gleason *et al*. 2011) who wrote about the need to carry out conservation programs on wetlands due to their ecological value. On economic evaluation, lagoon ecosystems help in the supply of fuelwood, improving fishing-based industries and contributing to national and local economies (Ranjan, 2019). They are also avenues for recreation and tourism opportunities. The Chief fisherman has this to say about how they have benefited economically from the Muni Lagoon. He reported that:

> *"The Muni lagoon has been the source of livelihood for most fishermen and their families as it provides fish for our daily intake and surpluses for the market which gives us economic empowerment"*

On the side of ecological benefits, an Assembly member stated:

> *"The Muni lagoon is the most effective floodplain for Winneba and its environs. It serves as a sponge for retaining excess floods before they are emptied into the sea. It has in a way prevented the Effutu community from inundation during the rainy season"*

It was necessary to gather information from the field to support what was acquired from the imagery analysis. During interaction with key informants from the Akosua Village and the Wildlife Department, they revealed that, indeed, there has been an extensive encroachment on the lagoon catchment.

The wildlife department stated that:

> "*In 2017, the coordinates we took for the catchment were up to the seed company around Lowcost but now they have built deep into the catchment hence the coordinates we just took this year (2020) were far from the seed company indicating a great range of encroachment. The pillars we placed some years back within the catchment are now found closer to people's houses*"

The Wildlife Department further added that, as people build within the wetlands, they do a lot of filling, where they claim part of the water body, which contributes to the dwindling of the lagoon. Regular encroachment also leads to siltation in the lagoon as loose sediment accrued from constructional activities is later washed into the lagoon (WRA framework) (Van Dam *et al*., 1999). They reiterated that people are just building closer to the lagoon day in and day out. According to officials from the Wildlife Department, there has been a lot of demolishing exercises within the area, yet people are still putting up structures within the lagoon catchment. One participant (an indigene) added that most areas that were formerly covered with vegetation and coconut cover within the catchment are being replaced with residential structures, affirming that people are actually encroaching and building close to the lagoon. The Wildlife Department elaborated on how vegetation cover has reduced as a result of people clearing vegetation to put up buildings, leading to the seizure of ecological services. Concerning the area coverage of the lagoon, one of the participants stated that there has been a slight reduction in the areal extent of the lagoon. It was explained further that in recent years, the lagoon has been exhibiting characteristics that are not usual. For instance, one of the participants said:

> *"Last year, the lagoon flooded as never before affecting lots of houses. It went very far and persisted for days. This affects fingerlings as they are being carried away and cannot easily return to the lagoon when floods recede"*

The above indicates that the carrying capacity of the catchment is exceeded, as captured by Basiago (1998), who said that when a resource is exploited beyond its carrying capacity, it loses its ability to perform regular functions. The participants said that most houses were affected because areas that were formerly bare are now replaced with houses. Again, the flood persisted because the houses had blocked the pathway of the water bodies within the catchment that could allow them to move to and fro during the peak of the rainy season. The participants believe that building within the catchment has led to an increase in sand wining along the beach, something they have been cautioned against. These findings are in consonance with Mureti (2014) study of the Rukaka River riparian zone, where he found that the effects of encroachment on this zone included loss of vegetation, soil erosion, and flooding.

Another participant added that he believes it is the presence of the abandoned salt pan that causes the annual flooding of the lagoon. He said that the salt pans acted as a barrier, preventing the free movement of the lagoon. These structures are all part of the anthropogenic activities that were recorded by the image analysis. Speaking of the changes, another participant indicated that he has not seen any change with regard to the area extent of the lagoon within the 44 years he has stayed there. The only area coverage change is with regard to seasonal variations and the opening of the lagoon, but he is aware of other changes associated with the lagoon. This is in line with the stage one and two of the WRA framework which talks of problem identification and impacts respectively when analyzing threats to wetlands. Typically, he said:

> *"During the early years, the lagoon produced salt by itself during the dry season which we went there to pick and bring home but now, we don't see any of such things. Again, there have been a lot of changes with the vegetative cover. Women come from Winneba town to harvest the "neem" trees and the mangroves planted by the Wildlife Division"*

However, the Wildlife Division stated that indeed there has been a dwindling of the lagoon due to siltation.

The researchers attempted to find out how people obtain land within the catchment area to build on. The participants explained that two groups of people own the land traditionally. What are the "Dente and the Tuafo" groups? They got this ownership due to the areas assigned to them for bushbuck hunting during the Aboakyir festival. Despite the fact that they are unsure whether these groups distribute the land within the catchment, the participants indicated that the two groups own portions of the lagoon catchment. However, the Wildlife Division gave a more concrete response on how land is acquired. They said that, though most of the lands are vested lands, a section of the traditional council sells lands to rich people to build within the catchment (Fig. 2).

The researchers queried the participants about their views on the impact of encroachment on Muni Lagoon. Encroachment speeds up the rate at which lakes, rivers, lagoons, and other wetland regions are impacted by the environment. The study found that runoff into the Muni Lagoon is escalating in both volume and rate. Moreover, various contaminants and the loading of sediments were found. The participants reported that the lagoon water has grown a little bit warmer, therefore there was an increase in temperature once more. The loss of wetlands can also affect aquatic resources' interconnectedness, diversity of the landscape, and habitat (Schofield *et al*., 2018). One of the participants stated that:

> *"I believe that the current difficulty we experience in getting bushbuck for the Aboakyir festival may be due to the encroachment of the hunting grounds which forms part of the wetland area"*

Another effect put forth by the participants was the rapid conversion of wetlands into residential, commercial, and industrial land uses which reduces the size and quality of the wetland. This confirms the assertion by Lee *et al*. (2006) on urbanization's impacts on wetlands. Another effect of the lagoon's invasion has been habitat loss and freshwater extraction from the ecosystem, which has decreased biodiversity and changed the ranges and interactions of species. One participant noted that:

> *"The establishment of the Nixin paper factory and a private basic school, as well as a number of residential structures within the catchment area of the lagoon, has been a bane on the water quality and size of the lagoon"*

The information gathered through the interview affirms the findings from the satellite imagery analysis, which revealed that indeed encroachment is taking place and vegetation is decreasing within the catchment. However, the interview indicated a dwindling of the lagoon area in recent years, whilst the imagery analysis showed that the lagoon has extended slightly in area coverage in 2019. Further investigations were carried out, which revealed that the lagoon was opened in 2019 to have direct access to the sea and that might have caused the water volume within the lagoon to increase, forcing it to acquire new areas through erosion. The findings above confirm the study by Bassi *et al*. (2014) when they conducted a similar study in India and found that encroachment is a headache as far as the management of wetlands is concerned. Again, Kraemer *et al*. (2015) added water bodies respond to human-induced climate change as it leads to an increase in their surface temperatures.

Conclusion

There is a high rate of encroachment occurring within the Muni Lagoon catchment, revealed through the analysis of remotely sensed data as suggested by the WRA framework. This was confirmed by the community members and officials of the Wildlife Division of the Forestry Commission and other stakeholders through the interviews in line with the WRA framework which recommends the involvement of community members in assessing risks posed to wetlands. The encroachment is rampant and not easily monitored as a result of the unclearly defined boundary of the protected area. Based on the analysis of the remotely sensed images (1990-2019), there is a high loss of open forest to settlement and agricultural activities. The area coverage of the lagoon from the satellite imagery analysis reveals the waterbodies are increasing, but most of the community members claim it has reduced in size. From recent observations by the researchers, it could be seen that the lagoon is expanding due to the breaching of the sandbar. It is possible that before the lagoon was breached, it was dwindling, hence the local people's assertion that it has decreased in area coverage over the years. The catchment area is, however, to be kept free from developmental planning of residential, educational, or industrial activities within the municipality. Land for residential development was mainly acquired from a section of the traditional authority that claims ownership of lands within the catchment. The study revealed that all lands within the catchment are not registered; neither do those buildings within the catchment have permits. Encroachment within the catchment has led to an increase in flooding of the lagoon during the major rainy season. Moreover, the frequent building of residential apartments within the study area has caused an increase in sand-wining activities along the Winneba beach, which is likely to result in coastal erosion in the future. This study has tried to make a contribution to the final stage of the WRA framework (monitoring phase) by bringing to bear that the management strategies in place within the wetland system are not enough and needs up- scaling.

It is therefore recommended that traditional authorities, together with the Wildlife Division of the Forestry Commission, ensure that the lagoon is opened more often to reduce the pollution rate of the lagoon. Moreover, more mangroves should be planted along the banks of the lagoon to control excess evaporation and provide spawning grounds for fish. Agricultural activities carried out within the catchment should be controlled to avoid the introduction of chemicals into the lagoon.

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Author’s Contributions

Emmanuel Yeboah Okyere: Conceptualization, investigation, project administration, and validation, original drafted.

Kofi Adu-Boahen: Supervision, data curation, and methodology and approved final drafted.

Bismark Mensah: Resource provision, did software analysis, validation, and visualization.

Ethics

Approval obtained from the Ethical Review Board of authors institution. The procedures used in this study follow the tenets outlined by the Declaration of Helsinki.

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Conflict of Interest

The authors have no conflict of interest to declare.

References

Adu-Boahen, K., Dadson, I. Y., & Atubiga, J. A. (2018). Customary practices and wetland management in Ghana: A case of Muni Lagoon Ramsar site in the Central Region. *KNUST Journal of Geography and Rural Development*, *2*(1), 27-45. https://www.researchgate.net/publication/323512160_Customary_Practices_and_Wetland_Management_in_Ghana_a_case_of_Muni_Lagoon_Ramsar_Site_in_the_Central_Region

Al-Kodmany, K. (2018). The vertical farm: A review of developments and implications for the vertical city. *Buildings*, *8*(2), 24. https://doi.org/10.3390/buildings8020024

Amatekpor, J. K. (1994). Muni-Pomadze Ramsar Site: Soils and land use. Ghana Coastal Wetland Management Project. *Department of Game and Wildlife*, *Government of Ghana*, 52 pp.

Atampugre, G. (2010). *Spatio-temporal information and analysis of land use/land cover changes in the Muni-Pomadze wetland* (Doctoral dissertation, University of Cape Coast). http://hdl.handle.net/123456789/1762

Bayliss, P., Van Dam, R. A., & Bartolo, R. E. (2012). Quantitative ecological risk assessment of the Magela Creek Floodplain in Kakadu National Park, Australia: Comparing point source risks from the ranger uranium mine to diffuse landscape-scale risks. *Human and Ecological Risk Assessment: An International Journal*, *18*(1), 115-151. https://doi.org/10.1080/10807039.2012.632290

Basiago, A. D. (1998). Economic, social and environmental sustainability in development theory and urban planning practice. *Environmentalist*, *19*(2), 145-161. https://doi.org/10.1023/A:1006697118620

Bassi, N., Kumar, M. D., Sharma, A., & Pardha-Saradhi, P. (2014). Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. *Journal of Hydrology: Regional Studies*, *2*, 1-19. https://doi.org/10.1016/j.ejrh.2014.07. 001

Biney, C. A. (1995). Limnology of Muni-Pomadze Ramsar Site. *Unpublished report to Ghana Game and Wildlife Department of the Forestry Commission*.

Breuste, J., Haase, D., & Elmqvist, T. (2013). Urban landscapes and ecosystem services. *Ecosystem services in Agricultural and Urban Landscapes*, 83-104. https://doi.org/10.1002/9781118506271.ch6

Brown, C. J., Adame, M. F., Buelow, C. A., Frassl, M. A., Lee, S. Y., Mackey, B., ... & Connolly, R. M. (2021). Opportunities for improving recognition of coastal wetlands in global ecosystem assessment frameworks. *Ecological Indicators*, *126*, 107694. https://doi.org/10.1016/j.ecolind.2021. 107694

Boanu, N. Y., Dadson, I. Y., Adu-Boahen, K., & Yeboah, E. O. (2022). Assessment of the physico-chemical properties in the Muni-Pomadze Ramsar Site and its catchment in Winneba, Ghana. *Environmental Protection Research*, 95-111. https://doi.org/10.37256/epr.222022786

CERSGIS. (2021). *Encroachment on Sakumo Ramsar site*. https://cersgis.org/news/?blog_id=10

Cobbinah, P. B., Asibey, M. O., & Gyedu-Pensang, Y. A. (2020). Urban land use planning in Ghana: Navigating complex coalescence of land ownership and administration. *Land Use Policy*, *99*, 105054. https://doi.org/10.1016/j.landusepol.2020.105054

Danso, G. K., Takyi, S. A., Amponsah, O., Yeboah, A. S., & Owusu, R. O. (2021). Exploring the effects of rapid urbanization on wetlands: insights from the Greater Accra Metropolitan Area, Ghana. *SN Social Sciences*, *1*, 1-21. https://doi.org/10.1007/s43545-021-00218-2

Eze, B. E., Dadson, I. Y., & Adu- Boahen, K. (2023). *Geographical location and physical characteristics of Winneba*. In Danso-Wiredu, E. Y. & Weiler, J. (eds). Winneba: Geography, People's and Systems. Digibooks, Accra. https://www.researchgate.net/publication/370108741_Geographical_Location_and_Physical_Characteristics_of_Winneba

Ghosh, S., & Das, A. (2020). Wetland conversion risk assessment of East Kolkata Wetland: A Ramsar site using random forest and support vector machine model. *Journal of Cleaner Production*, *275*, 123475. https://doi.org/10.1016/j.jclepro.2020.123475

Gleason, R. A., Euliss Jr, N. H., Tangen, B. A., Laubhan, M. K., & Browne, B. A. (2011). USDA conservation program and practice effects on wetland ecosystem services in the Prairie Pothole Region. *Ecological Applications*, *21*(sp1), S65-S81. https://doi.org/10.1890/09-0216.1

Gordon, C., Ntiamoa-Baidu, Y., & Ryan, J. M. (2000). The Muni-Pomadze Ramsar site. *Biodivers Conserv*, *9*, 447-464.

Gryczkowski, L. (2015). *Surface water and groundwater interactions in the Walla Walla River, Northeast Oregon, USA: A Multi-Method Field-Based Approach* (PhD dissertation, Oregon State University). https://ir.library.oregonstate.edu/concern/file_sets/4m90dx98b

Jiang, D., Wang, J., Huang, Y., Zhou, K., Ding, X., & Fu, J. (2014). The review of GRACE data applications in terrestrial hydrology monitoring. *Advances in Meteorology*, *2014*. https://doi.org/10.1155/2014/725131

Keraita, B., Drechsel, P., & Konradsen, F. (2008). Perceptions of farmers on health risks and risk reduction measures in wastewater-irrigated urban vegetable farming in Ghana. *Journal of Risk Research*, *11*(8), 1047-1061. https://doi.org/10.1080/13669870802380825

Kopeć, D., & Sławik, Ł. (2020). How to effectively use long-term remotely sensed data to analyze the process of tree and shrub encroachment into open protected wetlands. *Applied Geography*, *125*, 102345. https://doi.org/10.1016/j.apgeog.2020.102345

Korah, P. I., & Cobbinah, P. B. (2017). Juggling through Ghanaian urbanisation: Flood hazard mapping of Kumasi. *GeoJournal*, *82*, 1195-1212. https://doi.org/10.1007/s10708-016-9746-7

Kraemer, B. M., Anneville, O., Chandra, S., Dix, M., Kuusisto, E., Livingstone, D. M., ... & McIntyre, P. B. (2015). Morphometry and average temperature affect lake stratification responses to climate change. *Geophysical Research Letters*, *42*(12), 4981-4988. https://doi.org/10.1002/2015GL064097

Kuusaana, E. D., Ahmed, A., Campion, B. B., & Dongzagla, A. (2021). Characterisation and typology of urban wetlands in Ghana: Implications for the governance of urban commons in secondary cities in Africa. *Urban Governance*, *1*(1), 38-50. https://doi.org/10.1016/j.ugj.2021.09.002

Lee, S. Y., Dunn, R. J. K., Young, R. A., Connolly, R. M., Dale, P. E. R., Dehayr, R., ... & Welsh, D. T. (2006). Impact of urbanization on coastal wetland structure and function. *Austral Ecology*, *31*(2), 149-163. https://doi.org/10.1111/j.1442-9993.2006.01581.x

Malekmohammadi, B., Uvo, C. B., Moghadam, N. T., Noori, R., & Abolfathi, S. (2023). Environmental Risk Assessment of Wetland Ecosystems Using Bayesian Belief Networks. *Hydrology*, *10*(1), 16. https://doi.org/10.3390/hydrology10010016

Mensah, C. A. (2016). The state of green spaces in Kumasi city (Ghana): Lessons for other African cities. *Journal of Urban and Regional Analysis*, *8*(2), 159-177. https://www.ceeol.com/search/article-detail?id=726104

Mao, D., Wang, Z., Wu, J., Wu, B., Zeng, Y., Song, K., ... & Luo, L. (2018). China's wetlands loss to urban expansion. *Land Degradation & Development*, *29*(8), 2644-2657. https://doi.org/10.1002/ldr.2939

Mukherjee, F., & Singh, D. (2020). Assessing land use–land cover change and its impact on land surface temperature using LANDSAT data: A comparison of two urban areas in India. *Earth Systems and Environment*, *4*, 385-407. https://doi.org/10.1007/s41748-020-00155-9

Mureti, M. C. (2014). An investigation into causes and effects of encroachments on riparian reserves a case study of Ruaka River. (*Unpublished Bachelor's Thesis*). *University of Nairobi, Kenya*.

Norton, S. B., Rodier, D. J., van der Schalie, W. H., Wood, W. P., Slimak, M. W., & Gentile, J. H. (1992). A framework for ecological risk assessment at the EPA. *Environmental Toxicology and Chemistry*, *11*(12), 1663-1672. https://doi.org/10.1002/etc.5620111202

Okyere, E. Y., Adu-Boahen, K., Boateng, I., Dadson, I. Y., Boanu, N. Y., & Kyeremeh, S. (2023). Analysis of ecological health status of the Muni Lagoon: Evidence from heavy metal content in its water and fish samples. *Geo: Geography and Environment*, *10*(1). https://doi.org/10.1002/geo2.115

Osman, A., Adu-Boahen, K., Arko, B., & Okyere, E. Y. (2022). Analysis of planting practices and post-planting stewardship intention of participants of Arbor Day tree planting practices and stewardship intention. *Restoration Ecology*, e13838. https://doi.org/10.1111/rec.13838

Oteng-Yeboah, A.A. (1994). Detailed baseline studies of Muni-Pomadze Ramsar site: Plant Ecology, Ghana Coastal Wetlands Management Project, GW/A.285/SF.2/34. https://www.aeon.info/ef/midoripress/prize/prize_winner/2014/CV%20A%20Oteng-Yeboah.pdf

Ranjan, R. (2019). A forestry-based PES mechanism for enhancing the sustainability of Chilika Lake through reduced siltation loading. *Forest Policy and Economics*, *106*, 101944. https://doi.org/10.1016/j.forpol.2019.06.001

RSIS. (2015, August 13). *Muni-Pomadze Ramsar Site*. Ramsar Site Information Service https://rsis.ramsar.org/ris/563

Rocha Ghana, A. (2021). Muni-Pomadze Ramsar Site under threat... as biodiversity declines - Ghana: A Rocha Ghana. https://ghana.arocha.org/news/muni-pomadze-ramsar-site-under-threatas-biodiversity-declines/

Ryan, J. M., & Attuquayefio, D. (2000). Mammal fauna of the Muni-Pomadze Ramsar site, Ghana. *Biodiversity & Conservation*, *9*, 541-560. https://doi.org/10.1023/A:1008964000018

Schofield, K. A., Alexander, L. C., Ridley, C. E., Vanderhoof, M. K., Fritz, K. M., Autrey, B. C., ... & Pollard, A. I. (2018). Biota connect aquatic habitats throughout freshwater ecosystem mosaics. *JAWRA Journal of the American Water Resources Association*, *54*(2), 372-399. https://doi.org/10.1111/1752-1688.12634

Shrestha, S. (2015). *Assessment of Bagmati River encroachment through Application of GIS and Remote Sensing*. Pokhara University. https://doi.org/110.13140/RG.2.2.26874.18884

Tay, C. K., Asmah, R., & Biney, C. A. (2010). Trace metal levels in water and sediment from the Sakumo II and Muni Lagoons, Ghana. *West African Journal of Applied Ecology*, *16*(1). https://doi.org/10.4314/wajae.v16i1.55870

Tumbulto, J. W., & Bannerman, R. R. (1995). Environmental baseline studies, Muni Pomadze Ramser Site, Hydrology. *Report prepared for the Ghana Coastal Wetland Management Project. Department of Game and Wildlife, Government of Ghana*.

USGS. (2010). Land cover classification scheme. https://pubs.usgs.gov/pp/0964/report.pdf

Van Dam, R. A., Camilleri, C., & Finlayson, C. M. (1998). The potential of rapid assessment techniques as early warning indicators of wetland degradation: A review. *Environmental Toxicology and Water Quality: An International Journal*, *13*(4), 297-312. https://doi.org/10.1002/(SICI)1098-2256(1998)13:4<297::AID-TOX3>3.0.CO;2-2

Van Dam, R. A., Finlayson, C. M., & Humphrey, C. L. (1999). Wetland risk assessment: A framework and methods for predicting and assessing change in ecological character. I*n Techniques for Enhanced Wetland Inventory and Monitoring*. Eds C.M. Finlayson & A. G. Spiers, supervising scientist report 147, supervising scientist report, Canberra, 83-118. https://www.agriculture.gov.au/sites/default/files/documents/ssr147-web.pdf#page=89

WRC. (2013). Riparian buffer zone policy for managing freshwater bodies in Ghana. https://www.wrc-gh.org/dmsdocument/93

World Population Review. (2019). http://worldpopulationreview.com/countries/ghana-population

Wuver, A. M. (2006). The impact of human activities on biodiversity conservation in a coastal wetland in Ghana. *West African Journal of Applied Ecology*, *9*(1). https://doi.org/10.4314/wajae.v9i1.45690