African Lake Basin Management: Key Issues and Challenges

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1. Introduction

1.1. The evolution of the water sector in Africa

Over the last 20 years, there has been active national, regional and transboundary water sector reforms continent-wide. The 2025 Africa Water Vision of the African Ministerial Council on Water (AMCOW) is to realize equitable and sustainable use and management of water resources to promote cooperation, security, social and economic development, and poverty eradication among member states. In order to provide political leadership, policy direction and advocacy, various regional bodies (AU, EAC, ECCAS, IGAD, AfDB, COMESA[1]) have been involved in providing the guiding framework for national and transboundary resource development and management. Within the continent, the role of the national water ministries is to provide guidance and formulate policies for the management of water resources and provision of water services; they tend to incorporate into policy reforms elements of relevant regional, continental (AU Agenda 2063) and global agenda (such as the Sustainable Development Goals - SDGs), with variable emphasis depending on country or regional needs. For example, the AU Agenda 2063 goal 7, which calls for "environmentally sustainable and climate resilient economies and communities" in three priority areas (1) biodiversity, conservation and sustainable natural resource management, (2) water security, and (3) climate resilience and natural disaster preparedness, links up with four SDGs, namely; SDG 6 - ensure availability and sustainable management of water and sanitation for all, SDG 7 - ensure access to affordable, reliable, sustainable and modern energy for all, SDG 13 - take urgent action to combat climate change and its impacts, and SDG 15 - protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Thus, in addition to the national water agendas, the regional, continental and global agendas are also very important for policies and management targeted at lakes and their basins, and particularly so for transboundary lakes.

1.2. Continental strategies for water security

The Africa Water Facility was established under AMCOW to mobilize resources to finance water resources development activities in Africa. Its vision is "a water secure Africa where the continent's water resources are developed and managed equitably and sustainably for poverty alleviation, socio-economic development, regional cooperation, environment protection and climate change resilience". It realigned its strategy 2017 – 2025 to ensure water security in Africa contributes to meeting goals and targets established by the Africa Water Vision, the AU Agenda 2063 and the SDGs. The Science, Technology and Innovation

[1] AU – African Union; EAC – East African Community; ECCAS - Economic Community of Central African States; IGAD - Intergovernmental Authority on Development (IGAD) in Eastern Africa; AfDB – African Development Bank; COMESA - Common Market for Eastern and Southern Africa.

Strategy for Africa 2024 is another very important document. It is "the first of the ten-year incremental phasing strategies to respond to the demand for science, technology and innovation to impact across critical sectors such as water, agriculture, energy, environment, and health, among others". It notes that water is essential and has a cross-cutting contribution across the strategy's six priority areas, and that it is important to set up flagship programmes to address issues related to water availability, quality, river regimes, water cycles and water resources in different regions of the continent.

2. Lake basins and their importance

2.1. Africa's lakes

Africa is endowed with both natural (e.g. L. Nakuru, L. Tana) and man-made (e.g. L. Nasser, L. Kariba) lakes (Figure 1). The precise number of lakes is unknown; however, according to UNEP (2006) the total number of lakes in the WORLDLAKE database for the continent is 677. These lakes fall either within national or transboundary jurisdictions; those that fall in the latter category include Lakes Victoria, Tanganyika and Turkana. The largest and best-known lakes are those in the eastern and southern Africa region, such as Lakes Victoria, Tanganyika, Malawi/Nyasa and Turkana, and are collectively termed the "African Great Lakes". Lake Volta is the largest man-made lake in west Africa, while Lake Kariba is the largest in southern Africa and Lake Nasser, which sits astride the River Nile, is the largest in northern Africa. Importantly, the lakes harbour a diverse range of biodiversity and endemism, and while there are some commonalities particularly with regard to aquatic plant types, many of the lakes have aquatic vertebrate and invertebrate species and species associations that are unique to them as a consequence of their geological history, climatic and geomorphological setting, hydrological sensitivity to natural and anthropogenic factors, and *in-situ* physical and chemical lake characteristics.

Figure 1. Distribution of Africa's major lakes (UNEP 2006)

2.2. The importance of Africa's lakes

The lakes and their associated rivers and wetlands in the African continent are unique natural resources that are heavily utilized for transportation, water supply, fisheries, waste disposal, recreation and tourism, among other uses/services. The density of human populations along the lakeshores and within their catchments tend to be higher than in areas which lack lakes. More generally, the human populations are fast increasing in many of Africa's lake basins, and they exert increasingly rising pressures on the lakes as they exploit their ecosystem goods and services. Consequently, over the past couple of decades, a variety of inter-linked human activities in the lakes and their catchments have led to in-lake problems such as sedimentation, eutrophication, overfishing, species introductions, and industrial pollution. Global warming and climate change pose the latest threat to the natural state and function of the lakes as we have known them through human history. All these problems and threats have implications on the human livelihoods, lake ecosystem goods and services, lake health and aquatic biodiversity. There have been numerous studies published on almost all the known

African lakes and their catchments; these and ongoing research provide the context and evidence-base for their effective and sustainable management.

3. The implications of the geological context of lake basins

3.1 The present climatic and hydrological context

On the African continent, rainfall amounts to about 20,360 km^3/yr, with an average of 678 mm/yr, and is highly variable in space and time (FAO, 2016), and evaporation is generally high. Consequently, much of the continent experiences extreme hydrological variability. Its renewable water resource, distributed among lakes and reservoirs, rivers, glaciers, and groundwater, is estimated at 3,930 km^3/yr, and is also recognized to be highly variable in time and space (FAO, 2016).

3.2 The geological context

As noted above, most of the large lakes in Africa, and numerous small lakes, occur within the confines of the East African Rift System (EARS). The larger rift lakes such as Tanganyika, Albert, and Malawi/Nyasa (which started forming between 12 and 8 million years ago), with the exception of Lake Victoria, and some smaller lakes such as Naivasha and Nakuru, occur on the floor of the rift. There are other much smaller lakes that form within volcanic craters either on the floor of the rift or on volcanic mountains that flank the rift system to the east and west. Similar types of crater lakes are seen also in west Africa (e.g. Lake Barombi Mbo in Cameroon). Lake Bosumtwi in Ghana is a unique impact crater lake that was formed about one million years ago and is the only natural lake in that country. The larger rift lakes such as Tanganyika, Albert, and Malawi/Nyasa started forming between 12 and 8 million years ago (Tiercelin et al., 2002). The present-day lakes Baringo, Nakuru, Elementaita and Naivasha, for example, are the remnants formerly much larger lakes that developed during the Lower-Middle Pleistocene times (ca. <780,000 yr ago) (Tiercelin et al., 2002; Woldegabriel et al., 2016). Lake Victoria, on the other hand, formed by uplift along western branch of EARS in late Pleistocene (ca. 400,000 yr ago), and back-ponding of rivers that previously drained westwards (Johnson et al., 2000).

3.3 Climate-sensitive "amplifier" lakes

Studies of the African lakes over geological timescales have been undertaken, and they show that the lakes are highly sensitive to climatic changes, particularly in rainfall and temperature. The term "amplifier lake" was introduced by Street (1980) and Street-Perrott and Harrison (1985), and further elaborated upon by Olaka et al. (2010)[2] and Trauth et al. (2010). Thus, apparently small changes in precipitation if persistent, can result in large hydrological responses – such abrupt changes can result in climate surprises that would have adverse impacts on the lakes themselves, environment and human civilisation (Alverson et al., 2003; Olago and Odada, 2004; Olago et al., 2007). Lake Victoria, though not considered an amplifier lake, is sensitive to climate change as its water balance is dominated by rainfall on the lake and evaporation, with river inflow and outflow making minor contributions (UNEP 2004; Olago et al. 2007).

[2] A lake basin with a hypsometric integral of between 0.23 and 0.30 and a UNEP aridity index that is above unity is an amplifier lake that responds sensitively to climate changes; the characteristics of such basins include high precipitation on the flanks and high evaporation over the lake area (Olaka et al., 2010, Trauth et al., 2010).

4. Exploitation of lake basins and their impacts

4.1 Environmental factors

Land degradation has been a major issue in many lake basins over the past century (e.g. Thom and Martin, 1983), but particularly since the 1960s to date (e.g. Verschuren et al., 2002; Adjei et al. 2014). The main driver of land degradation in the lake catchments has been agricultural expansion and related poor land management (e.g. slash and burn practices), resulting in erosion, turbid rivers and lakes, and sediment accumulation in lakes and rivers. In the southern parts of the East African Great Lakes region, land clearing using uncontrolled large fires is proceeding at an alarming rate (Cohen et al., 1996). Large-scale biomass burning during the dry seasons conveys nutrient elements (nitrogen and phosphorus) to the lakes via the atmosphere (Bootsma and Hecky, 1999); these nutrients affect the nutrient balances of the large lakes, enhancing the rate of lake eutrophication. Use of agrochemicals in agriculture (Ayenew 2007, Lemma and Desta 2016) and in industries along rivers draining into lakes, has introduced different types of pollutants in the lake environment (Talling, 1965, 1966; Hecky, 1993; LVEMP, 2002). Poor waste management, and particularly the discharge of untreated sewage into lakes (Scheren et al., 2000; Adom 2018), has also exacerbated the problem. Resulting impacts include changes to the water quality (UNEP-IETC, 2003; Kasweswe-Mafongo, 2003) and phytoplankton communities present in the lake water (Lemma and Desta 2016), with resultant knock-on effects on the trophic chain (cf. Wandiga, 2002), economic fish stocks and overall biodiversity (West, 2001; Duda, 2002), and disruptions to transportation and industrial operations as a consequence of the proliferation of water hyacinth and accumulated sediments (Twongo, 1996; UNEP, 2006). Lakes, particularly the large ones, have a long water residence time; given this situation, pollution resulting from the effects of human activities and development in a lake catchment is potentially catastrophic to the lake's water quality. In addition, it is less likely that damage can be reversed once it occurs (Spigel and Coulter, 1996).

4.2 Ecological aspects

The ecological impacts of environmental changes resulting from human activities that have been outlined in the section above include: changing food web structure due to hydrological changes and water/sediment contamination; eutrophia and anoxia in lake waters; aquatic species extinctions, invasions and introductions; habitat degradation and biodiversity loss, and; increased frequency of algal blooms. A study in Lake Victoria (Uganda) has shown that, in the vicinity of the water hyacinth (reduced oxygen levels), fish species number, biomass and diversity are reduced, the former two very significantly (Willoughby et al., 1996). In Lake Turkana, sedimentation has partly contributed to the growth of the Omo river delta, reflecting a measurable shallowing of the depth range of macrophytes, and has probably affected the local aquatic benthic or pelagic biodiversity (Haack and Messina, 2001). Alin et al. (1999) have noted that sediment inundation of lacustrine habitats in Lake Tanganyika has reduced species richness and density of molluscs, and the species richness of ostracods. Benthic algae productivity studies show that sediment inputs from deforestation probably reduce the amount of available habitat for colonization, decrease the nutrient value of the food source, and reduce the feeding efficiency of the primary consumers (O'Reilly, 1998). Some fish species e.g., the cyprinid fish *Opsaridium microlepsis*, which is endemic to Lake Malawi, has now been largely eliminated from Malawian waters through a combination of siltation and fishing pressure (Cohen *et al.*, 1996). Some lakes could be particularly sensitive of human pressures; for example, due to their low species diversity, the Naivasha and Albert lake systems lack the possible buffering effect of species redundancy that could offer resilience to both climatic and human-induced disturbances (cf. Martens, 2002).

4.3 Ecosystem goods and services

Numerous ecosystem goods and services are derived from lakes and their associated wetlands and rivers, but these have also come under threat from extensive use and exploitation by humans. The modification of aquatic ecosystems, particularly through increased sedimentation, pollution, species introductions, and overfishing, has led to the continual, and sometimes dramatic, change in the structure of fish communities in many lakes over time. In Lake Victoria, a notable decline in in haplochromines has been related to the introduction of the Nile perch has led to the decline although the revenue from the Nile perch fisheries is a great contributor to GDP. Water birds are not exempt from this effect – in the Lake Nakuru basin, pollution from the discharge of industrial effluents poses danger to millions of flamingos on the lake banks, and adversely affects the lakes aesthetics and tourism. Within the rivers most fish have been virtually wiped out, and in many lakes, there are reports of reduced fish catches as a consequence of habitat modification through sedimentation, nutrient loading, destructive fishing practices and overfishing. Wetlands are threatened by irrigation schemes, improved transport along waterways, industrial pollution, and mining extracts (Wilson et al., 1999; UNEP 2005). On a more local scale, overexploitation occurs in the context of harvesting resources like clay for bricks, buildings, and pottery, and papyrus for thatching houses and making carpets/mats. Small wetlands are also degraded by repeated cultivation and land clearance for expansion of the agricultural land, over-grazing of cattle in the wetlands, and small-scale burning by individual farmers. The declining quality and quantity of ecosystem goods and services is directly and slowly eroding the ability of the communities' dependent upon them to sustain their livelihoods, eroding their livelihood options, and undermining their capacity to adapt to future climate changes.

4.4 Economic aspects

The key sectors that derive high incomes from lake resources are fisheries and tourism, with the fisheries sector having a much greater impact. These sectors are being affected by the anthropogenically driven environmental and aquatic ecological changes that have been outlined in sections 4.1 to 4.3 above, and affect both the commercial-scale and subsistence-scale economic uses of the resources. The subsistence resource users are particularly vulnerable to the mentioned adverse changes which lock them in the poverty trap. Fisheries and aquaculture are an integral part of food security for Africa, and more generally, fish are important to the livelihoods of the numerous artisanal fishers and their dependents in terms of food security and employment. The importance of fisheries is outlined in the Comprehensive Africa Agriculture Development Programme (CAADP), a program of the New Partnership for Africa's Development (NEPAD) under the AU that addresses policy and capacity issues in the entire continent (de Graaf and Garibaldi 2014). The total revenue generated from inland fisheries (lakes, reservoirs and their catchments) is US$ 6,275 million contributing to 1.26% GDP of the continent (de Graaf and Garibaldi 2014). This sector alone provides employment to 4,958,000 people which is about 40.4% of all employment in the fisheries sector (de Graaf and Garibaldi 2014). Thus, the economic value of fisheries for food supply and its contribution to the GDP is undeniable. Sixty percent (60%) of fish consumed in countries such as Tanzania and Malawi is from freshwater fish predominantly from the lakes (UNEP, 2006). The creation of Lake Kariba introduced freshwater fishing in Zimbabwe in a region where fishing was absent. The Lake Victoria economy is one of the biggest in the continent and generates an annual GDP of US$ 3 – 4 Billion (UNEP, 2006). The over exploitation, illegal fishing and harvesting of juvenile fish in lakes is a key threat to the sustainability of the fisheries sector. These activities have led to an annual decline in fish harvests reported from a number of lakes. The introduction of cage culture in lakes such as Lake Victoria and Malawi has led to new challenges related to hypoxia/anoxia (low oxygen level), increase in algal blooms, the introduction of new exotic species (e.g. carp) and the introduction of diseases to the wild (e.g. Njiru et al., 2018).

4.5 Social aspects

There are many social factors that relate to the utilization of lakes and their resources. Rapid population growth, expanding settlements and land use changes can increase the level of waste and pollutant discharge into the lakes, reducing their aesthetics and restricting other traditional and non-economic uses of the lake waters, such as for bathing and washing. The demand for water for multiple uses threatens, through abstractions, the quantity of water available to lakes from influent rivers and groundwater systems that discharge into lakes. Loss of fish foods has been reported to adversely affect the nutritional status of communities living around lakes. Income from lake tourism and fish revenues have declined, reducing the incomes of dependent communities and hence affecting their quality of life and general wellbeing. There are also gender aspects that have to be considered. For example, degradation of wetlands tends to affect men and women differently as evidenced by the impact of wetland reclamation in Kampala area (Nakijoba, 1996; UNEP, 2006).

4.6 Governance aspects

There are a number of factors that make it difficult to manage lakes and their basins. The main one is that there are very few lakes in Africa where an integrated lake basin management (ILBM) plan has been implemented, and none where the different facets of such a plan have been seen to be working properly. These factors include:

- Political jurisdictions (within and between countries) with competing needs;
- Sectorally driven approaches to governance and management that result into multiple policies, strategies and programmes that apply to a single lake and its basin;
- Different institutions have overlapping or duplicated mandates;
- Inadequate levels of, or complete absence of, transboundary coordination and/or institutional structures in the case of transboundary lakes;
- Differentiated and generally low capacities to manage the lakes and their basins within and across borders;
- Lack of embedment of management plans within a risk-oriented framework precludes the likelihood of identification or the consequences of alternative actions and their outcomes;
- Inadequate or ineffective decision-support tools;
- Low and uncoordinated participation by stakeholders; and
- Shifting climate and environmental baselines e.g. due to global warming, that increase uncertainty in decision making.

Although the Integrated Water Resources Management (IWRM) approach has been adopted by most governments and basin organisations, and more recently the Integrated River Basin Management (IRBM) framework, these have still not given lakes the kind of attention they deserve because of the complex socio-ecological systems. Thus, ILBM implementation has been promoted as a useful conceptual framework to compliment IWRM and IRBM towards the sustainable use and management of aquatic system in many parts of the world, such as at Lake Trasimeno in Italy, Lake Biwa in Japan, Lake Poyang in China, Lake Atitlán in Guatemala, the Lakes Chapala and Coahuayana-Zapotlan Basin in Mexico, Chini Lake in Malaysia, Sarowar Samwardhini of Lonar Crater Lake and Lake Chilika in India, Lakes Lanao and Laguna de Bay in Philippines, Lake Buyan in Indonesia, and others.

5. Lakes and climate change

As has been mentioned in section 3 above, lakes are sensitive to changes in climate that are due to global warming (IPCC 2001). Global warming will lead to higher temperatures estimated to be between 0.2 and 0.5 ºC per decade for Africa (Hulme et al. 2001). Indeed, warming has been observed in the recent decades in air and water temperatures of tropical lakes (Olago et al., in press). Global warming gives rise to climate change, which will alter the timing, distribution and quantity of water resources across the region (Goulden et al. 2009). Lake Victoria, for example, was one half of a degree (°C) warmer in the 1990s than in the 1960s (Hecky et al., 1994; Bugenyi and Magumba, 1996). In Lake Tanganyika, lake surface temperatures have drastically altered the nutrient balance, cutting off fish production (O'Reilly et al., 2003; Verburg et al., 2003). There are also other consequences related to warming and climate change. In Lake Turkana, for example, thermal stratification has been shown to influence the distribution of fish in the deep water over as much as 20% of the lake area (Kallqvist et al., 1988). Further, extreme droughts and flood events are being experienced more frequently across the continent, and have become more intense. The 1997 El Niño which saw Lake Victoria level rise by 2.4m (Birkett et al., 1999) was the strongest in the region and caused wide-ranging agricultural, hydrological, ecological, economic and health impacts (Conway, 2002). Changes in the lake levels themselves, associated with changes in the hydrological cycle due to climate change, can have significant impacts on a lakes habitat and food web structures through exposure/submergence of littoral communities and changes in the lake water's physico-chemical properties, among other effects.

6. Integrated Lake Basin Management

Recognising the complexity of Lake Basin Governance, and that sectoral interventions have not been as successful as desired because they have not been able to anticipate or redress the impacts from other sectors, the ILBM approach was proposed to provide an integrated framework for the sustainable management and use of lake basin resources through informing policies, strategies, plans, projects and programmes, as well as to guide coordinated agency actions (ILEC, 2007). The ILBM approach is anchored on six inter-related and supporting pillars, namely; policies, institutions, participation, technologies, institutions, and finance. ILBM is an holistic and integrated approach, as it incorporates lakes and river basins and their associated wetlands as well as the entire scope of the biophysical, socioeconomic and governance aspects, while fully incorporating Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM) principles and approaches, to ensure that there is a balance between conservation and sustainable development of lakes and their resources.

A high-level African Water Ministerial Dialogue on "Management of Lake Basins for their Sustainable Use: Global Experience and African Issues" held during the 11th World Lakes

Conference in Nairobi from 31st October to 4th November 2005, reinforced the fact that lakes and reservoirs play a central role in integrated water resources management, sustainable development and responsible economic growth, and that sound policies, good governance, investment, and sustainable institutions including community-based, private sector, local, national and transboundary structures underpinned by scientific and local knowledge and gender mainstreaming, need to be encouraged and promoted in the planning and management of lake basins. With support from ILEC, the Government of Kenya has been developing a national ILBM strategy for implementation countrywide. Such efforts are expected to be replicated in other African countries over the coming years, to ensure sustainable management of lakes in the content.

7. Conclusions

A number of issues or factors can be noted from the discussion presented in this paper. Lakes are highly sensitive to natural changes and anthropogenic activities within their basins, and the latter adversely impacts on a lake's ecosystem health and resource values. The relationships between human activities and the biophysical environment are complex and any productive activity can deplete a lake's natural resources and cause environmental stress. On the other hand, environmental problems can prevent people from reaching an acceptable standard of living, and this is particularly true for poor people who are dependent on a lake's resources for their livelihoods. To understand and solve the problems relating to lakes and their sustainable management requires many different insights and contributions encompassing considerations of the geological context, historical factors/decisions through to cultural, ecological, socio-economic, governance and other aspects. Further, taking a long-term view (trans-generational) is important since lakes tend to have a slow response time to some types of perturbations (e.g. pollution), a rapid response time to other types of perturbations (e.g. hydrological changes), and react with perceptible ecological effects to climate change. These are well captured in the ILBM framework, which we recognize, at least for lakes and their basins as a functional whole, to be the best context within which to sustain healthy and productive lakes for posterity in the context of sustainable development.

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