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Exploring the Influence of the Interaction of Climate Change, Manmade Threats and COVID-19 on the Livelihoods of Wetland Communities in Sub-Saharan Africa

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Abstract

Wetlands are very important because of the wide range of ecosystem services they provide. Despite their ecological, social and environmental importance, these ecosystems are threatened and fragmented under the combined effects of climate change (CC) and man-made activities (MMA). Such a state of things could be exacerbated by the advent of the coronavirus disease 2019 (COVID-19) pandemic with its many implications. In order to help decision-makers take good decisions, the combined effect of CC, MMA and COVID-19 on the livelihoods of communities around wetland ecosystems have been reviewed based on available scientific knowledge. First, we analyzed the different concepts and theories underlying the wetlands-related studies and then summarized the merits and demerits of the different methodologies underlying wetland studies. The empirical evidences that exist in previous literatures have been highlighted. Similarly, common livelihood strategies for wetland communities in Sub-Saharan Africa (SSA) have been highlighted. The diversity of wetlands' functions and services makes them a source of livelihood, food security and poverty alleviation for riverside communities. However, these communities lack the knowledge and awareness to understand the impact of their activities and CC on their livelihoods. The review also helped to identify that, out of the three factors investigated, the livelihoods of rural wetland dwellers in SSA are mostly influenced by CC and MMA. However, climate change and COVID-19 remain life-altering transboundary threats that extend in space and time, with large uncertainties on wetlands communities livelihoods.

Keywords: climate change, wetlands, mangroves, marshes, bogs, swamps, communities' livelihoods

1. Introduction

Wetlands are among aquatic ecosystems that are well known to purify water and recharge the aquifers from which springs flow (WWF, 2018). Wetlands, referred to as swamps or marshes, are among the most important ecosystems in the world. Wetlands like mangroves can serve as refuge for numerous coral species by reducing environmental stress in the context of global climate change (Stewart et al., 2021). In Sub-Saharan Africa (SSA), wetlands are not only an important source for biological productivity, but they are also a source of income-generating activities for communities (Schuyt, 2005). However, these ecosystems are suffering degradation and loss of biodiversity through conversion to agriculture, mining, deforestation, overhunting, overfishing, invasive species and climate change (CC). In Zambia for instance, the red-clawed crayfish (*Cherax quadricarinatus*) has spread in many wetlands ecosystems including the Barotse (Zambezi) Floodplains and Kafue flats. The red-clawed crayfish has resulted in increased fish post-harvest loss and destruction of fishing gear (MLNR, 2018). Similarly, the Mweru-Luapula system of Luapula province of Zambia has been invaded by the obscure snakehead (*Parachanna obscura*), a freshwater fish native to western central Africa. This predatory species of fish may compete with native species for food and habitat and is likely to expand its range with potential to permanently alter the balance of aquatic ecosystems throughout Mweru-Luapula if left uncontrolled (MLNR, 2018). On the Kafue Flats of Zambia, the invasive plant *Mimosa pigra* has spread and occupies significant proportions of the floodplains resulting in the displacement of animal species, blocking of water ways and reducing the availability of food for wildlife and domestic animals as well as impeding access to fishing grounds. The spread of *Mimosa pigra* has also negatively affected breeding grounds of water bird species of global conservation concern such as Wattled Cranes. Furthermore, the spread of invasive *Mimosa pigra* has occupied significant proportions of habitat for large herbivores such as the endemic Kafue lechwe (*Kobus leche kafuensis*) contributing to the rapid population decline of this endemic antelope species. Other invasive plants species include water hyacinth (*Eicchornia crassipes*), commonly referred to as Kafue weed, Kariba weed (*Salvinia molesta*) and Azzola (*Azzola pinata*). Water hyacinth, in particular, has affected the generation of power resulting in the expenditure of millions of US dollars (USD) by power utility companies in clearing the weed to prevent it from damaging their turbines. In Nigeria, the Niger Delta's ecosystem is estimated to have lost ecosystem services of up to USD 65 million in value between 1984 and 2011, due particularly to forest loss (Ayanlade & Proske, 2015). The loss of ecosystem services in Nigeria's wetlands has been exacerbated by the fact that majority of Nigeria's rural populations depend on wetlands for fishing, for resources collection and for agriculture; activities whose intensity has in most times resulted into degradation. These activities are also common in the Lower Kaduna-Middle Niger Floodplain where the intensive commercial cultivation of sugarcane and rice on the floodplains has led to the rainforest swamp degradation and desiccation as a result of declining rainfall. Similar occurrences have been reported in many others SSA countries (Adite et al., 2013; Azonningbo et al., 2018; Lalèyè et al., 2019; MLNR, 2018). In addition to human activities and population growth of both human and invasive species in the wetlands, climatic variations characterized by (i) rainfall deficits and (ii) reduction in the duration of the rainy season, exacerbate the fragility of these ever-decreasing ecosystems (FAO-LEA, 2018). Furthermore, the use of pesticides in arable wetlands also has a negative impact on both plant and animal species. Additionally, the global ocean has absorbed about 30% of the anthropogenic carbon dioxide (CO_2) emitted by industry and agriculture thereby causing ocean acidification (IPCC, 2015). Many wetland-dependent land and aquatic species are either extinct, endangered, threatened or vulnerable (Cook, 2004). These problems have led to the delimitation of protected areas, 9% of them are still arid, even though these protected areas contain many endemic species (UNEP-WCMC-IUCN, 2016).

In SSA, most wetland users lack the knowledge and information to make the link between the consequences of their activities (crop production and natural resource harvesting) and CC on their livelihoods (Wood et al., 2013). Similarly, decision-makers do not sufficiently understand the consequences of policy regimes on wetland functioning, ecosystem services and human well-being (Jogo & Hassan, 2010; Kangalawe & Liwenga, 2005). However, it has been suggested that where multiple wetland uses exist, a range of benefits can be sustained with little evidence of environmental degradation (Dixon & Wood, 2003). The wetland-dependent rural populations are predominantly characterized by poverty (Kabumbuli & Kiwazi, 2009). This state of poverty is exacerbated by CC, which increases their vulnerability in the context of rising populations. The vulnerability of wetland-dependent communities is expected to increase as a result of the coronavirus disease (COVID-19) pandemic that continues to affect the global economy. Restrictive measures relating to COVID-19 should therefore impact the livelihoods of these communities. These communities are already feeling the effects on (i) supplies, (ii) agricultural production, (iii) the conservation and processing of production, (iv) consumption and (v) the marketing of production (Amoussou et al., 2022). Furthermore, these wetland populations will have to adapt to diurnal temperature fluctuations, which have been reported to be related to the number of deaths related to COVID-19 (Ma et al., 2020).

Ensuring the environmental sustainability of wetlands in SSA through the sustainable use of biodiversity, the promotion of access to genetic resources, the fair and equitable sharing of benefits arising from biodiversity use, are important for food production and for the conservation of the ecological foundations on which rural livelihoods depend (IPBES, 2018). That is why, it is important to highlight what has already been done, the gaps and pitfalls in studies relating to the effects of CC, and COVID-19 on the livelihoods of wetland communities in order to generate valid evidence for decision-makers. Thus, the study aims to determine what influences the livelihood of wetland rural dwellers in SSA in a context of CC and/or COVID-19 and man-made activities (MMA).

2. Methodology and Conceptualization

We conducted a methodological review on the merits and demerits of the various methodologies underlying studies on wetlands. The elaboration of this review paper was adapted from the Preferred Reporting Items for Systematic

Reviews and Meta-Analyses (PRISMA) guidelines (Hutton et al., 2015; Moher et al., 2009a,b) and was done in four stages: (i) the description of literature sources, (ii) the articulation of search terms and detailed description of the research process, (iii) the description of inclusion and exclusion criteria, and (iv) the detailed analysis of the selected documentation. The identification of literature was made using the following three search engines: Google Scholar, ISI Web of Science and Scopus. We then identified publications that mentioned the key themes in the title, the abstract, the keywords and the main text. Only references in English were selected. The types of literature considered are peer-reviewed articles, and book chapters. The documents reviewed are those published between 1990 and 2020. For the identification of relevant literature, we combined the research themes "climat* chang*" OR "climat* COVID-19" OR "climat* communit*" OR "climat* inhabitant*" OR "climat* dweller*" with descriptions (or keywords) related to wetlands (Appendix A). For this review, wetlands are conceptualized as including only marshes, bogs, mangroves and/or swamps. Both inclusion and exclusion criteria were used for the selection of literature. The first inclusion criterion was the language in which the literature was written, which was English. In addition, the literature review focused on wetlands and addresses at least one of the wetland-related CC, COVID-19 pillars (conservation, protection, livelihood, adaptation, resilience, vulnerability, mitigation). The text reviewed included sufficient detail to extract information. The literature focused solely on aquatic ecosystems other than wetlands (e.g., fisheries, lakes, rivers, oceans). All data were recorded on the impact of CC, MMA and COVID-19. Data obtained from other continents were used for comparisons with data from SSA and this assisted in the formulation of appropriate recommendations.

3. Results and Discussion

The review was presented and discussed in four sections based on the different types of wetlands. Each wetland was presented on the basis of its characteristics, its importance for the livelihoods of communities as well as the climatic threats and MMA to which they are exposed. The effects of the interaction of anthropogenic climate change, MMA and COVID-19 on wetlands dwellers' livelihoods are presented, as well.

3.1 Climate Risks and MMA Threats to Wetlands

Wetlands refer to "areas where water is the primary factor controlling the environment and the associated plant and animal life" (Zedler & Kercher, 2005). The Ramsar convention of 1971, an international treaty which focused on the promotion of wetland conservation and wise use, defines wetlands as areas covered by natural or artificial, permanent or temporal still-water or running water, freshwater, salt-water, marshlands, peatlands, or water bodies including sea water less than 6 m depth under low tides (Gong et al., 2010). Wetlands are considered a resource because of their primary role of supplying products such as peat and performing valued ecosystem functions such a water purification, flood control, biodiversity conservation and carbon sequestration (Mitchell, 2013). These ecosystems play an important role in CC, because of their capacity to modulate atmospheric concentrations of greenhouse gases such as methane, carbon dioxide and nitrous oxide, which are dominant greenhouse gases contributing to about 60%, 20% and 6% of the global warming potential, respectively (IPCC, 2007).

Globally, nearly 124 million ha of wetlands in 1421 sites have been designated as wetlands of international importance (Zedler & Kercher, 2005). Of the 1421 global Ramsar sites, 190 sites are in SSA, representing 41.4% of the designated wetlands (Ramsar, 2020). Adding the non-Ramsar sites, larger wetlands in SSA cover an expanse of 2,072,775 km^2, 9.01% of the Landmass (Mitchell, 2013). However, in the past decades, wetlands are estimated to have been shrinking (Creed et al., 2017; Davidson, 2014; Gong et al., 2010; Zedler & Kercher, 2005), jeopardizing their ecosystem services provision (Moomaw et al., 2018). The 1971 Ramsar convention was a response to the global wetlands loss that the world is suffering (Creed et al., 2017; Davidson, 2014; Gong et al., 2010; Zedler & Kercher, 2005).

CC has been identified as one of the major threats to wetlands, especially of SSA, most of which lie in the semi-arid regions and this has been reported in scientific literature. For instance, Mitchell (2013) reviewed the major threats, including CC to the wetlands of SSA. He used a case studies approach to illustrate specific threats to the long-term sustainability of wetlands in Africa, and in each case, the wetland status, specific threats and the effect of CC were discussed. In his study, Mitchell (Mitchell, 2013) revealed that, CC would cause the arid or semi-arid regions of Africa in the latitudes around the Tropics of Capricorn and Cancer to become drier. This would in turn affect majority of Africa's poor who largely depend on ecosystem services for at least part of their livelihood. This is particularly so in the semi-arid Sahel in the North and equivalent latitudes in the South, which are seen as vulnerable to CC largely due to high levels of poverty and low adaptive capacity. As such, the effects of CC on wetlands can-not be separated from human activities occurring in and around wetlands.

In their study, Xi et al. (2020) assessed the future impacts of CC on inland Ramsar wetlands. They utilized hydrological models and soil moisture estimates to quantify CC-driven shifts in wetland areas across 1,250 inland

Ramsar sites. Xi et al. (2020) estimated that the net wetland global area expanded during the period 1980 to 2014, but 47% of the sites experienced wetland loss. They also projected a net area loss of at least 6,000 km^2 (about 1%) by 2100. Xi et al. (2020) also projected a 19 – 65% increase in sites with an area loss of 10% under low emissions, 148-243% under high emissions and 16% with global mean warming of 2°C relative to 1.5°C, making CC mitigation essential for future Ramsar wetlands conservation.

Wasswa et al. (2018) assessed the temporal loss of wetlands to development projects (DPs) in the Kampala–Mukono Corridor (KMC) in Uganda. Field data, historical data and four sets of satellite images from 1997 to 2013 were used to assess changes in the spatial extent of wetland land cover types. Wetland cover types were defined through unofficial classification while potential wetland losses to DPs were projected through the IDRISI Selva-based Markov Chain model. Since 1974, the KMC wetlands had reduced by 47% with 56% of the total loss from the DPs. They further identified the preference for Kampala as an industrial zone and inadequate development planning as the main factors driving wetland losses. Future projections by 2040 have indicated that 61% of the gross KMC wetland loss (42.7%) will amass to more DPs.

Orimoloye et al. (2019) used four satellite images to map wetland dynamics in Isimangaliso Wetland Park, South Africa. They reported that competition for water, intensification of agricultural practices and rapid urbanization in South Africa are at the fore front of the destruction of natural wetlands and their biodiversity benefits. Nwankwoala (2012) examined the fate of wetlands in the face of CC and recommended that efforts should be made to accurately document the country's wetland. Their paper therefore suggested sustainable options for wetlands and water resources management in Nigeria. They opined that strengthening of wetlands preservation and conservation regulations, mitigating the effects of CC as well as the development of deliberate restoration programmes and policies can be aimed at sustaining degraded wetlands in Nigeria.

The Niger Delta wetland ecosystem is of high economic importance to the local dwellers and the nation in general. This is because the region is rich in both aquatic and terrestrial biodiversity, serves as a main source of livelihood for rural dwellers and help in stabilizing the ecosystem. Tremendous changes have occurred recently in the Niger Delta wetlands due to anthropogenic activities, thus raising awareness on the need for effective monitoring, protection and conservation of the wetland ecosystem. A good knowledge of the services provided by wetland ecosystems is an important key for an effective ecosystem management. Their review showed that the region is rich in biodiversity of high economic importance to national development, and has been under severe threat from human activities, especially pollution. Eze et al. (2016) recommended that effective monitoring be employed using modern techniques such as GIS and remote sensing in the conservation and management of this important ecosystem.

3.2 Climate Risks and MMA Threats to Mangroves

Mangroves are among the most well described and widely studied wetland communities in the world (Krauss et al., 2014). Mangroves are tropical and sub-tropical woody trees or shrubs that occur naturally in brackish waters or estuarine wetlands in intertidal zone, most often, at the confluence of land and sea, and have been heavily used traditionally for food, timber, fuel and medicine (Alongi, 2002; Tomlinson, 1986). There are 9 orders, 20 families, 27 genera and roughly 70 species of mangroves occupying a total estimated area of 181,000 km^2 (Spalding et al., 1997). The most commonly encountered genera are *Rhizophora* (Rhizophoraceae), *Avicennia* (Avicenniaceae), *Bruguiera* (Rhizophoraceae), *Sonneratia* (Sonneratiaceae), and *Pelliciera* (Tetrameristaceae) (Duke et al., 1998; Ellison et al., 1999; Tomlinson, 1986).

Global CC is one of the greatest challenges that humans will face in this century. Although geological records show climatic changes throughout history, the present rate of global warming threatens the survival of entire ecosystems. Among the most at-risk ecosystems are mangroves, which are especially vulnerable to sea-level rise and then to salinity (Amoussou et al., 2021). According to Valiela et al. (2001), the decline of mangroves per year on a world scale is slightly higher than that of tropical forests (2.07% vs 1.25%). This was further itinerated by Duke et al. (2007) who stated that there is a likelihood that the world would be without mangroves within 100 years.

Factors influencing the structure and function of mangrove forests vary in relation to global, regional and local scales over different time scales (Duke et al., 1998). At the global scale, mangroves are ultimately limited by temperature, but at the regional scale the area and biomass of mangrove forests vary in relation to rainfall, tides, waves and rivers. Various schemes have been developed to classify mangroves on local scales (Twilley, 1998). The utilization of mangrove resources by humans also can have negative feedback effects on the ecological processes of mangrove ecosystems (Twilley et al., 1998). These feedbacks can have indirect impacts such as diversion of freshwater, which can cause changes in the productivity, litter export, and biogeochemistry of mangrove wetlands, among other processes. Other human impacts on mangrove wetlands can be more direct such as the introduction of contaminants that can disrupt the natural ecological processes of these forested wetlands. Deterioration of water quality includes inputs of excessive nutriments to coastal waters (eutrophication) and toxic materials (heavy metals, oil spills, and pesticides) (Twilley, 1998). Agriculture impacts on mangrove wetlands are most noted in West Africa and parts of Indonesia (Ponnamperuma, 1984).

Almost one fifth of the world's mangroves are found in SSA, and 70% of these are found in 19 countries of West Africa (UNEP, 2007). From the 70 species of true mangrove recorded (Spalding et al., 1997), 17 species exist in 26 countries of SSA. African mangroves are widespread along the West coast from Senegal to the Congo, and occur locally in East Africa, interlinked with highly productive coastal lagoons, tidal estuaries and deltas. They provide these areas with essential organic nutrients as well as critical breeding grounds and nurseries for larval and juvenile stages of important fisheries species (Shumway, 1999). Global data on mangroves report that 19% of mangrove habitat is currently contained within designated protected areas (Chape et al., 2005).

In Senegal, Sakho et al. (2011) went back 60 years in their description of the evolution of mangrove vegetation in the Somone estuary, where the mangrove area decreased from 1.5 km^2 between 1940 and 1950 to 0.1 km^2 between 1970 and 1990, and then steadily increased to 1 km^2 between 2000 and 2010. A similar pattern was observed in the nearby large estuaries, the Sine-Saloum, the Gambia and the Casamance. The flow of these estuaries varies seasonally due to the short raining season. Thus, the water salinity is more or less stable in the mouth of the estuaries, but further upstream, the salinity increases during the dry season (i.e., from november to may) due to evaporation (Bertrand, 1999; Savenije & Pagès, 1992). During the great drought of the 1980s, the upper reaches of the estuaries became even hypersaline, causing a mass mortality of mangrove-inhabiting species (Diop et al., 1997; Marius, 1995).

In Kenya, clearing of mangrove areas for uses such as aquaculture, salt manufacture, fuelwood, oil pollution, agriculture and housing, etc. has resulted in the loss of 10,310 ha, representing about 20% of the total mangrove forest in the country's coastal region (Abuodha & Kairo, 2001). Areas particularly affected include Ngomeni, Karawa, Lamu, Gazi Bay, Makupa Creek, and Mombasa.

3.3 Climate Risks and MMA Threats to Marshes

Marshes commonly refer to a landscape formation where the ground is covered, permanently or intermittently, by a layer of stagnant water, usually shallow and covered with vegetation. Marshes are formed in areas of low relief, poorly drained by the water system, with impermeable subsoil, either near rivers or the sea. The water in a marsh may be fresh, stagnant, or more or less salty. Coastal marshes may be associated with estuaries or coastal lagoons (Adams, 2020; Townend et al., 2011). Plant species adapted to the wetland environment are distributed depending on the height of the water, the extent of the drying periods and the level of salinity. Among the dominant species are poaceae, typhaceae, juncaceae and cyperaceae. In addition, marshes are home to important wildlife: fish and amphibians breeds that feed on the millions of insects that emerge from the shallow waters. Out of the water, these insects also serve as a food source for birds and bats up to several kilometers away from the area, thereby playing a vital role in the local wildlife. The water can be fresh, brackish or salty, hence determining the type of vegetation. The marshes are home to an important and original biodiversity. In addition to being a place where remarkable flora and fauna live, they play an important role in hydraulic regulation and water purification through decantation and oxygenation.

Depending on their location inland or on the maritime edge, marshes can be continental or coastal. Continental marshes constitute a group of very varied freshwater environments and are characterized by their great biological richness. In addition, they constitute the fringe or relics of lakes and are destined to disappear through a long process of natural filling. They therefore play a major role in maintaining natural balances and biodiversity. They can also be converted to agriculture after drainage (Rejmánková et al., 2004; Simioni et al., 2020). On the other hand, coastal marshes are generally land reclaimed from the sea and their permanence is linked to the stability of the sea level. However, global warming and rising sea levels are likely to change this fragile balance. These marshes are most often bordered on the seaward side by mudflats. They are the result of the filling in of mudflats in coastal bays by the flocculation of clay in suspension in the river water. They extend over the entire tidal range, between low and high spring tides (Kneib, 1998; MacDonald et al., 2010; Odum, 2002). They are ideal feeding and resting places for fauna, especially birds. Furthermore, depending on their physical and hydrological characteristics, there are different types of marshes. Firstly, there are wet marshes, which are floodable marshes that serve as flood expansion zones in winter and constitute water reserves that can be restored in the summer. Secondly, there are dried out marshes, which are marshes isolated from the influence of river flooding by diking (polder). When a marsh has been completely drained for breeding, cultivation or construction, it gives way to what is called a polder. Thirdly, there are intermediate marshes, which are equipped with drainage structures such as dykes or pumps.

3.4 Climate Risks and MMA Threats to Swamps

Swamps are areas of wetland with a shrub cover over part of their surface. These ecosystems are either permanent or seasonal (Taylor et al., 1995). Swamp ecosystems are generally found in the coastal plains (Blivi et al., 2002), the ecological corridors and valley floors (Hilty et al., 2020), the river deltas (OECD/SWAC, 2020), the coastal lagoons (Teka et al., 2012), the valley bottoms (Dossou & Gléhouenou-Dossou, 2007), the channels (Zeff, 2011), and the nearby hydroelectric dams (Adite et al., 2013). Swampy meadows are most often characterized by species such as *Cyperus laevigatus*, *Typha angustifolia*, *Salicornia* sp., *Phragmites* sp., *Cyperus papyrus*, *Syzygium owariense*, *Xylopia rubescens*, *Phoenix reclinata*, *Kobus megaceros*, *Atilax* sp., *Cyrilla racemiflora* (Brooks et al., 2019), many crustaceans and many fish species including the Nile perch and Tilapia (Schuyt, 2005). In addition, swampy areas have an animal community including frogs whose croaking serves as a native indicator of weather and climate, specifically as onset of rains (Mafongoya & Ajayi, 2017). The distribution of swampy ecosystems across SSA covers approximately 179,843 km^2 (Rebelo et al., 2010). In particular, SSA countries possessing mangrove-inhabiting swamps include, among others, Benin, Cameroon, Gabon, Gambia, Ghana, Guinea Bissau, Liberia, Mauritania, Nigeria, Sierra Leone, Togo, and Mozambique (Lacerda, 1993; Taylor et al., 1995; UNEP, 2007).

Swamps have many functions including groundwater discharge, flood control/regulation, sediment/toxicant retention, nutrient retention, and anaerobic digestion (Dugan, 1990; Singh, 2017). In these ecosystems, anaerobic digestion is the biological decomposition of biomass under oxygen-free conditions (Singh, 2017). The decrease in oxygen content of swamps most often attributed to logging debris and algal biomass resulting from biochemical oxygen demand loads (Ensign & Mallin, 2001). For the algal biomass, the factors governing their presence are mainly those of the microclimate in the swamps (Thatoi et al., 2013).

The swamp dweller communities heavily depend on the adjoining swamp resources. They are engaged in artisanal livelihood activities to cope with natural resource fluctuations on seasonal and interannual scales (FAO, 2018). The swamps provide many livelihood activities including food production (e.g., cultivation of swamps for rice (rice paddies), cranberries, fish, salmon) (Nwankwoala, 2012), ecosystem functions (e.g., providing water, food and building materials) (van Dam et al., 2014), agricultural drainage (e.g., agricultural water drainage) (Dixon & Wood, 2003), shellfish aquaculture (e.g., shrimp aquaculture) (Pantanella et al., 2012), water extraction (e.g., water extraction for drinking, cooking and washing) (Schuyt, 2005), ecosystem services and human well-being (e.g., economic well-being and ecological security) (Jogo & Hassan, 2010). Many swamp ecosystems are currently undergoing very uncertain changes, ecologically and socio-economically, as they are overexploited by farmers. In the same way, many local farmers face the challenge of knowing and using crops adapted to swampy areas (Giertz et al., 2012). Hence, the implementation of innovative large-scale rehabilitation initiatives should allow a good proportion of these ecosystems to be recovered. It has also been suggested local actions for conserving and rehabilitating water resources (Martins et al., 2020). These initiatives should include proper management and conservation measures.

3.5 Combined Effects of MMA, CC and COVID-19 on Livelihoods

The functions and services around wetlands are summarized in Figure 1. In SSA, wetlands have many function as they (i) provide groundwater discharge, (ii) control and regulate floods, (iii) provide retention of sediment, toxicant, nutrients, (iv) ensure anaerobic digestion, (v) provide water purification, (vi) provide biodiversity conservation, and (vii) contribute to carbon sequestration (Dugan, 1990; Gong et al., 2010; Singh, 2017). The variety of functions of wetlands makes them a source of livelihood for the people living alongside them. They offer various services including agricultural drainage, aquaculture, firewood, medicinal plants, etc. (Dixon & Wood, 2003; Jogo & Hassan, 2010; Nwankwoala, 2012; Pantanella et al., 2012; Schuyt, 2005; van Dam et al., 2014). Thus, wetlands provide vital resources for food security and poverty alleviation for riparian communities (Figure 1). However, these ecosystem assets remain under threat nowadays.

SSA wetlands' biodiversity is vulnerable to many problems with different causes, effects, consequences and impacts. The major problems identified were overexploitation, sand-mining, water pollution, and climate change. There is an interchangeable relationship between the above-mentioned problems (Figure 2). Indeed, the poor organization of the fisheries sector was observed to foster MMA with an increase in human density and pressure. It was noted that currently, the number of fishers operating on the waterways continues to increase day by day without any real plan to renew the resource. These local fishers are using fishing gears that are not well developed or recommended for such ecosystems. Commonly used fishing gears with reduced mesh size. Additionally, the major mangrove-dependent plant species (e.g., *Rizophora racemosa* and *Avicennia africana*) are being intensively degraded for domestic use: firewood (i.e., household use, salt production, bakeries and potteries) and house building. Some fish and plant species are in way of disappearance while some are almost extinct. The aquatic environment was observed to also be affected, directly or indirectly, by the deleterious effects of the pollutants that alter the physical and chemical quality of waters as well as the demographic expansion of aquatic communities and as earlier mentioned, by the increase of human activities. Pollution problems in the aquatic environment include both anthropogenic and tidal types. It was observed that adjacent wetlands are intensively utilized to grow legumes, onions, carrots, red papers, tomatoes, cotton, etc.. This favours the discharge of polluting substances (i.e., agricultural pesticides and fertilizers) into the aquatic environment. The daily dumping of huge domestic wastes has also lead to organic or anthropogenic pollution. Some rivers' hydro-electrical dams represent a major source of degradation that affects the flooding regime and the hydrology of wetlands as well as the aquatic living resources. All this has the consequence of anthropogenic saline intrusion into the aquatic environment. The concentrations in heavy metals (e.g., copper, chloride and zinc, etc.), polycyclic aromatic hydrocarbons, bisphenol A, and phthalates are of high risk to the aquatic organisms since they contribute to high tides. Apart from human activities, the hydrological dynamics of the surrounding oceans also helps explain the fluctuation of salinity in the wetlands' waters. In addition to these threats, global climate change is causing modifications in water flow in the SSA region through the greater frequency of floods, monsoon precipitations by increasing the rise in sea level. This is associated with both a rise in lakes and rivers' level and increased their water salinity. Overall, CC can affect wetlands by direct and indirect effects of rising temperature, changes in rainfall intensity and frequency, extreme climatic events such as drought, flooding and the frequency of storms. Altered hydrology and rising temperature can change the biogeochemistry and function of the wetland to the degree that some important services might be turned into disservices. This means that they will no longer provide a water purification service and adversely they may start to decompose and release nutrients to the surface water causing problems such as eutrophication, acidification and brownification in the water bodies (Corman et al., 2018; Roulet & Moore, 2006; Stets & Cotner, 2008). This state of things also increase the social vulnerability of wetlands dwellers through poverty, malnutrition, and disease (IPCC, 2021). According to Salimi et al., (2021), drought is the most deleterious climate phenomenon, which might considerably damage the wetland ecosystem especially for peat-lands. This may trigger a shift from the dominant plants, *Sphagnum mosses*, to the more drought-tolerant vascular plants. Therefore, studying the succession of vegetation in peatlands before any management action would be recommended. The management strategy should protect *Sphagnum mosses*, which have a low decay rate, maintain the optimal water level to avoid peat decomposition and promote the rate of photosynthesis. Furthermore, CC and COVID-19 have some shared characteristics. Both are life-altering transboundary threats that extend in space and time. With their large uncertainties, both crises underscore the increasing, complex, and close interconnections among food, water, health, energy, and infrastructure systems. They further increase the already-vulnerable and marginalized communities Ebi et al. (2021) like those living around wetlands.

Societal adaptation has the potential to decrease global climate risk substantially, but cannot fully prevent residual risks from increasing Magnan et al. (2021). In addition, poverty decreases CC literacy across the global South Simpson et al. (2021), and CC literacy rates among wetland communities might need to be improved in order to hope for a reversal of at least CC's anthropogenic causes. However, in the rural world, the preconditions for designing strategies with greater transformative potential must include land titling, access to markets and credit, climate information, and ecosystem conservation zonings and guidelines Milhorance et al. (2021). As for the resource's overexploitation, the setting of fishing months seems, for the time being, the best approach to overcome the overexploitation of fisheries resources in the wetlands. This is the case in South Sudan where the best fishing months are August, September and May in the Sudd wetlands (Benansio et al., 2021). This step was preceded by the determination of periods of peak catches as well as peak reproduction periods (Hickley & Bailey, 1986) in the Sudd wetlands. In the aquaculture sector, the effects of anthropogenic stressors and the COVID-19 pandemic are very much inter-related (Sarà et al., 2021). The adoption of Integrated MultiTrophic Aquaculture (IMTA) might enhance resilience of wetlands' riparian communities to these stressors.

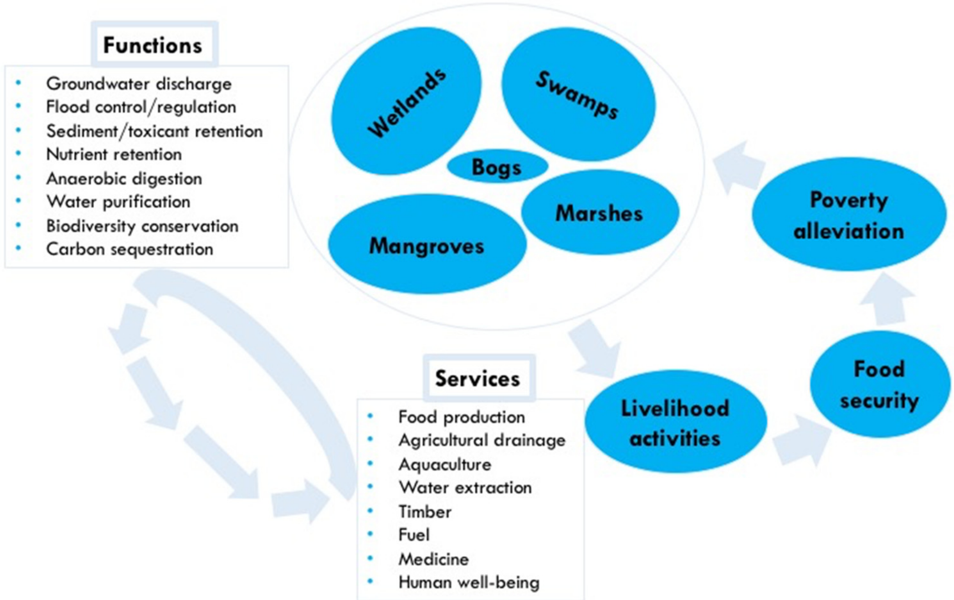

Figure 1. Shared functions of diverse wetland types together with the different types of ecosystem services they provide for the well-being of riverine communities in Sub-Saharan Africa (SSA)

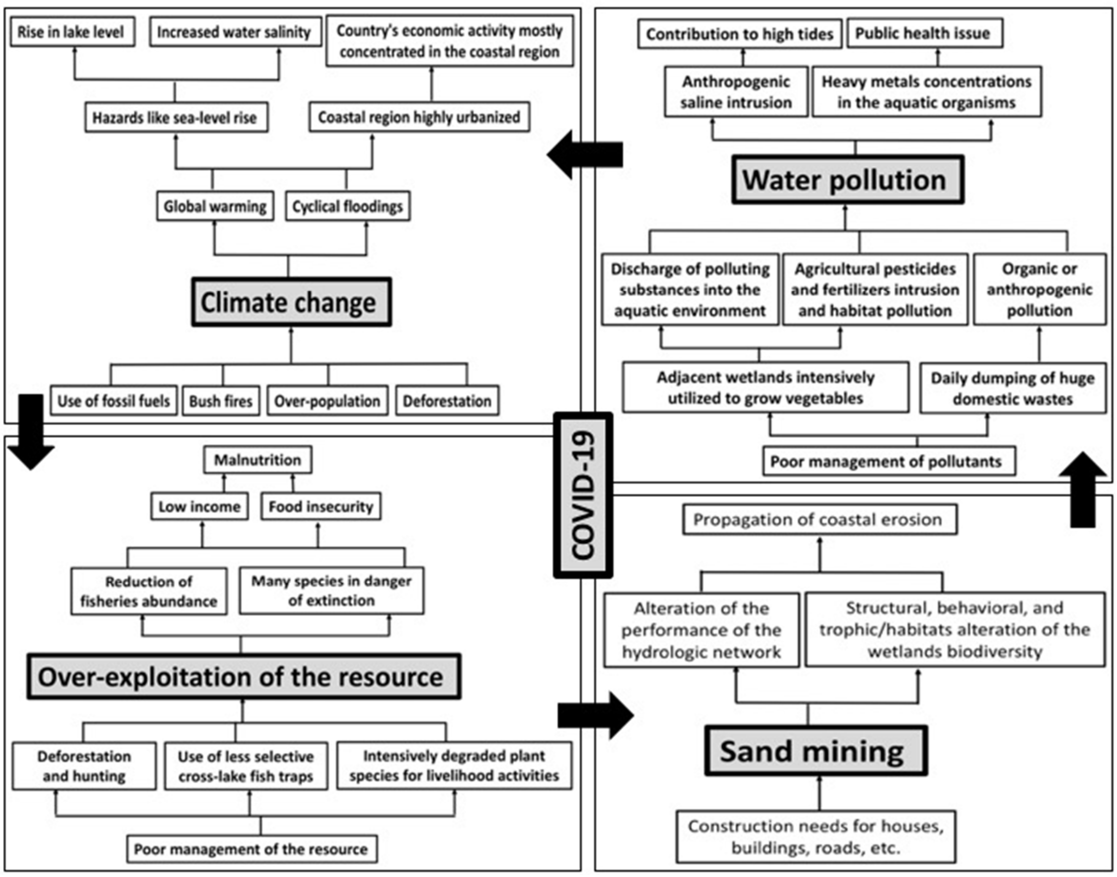

Figure 2. Analysis of the problems around wetlands in the face of climate change (CC), coronavirus disease 2019 (COVID-19) and man-made activities (MMA): water pollution, resource's overexploitation, and sand mining

4. Conclusions

This paper explored the influence of the interaction of CC, MMA and COVID-19 on the livelihoods of wetland communities in Sub-Saharan Africa. Over the years, there has been a steady decline in wetland ecosystems and services in SSA thereby leading to a high level of vulnerability. The vulnerability of wetland communities is multidimensional thus making their livelihoods significantly affected. The main causes of this vulnerability stem from their economic dependence on the ecosystem and its services. They are generally fishermen, farmers, salt producers or live from tourism. Often, most are generally fishers, farmers, salt producers or highly dependent on tourism. In most cases, these communities are ill prepared to face climatic disasters which affect their environment. Indeed, they lack means and in general, they do not have government supervision and are poorly informed on certain scientific subjects. Furthermore, these communities likely endure the disasters associated with the current COVID-19. This vulnerability has the consequence of increasing poverty, malnutrition, unemployment and famine in these communities and these sometimes pushes them to migrate to other horizons. This is often the case in the events of droughts, floods, the disappearance of aquatic species and other effects of CC which tend to push wetland residents to move in order to survive. Loss of livelihood could also expose their children and other dependents to malnutrition and even more, families could separate, thus generating other societal plagues such as delinquency, violence and high rates of crimes. Based on the findings from this review, it is recommended that effective governance efforts from various national Governments and Non-Governmental Organizations be geared towards the recovery or the rehabilitation of wetland areas, as this will greatly restore and improve ecosystems services and improve the livelihood of wetland dependent households.

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Appendix A

Definition of the Boolean search terms used to track the relevant literature

Focus	Boolean Search Term
Wetland	wetland* OR "wetland* environn*" OR "wetland* system*" OR "wetland* communit*" OR "wetland* inhabitant*" OR "wetland* dweller*" OR "wetland* livelihood*" OR "wetland* climat*" OR "wetland* chang*" OR "wetland* covid-19" OR "wetland* manag*" OR "wetland* water*" OR "wetland* conservation" OR "wetland* greenhouse gas" OR "wetland* climate change" OR "wetland* global warming" OR "wetland* climate variability" OR "wetland* climate warming" OR "wetland* adapt*" OR "wetland* resilien*" OR "wetland* risk manag*" OR "wetland* risk reduc*" OR "wetland* maladapt*" OR "wetland* adaptive capacity*" OR "wetland* gender*" OR "wetland* wom*" OR "wetland* matern*" OR "wetland* intersectional*" OR "wetland* sub-sahara*"
Mangrove	mangrov* OR "mangrov* environn*" OR "mangrov* system*" OR "mangrov* communit*" OR "mangrov* inhabitant*" OR "mangrov* dweller*" OR "mangrov* livelihood*" OR "mangrov* climat*" OR "mangrov* chang*" OR "mangrov* covid-19" OR "mangrov* manag*" OR "mangrov* water*" OR "mangrov* conservation*" OR "mangrov* greenhouse gas" OR "mangrov* climate change" OR "mangrov* global warming" OR "mangrov* climate variability" OR "mangrov* climate warming" OR "mangrov* adapt*" OR "mangrov* resilien*" OR "mangrov* risk manag*" OR "mangrov* risk reduc*" OR "mangrov* maladapt*" OR "mangrov* adaptive capacity*" OR "mangrov* gender*" OR "mangrov* wom*" OR "mangrov* matern*" OR "mangrov* intersectional*" OR "mangrov* sub-sahara*"
Swamp	swamp* OR "swamp* environn*" OR "swamp* system*" OR "swamp* communit*" OR "swamp* inhabitant*" OR "swamp* dweller*" OR "swamp* livelihood*" OR "swamp* climat*" OR OR "swamp* chang*" OR "swamp* covid-19" OR "swamp* manag*" OR "swamp* water*" OR "swamp* conservation*" OR "swamp* greenhouse gas" OR "swamp* climate change" OR "swamp* global warming" OR "swamp* climate variability" OR "swamp* climate warming" OR "swamp* adapt*" OR "swamp* resilien*" OR "swamp* risk manag*" OR "swamp* risk reduc*" OR "swamp* maladapt*" OR "swamp* adaptive capacity*" OR "swamp* gender*" OR "swamp* wom*" OR "swamp* matern*" OR "swamp* intersectional*" OR "swamp* sub-sahara*"
Marshe	marshe* OR "marshe* environn*" OR "marshe* system*" OR "marshe* communit*" OR "marshe* inhabitant*" OR "marshe* dweller*" OR "marshe* livelihood*" OR "marshe* climat*" OR OR "marshe* chang*" OR "marshe* covid-19" OR "marshe* manag*" OR "marshe* water*" OR "marshe* conservation*" OR "marshe* greenhouse gas" OR "marshe* climate change" OR "marshe* global warming" OR "marshe* climate variability" OR "marshe* climate warming" OR "marshe* adapt*" OR "marshe* resilien*" OR "marshe* risk manag*" OR "marshe* risk reduc*" OR "marshe* maladapt*" OR "marshe* adaptive capacity*" OR "marshe* gender*" OR "marshe* wom*" OR "marshe* matern*" OR "marshe* intersectional*" OR "marshe* sub-sahara*"
Bog	bog* OR "bog* environn*" OR "bog* system*" OR "bog* communit*" OR "bog* inhabitant*" OR "bog* dweller*" OR "bog* livelihood*" OR "bog* climat*" OR OR "bog* chang*" OR "bog* covid-19" OR "bog* manag*" OR "bog* water*" OR "bog* conservation*" OR "bog* greenhouse gas" OR "bog* climate change" OR "bog* global warming" OR "bog* climate variability" OR "bog* climate warming" OR "bog* adapt*" OR "bog* resilien*" OR "bog* risk manag*" OR "bog* risk reduc*" OR "bog* maladapt*" OR "bog* adaptive capacity*" OR "bog* gender*" OR "bog* wom*" OR "bog* matern*" OR "bog* intersectional*" OR "bog* sub-sahara*"