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A Review on Ecosystem Services and their Threats in the Conservation of Nyando Wetland, Kisumu County, Kenya

Joseph K. Maithya[1], Felix L.M. Ming'ate[2*] and Sammy C. Letema[3]
[1]*Department of Landscape and Environmental Science, Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62,000-00200, Nairobi, Kenya, Email: jmaithya@jkuat.ac.ke*
[2*]*Department of Environmental Studies and Community Development, Kenyatta University, P. O. Box 43844-00100 Nairobi, Kenya, E-mail: mingate.felix@ku.ac.ke*
[3]*Department of Environmental Planning and Management, Kenyatta University, P. O. Box 43844-00100 Nairobi, Kenya, Email: Letema.Sammy@ku.ac.ke*
** Corresponding author*

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Abstract

Wetlands are vital ecosystems as they are essential to human health, wellbeing, ecological integrity and national development as well as in the attainment of the Sustainable Development Goals. However, despite their contributions to human wellbeing, they have been destroyed and degraded over years. The aim of this paper is to review literature on the ecosystem services in Nyando wetland ecosystem and how they have been helpful to the well-being of its residents and also to determine the threats to the Nyando ecosystem services. A total of 88 documents were reviewed out of 20,400 documents from the Google engine search. It is concluded in this paper that ecosystem services in the Nyando wetland contribute significantly to the sustenance of the livelihood of the local communities and that the over dependency on the Nyando wetland by the local communities has resulted to over-exploitation of its resources leading to the degradation of the ecosystem. It is recommended that since the Nyando ecosystem is of high value to the communities living there, sustainable utilization of its resources is important for its sustenance and also in the reduction of the degradation of its resources.

Keywords: Wetlands, ecosystem services, livelihoods, sustainability, conservation.

Introduction

Wetlands are those ecosystems integrating the characteristics of both aquatic and terrestrial environments particularly water, soil and vegetation (Lathrop 2011). The Millennium Ecosystem Assessment (MEA) 2005) defines ecosystem services as the benefits that people obtain from ecosystems, e.g. provisioning, regulating, supporting and cultural services, which are essential for sustaining livelihoods.

Wetlands have been reported to be among the world's most important natural resources but also known to be least understood and most abused assets (Maltby1991). For instance, MEA (2005) describes wetland ecosystems as the habitats that have been most affected by development and are therefore being lost more rapidly than any other habitat in the world.

The loss of these wetlands has led to environmental and ecological problems, therefore depreciating the socio-economic benefits of the communities that depend on them, since multiple ecosystem services that are produced from well-functioning wetlands

(Morrison and Harper 2009) and the potential consequences of their loss to the communities that depend on them are becoming of particular interest internationally (Maclean et al. 2011).

Wetland ecosystems cover an estimated area of more than 9% (1,280 million hectares) of the global land surface (Malabika et al. 2015). They are rich in species diversity and therefore part of the most biologically productive ecosystems on earth (Mwakaje 2009), as they provide important ecosystem services and functions such as habitats for wildlife, flood control, water purification, carbon storage, food supply, and play an important role in hydrologic cycle (National Research Council 1992) and ecosystem goods such as food (meat, fish, vegetables, etc.), water, fuels, and timber (Brown et al. 2007).

Despite their importance and contributions to livelihoods as outlined above, they are part of the most threatened environmental resources (Abraham 2015), and globally, more than half of the earth's original wetlands are estimated to have been destroyed or degraded (Ofei-Manu and Shimano 2010). For instance, between the years 1997 and 2011, the cost of loss of freshwater wetlands in the world has been valued at US$ 2.7 trillion per year (Costanza et al. 2014).

The Ramsar Convention Secretariat (2015) reported that land conversion, infrastructure development, water use, pollution and eutrophication, overexploitation, overharvesting of wetland resources, climate change and invasive alien species are the primary direct drivers, while population growth and economic activity changes are the primary indirect drivers of degradation and loss of wetlands.

In Kenya, the process of wetland management has not been up to date (Ministry of Environment and Mineral Resources (MEMR) 2012). The ecosystem services and goods have been faced with a myriad of issues in the process of conservation. In order to propose policy options for better ecosystem services management process in Kenya, this review of literature aims at using the Nyando wetland ecosystem as a case study to gather information on the processes that have been used in conservation of the ecosystems. Thus the review explores two questions: (1) What are the ecosystem services in Nyando wetland ecosystem and how have they been helpful to the wellbeing of its residents? (2) What are the threats to the Nyando ecosystem services and how can they be overcome?

Materials and Methods

Study area

Kenya is home to six main types of wetlands (MEMR) 2012). These include riverine, lacustrine, palustrine, estuarine, marine, and constructed wetlands (Table 1). Kenyan wetlands cover an area of up to 3-4% (approximately 14,000 km^2) of the total landmass which could increase up to 6% during the rainy season, many of which have been converted for alternative uses (Oduor et al. 2015). The distribution of Kenyan wetlands depends mostly on the land topography and the rainfall amount received (Macharia et al. 2007).

The Lake Victoria is the largest fresh water lake in Africa and the world's second largest with a total catchment area of 194,000 km^2 out of which 68,000 km^2 is the actual lake surface area (Lake Victoria Basin Commission (LVBC) 2011).

It is the main source of livelihood to the surrounding riparian communities within the three East African countries sharing it, namely Kenya (6%), Uganda (43%) and Tanzania (51%). Burundi and Rwanda are within the upper watershed that drains into the lake through river Kagera (Swallow et al. 2003).

The Lake Victoria basin includes the inshore areas of the lake, papyrus wetlands including the Nyando wetland (Kansiime et al. 2007). These papyrus wetlands have been described as highly productive and supporting ecosystem services of great

importance due to them occupying the transitional zone between permanently wet and dry environments (Osumba et al. 2010).

Table 1: Kenya's wetland classification and their components

Formation	System	Sub-system	Hydrology	Description
Natural	Coastal and Marine	Marine	Sub-tidal	Shallow marine waters
				Coral reefs
				Marine aquatic beds
			Intertidal	Rocky marine shores
				Sand and shingle beaches
		Estuarine	Sub-tidal	Estuarine waters
			Intertidal	Intertidal mudflats
				Salt mashes
				Mangrove and tidal forests
		Lacustrine/ palustrine	Permanent or seasonal	Coastal fresh lagoons
				Saline and brackish lagoons
	Inland	Riverine	Perennial	Permanent rivers and streams
				Inland deltas
				Intermittent rivers and streams
			Intermittent	Floodplain wetlands
		Lacustrine	Permanent	Permanent fresh water lakes
			Seasonal	Seasonal fresh water lakes
			Permanent/ seasonal	Permanent and or seasonal saline lakes and marshes
		Palustrine	Permanent	Permanent fresh water ponds and marshes
				Open peat bogs and fens
				Fresh water swamp forests
				Shrub dominated swamps
				Peat swamp forests
			Seasonal	Seasonal fresh water marshes
				Fresh water springs and oases
		Geothermal		Geothermal wetlands
Human-made		Agriculture		Seasonally flooded arable land
				Irrigated land and rice fields
				Small tanks and farm ponds
		Aquaculture		Fish and shrimp ponds
		Urban and industrial		Sewage treatment plants
				Gravel pits
				Reservoirs and barrages
		Salt exploitation		Salt pans, salines

Nyando wetland is the second largest wetland ecosystem in Kenya (Okotto-Okotto et al. 2018) after the Tana Delta (Njuguna et al. 1992). The wetland lies between 0^{o} 11'- 0^{o}

19'S/34°47'- 34°57'E and is a substantial floodplain forming major Nyakach and Kano swamps with an average elevation of 1134 m above the sea level (Nasongo et al. 2015, Raburu et al. 2012) (Figure 1).

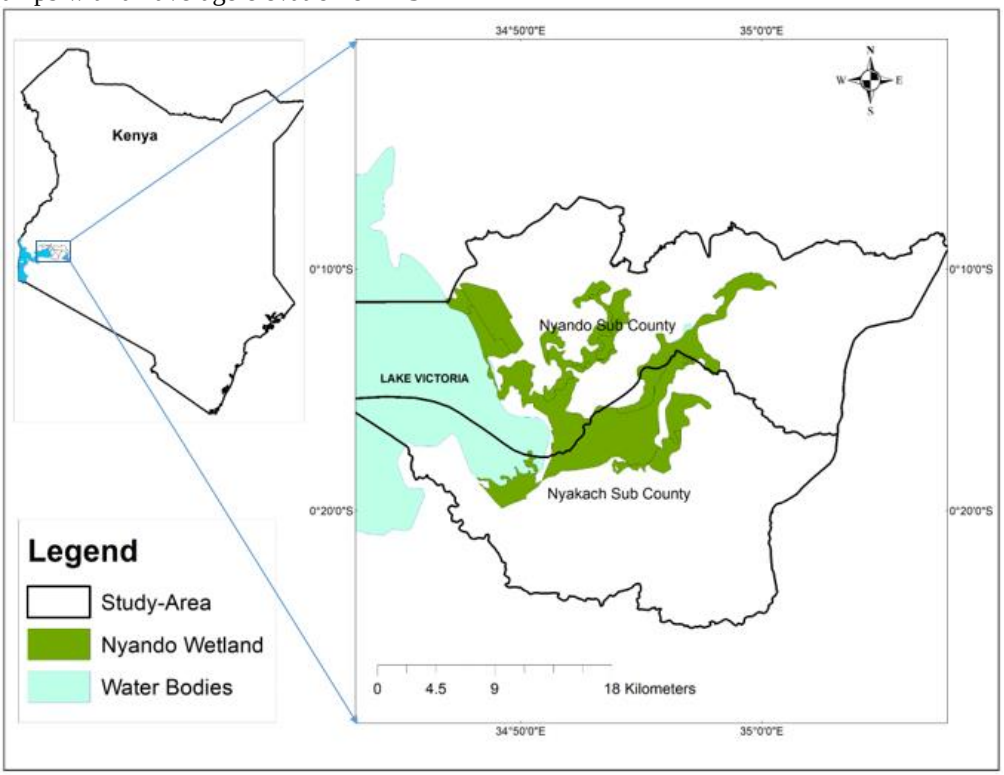

Figure 1: Area of study.

The main source of water to the wetland is River Nyando, which has its origin from the Mau escarpment. Nyando River has a catchment area of 3600 km^2 and a discharge rate of 15 m^3 S^{-1} into Lake Victoria and has been described as the main contributor to sediment and phosphorus pollution into Lake Victoria (Opere and Okello 2011). The size of Nyando wetland varies from 3000 Ha in the dry season to 5000 Ha in the wet season (Kipkemboi 2006, Mwakubo and Obare 2009). The wetland lies in the Kano plains at the mouth of the Nyando River and along the shores of Lake Victoria and has three ecological zones, namely flood plains, permanent swamps and seasonal swamps (Wakwabi et al. 2006).

Land use changes in the Nyando River basin have impacted negatively on wetland ecosystems over the past decades, causing loss of wetland values and services (Swallow et al. 2008). This domination of land use practices in the Lake Victoria wetlands for agricultural activities has been driven by exposure of large tracts of fertile lands along the lake/land interface which come as a result of Lake Victoria water recession (Obiero et al. 2012).

Global International Water Assessment (GIWA) (2006) reported that about 80% of the human population living in Nyando derives its livelihoods from subsistence agriculture. This implies that as agriculture continues to intensify, Nyando catchment will continue to have significant impacts on

the environment hence creating a challenge among wetland scientists.

Data collection procedures

Data collection was done through search of scientific articles in the websites using terms such as ecosystem services in Nyando wetland, threats to Nyando wetland, and wetland conservation (Table 2). The number of documents obtained through the search engine for each word search was sorted out for relevance which resulted to the use of 23 review papers for ecosystem services, 35 review papers for threats to Nyando wetland and 30 review papers for wetland conservation (Table 2).

Table 2: Data collection sources

Words used to search for results	Type of search engine	Number of documents from the search engine	Number of documents used for this paper
Ecosystem services in Nyando wetland	Google scholar	1080	23
Threats to Nyando wetland	Google scholar	654	35
Wetland conservation	Google scholar	20,400	30

Data analysis and presentation

Data collected from this review was analyzed through content analysis. The documents obtained through Google scholar search engine were ordered into distinct themes and categories obtained in relation to the study aims. The information was then analyzed and ordered to answer the aims of the study (Ming'ate 2014).

Results and Discussion

Nyando wetland ecosystem services and human wellbeing

The first aim of this review was to determine the ecosystem services in Nyando wetland ecosystem and how they have been helpful to the wellbeing of its residents. The review found that Nyando wetland like many other wetlands provides the local community with a range of ecosystem services. These ecosystems services are explained as follows:

a) Provisioning ecosystem goods

Provisioning services include food, fresh water, fibre and wood, raw materials and medicinal resources (MEA 2005). From the documents reviewed on ecosystem services in Nyando wetland, it was revealed that Nyando wetland like most other wetlands is a source of fuel, food, fibre, fodder, freshwater, and raw materials such as papyrus, reeds, wood, grass, sedges, sand and clay.

Majority of people living in the Nyando wetland use its fertile grounds for growing crops such as sugarcane, kales, arrowroots, bananas, pawpaws, onions, sweet potatoes, millet, beans, maize, sorghum, peas and cassava (Obiero et al. 2012).

Lake Victoria and its surrounding Nyando wetland is a source of tilapia and Nile perch which provide fish protein to its adjacent communities (Goudswaard et al. 2002).

The wetland is also valued for its dominant papyrus reeds which are harvested to make handicrafts (Osumba et al. 2010, Terer et al. 2012, Perbangkhem and Polprasert 2010).

Nyando wetland is also valued for its water supply for domestic and wildlife as well as human population (Keter 1992, Postel and Thompson 2005), and also for transportation of the residents (Kansiime et al. 2007, Abila 2002, Terer et al. 2004).

Nyando wetland is valued for its sources of medicinal plants which are used to treat different types of ailments and a source of

income from the sale of such herbal medicines (Obiero et al. 2012).

Provisioning services were found to be the most mentioned and discussed in most of the literature reviewed documents. Though their mention in most of these documents does not necessary indicate that they are the most important ecosystem services of the wetland, rather this could be an indication of their importance in contribution to the livelihoods of the local community thus resulting to their exploitation (Obiero et al. 2012).

b) Regulating services

Regulating services include water purification, climate regulation, controlling the water hydrological flows, provision of habitats for pollinators and soil erosion control (MEA 2005). It was also found that pollution from agricultural, industrial activities or human waste disposal have always found their ways to the wetland, however, the wetlands' vegetation helps in water purification through the uptake of phosphates, nitrates and toxins, hence reducing the nutrient loads into Lake Victoria (Verhoeven et al. 2006).

Additionally, the soil erosion control by the wetland vegetation ensures that the top soil is retained hence enhancing the sustainability of agriculture in the Nyando wetland ecosystem (GoK 2007).

c) Cultural services

Cultural services include aesthetic, recreational, spiritual and educational functions (MEA 2005). It was apparent from the review that wetlands influence the myths, cultural activities, traditional religious practices as well as traditional arts and crafts of several of the communities residing in Nyando wetland (Ndaruga and Irwin 2003).The wetland is used for cleansing, as shrines, appeasing evil spirits and a source of historical ancestry (Raburu et al. 2012). The wetland is also endowed with a rich variety of flora and fauna, which are sources of recreation and eco-tourism (Raburu et al. 2012, Obiero et al. 2012). The literature also found out that the wetland is an important area for research and provides opportunities for nature studies and excursions (Fanshawe and Bennun 1991). Further documents reviewed reported that precipitation and evapotranspiration control by Nyando wetland influence the micro and regional climate which are necessary for human health and recreation activities (Gichuki 2000, Hamerlynck et al. 2010).

d) Supporting services

Supporting services include nutrient cycling, soil formation, primary production and provision of habitats for biodiversity (MEA 2005). Nyando wetland hosts a high diversity of plants, fish and wildlife which are endemic or threatened hence acting as a source of biological diversity. The wetland provides a habitat for rare bird species including papyrus gonolek (*Laniarius mufumbiri*) with other bird species being endemic to the papyrus (BirdLife 2014). The wetlands also act as breeding and nursery grounds for fish (Lake Victoria Fisheries Organization, (LVFO) 2014, African Union–InterAfrican Bureau for Animal Resources (AU-IBAR) 2016) and support the almost extinct native tilapia species in the Lake Victoria (Balirwa 1998).

Threats to Nyando wetland

The second aim of this review was to examine the threats to the Nyando wet land ecosystem services. It became apparent from the review that human dependency on wetlands for their livelihood and their associated activities, e.g. vegetation burning, over-exploitation of wetland resources through unsustainable harvesting, reclamation for agriculture and settlement, pollution, introduction of invasive plant species and population growth are exerting a lot of pressure on the Nyando wetland ecosystem (Osumba et al. 2010, Morrison et al. 2012). The threats are explained below.

a) Population growth

The Lake Victoria basin has one of the world's densest rural populations with a population density of up to 1,200 persons per km^2 (World Agroforestry Centre 2012) in parts of Kenya. Kisumu city is the main city on the Kenyan waters of the Lake Victoria basin. It has a population of 1,155,574 persons and a population density of 554 persons per km^2 (Kenya National Bureau of Statistics (KNBS 2019). This population density is quite high compared to the Kenya's density of 66 persons per km^2 (Commission of Revenue Allocation (CRA) 2011) and has been growing over time with the increasing population. This population growth is fuelling rapid urbanization, conversion of land to agriculture, industry and settlement (Odada et al. 2004, Kairu 2001). These are in turn depleting wetland resources at a rate that outstrips their natural replenishments as the reduction in fringing lakeside vegetation and in fish populations and diversity attests (Kairu 2001, Masifwa et al. 2001). These problems threaten the Lake Victoria and Nyando wetland ecology and potential recreational opportunities in addition to affecting the lifestyles and livelihoods of local communities. Increasing population results to land clearance for settlements and habitat fragmentations reducing the wildlife habitats (Hill et al. 2002, Mwamidi et al. 2012).

b) Wetland reclamation and vegetation burning

Large portions of wetlands are cleared especially during the dry period to pave way for human encroachment for settlement, cultivation of crops and grazing (Muyodi et al. 2010, Twesigye et al. 2011). The review also found that the burning of wetland vegetation and clearing have led to the loss of habitats and biodiversity, livelihoods and of breeding and nursery grounds for fish (Lake Victoria Fisheries Organization 2014, AU-IBAR 2016).

c) Unsustainable harvesting of wetland resources

Papyrus (*Cyperus papyrus* L.) which is harvested for use in making handicrafts, fuel wood and thatching of houses is the most over-exploited macrophyte in the Nyando wetland (Masese et al. 2012). Other species targeted within the Nyando wetland are *Phragmites australis* (odundu) used for fish traps, rafts and boat making as well as *Sesbania sesban* (asao) and *Pycreus nitidus* (*Se*) which is used for construction. Between 1969 and 2000, unsustainable harvesting of papyrus for the handicraft industry led to a loss of 34-50% of the Nyando (Kusa) swamp's papyrus (Owino and Ryan 2007). This loss has had negative impacts on the wetland ecological functions (Birdlife 2014). The sustainability of Nyando wetland is threatened by such over-exploitation of its resources. A great reduction in fish sizes, catches and beach landings have been reported with many fish species being almost extinct (Twong'o and Sikoyo 2004, Odada et al. 2006, LVFO 2015, 2016, 2017). Factors which have caused the reduction in fish stocks include pollution, eutrophication, use of destructive fishing gears and overfishing (Goudswaard and Wanink 1993, Seehausen et al. 1997, Verschuren et al. 2002, Kolding et al. 2008, AU-IBAR 2016).

d) Invasive alien species infestation

Water hyacinth infested Lake Victoria and its fringing Nyando wetland in 1990s and has been difficult to eradicate despite numerous attempts both biological and mechanical (MEMR 2012, Masese et al. 2012). Its infestation has had negative effects on the livelihoods of the local communities around the Lake and its surrounding Nyando wetland. The weed has eroded the Lake's and wetland aesthetic beauty, thus affecting tourism, de-oxygenates water resulting to fish deaths which negatively affects the livelihoods of the fishing communities and chokes off competing plant life affecting biodiversity (MEMR 2012, Mailu 2002).

e) Lack of institutional framework and policy failures

Institutionally, wetlands in Kenya are managed by diverse government ministries and departments, and this has led to overlapping mandates and responsibilities causing confusion among the stakeholders; thus aggravating the wetland degradation problems (Raburu et al. 2012, MEMR 2012). The poor enforcement of wetland conservation and management policies has negatively impacted the ecological integrity of Nyando wetland (Raburu et al. 2012).

Conclusions and Policy Recommendations

From the review of the first aim of the paper, it can be concluded that ecosystem services in the Nyando wetland contribute significantly to sustenance of livelihood of the local communities. The provisioning services such as supply of food, raw materials, fuel, and fibres are some of the most sought after by the local community for their livelihoods. Subsistence and commercial crop cultivation as well as fishing activities are very important services within the Nyando wetland.

In the case of the second aim of the review, it can be concluded that this over dependency on the Nyando wetland by the local community has resulted to over-exploitation of its resources leading to the degradation of the ecosystem, through unsustainable harvesting of the wetland resources, wetland reclamation and burning of vegetation to pave way for agriculture and settlements. Population growth has also led to continued encroachment resulting to opening up of new wetland areas and land fragmentations over time.

It is thus recommended that since the Nyando ecosystem is of high value to the communities living there, sustainable utilization of its resources is important for its sustenance and also to help reduce degradation of its resources. Further, the government of Kenya should provide alternative sources of livelihoods in order to control the increasing population encroachment into the wetland. Education programmes about the benefits of wetlands should be strongly supported to reduce degradation of the Nyando wetland. For instance, landowners need to know how to conserve their wetland as they use it for their economic benefits. Finally, there is need for review of the existing and future legislation and other national policies affecting wetlands to ensure proper utilization of Nyando wetland.

Declaration of conflict of interest

There is no conflict of interest.

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