Impacts of Rice Production on Nyando Wetlands Ecosystem in Lake Victoria Basin, Kenya

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Abstract

Wetlands are important resources that provide the community with many inter-related environmental functions and socio-economic benefits, which support a variety of livelihood strategies. In Kenya, wetlands are often utilized for rice production due to their favorable hydrological conditions and nutrient-rich soils. The unique climatic and geographical characteristics of the Nyando wetland in the Lake Victoria basin, coupled with the availability of water resources, make it suitable for rice cultivation. As rice cultivation intensifies in the region to meet rising food demand and economic opportunities in the country, Nyando Wetland has been extensively exploited, disrupting the ecological balance of the wetland ecosystem and negatively impacting biodiversity and livelihood of riparian communities. Therefore, this study evaluated the impacts of rice production on Nyando Wetlands Ecosystem in Lake Victoria Basin, Kenya. The study was based on the assumptions of the Hardy-Weinberg equilibrium principle. This study adopted mixed research design which integrated both qualitative and quantitative methodologies. This study target population were 80,509 households using wetland resources and rice farmers in South West Kano Irrigation Schemes which neighbours Nyando wetlands Kabonyo Ward in Nyando sub-county, Kisumu County, Kenya. The sample size of 213 was derived using Krejcie & Morgan (1970) formula. Data was collected using structured questionnaires, interview with key informants, Focus Group Discussion, observation and photography. Cronbach's alpha was used to determine reliability of the research instruments and this study alpha value of 0.84 was regarded as being indicative of good reliability. The quantitative data was subjected to descriptive statistics and presented in the form of tables, pie-charts and graphs. Pearson correlation analysis was performed in SPSS version 20 to understand the relationship between rice production and the impact on ecosystem. Qualitative data from the interview guide and household questionnaire was analyzed through content analysis. Nyando wetland has experienced a significant reduction in size (91%) as farmers encroach into the wetlands to cultivate rice crops. Peaerson correlation between rice production and biodiversity, negative relationships were observed between the increase in rice crop production and the reduction of fish abundance ($r = -0.481$, $p = 0.001$), decrease in wetland size ($r = -0.984$, $p = 0.000$), and water quality ($r = -0.323$, $p = 0.001$). However, a positive relationship was observed between rice production and the increase in bird populations ($r = 0.223$, $p = 0.003$), while a weak positive relationship was found between rice production and the increase in floods ($r = 0.018$, $p = 0.002$). The study recommends that there is need for relevant actors such as NEMA, MOA and County Government of Kisumu to empower local communities through sensitization, awareness creation and trainings on importance of conserving

wetlands and ensure implementation of sustainable intensification of rice production to achieve food security with minimal disturbance of the wetlands.

Keywords: Wetland, rice production, Nyando, Impacts, Lake Victoria Basin

INTRODUCTION

Wetlands are ecotone systems between terrestrial and aquatic landscapes (Hong et al., 2010). They are among the most productive ecosystems of the earth (Wu & Chen, 2020). Wetlands are of great importance and amongst the important natural resource of the world (Gardner et al., 2015). The Millennium Ecosystem Assessment (MEA) describes four major classes of ecosystem services namely; provisional such as water and food, cultural services such as spiritual, recreational and religious, regulating services including regulation of floods, droughts, diseases and land degradation and supporting services such as nutrient cycling and soil formation (MEA, 2005). Wetlands have a vital role in not only delivering ecological services to meet human needs, but also in biodiversity conservation (Onganya, 2023). Wetlands provide habitats to many species and are source of water, food which contribute to biodiversity protection (Kariuki et al., 2021). Despite their importance, they have been described as least understood and most abused assets (Maithya et al., 2020). According to Abraham (2015), wetland ecosystems are more rapidly lost than other world's habitats as a result of their ecosystems being affected mostly by development. Wetlands areas have high potential for agricultural activity and provide food and income as well as a wide range of ecosystem services for riparian communities (MEA, 2005).

The percentage of wetland area in Africa is uncertain but estimated to be between 1% and 16% of the total land area (Davison et al., 2018). Wetlands make up between 3 and 4 % of Kenya's total land area, which increases to 6 % during the rainy season (Aron Keche et al., 2007). They consist of deltas, estuaries, mangroves and mudflats, swamps, marshes, flood plains, small lakes, rivers, and the margins of deep lakes and rivers (Okeyo-Owuor et al., 2012). Despite the fact that they are valuable, wetland habitats are quickly disappearing because to human activities such as agriculture, settlement, and industry (Dalu & Chauke, 2020).

The Lake Victoria Basin is a vast geographical region in East Africa that encompasses the area surrounding Lake Victoria, the largest lake in Africa and the second-largest freshwater lake in the world (Berke et al., 2012; Sayer et al., 2018). The basin covers parts of Kenya, Uganda, Tanzania, Rwanda, and Burundi. The Lake Victoria Basin estimated to occupy about 535,453 hectares (Lake Victoria Basin Commission, 2011). Therefore, they cover an extensive area and support a wide range of economic activities that sustain a significant proportion of the population in the basin (Kairu, 2001). The wetlands are biologically diverse and provide essential habitats for many species such as water birds, amphibians and wetland-dependent mammals such as hippopotamus and sitatunga. They are also important fish spawning grounds and major sources of livelihoods, many of which are important for the economic progress of the local communities. The wetlands also provide physical stability, critical water filtration functions and pollution abatement for Lake Victoria (LVBC, 2011). Larger population of Lake Victoria draw their livelihoods from the wetlands or wetland related resources (Kairu, 2001; Okeyo-Owuor et al., 2012). Despite wetlands being important ecosystem to riparian community, these wetlands are undergoing severe stress.

The Nyando Wetland is one of the numerous wetlands in the Lake Victoria Basin that are characterized by a preponderance of papyrus vegetation. The wetland situated at the

Nyando River estuary and constitute the second largest wetland (14,400ha) within the Kenyan region of the Lake Victoria Basin (Raburu et al., 2012). The Nyando Wetland is a significant wetland area consisting of marshes, swamps, and floodplains along the Nyando River and its tributaries (Khisa et al., 2013; Raburu et al., 2012). It plays a crucial role in the ecological dynamics of the Lake Victoria Basin, contributing to water filtration and flood regulation, The wetland is known for its diverse flora and fauna (Obiero et al., 2012). It supports a variety of aquatic plants, including water lilies, papyrus, and other wetland vegetation (Rongoei et al., 2013). The wetland's habitats provide shelter and feeding grounds for numerous bird species, such as herons, egrets, kingfishers, and waterfowl. Additionally, it is home to fish species, amphibians, reptiles, and other wildlife. The fertile soils of the Nyando Wetland have made it an ideal location for rice cultivation. Rice farming in the region has become a significant economic activity and a source of livelihood for local communities. The wetland's water availability, suitable soil conditions, and a relatively flat terrain make it conducive for rice production (Okeyo-Owuor et al., 2012).

Rice has become the third most important stapple crop after maize and wheat (Maclean et al., 2013; Mwajita et al., 2013). The total annual world production of milled rice currently stands at 400 million metric tons which compares favorably well with maize and wheat. Rice production in Africa plays a critical role in ensuring food security, reducing import dependency, and providing livelihoods for millions of smallholder farmers (Norman & Kebe, 2006). It is widely cultivated throughout the tropics and where flood controls are effective. Much of the foreign rice imported into West Africa is from South-east Asia.

Rice cultivation was introduced in Kenya in 1907 from Asia (Ouma-Onyango, 2014). It is currently the third most important cereal crop after maize and wheat and it is grown in all rice production ecologies and the current rice production is estimated at 80,000 metric tones on about 20000 hactares of land, but there is still deficit (Kihoro et al., 2013). Rice consumption is increasing at a rate of 12% annually as compared to 4% for wheat and 1% for maize. Future increase in rice production will rely on improved yields, and expanded area under production which is a threat to wetland (Rice Cultivation Manual, 2015).

In Kenya rice is mainly produced by small scale farmers in Central (Mwea), Western (Bunyala), Coast (Tana Delta, Msambweni) And Nyanza (Ahero, West Kano, Migori, and Kuria) as commercial and food crop (Kungu et al., 2019). The development of rice started in 1946 under the African land development unit which started as a broad Agricultural rehabilitation that included irrigation (Ngigi, 2002). About 80% of rice grown in Kenya is from irrigation schemes established by government while the remaining 20% is produced under rain- fed conditions (Onyango, 2014).

Rice farming has a significant impact on a variety of habitats and species, particularly those related to water (Barrett & Seaman, 1980). Traditional rice production methods which were practiced for hundreds of years were characterized by small-scale farming and low external inputs which generally had minimal impacts on wetland ecosystems (Bambaradeniya & Amerasinghe, 2004). However, with the increasing global demand for food, including rice, to support the growing population, there has been a shift towards modern technologies and intensive agricultural practices to boost rice production and meet this demand. While these modern approaches have significantly increased productivity, they have also introduced new challenges and impacts on wetlands. The intensification of rice farming and the adoption of advanced technologies have led to land conversion, hydrological alterations, water pollution, soil

degradation, and biodiversity loss in wetland ecosystems (Roger et al., 1991). The Nyando Wetlands, located within the Lake Victoria Basin in Kenya, are important ecological systems known for their rich biodiversity and provision of vital ecosystem services. However, the expansion of intensive rice production in this region raises concerns about potential wetland degradation and the associated environmental impacts. This study aims to evaluate the impacts of rice production on the Nyando Wetlands Ecosystem, providing valuable insights for sustainable land use planning and conservation efforts in the area.

METHODOLOGY

The Lake Victoria is the largest fresh water lake in Africa and the world's second largest having a catchment area totalling to 250,000 Km2 out of which 68,000 Km2 is the actual lake surface area (LVBC, 2011). Lake Victoria is valuable for its wetland resources in which the surrounding riparian community depend upon for their livelihood. In Kenya, Lake Victoria wetland occupy approximately 37% of the total wetland surface area in the country (Koyombo and Jorgensen, 2006). Wetlands have been described as highly productive and supporting ecological services of great importance due to them occupying the transitional zone between permanently dry and wet environments (Osumba et al., 2010).

The study was conducted in Nyando wetland which is the second largest wetland ecosystem in Kenya after the Tana Delta (Okotto-Okotto et al., 2018). The research was conducted in rice growing areas inNyando sub-couty, Kisumu County, Kenya. The target population involved people using wetland resources and rice farmers in South West Kano Irrigation Schemes which neighbours Nyando wetlands Kabonyo Ward in Nyando sub-county, Kisumu County, Kenya.'. The Nyando Wetland is located between latitudes 00º 09' S and 00º 20' S and longitudes 34º 45' E and 35º 00' E in the sub-count (Figure 1). In 1948, the wetland was estimated to cover some 90 km^2. It lies astride the Nyakach and Kano Plains at the Mouth of River Nyando on the edge of Winam Gulf on the shores of Lake Victoria (Okeyo-Owuor et al., 2010). Nyando River has a catchment area of 3,600 Km2 and a discharge rate of 15m3 S -1 into Lake Victoria and has been described as the main contributor to sediment and phosphorous pollution into Lake Victoria (Opere and Okello, 2011).

The area receives a bimodal rainfall with long rains falling in the months of March and May while October to December is the period for the short rains (Khisa et al., 2013). Due to the changing climatic conditions, the seasons are normally not consistent. Most at times the area experiences flooding during the long rains due to their heaviness and intensity. Nyando climate is sub-humid with the mean annual rainfall ranging between 1000-1800mm and a mean annual temperature range of 20-23°C (Maithya, 2021). The soil is deep clay which is rich in organic matter and poorly drained (Khisa et al., 2013), hence influencing the crops grown and natural vegetation distribution. The human communities living in the floodplain is predominantly the Luo ethnic group who practice subsistence farming, livestock herding and fishing (Kipkemboi, 2006). The main crops under cultivation in this wetland include sugarcane, rice, maize and vegetables. Other activities in the wetland are cattle grazing, domestic washing, macrophyte harvesting, and fishing (Orwa et al., 2012). Communities around Lake Victoria and its surrounding wetlands depend on the lake and the wetlands resources for their livelihood.

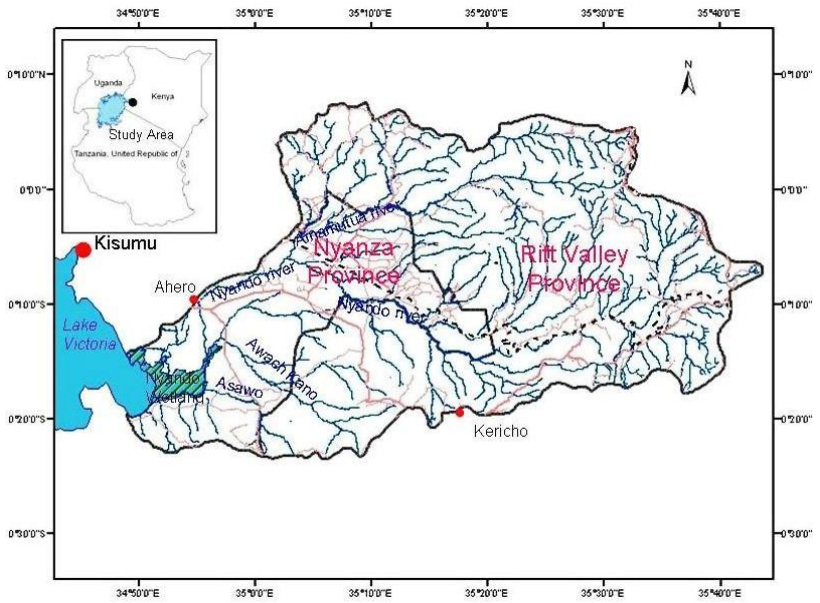

Figure 1: Location map of Nyando Wetlands

Source: Community based approach to the management of Nyando Wetland, Lake Victoria Basin, Kenya

In a mixed-methods research design, data is gathered using a combination of quantitative and qualitative research methods. The target population was 80,509 households which formed the population for this study was from which the sample size was derived (KNBS, 2019) confirmed from Kisumu County population data and local administration for South West Kano Irrigation Scheme (SWKIS). Six Wards were purposively selected where rice growing is concentrated. The following Wards were sampled namely Kobura, Kanyagwal, Kombura, Kawino North, Kawino South, Bwanda. In the first stage wards were purposively selected with aim of getting ward where rice farming is concentrated in the sub-county. The sub-county agricultural officer and ward administrators helped in identifying such areas. In the second stage, locations where rice growing concentrated most were selected. The required households for administering the questionnaires were identified. The sample size was derived using Krejcie & Morgan (1970) formula.

A stratified random (multi-stage sampling) sampling technique was used to select households to be interviewed. Three main strata were identified i.e. households who grow only rice, those who use/protect wetland and both rice and wetland users to provide a valuable comparison in the study area. This study utilized both primary and secondary data sources. In this study primary data sources questionnaires, interviews, focus group discussion and field observations and photography were used to collected data. The questionnaires were administered to randomly selected households in the study area while the survey field observation and photography was used to compare various activities in the study area and examine possible effects of rice cultivation on close by wetland ecosystems.

In this study three Focus Group Discussions were conducted with each group comprising between 8-12 participants drawn from the community growing rice only, conserving/using wetland and those on both activities. The composition of the groups interviewed took into account gender considerations thus, the male and the female as well as youths were represented.

Photography- Visual field observation was used as an important method for gathering data from the rice production field and nearby wetland areas. Rice sites was examined to capture production methods, areas under crops, types of crops and varieties, general field conditions and farmers activities. During the study, photography was used to make deductions and identify various and important field operations in rice crops. Observations and photography were also made to capture changes that have occurred to local wetland habitats and its relation to rice growing.

Collected data was edited, coded, tabulated and analyzed descriptively using SPSS. The analysed data was presented in the form of frequency tables, pie-charts and graphs.

RESULTS

Land size

Considering land size in this study allowed for a comprehensive understanding of the relationship between agriculture and the environment. It also helped in quantifying the extent of wetland conversion or encroachment for rice farming. There was variation in land sizes owned by different households in the study area as presented in figure 2 below.

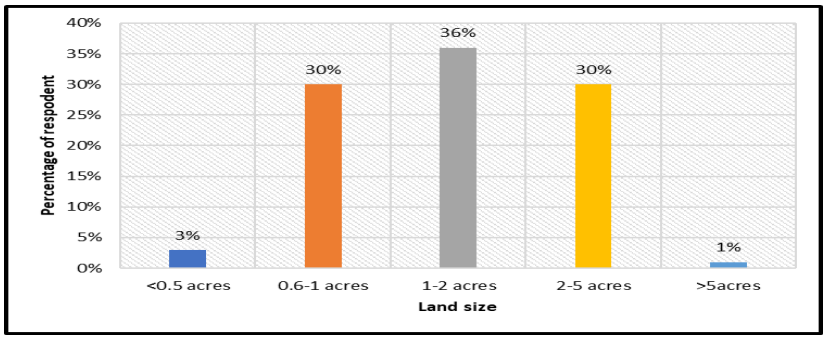

Figure 2:The land sizes of the respodents

According to figure 2 presented above majority of the respopodents (36%) owned between 1 and 2 acres, 30% owned between 2-5 acres and 0.6 to 1 acres, a few owned less than 0.5 acres (3%) and more than 5 acres (1%).

Rice varieties in SWKIS

According to the study, rice is grown by half of the respondents (52%), with an economic output per acre of Ksh.99,000. The study revealed that farmers in the SWKIS plant different rice varieties using seeds obtained from NIB or nearby farmers.

Table 1: Rice varieties grown in the in SWKIS

Variety	Frequencies	Percentages
IR-27	175	82
Arize Gold	20	10
Basmati	12	6
Others	4	2
Total	211	100

Figure 3: Rice farming in Nyando Wetland

Benefits of growing rice crop under wetland conditions in WKRIS

The study found that most farmers prefer growing rice crop under wetland conditions. Farmers selection on rice cultivation was based on multiple benefits related to wetlands.Their reasons for this practice are varied and can be scaled as shown in Table 2. For instace the results show that (34%) of the respondents stated that rice when grown under wetland conditions provide high grain yields while others held that rice grown under wetland condtions provide a good source of income compared to when the crop is grown under rainfed conditions (26%). Further, the respondents consider rice grown under wetland as a good source of food (18%) because it provides high quality grains (9%). When rice is grown under wetlands, water is available during the growing season providing a suitable condition for the crop growth and development(7%). Rice grown in WKRIS is an excellent source of employment for people in the area especially youths and women (6%).

Table 2: Benefits of growing rice under wetland condition/changes as aresult of rice growing in Nyando Wetlands

Factors	No of respondents	Percentage
High yield of rice	73	34
Source of income	55	26
Source of food	38	18
High quality rice	18	9
Availability of water for growing rice	14	7
Source of employment	13	6
	211	100

Negative impacts of growing rice crop under wetland conditions in WKRIS

However, the respondents also mentioned several diadvantages of growing rice under wetlands as shown in Table 3. Some respondents observed that rice grown under wetlands causes increased flooding even where floods do not usually occur (6%). Also in case of too much rains which results in increased flooding rice crops grown here may suffers crop failure due to too much water especially when the crop is still young. According to the respondents, wetlands habour many rice eating birds as well as diseases and pests. These are difficult to control and leads to less grain yields expected.

Table 3: Negative impacts of growing rice under wetland condition/changes as aresult of rice growing in Nyando Wetlands

Factors	No.of respondents	Percentages
Loss of wetland biodiversity	82	39
Pests and diseases increased	32	15
Human animal conflicts	30	14
Wetand degradation, reduced wetland size	29	14
Reduced production of other food crops	25	12
Flooding problems,drought	13	6
Total	211	100

Wetlands in WKRIS are a home to some herbivorous mammals which feed on growing rice plants. The respondents mentioned the Hippos and sitatunga which can raid rice crops grown in wetlands. They complained that especially hippos living in the wetlands are a common cause of conflict and farmers have to scare them from raiding the rice crop especially at night. Respondents mentioned that producing rice under wetland conditions is a costly affair especially land preparation, labour for planting, weeding and harvesting all of which are done under water conditions and require a lot of cash. For farmers who higher land for growing rice the cost is even higher (Khs 10,000/acre). Some respondents and particippants in KII and FGDs argued growing rice under wetland conditions cause loss of biodiversity (especially species of aquatic plants, mamals,amphibians, fish and reptiles). Some respondents felt that growing rice under wetland leads to wetland degredation and reduction in wetland size, soil fertility and can cause drought which leads to climate change. It was also observed that over reliance on rice growing in wetland areas leads to reduction in producing of other food crops such as maize, sorghum and vegetables

Wetland size

Wetlands are often targeted for conversion into agricultural land due to their fertile soils and water availability. However, indiscriminate encroachment can lead to the loss of valuable wetland ecosystems and the services they provide. while minimizing the negative impact on wetland areas. Nyando wetland have reduced in size (91%) as farmers encroach into wetlands in search of more fertile lands to cultivate rice crop, a few mentioned that it has remained constant while 1% reported that they have seen an increase of the years. Encroachment can involve clearing vegetation, draining wetland areas, or converting them into agricultural fields. Such activities can lead to the loss of wetland ecosystems, biodiversity, and the services they provide.

Status of biodiversity in Wetland area of SWKIS

Wetlands are host to a rich species diversity because they offers arange of ecological niches for wildlife both spartially and temporally (Denny, 1994). Nyando wetlands is known to its high productivity despite presure of enviromental degradation, it use to host diverse and abundant biota (Raburu 2003).

According to the findings presented in figure 4 above, majority of the respodents (57%) indicated that they have observed slight increase of mammal population in Nyando wetland over the years while 40% observed a decrease in mammals' populations. This is because they are experiencing conflict with wildlife like hypopotomus which comes to feed on rice and very few said that these animals are still existing.

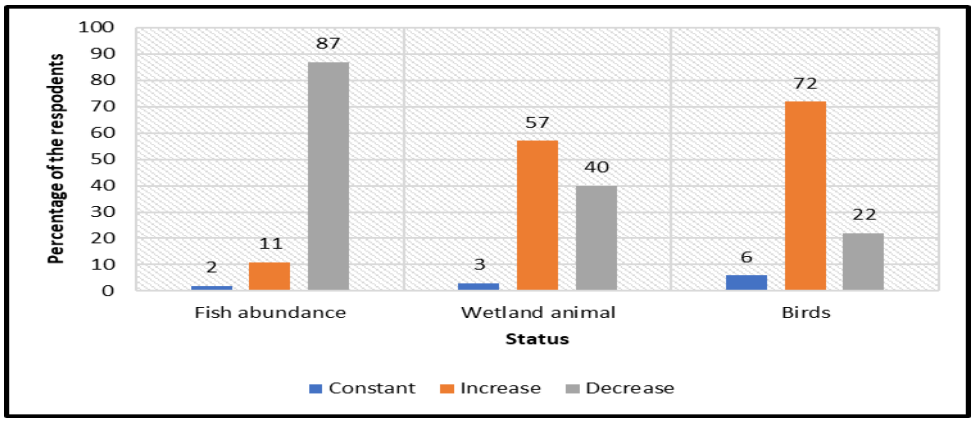

Figure 4: Changes in wetland as a result of rice cultivation

According to the respondents there has been a declining trend in plants species abundance and distribution in vegetation cover.It was observed that there is loss of indigenious plants species which used to be found naturally in wetlands. Through physical counting in areas demarketed of 25metre square in area having no rice and compared to rice fields.there significant change. Plants such as Papyrus which use to dorminate Nyando Wetlands are now facing degradation due to overharvesting by the riperian communities as they use it for making mats,baskets, fishing gears,,ropes building materials and source of wood. Further more plants are bing cleared, burned to create land for Agriculture including growing crops like Rice which has been difficult to control in the entire region. Agricultural transformation which includes practices that creates pressure on wetland ecosystems such as drainage,application of fertilizers,pesticide, livestockgrazing, fishing,gatering of reeds and plant materials degrade the wetlands. In Nyando wetlands expanding rice farms in to wetlands continue unabated due to lack of wetland policy and need for people to meet Food Security and market demands so wetland conservation, protection, and rehabilitation is still wanting. As reported by majority and from observation fish species and abunance has reduced as also mention during FGD that their habitat for breeding has been interfered with hence some species like cut fish, mud fish

Types of plant species in Nyando wetland

Wetland plants play a vital role in the functioning of wetland ecosystems. They help in water filtration, nutrient cycling, sediment stabilization, and flood regulation. Evaluating the types of wetland plants provides insights into the effects of rice production on these ecosystem processes. Excessive nutrient inputs from rice cultivation may alter the composition and growth of wetland plant communities, affecting their ability to perform these important functions. Therefore, this study evaluated the types of plant species that can be found in Nyando wetland and table 5 presents the findings.

Based on table 5 above, the types of plants found include; Fig tree, Nut grass, Common reed, Shrub, Sensitive plant, Jute mallow among others. Water hyyacinth is also investing the wetland. The study conducted by Raburu et al. (2012) identified the presence of invasive species, specifically *Mimosa pigra* and the herbaceous creeper *Ipomea aquatica*, in the Nyando wetland. These findings align with the results of our study, indicating a similarity in the identification of these plants in the wetland. Furthermore, Ondiek (2015), in their assessment of ecosystem services in the natural wetlands and rice fields of the Nyando floodplain in Kenya, observed that the wetland vegetation is primarily characterized by *Cyperus papyrus*. Other prominent

macrophytes found in the wetland include *Phragmites australis*, *Cyperus imensis*, and *Typha domingensis*, among others.

Table 5: Types of wetland plants

Local name	Common name	Scientific name
Ngou	Fig tree	*Ficus spp*
Oluga	Nut grass	*Cyperus spp*
selesele	Morning glory	*Ipomea spp*
Osiri	Sensitive plant	*Momosa pigra*
Odundu	Common reed	*Phragmites spp*
Olando	Shrub	*Phyllanthus fischeri*
See	Sedges	*Pycreus nitidus*
Nyabende	Lantana	*Lantana camara*
Saka	Hippo grass	*Vasia cuspidate*
Fod	Water hyyacinth	*Eichhornia crassipes*
Odielo	Day flower benghal	*Comelina banghalensis*
Awayo	Double thorn	*Oxygonum sinuatum*
Akajo	Devil's hores whip	*Achyranthes aspera*
Apoth	Jute mallow	*Corchorus olitoriou*

Types of birds species in Nyando wetland

The surveillance of birds populations in wetland environments yields significant insights into the ecological well-being and condition of wetlands, serving as an invaluable tool in fostering public understanding and appreciation for the preserving significance of these habitats. In order to understand the impacts of rice production in Nyando wetland, this study evaluated the types of birds' species that can be found and presented the findings in table 6.

Table 6: Types of birds species in Nyando wetland

Local name	Comon name	Scientific name
Nganga	Hadala ibis	*Hagedashia hagedash*
Okok	Buff backed heron	*Ardeola ibis*
Tula	African marsh owl	*Asio capensis*
Agak	African pied crow	*Corvus albus*
Nyinyodhi	Sun bird	*Cinnyris asiatics*
Ongowang	Crowned crane	*Belearica regulorum*
Oluru	Quail	*Perdix perdix*
Osogo	Northern brown throated weaver	*Ploceus castanops*
Akuru	Morning dove	*Streptopelia decipiens*
Oyundi	African firefinch	*Logonosticta rubricate*
Abang' chieth	Grey headed sparow	*Paser griseus*
Ochongorio	Yellow vented bulbul	*Pyconotus barabatus*

The most common birds species found in Nyando wetland includes; African marsh owl, African pied crow, Hadala ibis, Crowned crane, Grey headed sparow, Morning dove, Northern brown throated weaver, Buff backed heron among others. Nyando Wetland is rich in avifauna. In the Nyando wetland area, a total of 167 species from 50 families were documented. Among these species, 111 were found in the managed wetlands (rice irrigation schemes), while 123 were observed in the natural wetlands.

The families Ploceidae and Sylviidae had the highest species count, with 19 and 11 species respectively. It is important to note that this diversity is influenced by the presence of irrigated rice crops in the managed wetlands, resulting in dynamic changes (Raburu et al., 2012).

Types of fish species in Nyando wetland

The presence and abundance of fish species at a particular location can serve as a reliable indicator of the ecological health and water quality due to their significant roles within aquatic ecosystems and their adaptability to changing environmental conditions. In order to comprehend the impacts of rice production in Nyando wetland, this study evaluated the types of fish species that can be found and presented the findings in table 7.

Table 7: Types of fish in Nyando wetland

Local name	Common name	Scientific name
Ndira	Mud-fish	*Neochanna ssp*
Mumi	Cat-fish	*Ictalurus punctatus*
Mbuta	Nileperch	*Lates niloticus*
Fuani	Ripon fall burb	*Barbus alternialis*
Kamongo	Lung fish	*Proptopterus aethiopicus*
Seu	Siver cat fish	*Bagrus docmac*
Sire	African batler cat fish	*Schilbe mystus*
Adel	Luambwa barb	*Barbus spp*
Okoko	Victoria squeaker	*Synodontis spp*
Suma	longnosestonebasher	*Gnathonemus longibarbis*
Fulu	haplochromines	*Haplochromine spp*

The most common fish species found in Nyando wetland includes; Mud-fish, Cat-fish, Nileperch, Ripon fall burb, Lung fish, African batler cat fish, Victoria squeaker, haplochromines among others. In the study conducted by Raburu (2003) on water quality and the status of aquatic macroinvertebrates and ichthyofauna in River Nyando, Kenya, various species were identified, including *Barbus alternialis*, *Barbus numayeri*, *Barbus nyanzae* and *Barbus cercops*. These findings align with the results of our study, indicating a similarity in the identification of these species in the wetland. The findings of this study are further supported by the finding of Ondiek (2015) who reported that lung fish (*Protopterus aethiopicus*) and catfish (*Clarias gariepinus*). Other fish species harvested but not quantified in this study were Longtail spiny eel (*Mastacembelus fretanus*) and Luambwa barb (*Barbus cercops*) are found in Nyando wetlands.

Types of mammals species in Nyando wetland

The study further evaluated the mammals species forund in Nyando wetland and presented the findings in table 8.

Table 8: Types of mammals in Nyando wetland

Local name	Common name	Scientific name
Rao	Hyppopotmus	*Hyppopotamus amphibius*
Onger	Vervet monkeys	*Cercopithecus aethiops*
Dwe	Sitatunga	*Tragelaphus spekii*
Chiewo	Crested porcupine	*Xystrix spp*
Aidha	Pallid ground squirrel	*Xerus rutilus*
Mbidhi	Warthog	*Phacochoerus aethiopics*
kalangena	Salamander	*Candata*

The most common mammals species found in Nyando wetland includes; Hyppopotmus, Vervet monkeys, Sitatunga, Crested porcupine, Pallid ground squirrel, Warthog and Salamander. Raburu et al. (2012) documented the presence of similar mammal species in the Nyando wetland, including *Tragelaphus spekei* (Sitatunga), *Hippoppotamus amphibius* (Hippos), *Viverra civetta* (African civet), and *Lutra maculicollis* (spotted-necked otter).

Types of amphibians and reptiles species in Nyando wetland

The study further evaluated the mammals species forund in Nyando wetland and presented the findings in table 9.

Table 9: Status of Amphibians and Reptiles

Local name	Common name	Scientific name
Ngielo	African rock python	*Python sebae*
Ogwal	Common frog	*Rana temporaria*
Opuk	African spurred tortoise	*Geochelone sulcata*

The Nyando wetland is home to a limited number of amphibian and reptile species, with only three being particularly prevalent. These species are the African rock python, the Common frog, and the African spurred tortoise. *Python sabae* (Python) was one of the reptiles reported by Raburu et al. (2012) in Nyando wetlands. The study establishes that currently there is loss of wetland biodiversity.

Vegetation

Wetland vegetation plays a crucial role in supporting the nutritional needs and providing essential habitats for various organisms inhabiting or closely associated with aquatic environments, including algae, macroinvertebrates, amphibians, fish, and avian species. In the case of vegetation cover most respondents (84%) observed declining situation, while other (14%) reported increasing vegetation cover and only a few (2%) respondents resported no change in vegetation despite the rice cultivation. These cluster of people considered rice as vegetation cover which has replaced wetland vegetation without considering that the natural wetland vegetation is lost through bush clearing, burning to open fields for rice cultivation.

Area under crop production in Nyando wetland

In order to determine the extent of Nyando wetland encroachment, the study assessed the status of area under crops production. Area under cropland had increased (81%) and this is dorminated by rice plantation at the expence of other crops such as maize, sorghum,horticulture. Some farmers mention that there is decrease in crop land (18%) as they ment decrease in other agricultural crops like maize, sorghum whem farmers diverted to rice farming this was confirmed during focus group discussion and only (1%) reported that cropland has remained constant but this was disaproved from oservation during the study.

Water quality

Wetlands are important habitats for a variety of plant and animal species, and they contribute to the overall ecological balance. It was observed that there is a decline in water quality in the study area as main source of water used for irrigation is from river Nyando. Due to irrigation activities and poor water management there has been water pollution realized as a result of soil erosion and siltation. The decline in water quality from River Nyando can have adverse effects on the surrounding ecosystem and aquatic life. Pollutants and excessive nutrients in the water can result in eutrophication, where

nutrient overloading leads to excessive plant growth (such as harmful algal blooms), oxygen depletion, and disruption of the ecological balance. This can negatively impact fish populations, water-dependent species, and overall biodiversity in the river and its associated ecosystems.

Floods

In order to determine the extent of Nyando wetland encroachment, the study assessed the status of floods.The respondents also said they have been facing frequent flooding (87%). Frequent flooding had led to soil erosion, as the force of water can wash away the topsoil, nutrients, and organic matter. This erosion has reduced soil fertility, disrupted soil structure, and affected agricultural productivity. It also resulted in sedimentation in water bodies, impacting water quality and aquatic ecosystems. Addressing soil erosion requires implementing erosion control measures such as terracing, contour farming, and maintaining vegetative cover to stabilize the soil. Flooding also created favorable conditions for the proliferation of pests and diseases such as Bilharzia, Mosquitoes etc. Standing water provides breeding grounds for mosquitoes.

Climatic change

Climate change can lead to irregular water supply for irrigation, affecting crop growth and yield. Also, it contributes to the degradation and loss of wetland habitats disrupting the delicate balance of these ecosystems, leading to shifts in species composition, population declines, and loss of biodiversity. According to results, climatic change was reported by the farmers (89%) saying that they have been experiensing increase in temperature and drought and that the amount of rainfall received has reduced. Only few people (11%) mentioned no change in climatic conditions. The reported increase in temperature has accelerated evaporation, leading to increased water demand for irrigation and exacerbating water scarcity and affecting the wetland. Further, most of the people interviewed (71%) said there has been a reduction in the amount of rainfall received in the study area which has facilitated drought by (81%) resulting to poor yield for other crops such as maize,sorghum, and Horticultural crops hence farmers depends more on rice which they irrigate.

Pest and diseases

The study also assessed the impacts of rice production and pest and diseases. Results indicated that there was an increase (74%) of pest and diseases over a period of time due to rice production, 25% indicated that there was a reducution while only 1% indicated that it was constant.

Correlation between rice production and its impact on the Nyando ecosystem

The study assessed the relationship between rice production and its impact on Nyando wetland and biodiversity, results are presented in table 10 below. Peaerson correlation between rice production and biodiversity, negative relationships were observed between the increase in rice crop production and the reduction of fish abundance ($r = -0.481$, $p = 0.001$), decrease in wetland size ($r = -0.984$, $p = 0.000$), and water quality ($r = -0.323$, $p = 0.001$). However, a positive relationship was observed between rice production and the increase in bird populations ($r = 0.223$, $p = 0.003$), while a weak positive relationship was found between rice production and the increase in floods ($r = 0.018$, $p = 0.002$).

Table 10: Correlation analysis between rice production and impact on ecosystem

		Fish abundance	Wetland animal	Wetland size	Birds	Floods	Vegetation	Water quality
Rice Crop production	Pearson Correlation	-.481**	-.321*	-.984**	.223**	.018	-.623**	-.323**
	Sig. (2-tailed)	.000	.038	.000	.003	.002	.001	.001
	N	210	210	210	210	210	210	210

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2 tailed).

CONCLUSION AND RECOMMEDATIONS

More than half of the respondents indicated that rice is the predominant crop grown in the Nyando wetland, with IR-27 from the International Rice research Institute (IRRI) being the most prevalent variety. According to the respondents, among the benefits of cultivating rice in a wetland environment are a high rice yield and employment opportunities. Loss of wetland biodiversity, an increase in the incidence of pests and diseases, wetland degradation, a reduction in wetland size, and inundation issues are among the negative effects of rice cultivation indicated by the respondents. According to the majority of respondents, plant species have decreased, amphibians, mammals and fish are rare while invasive birds have increased and native birds have decreased. It was reported that the vegetation and size of the wetland had diminished significantly. The majority of respondents concurred that it is necessary to preserve Nyando's wetlands.

There is need for relevant actors such as NEMA, MOA and County Government of Kisumu to empower local communities through sensitization, awareness creation and trainings on importance of conserving wetlands and ensure implementation of sustainable intensification of rice production to achieve food security with minimal disturbance of the wetlands. The organizations should promote income diversification to minimize overdependence on rice as a major source of income and as a strategy for reducing pressure on the resources of Nyando wetland. Various development partners, stakeholders such as NEMA, MOA, and County Government of Kisumu, NationalGovernment, NGOs and local communities should come together with joint effort to initiate development and implementation of participatory wetland management plan that ensures effective conservation and management of Nyando Wetland.

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