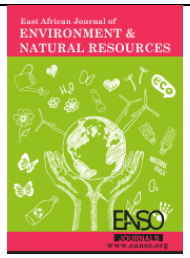

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Original Article

Climatic Variability and Change on Biodiversity, Freshwater Wetland Ecosystem Service and Livelihoods in Zanzibar

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ABSTRACT

Worldwide, freshwater wetland ecosystems are very important for maintaining the ecological stability of natural ecosystems as well as enhancing the human well-being of the surrounding community. This study was aimed at assessing the impacts of climatic variability and change on freshwater wetland ecosystem services and associated livelihoods in Zanzibar. The Islands are extremely vulnerable to climate change; However, a limited number of studies have been conducted on the possible effects of climate change on the wetlands. The study was carried out in eight wetland areas, four from Pemba, which include Machopozoni, Kangani, Bopwe, Shidi, and Tibirinzi, and four from Unguja Island, which include Mwera, Matetema, Kaburi kikombe and Mtwango. A purposive sampling technique was used to identify representative wetlands for this study. A total of 160 households living in the area for more than ten years were randomly selected and surveyed in this study, making an average of 20 households per study site. A semi-structured questionnaire was designed to capture different socio-wetland activities, and a checklist was used to record observations. The results show that about 98% of women interviewed mentioned that they used wetland for farming rather than other activities, while 88% of men depend on wetland for food and employment, and 30% of all respondents mentioned the importance of wetland for agricultural production. 57% of respondents in Unguja mentioned that pollution of wetlands is due to pesticides, while in Pemba, it is 78%. In the present study, there is no proper strategy set by communities for the conservation of wetlands. There is a decline in animal and plant species, Poor use and handling of pesticides, community dependent on wetland. Developed a wetland conservation strategic plan in both languages (English and Kiswahili). To encourage stakeholders to support the implementation plan.

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INTRODUCTION

The magnitude of the world's wetlands is generally thought to range from 7 to 9 million square kilometers (about 4 to 6% of the land surface of the earth) (Mitsch and Gosselink, 2000), and the minimum global estimate is considered to be 7.8 million km^2 (US EPA, 2004). But, according to Reddy and DeLaune (2003), approximately 6% of Earth's land surface, which equals about 2 billion acres (approximately 800 million hectares), is covered by wetlands. However, the coverage area in Africa has not yet been known exactly. As a result, different estimates have been given regarding the total wetland area. A study by Hillman (1993) estimated that the wetlands in Ethiopia have a total area of 13,699 km^2 (1.4%) of the country's land surface, whereas Beyene & Banerjee (2011) stated that wetland is estimated to cover 18,587 km2 (1.5%) of the total land area of Ethiopia. Globally, freshwater wetland ecosystems are very critical for maintaining the ecological stability of the natural ecosystems as well as enhancing the human well-being of the surrounding community. Other benefits that freshwater wetlands provide for human society include carbon cycling and climatic regulation, the supply of fresh water, maintenance of biodiversity, fish production, irrigation, and tourism (Keddy, 2010). In Tanzania, partnership and cooperation at the district/region, national, regional and international levels for the management of transboundary wetlands and migratory species is one of the key strategies for wetland conservation (Prasad et al., 2002, VPO, 2014, Wilson et al., 2017). A study by Okonkwo (2015) revealed that, inorder to enhance the conservation and management of this vital wetlands ecosystem in Niger Delta, it is advisable to implement advanced monitoring techniques, notably Geographic Information Systems (GIS) and remote sensing. In East Africa, mapping of wetland habitats and their definition was carried out from a remote sensing perspective.

(Amler et al., (2015). In Nepal, the removal of trees and shrubs from the lake complex has led to habitat destruction, significantly reducing the living space available for larger animals (Lamsal et al., 2025). On the other hand, wetlands play an integral role in the hydrologic cycle and thus provide important ecosystem services to nature and surrounding populations (NRC 1992). However, other research studies revealed that all wetland types are sensitive to alterations in their hydrologic regime (Mortsch and Quinn 1996). The anthropogenic disturbances, such as dredging and filling, water diversion, and degraded water quality, were reported as wetland ecosystems (MEA, 2005). *Freshwater wetlands in Zanzibar are also threatened by natural factors, mainly global climate change, which has concomitant effects on rising temperature, increasing level of carbon dioxide, change in precipitation pattern, storminess and sea-level rise (Watkiss et al., 2011). However, gradual sea level rise, which leads to an increase in saltwater*

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intrusion into lowland areas, poses a significant threat to the clean water sources and agricultural wetlands of Zanzibar (Watkiss et al., 2011). Currently, there is little information on freshwater wetland habitats, functions, and ecosystem services and the contribution of freshwater wetland ecosystem services to community livelihoods. In addition, the impacts of climate change and variability on freshwater wetlands are still unknown. Therefore, this study highlights the significance of the ecosystem services provided by the Zanzibar freshwater ecosystem and how they have been affected by climate change. Types of wetlands differ due to various factors such as hydrology (water regime), water chemistry, existing plant and animal life, etc. Verry (2018) stated that the source of water determines the wetland types. According to Bardecki (1991), wetlands include a wide variety of ecosystem types, including tidal salt marshes, freshwater marshes, forested swamps, mangrove swamps, fens, bogs, tropical reed swamps, seasonally flooded riparian forests, etc. In general, according to Cowardin et al. (1979), there are five recognised major wetland system types as marine, estuarine, lacustrine, riverine, and palustrine. Of the global total wetland area estimated, the greatest part is occupied by wetlands in freshwater environments. Marine and estuarine systems describe coastal, saltwater wetlands, whereas the other categories represent freshwater systems. Lacustrine wetlands are associated with lakes; riverine wetlands are found along rivers and streams; and palustrine wetlands represent those wetlands that are referred to as marshes, swamps and bogs (Cowardin et al., 1979).

METHODOLOGY

Study Design, Sampling Approaches and Sample Size

This study employed cross cross-sectional study design to collect different information at once, because it is the quickest and economical. Purposive sampling techniques were used to identify representative wetlands for this study. This sampling technique was used because it helps to select specific wetlands that are best suited to provide the information needed for this study. In addition, random sampling techniques were used to select representative household members living around the selected wetlands from the list of village leaders. *Because of age variation, only households with respondents aged fifty (50 years) and above who have lived in the site for more than thirty years were purposively selected.* A total of 160 households were randomly selected and surveyed in this study, making an average of 20 households per study village. The study was carried out in seven wetland areas, four from Pemba, which include Machopozoni, Kangani, Bopwe, Shidi, and Tibirinzi, and three from Unguja Island, which include Mwera, Matetema, Kaburi kikombe and Mtwango. These villages and their associated wetland areas have been chosen because the majority of wetlands are found, and the community is engaged in livelihood practices along with these wetlands and thus are familiar with what is happening in these areas.

Methods for Data Gathering

Both primary and secondary methods for data gathering were used in this study. Primary data was collected through survey methods, including household interviews and key informants. Key informants (Village leaders) were used to define and locate the wetlands they have in their areas. In addition, participants' observation was used to verify and collect data that are not easily available through interviews. Relevant documents and/or materials concerning socio-economic and conservation aspects, with emphasis on protected wetland vegetation in Zanzibar, were reviewed to provide secondary data for this study. Each of these methods was discussed in the following sub-sections in terms of the tools and techniques used to collect or gather the data.

Household Interviews

A household interview was conducted with the heads and/or spouses of the selected households living around the selected wetlands in each study

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site. A semi-structured questionnaire was used to interview respondents who are familiar with the freshwater wetlands ecosystem services and whose livelihoods rely on the ecosystem services. The developed Questionnaire was designed to capture different socio-activities of household members, wetland ecosystem services, *climatic variable impacts on wetland ecosystem services, contribution of wetlands to household livelihoods and responses to the impacts of community and ecosystem on climate change in wetland ecosystems.*

Observations.

An observation checklist was prepared, and observations were made at the surrounding wetland areas. Observations were focused on the general condition of wetland nature, livelihood activities such as fishing, agriculture, conservation, livestock, pollution, biodiversity, etc. GPS (Figures 12 and 13) and a Digital camera were used to take pictures for future analysis (Plates 1, 2, and 3).

Secondary Sources

A literature review was done on different research reports and archival data from various projects and institutions working in the area with more or less similar issues to add value to the primary data that will be collected from respondents.

Analysis of Key Informant and Household Data

Both qualitative and quantitative methods for data analysis were used to analyse data from household interviews and observations, and selected secondary sources. Qualitative data obtained through key informants and observations were summarised into meaningful sentences using content analysis. Quantitative data obtained through the household questionnaire survey were entered into the Statistical Package for Social Sciences (SPSS) software for storage and subsequent analyses to generate descriptive statistical results. Tables, charts and graphs were used to represent the results.

RESULTS

About 98% of women interviewed mentioned that they use the wetland for farming rather than other activities, while 88% of men depend on the wetland for food and employment. The finding highlights that if the wetland ecosystem is affected and its size declines, this will result to impinge on more women than men being impacted (Figure 1). In general, 93.8% of respondents depend on wetlands as their source of food and employment. The declining condition of wetlands has placed their ecosystem services and the people who depend on them are increasing risk (MEA 2005d). About 30% of all respondents who mentioned the uses of wetlands and agricultural production are higher and increasing. From the study observation, the main agricultural crops grown by the communities are rice, maize, cassava, yams, banana, vegetables and many fruit trees. However, fishing, domestic and livestock are also the main social benefits from wetlands (Figure 2).

Figure 1: Wetland Dependent and Non-dependent by Gender

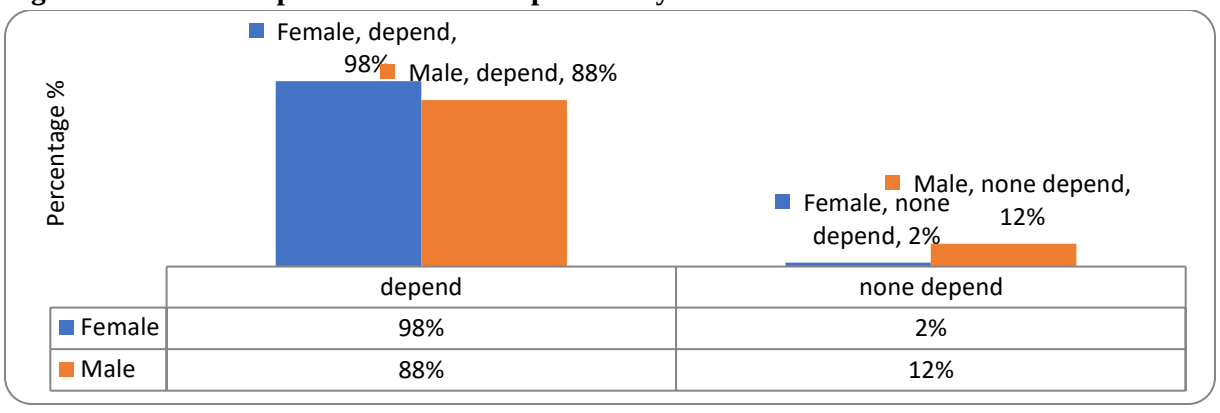

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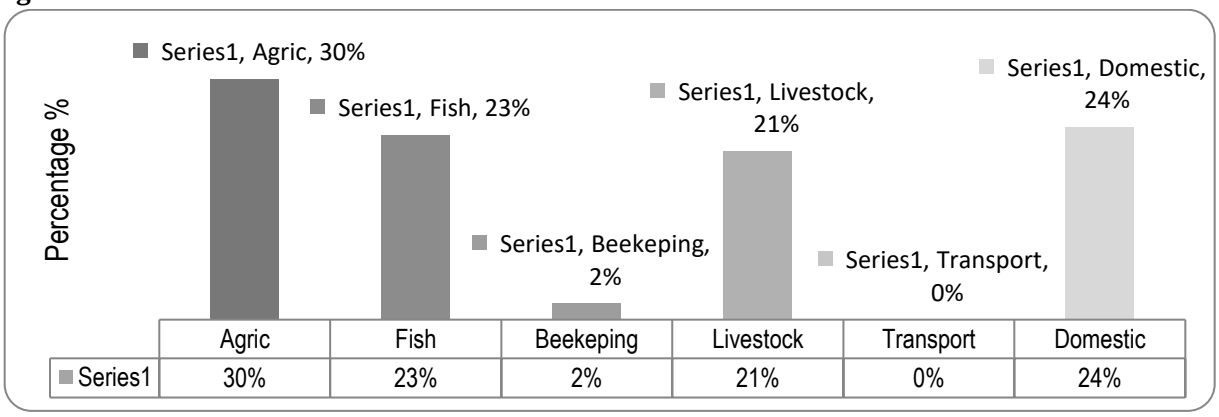
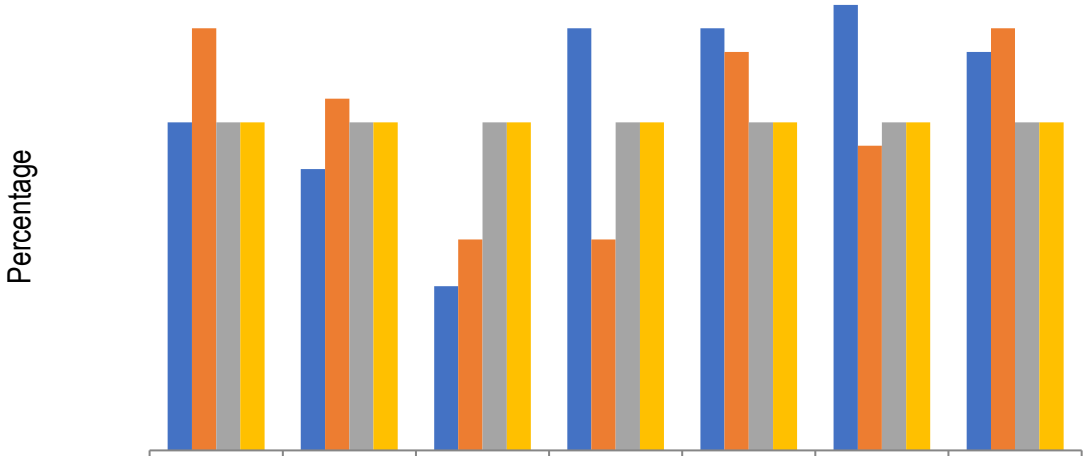
Figure 2: Wetlands' Social and Economic Services



	Agric	Fish	Beekeping	Livestock	Transport	Domestic
Series1	30%	23%	2%	21%	0%	24%

The study results show that in all sites, there are small variations in animal biodiversity. For example, in Kaburi kikombe wetland, the percentage of fish is less than the other sites; details of the findings are shown in Figure 3 below. Every 5 to 10 years, villagers experience the occurrence of floods and severe droughts in all study sites; this may change the nature of the areas. Despite the presence of amphibians and molluscs as part of animal biodiversity in these areas, the communities in all sites use pesticides to kill them, believing that these animals are the sources of many diseases like malaria, diarrhoea, schistosomiasis, etc. In Mwera and Mtwango in Unguja, all respondents answered the same. This is because the two sites are very close and share the same characteristics, features and livelihood activities. In Pemba, Machopozini showed a higher fish population compared to other sites. Details for other animals see figures 3a and 3b below.

Figure 3a: Animals Existing in the Wetland Ecosystem in Unguja



	Amphibian/Mollusks	Reptilian	Rats	Fish	Insects	Other mammals	Birds
Matetema	14%	12%	7%	18%	18%	19%	17%
K kikombe	18%	15%	9%	9%	17%	13%	18%
Mwera	14%	14%	14%	14%	14%	14%	14%
Mtwango	14%	14%	14%	14%	14%	14%	14%

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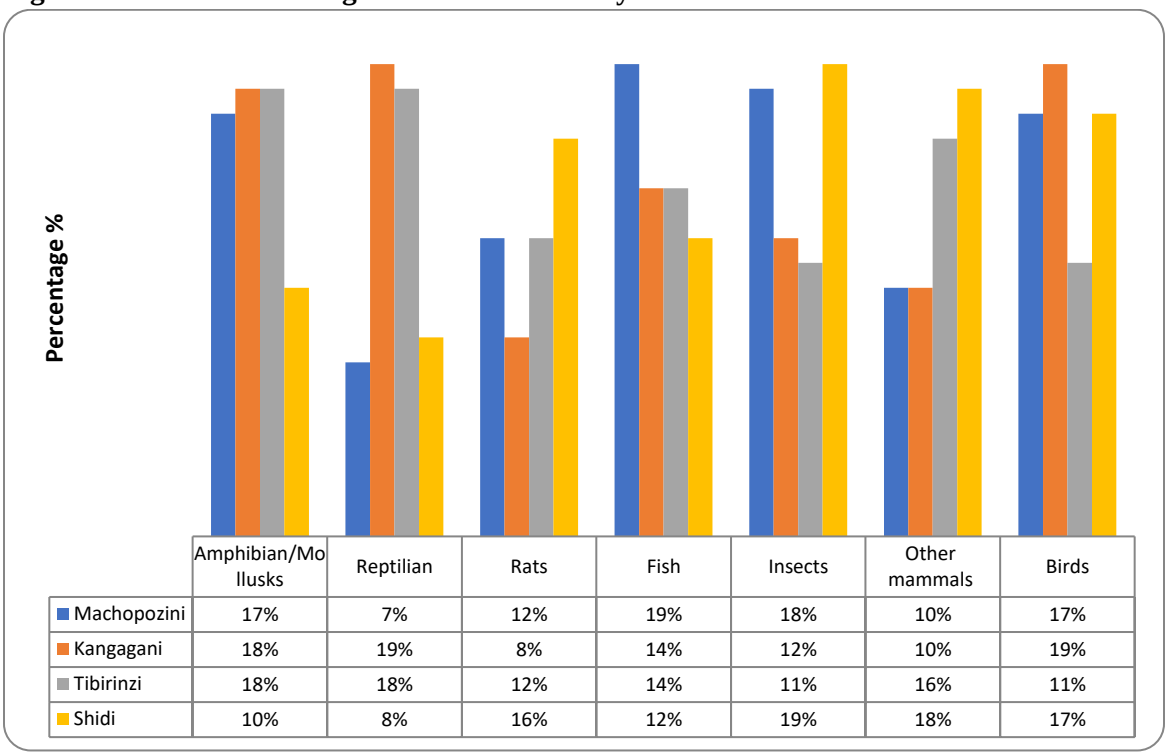
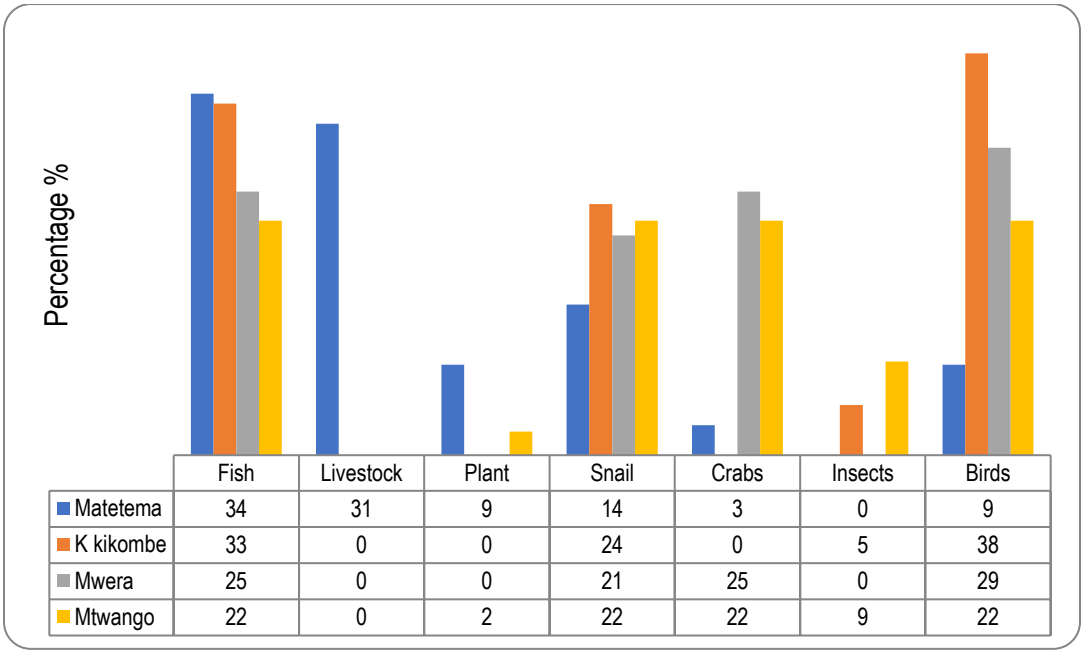
Figure 3b: Animals Existing in the Wetland Ecosystem in Pemba



	Amphibian/Mollusks	Reptilian	Rats	Fish	Insects	Other mammals	Birds
Machopozini	17%	7%	12%	19%	18%	10%	17%
Kangagani	18%	19%	8%	14%	12%	10%	19%
Tibirinzi	18%	18%	12%	14%	11%	16%	11%
Shidi	10%	8%	16%	12%	19%	18%	17%

There are variations in the perception of the effect of biodiversity in wetland ecosystems. For example, in figures 4 and 5 (Unguja and Pemba), many respondents interviewed revealed that fish, followed by birds, are more vulnerable to any changes in the wetland ecosystem. In Matetema village in Unguja, 34% of respondents insisted that fish can be more affected by any changes to wetlands, whereas in Machopozini in Pemba showed 45% of interviewees Figure 4) showed that fish can be more affected by any changes to wetlands.

Figure 4: Animal at Risk of Extinction in Unguja



	Fish	Livestock	Plant	Snail	Crabs	Insects	Birds
Matetema	34	31	9	14	3	0	9
K kikombe	33	0	0	24	0	5	38
Mwera	25	0	0	21	25	0	29
Mtwango	22	0	2	22	22	9	22

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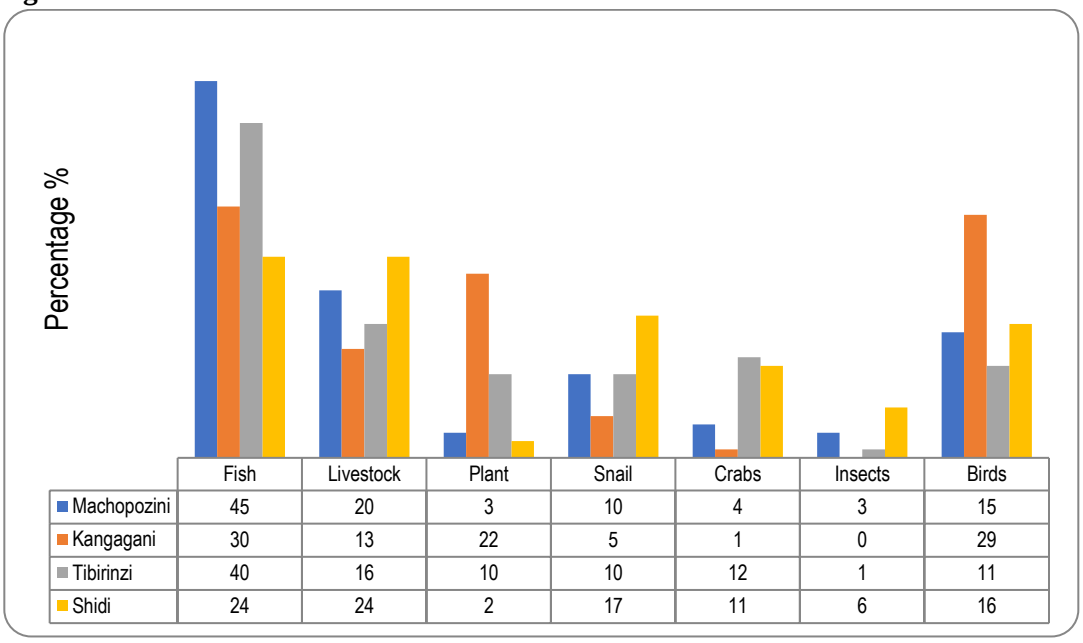
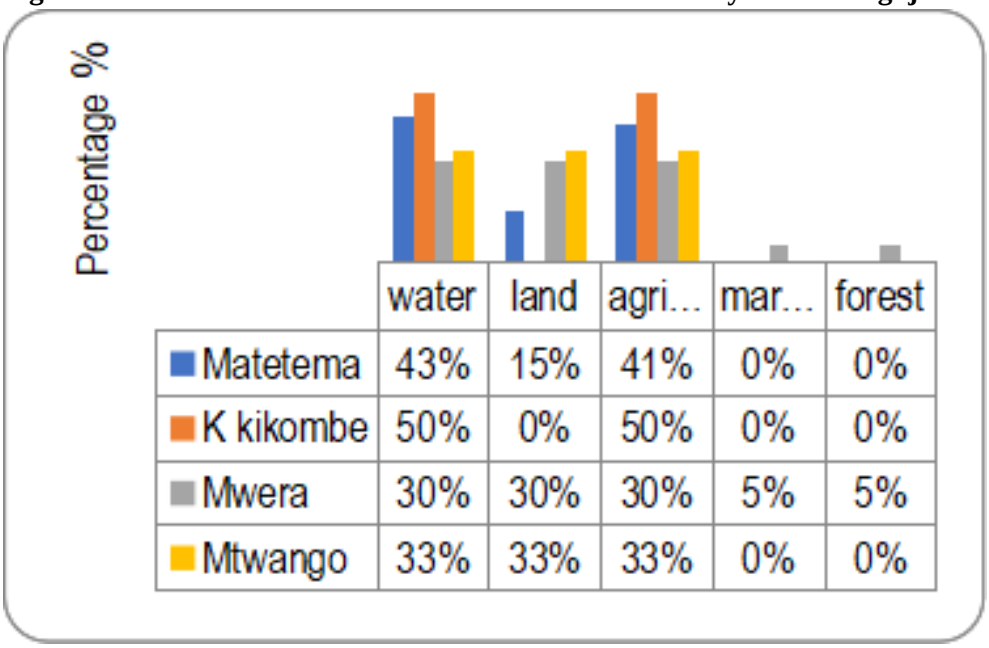
Figure 5: Animal at Risk of Extinction in Pemba



	Fish	Livestock	Plant	Snail	Crabs	Insects	Birds
Machopozini	45	20	3	10	4	3	15
Kangagani	30	13	22	5	1	0	29
Tibirinzi	40	16	10	10	12	1	11
Shidi	24	24	2	17	11	6	16

The extent to which individual wetland sites provide particular services differs. For example in Unguja water and agriculture/livestock crisis was frequently mentioned in Kaburi kikombe site, about 50% of respondents claimed about water conflicts between farmers and people living nearby and some periods of long drought the crisis become severe, this site is heavily populated and unplanned residential area, *In 30 years the size of wetland has been reduced from approximately 50 acres to 5 acres, in addition there is no land crisis reported in this site (by Resident) (Figure 6)*. Water, land, agriculture and livestock crises were also reported in all sites in Pemba, although the water crisis was reported mostly in Kangagani (60%) than in other study sites (Figure 7).

Figure 6: Level of Resource Conflicts in the Wetland Ecosystem in Unguja



	water	land	agri...	mar...	forest
Matetema	43%	15%	41%	0%	0%
K kikombe	50%	0%	50%	0%	0%
Mwera	30%	30%	30%	5%	5%
Mtwango	33%	33%	33%	0%	0%

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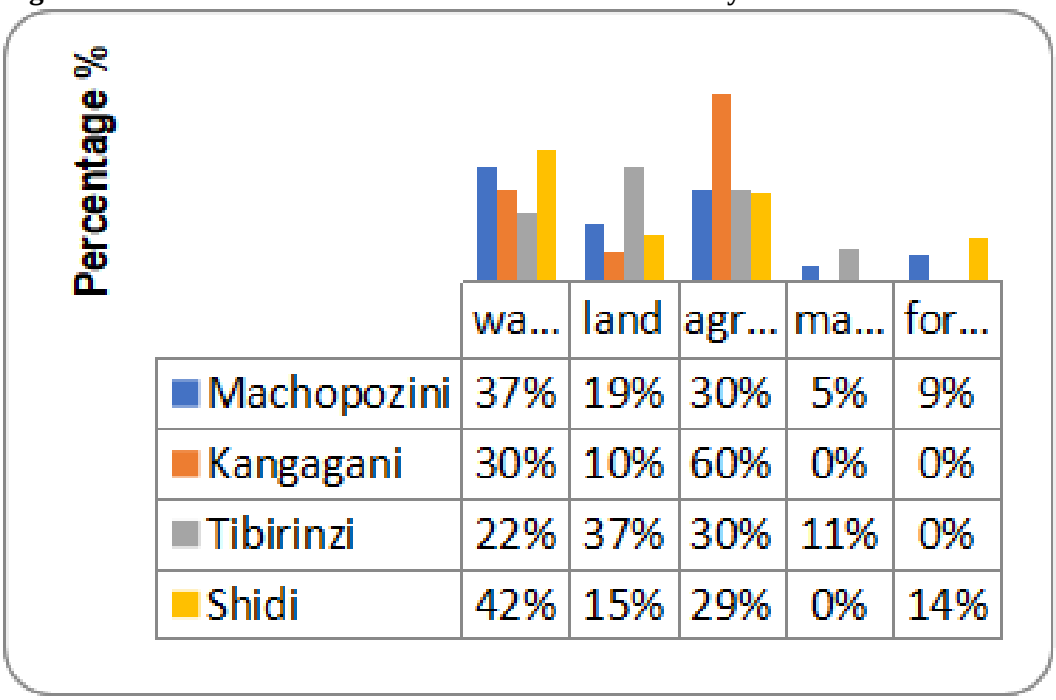
Figure 7: Level of Resource Conflicts in the Wetland Ecosystem in Pemba



	wa...	land	agr...	ma...	for...
Machopozini	37%	19%	30%	5%	9%
Kangagani	30%	10%	60%	0%	0%
Tibirinzi	22%	37%	30%	11%	0%
Shidi	42%	15%	29%	0%	14%

The benefits provided by a given wetland will depend, among other things, on the type and range of ecosystem services rendered. The life of wetlands depends upon human uses; misuse of wetlands will result in changes to their size and nature. In observation, we see a number of empty pesticide tins and sachets scattered on the surface, which shows that there is no control of chemicals in the study areas, and farmers tend to use these hazardous chemicals without consultation (Plate 2). About 57% of respondents in Unguja mentioned that pollution of wetlands is due to pesticides, while in Pemba, it is 78% (Figure 8). Village leaders revealed that the use of chemicals causes a decline of fish in all areas " *In the early 60s and 70s, we used to fish here and sell them in town, and we also dried and stored some of them (Kangagani Site)"*. Also, we witnessed ongoing construction of residential houses in all wetland study sites (Plate 3). We also observed that the sewage systems of houses from all sites of Unguja are directed toward the wetlands. In all study villages, the respondents agreed to the possibility of biodiversity losses. They revealed that the causes of losses are due to the continued conversion of wetlands to residential houses and other permanent structures. *"We don't know why the fish population and species richness have declined in this pond? In the last three decades, it was not like this. Three types of fish (brown catfish, river tilapia and Indigenous tilapia) are rarely found in this area". In addition, the migratory birds we used to see here during rice farming seasons have also declined in their population*. The key informants' information also concurs with Figure 9, the respondents from Unguja claimed that 31% of fish can become extinct if conservation is not enforced, while in Pemba, 52% mentioned that indigenous fish are an endangered species to extinction.

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Figure 8: Level and Source of Pollution in Wetlands

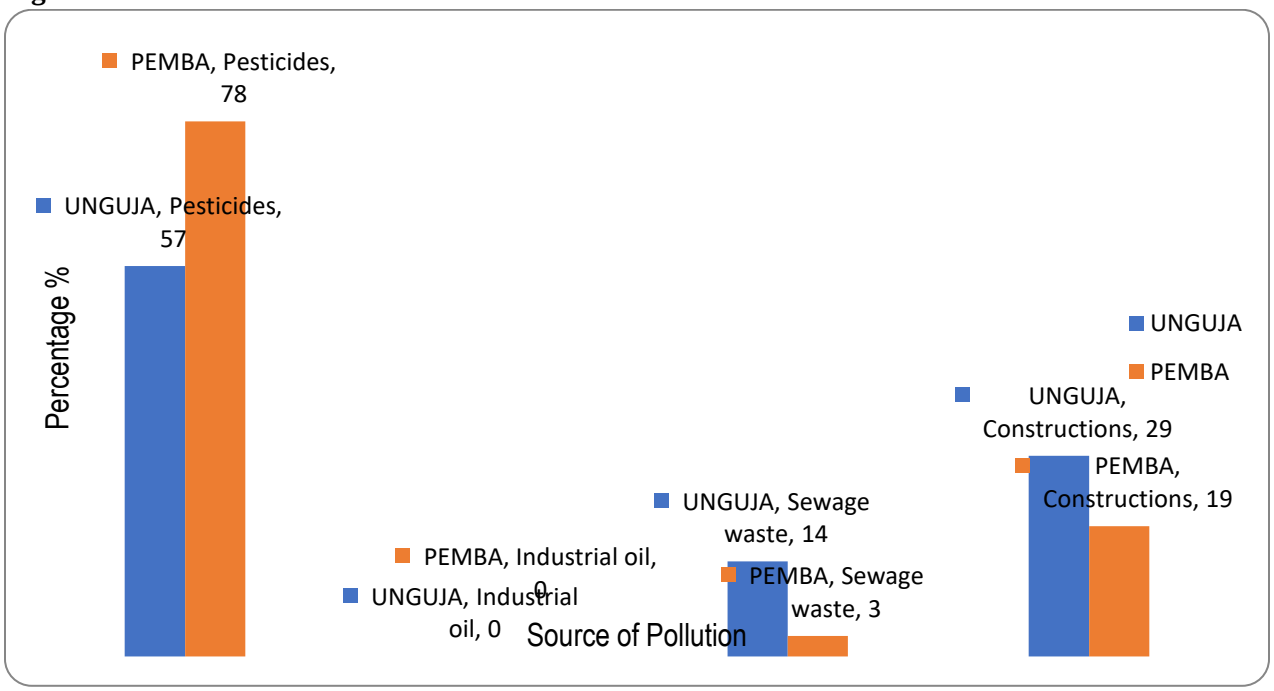
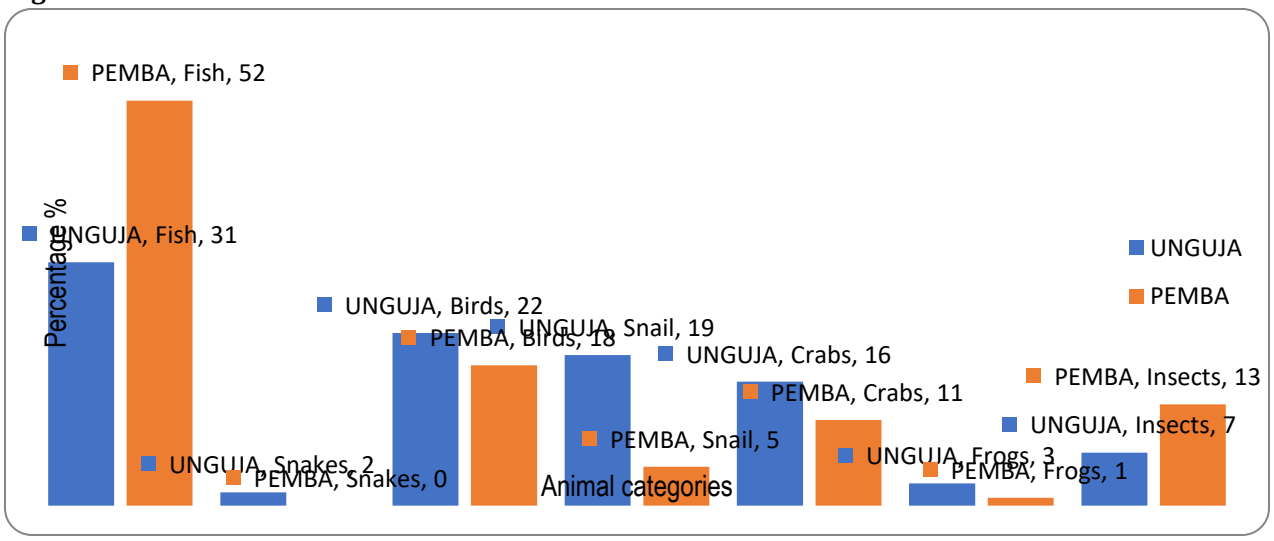


Figure 9: Wetlands and Animal Extinction



Changes size of wetlands not only affect food security but also have an impact on the ecosystem. Animals like fish, snails, amphibians, mammals, birds, and reptiles depend on wetlands for breeding and food. Also, surrounding grasses grown in wetlands are used by the community to feed their livestock. About 53% of respondents in Unguja said that any changes to wetlands could affect the nature of the ecosystem, while in Pemba, 51% mentioned that changes to wetlands would increase food insecurity (Figure 10). In the present study, there is no proper strategy set by the communities on the conservation of wetlands. The respondents do whatever they want to do in the wetlands, they cut the trees surrounding the land, they dispose of the pesticides, empty tins and bottles in water, they open new channels and divert the water to new land (Plates 1 and 2). However, they agreed with researchers on the conservation of these natural resources and on sustainable use. There is a variation of opinions between the two islands. In Unguja, the majority of respondents support

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establishing conservation groups (54%), while in Pemba, they support the provision of training as the first conservation mechanism for the wetland ecosystem (Figure 11).

Figure 10: Community Perception on Wetlands and Level Disasters

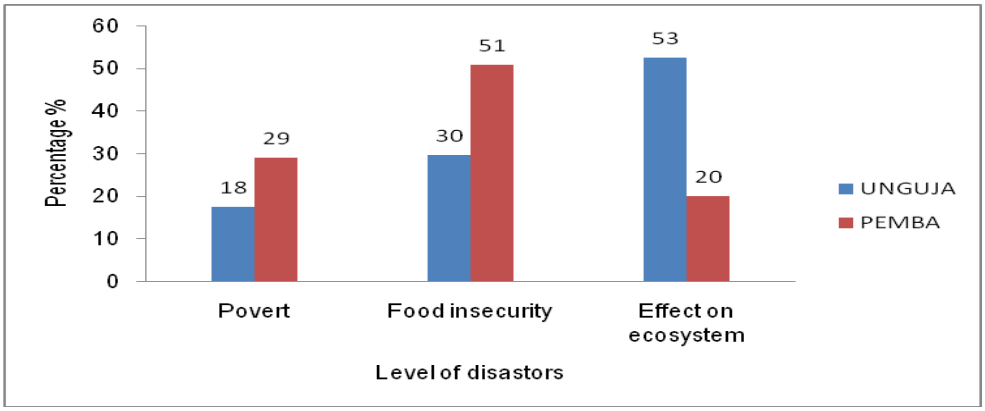
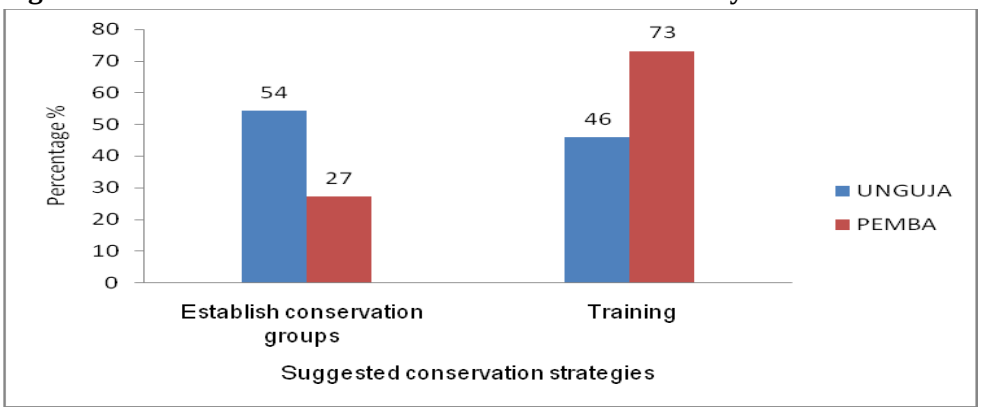


Figure 11: Conservation Mechanism of the Wetlands Ecosystem



DISCUSSION

Agriculture, fisheries, ecotourism, water supply and fuel wood collection are among the major uses of wetlands in the Gulf of Mexico (Engle, 2011) and India in Kerala, Goa, Odisha, Jammu and Kashmir, Assam, Bihar, Andhra Pradesh, Gujarat (Bassi et al., 2014). This study elaborates that people living in wetland areas also use them for agriculture, fishing, beekeeping, transport, livestock and domestic purposes. This indicates that there are similarities and differences in the uses of wetlands between regions and continents worldwide. Research and surveys have provided empirical evidence to show that wetlands are among the most productive ecosystems and multifunctional with diverse values and functions in Tanzania (Lema, 1979; LRDC and ODA, 1987; Bwathondi and Ngoile, 1990; Mwalyosi, 1990; Semesi, 1990). The study by Isaiah (2021) on gender roles in wetlands conservation and restoration in Murang'a County, Kenya, revealed that women's participation in the use of wetlands is higher compared with men living in that area. A study by Stephenson et al. (2020) Ramsar Sites in Ghana using a participatory combination of traditional monitoring methods, as well as innovative new tools such as remote sensing and environmental DNA in the conservation of wetland biodiversity, was found very effective.In this study, women depend more on wetlands for daily uses than men as similar to this study. A study conducted (Rajsekhar et al., 2018b and Chakraborty et al., 2018) in a raparian wetland squeeze in the Tangon river basin, Barind region in India revealed that agricultural extension substitutes the shallow water in the wetland, whereby, seasonal wetland is disconnecting water discharge, and gradual

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disconnection with the ground water column are the essential reasons for growing wetland habitat quality. Inconsistent water supply, frequent drying up of wetland fringe areas, withstand against health of the wetland environment. In this study, the causes of declining water sources in the wetland were due to the expansion of land for agriculture and the construction of new houses. The study conducted by Wolters et al. (2006) revealed that the relationship between wetland areas and species richness is very complex and varies among different taxa. Also, the association between proportional wetland cover and species richness showed mixed results, indicating that other factors, such as habitat quality and connectivity, also play crucial roles in determining biodiversity levels (Wolters et al, 2006), also amphibian declined in wetland due to climate change was mentioned by Chapin et al, (2000), Desta et al (2012). In this study, the association and relationship between wetlands are not much different. Change in biodiversity is often due to anthropogenic interference and global changes, which can lead to habitat degradation that reduces biodiversity in freshwater wetlands, destroying habitat stability, highlighting the importance of conserving diverse biological communities to maintain ecosystem functions. Climate change currently affects at least 10,967 species on the IUCN Red List of Threatened Species Dugan (1990). Indirect effects of climate change on amphibian populations involve intermediary factors that ultimately lead to increased mortality. For instance, climate-induced alterations in temperature and precipitation patterns can modify habitats, disrupt breeding cycles, or facilitate the spread of diseases, all of which can adversely affect amphibian survival (Carey and Alexander 2003). In Nepal, a study by IUCN (1998) both ethnic groups stated that mammals, reptiles, amphibians, and resident and migratory birds had decreased. In addition, World biodiversity has declined alarmingly in half a century: more than 25,000 species, almost a third of those known, are in danger of disappearing. In this study, it was mentioned that the source of pollution to wetlands is due to pesticides, industrial oil, construction materials and sewage waste, which concurred with the study by Sharma and Ghose (1987). A study by Sun et al. (2015) on the analysis of the primary coastal wetlands across various provinces in China revealed significant declines in wetland areas prior to 2007. Notably, regions such as the Luan River estuary in Hebei, Binhai New Area in Tianjin, Laizhou Bay in Shandong, and Yancheng in Jiangsu experienced substantial reductions in their coastal wetland extents. Also, the study indicated that wetland fish in all sites are at risk of extinction compared with other living organisms. Developed a wetland conservation strategic plan in both languages (English and Kiswahili), encouraging stakeholders to support the implementation plan. and promote local participation in environmental management, community empowerment in local administration and planning for development were mentioned as some of the important interventions for wetland conservation. In the current study, and primary data reviewed show that there was no conservation policy, management and strategies for the wetlands of Zanzibar. In addition, there was no mapping report of the wetlands of Zanzibar. Therefore, the needs of mapping of wetland sites and policy development and management strategies should be considered by the authorities. The study by Benson et al (2022) revealed that wetland restoration is the best management approach for the Nyamuriro wetland of Uganda conservation and recommended that strict laws and procedures should be put in place to ease restrictions on wetland conservation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Wetlands are essential to the livelihoods of many families, providing resources for agriculture and domestic needs in Zanzibar. However, these ecosystems face significant threats, particularly from climate variability, the overuse of pesticides and habitat expansion, which leads to pollution and degradation. To address these challenges, it is crucial to implement comprehensive strategies that

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promote sustainable use and conservation of wetlands.

Key Recommendations:

- **Strengthen Legal Frameworks and Enforcement:**
- Develop and enforce robust environmental laws and regulations to prevent overexploitation and pollution of wetlands.
- Ensure that management plans are effectively implemented and monitored to protect wetland ecosystems.
- **Enhance Resource Mobilisation and Capacity Building:**
- Allocate sufficient resources and build institutional capacities to manage and protect wetlands effectively.
- Invest in training programs for stakeholders involved in wetland conservation and management.
- **Promote Education and Community Engagement:**
- Implement educational programs at all levels, starting from primary schools, to raise awareness about the importance of wetlands.
- Encourage active participation of local communities in conservation efforts through awareness campaigns and participatory management approaches.
- **Implement Monitoring and Evaluation Systems:**
- Establish regular monitoring and evaluation mechanisms to assess the effectiveness of wetland management practices.
- Use the findings to inform policy adjustments and improve conservation strategies.
- **Declare Wetlands as Conservation Areas:**
- Officially designate all wetlands as protected areas to ensure their preservation and sustainable use.
- Encourage collaboration among various sectors to support wetland conservation initiatives.
- **Disseminate Climate Information to Local Communities:**
- Enhance the accessibility of climate-related information through various channels such as radio, television, posters, and community meetings.
- Facilitate interactions between local communities and experts, including meteorological officers, agricultural extension workers, and conservationists, to improve preparedness for climate-related events like floods and droughts.

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Figure 12: Wetland Study Sites, Unguja Island

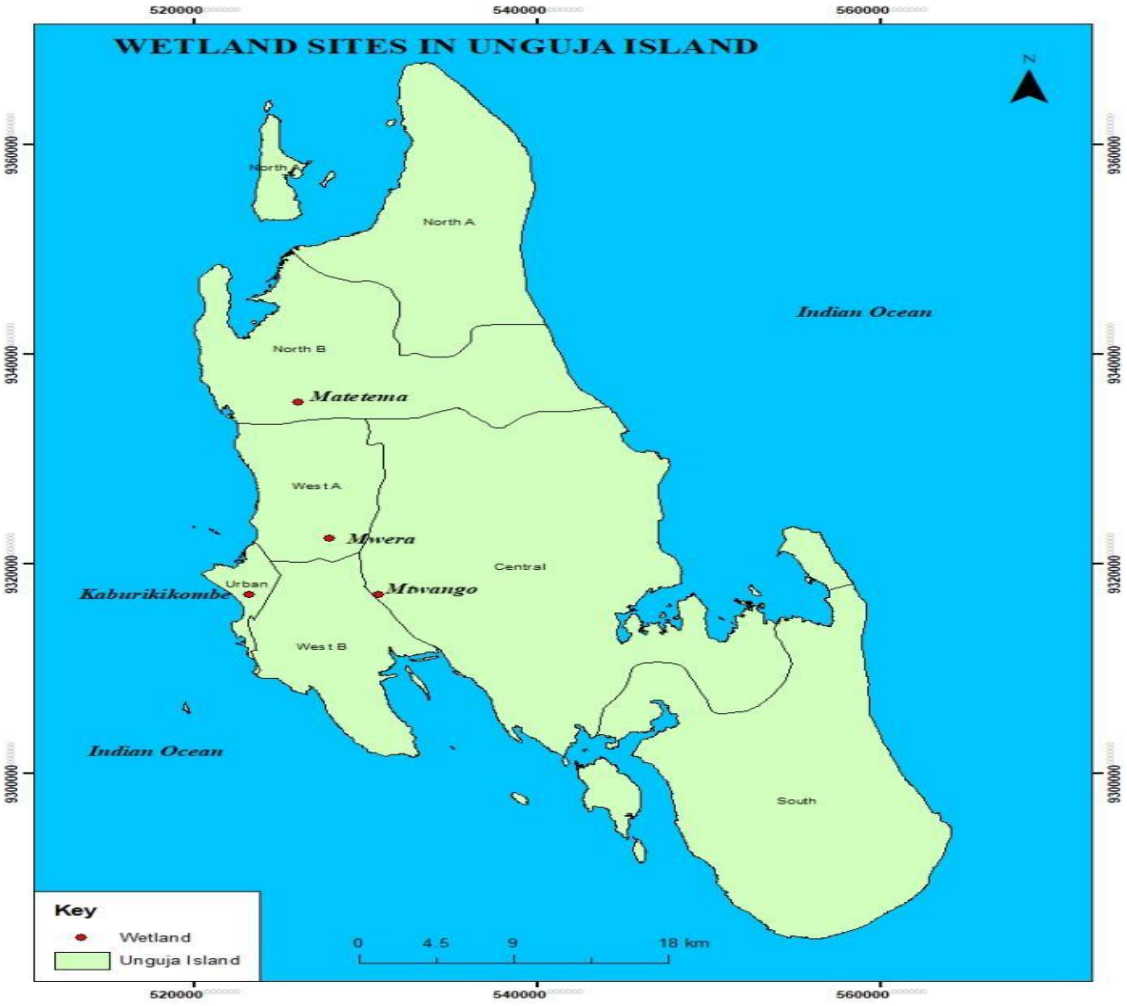

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Figure 13: Wetland Study Sites, Pemba Island

Plate 1: Used Packets of Pesticides (Pollution) in the Irrigation Channel

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Plate 2: Irrigation Channel Drain Wetland Water

Plate 3: Houses Construction (Invation) in the Wetland Site.