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Conservation of wetlands in Kenya; The case of Nyando river wetland size change from 1961-1991

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Abstract

This paper is based on a study that employed remote sensing and GIS techniques to map Nyando River wetlands in order to assess the change in size of the Wetland area between 1961 and 1991 as well as use the results of the data to suggest sustainable management strategies for the conservation of the Nyando River Wetlands. The study was conducted in Nyando River Wetland area comprising Nyando, Lower Nyakach and Kadibo Divisions in both Nyando and Kisumu Districts, Kenya. Primary data were obtained from remotely sensed data field survey. Secondary data were obtained from published and unpublished materials. The data obtained were analyzed using GIS based techniques to illustrate the results. The study revealed that the mapped wetlands areas in 1991 were smaller in size as compared to 1961. The comparison was done through the Arc View GIS software where an overlay was performed. The reduction in size of the wetland was interpreted as degradation caused by overgrazing during dry seasons, over harvesting of these wetlands, encroachment due to demand for agricultural land and lack of sustainable management skills. The study suggests the need to create a buffer zone, control of wetland harvesting. Community involvement in the conservation process should also be given priority. There is a need as well for a national wetlands conservation and monitoring and enforcement of comprehensive wetland management policy at national levels.

Keywords: Conservation, Wetlands, Kenya, Nyando River Wetland Size Change, 1961-1991

1. Introduction

In Kenya, wetlands are classified as marine, deltaic, lacustrine, riverine and plateau. Most of the wetlands occur in the well-watered areas such as the coastal strip, the highlands and the Lake Victoria Basin under whose location the Nyando wetlands occur. Wetlands in Kenya are recognized as falling under one or more of the following categories (Mavuti, 1981):

- (a) Permanent reed marshes and grassy swamps with extrinsic hydrophytes and hydric soils.
- (b) Hydric soil flats devoid of hydrophytes due to either drastic fluctuations in water level, high concentrations of salts or a combination of both.
- (c) Littoral areas of lakes with both floating or rooted fringing vegetation and deltaic swamps, including the draw down areas of the lake shores.
- (d) Permanent fresh water or saline shallow lakes and ponds that are not more than four metres in depth where light penetrates to the bottom.
- (e) Seasonal swamps, marshes, ponds and other temporary water bodies that persist long enough to develop hydrophytic floral and faunal complexes.
- (f) Margins of impoundments and reservoirs where hydrophytes have become established but hydric soils have not developed.
- (g) Seasonal and river flood plains and their associated lakes.
- (h) Agricultural wetlands resulting from irrigation, including rice fields and reclaimed natural swamps.

Wetlands in Kenya may be riparian (developing in the mid-courses of rivers), riverine (due to impeded drainage in valley bottoms) or deltaic (forming at the mouth of large rivers discharging into lakes, seasonal ponds or pools). Examples of riverine wetlands include those found at terminus of Ewaso Nyiro (north) River at Perra, the Horian swamps, Ewaso Narok swamps, Lenyurruahanye swamps at the head waters of the Tsavo River.

Grass swamps and irrigation wetlands: an expanse of mixed papyrus grass swamp is found on the deltaic plains between the Nzoia and Yala rivers and on the Kano plains on the Nyando-Sondu River flowing into Lake Victoria. The deltaic grass swamp of the Kano plains (14,000 ha) have had 50 ha reclaimed at Ahero and 900 ha in West Kano. Both are under rice and sugarcane (Mavuti, 1992)^[6].

Many species of fish breed in wetlands and at the same time harbour substantial population of fish; at the coasts in the mangroves fish breed within them as well as other fauna such as

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endangered marine turtles. The community living within easy reach of the wetlands use them as grazing grounds, especially during dry seasons, while in other communities wetlands have been used as religious sites and where cultural activities may be performed such as circumcision.

1.1. Wetlands Management and Protection

While many cultures have lived among and even depended upon wetlands for centuries, the modern wetland management has been driven by the dictum that wetlands are wastelands that at best should be avoided, or if possible, drained and filled. Wetland alteration continues to occur especially by filling, dredging, hydrolic modification and water pollution (Mitch, 1994; Michael, 1991). Wetlands can be managed at their natural state for certain objectives such as fish, wildlife, agriculture and aqua-culture productions, water quality improvement, waste water management, flood control, harvesting of plant and wildlife resources and ground water recharge. This paper will thus go a long way to supplement existing efforts in wetlands management. Wetland protection and conservation has been implemented through a number of local and international policies, laws and regulations. These range from land use policies, zoning restrictions to enforcement of dredge and landfill laws (Barbier *et al.*, 1999; Mitsch, 1994). Authorities are becoming increasingly aware that special efforts are needed to protect a representative selection of wetland habitats. The trend is towards integrating their uses and their catchment along lines laid down in agreed management plans. These efforts have been supported by international bodies such as UNEP, WWF and IUCN, which aid countries to inventory and support wetland biodiversity protection. Current measures follow the concept that integrated rather than single use maximizes the possibility of sustainable use in long run (Mitch, 1994; UNEP, 1992; Crafter *et al.*, 1991; RCB, 2001) ^[1, 8].

The concept "Sustainable Wetlands" is an economic perspective, which tries to incorporate principles and practices of sustainable development in the wetland context (Turner & Johns, 1991). According to the authors, wetland management practices must ensure that there is a balance between wetland conservation, sustainable utilization and economic development.

The Ramsar Convention of 1971 (RCB, 2001) recognizes wetlands as being important for ecological, economic and social processes and for biodiversity. The broad objective of the convention is to stem the loss of the wetlands of the world and ensure their sustainable utilization. The parties to this convention have a number of obligations for promoting international co-operation for wetland conservation and utilization and designation of certain wetlands for special protection. From the convention came the Wise Use Concept (WCMC, 1992). Global actions are geared towards the protection and sustainable utilization of these valuable resources. The current trend is towards the recognition of the diverse values of wetlands through research and promotion of those economic activities, which result in the conservation of wetlands (UNEP, 1992) ^[8]. Resolutions from the Ramsar Convention have aided a number of contracting parties to develop wetland conservation policies in their own country situation.

Kenya is a contracting party to the Convention and has fulfilled some of its obligations and in 1990 selected Lake Nakuru to be included in the List of Wetlands of International Importance and is considered a National Park (GOK, 1990). However, the vast wetlands around Lake Victoria are

considered as non-conservation areas and have been given limited or no attention. This is in spite of the fact that they are rich in birdlife especially waterfowl, reverine forests, tourist values and are also special habitats for both aquatic and terrestrial organisms (GOK, 1981) ^[2].

At the moment, Kenya has not yet developed a wetland policy. In the absence of a clear wetland policy, their planning and conservation has continued to pose the greatest challenge to conservationists and resource users. This is further compounded by lack of clear land-use policies (Wanjala, 1990). Integrated planning of wetlands requires identification and mapping of the wetland systems within the river basin or control zone, assessment of their functions, products they yield and evaluation of their social and economic values to the communities living nearby (Anonymous, 1997). Existing and potential land uses such as industrial development and human settlement should be reviewed, and their short and long-term effects analyzed (GOK/UNEP, 1992) ^[8].

Previous government development policies aimed at the reclamation of wetlands for settlement and agricultural development. For instance, the National Food Policy of 1981 (GOK, 1981) ^[2], while recognizing the need to accelerate food production in the country, encourages landowners with rivers frontages to make every effort to reclaim all the wetlands and swamps that may be adjacent to their land. This policy encourages the maximum use of land for the production of food and brings about conflict in the use of wetlands when such crops like rice and sugarcane are planted to reclaim them. Trees like Eucalyptus have been planted in wetland areas to accelerate their draining for agricultural purposes leading to the death of these fragile ecosystems. Efforts to achieve food sufficiency have also meant introduction of agro-chemical inputs into irrigated lands. Run-offs get into the wetlands which exceed their buffering capacity to filter unwanted chemicals and result into death of organisms and pollution of the larger Lake Victoria downstream (Olindo, 1992).

Eastern African wetlands are a priceless commodity, which should be utilized for many different purposes. With good management, they will also be conserved and their wildlife will be protected. Development and conservation are not necessarily mutually exclusive and the aspirations of both needs to be appreciated more fully (Whigham *et al.*, 1993).

The trend on indiscriminate reclamation of wetlands is now being reversed. The emphasis on wetland management has increased and is demonstrated by a verifiable pool of reports, scientific studies and conference proceedings both locally and internationally which provide the evidence for the values, threats and need for wetlands management. Several government ministries have some association with wetlands. These include the Ministry of Water Resources and Development, Ministry of Environment and Natural Resources, Ministry of Tourism and Information, Trade and Industry and the Ministry of Agriculture and Livestock Development.

The Kenya Wetlands Working Group (KWWC) which is composed of government, parastatals and private organization officials, has organized several meetings on the development of a national wetland policy, while the Kenya Wildlife Services (KWS) has been involved in the classification inventorying and the protection of a selected number of wetlands in the country. Notable protected areas include Lake Nakuru, Naivasha, Amboseli, Saiwa Swamp and Tsavo National Park. Where the parks are gazetted, the KWS has the mandate for research and full protection. The Nyanza gulf is

not accorded full protection (Ndeti, Obari & Atumbwa, as cited in Okeyo & Raburu, 1999).

The Lake Victoria Environmental Management Programme (LVEMP) is a project by the East African countries to study and manage resources around the Lake Victoria region for the sustainable development of the area. It has a component dealing with wetland management and protection. In addition to the efforts so far mentioned, an Act of Parliament for the conservation and management of the environment, *The Environmental Management and Co-ordination Act, 1999*, got into force in the early 2000. This Act will also assist in the management of wetlands in the region. The above information indicates that the Kenya government is earnestly involved in the management of wetlands. The role of the community is also increasingly being recognized. This paper thus goes a long way to supplement existing efforts in wetlands management.

1.2. Ownership of Wetlands

Wetlands have in many instances been referred to as “wastelands”. In order to elevate wetlands from this status and to recognize them as a useful resource, there is need for the Government to continue having control over their management, until such a time that developers would have understood the role and importance of wetlands in the environment. In this regard the following measures and strategies will be taken:

- (a) All wetlands are a public resource to be controlled by the Government on behalf of the public. There shall be no leasing of any wetland to any person or organization in Kenya at any given moment and for whatever reason other than conservation
- (b) Communal use of wetlands may be permitted but only if environmental conservation and sustainable use principles and strategies of this policy are adhered to. The government may terminate this communal use if it is found that the community or any person has not adhered to the environmental obligations, principles and strategies of this policy
- (c) All future land tenure documents including maps and layouts will indicate whether the area contains a wetland and will accordingly exclude wetlands from tenure
- (d) Government will include wetland conservation considerations in its national land use policy and plan so as to maintain the ecological character of wetlands
- (e) Government will issue permits for wetland developers and users. It also reserves the right for the national and public good to issue a permit to a single public authority or legally constituted community Group for the management of a part or entire wetland on behalf of the community.

Wetlands belong to the public but contrary to what might be expected from this ownership status, the Commissioner of Lands has often allotted parts or whole of wetland as private parcels of land. Government consequently lost control of any protective or conservatory requirements. While there is a necessity to prevent the sequestering of wetlands into the hands of a few private land owners, this has to be balanced against the legitimate needs of users who will not be encouraged to use long-term environmentally sound practices unless guarantees of long-term use exists and consequently there is freedom from interference by conflicting users.

1.3. Land Use Trends

From the beginning of the 21st century, there have been some major changes in land use especially in the water catchment

areas. These changes have mainly been due to agricultural land use practices that have severely affected the environment resulting in wetland degradation and loss. There is general failure to understand the natural values of wetlands, the contribution they make to human welfare and the importance of retaining them in their natural state.

Drainage and reclamation of wetlands for agricultural development is the biggest threat to wetlands conservation and management. Out of inadequate information and prejudice, wetland reclamation is perceived a positive development. This is often misguided in the sense that greater productivity would result from leaving wetlands intact and managing them properly that from reclaiming them. Consequently, large numbers of wetlands have already disappeared and once gone, they are extremely difficult to restore. Many more are threatened. This is due to lack of comprehensive land use and conservation policies, increasing human encroachment, current agricultural policies and non-enforcement of relevant land use statutes. As a consequence, wetland goods, services and other attributes, which they provide, are continually being destroyed at an alarming rate.

The continuing uncoordinated changes in land use are adversely affecting biological diversity in wetland ecosystems in Kenya. Development is often planned and executed sectorally whereas wetland benefits always contribute to a multitude of sectors under the responsibility of different agencies. To remedy this problem calls for an integrated management approach to wetlands conservation and management.

Integrated management is a continuous, proactive and adaptive process of resource management for environmentally sustainable development. Integrated management is not a substitute for sectoral planning, but focuses on the linkage between sectoral activities to achieve more comprehensive goals.

At local level, the most appropriate type of management system for any particular wetland will depend on a flux of factors: biological conservation needs, the wetland functions and services requiring protection and their value, local and national economic opportunities, the subsistence needs of local people, adjacent land use patterns and the availability of adequate resources.

1.4. Drainage of Wetlands

Kenya has experienced in the recent past massive drainage of wetlands for human development activities. The effects of this drainage are visible in many parts of the country. In this regard the following measures and strategies will be taken.

- (a) The Government will generally discourage drainage of wetlands.
- (b) Any alteration of wetland including drainage shall be subject to EIA.

Artificial large-scale removal or expulsion of water from a wetland by whatever means constitutes drainage. This may be by pumping, by excavation of water channels and perhaps combined with excessive growing of trees along the riverbank. Other drainage means include building of dams upstream of a wetland without allowing compensation flow.

1.5. Statement of the Problem

The research that informs the writing of this paper aimed at employing the techniques of Remote Sensing and GIS to map the extent of Nyando River wetlands as it were in the sixties and 30 years later. The research aimed at highlighting the threats to the existence of the wetlands by various factors and

at the same time show the benefits collectively received from wetlands. This is shown through employing the techniques of remote sensing and GIS to map out the land area extent of Nyando River wetlands as it were in the sixties and 30 years later.

The issue of land in Kenya is a very sensitive one. Large chunks of acreage of land are incisioned from government owned forestland for private use without due regard to the ecological, economic and other benefits accrued communally from these forests. Since 1984 when Kenya adopted the National Food Policy through Sessional Paper No. 4, many believe that Kenya needs food more than idle natural swamps and therefore the reclamation of these wetlands into agricultural units. According to Mavuti (1992) [6], this action seems legitimate and justified.

Despite the ecological and economic value of the Nyando River Wetlands, current trends in their exploitation may lead to their destruction unless wise policies are developed and enforced. Other factors such as escalating population growth have had mounting pressure to reclaim and convert certain major wetlands including Nyando River Wetlands into agricultural use. These wetlands are probably the most encroached and degraded due to poor land use practices, improper management and unsuitable use of its resources by activities such as over-grazing, over cropping, over harvesting of wetland vegetation, wildlife-human conflict and invasion by exotic weeds such as water hyacinth (Okeyo & Raburu, 1999).

Seasonal floods aggravate situations where local communities are displaced and crops fail (GOK, 1996) [3]. Since crops often fail in rainy seasons, intense utilization of the wetland during dry seasons is widespread, sometimes leading to total loss of certain species and habitat change, for instance the Okana wetland in Kadibo Wetland (CP, 1999; Mavuti, 1992), 6].

Specific studies are lacking on the extent and rate of the wetland's depletion over the years and the significance and importance of this to the wetland's future existence. This information may help the policy makers and the community to understand the ecological importance and consequences so as to develop sustainable use of the wetlands' products, without threatening their very existence.

Several plants and animals of socio-economic importance to the riparian communities are threatened. However, important is the harvesting of *Cyperus papyrus*, which has continued unchecked in the Nyando River wetlands is important. Over exploitation and/or degradation of this plant not only threatens the ecology and potential recreational opportunities of the wetlands, but also the lifestyle and livelihood of local communities and has become a major development challenge as major agricultural activities continue to encroach the wetland ecosystem.

A range of methods has emerged to assist in wetland valuation process (Turner & Jones, 1991). Despite the variability wetland benefits are usually very significant no matter how they are measured, whichever the management strategy.

1.6. Environmental Impact Assessment (EIA) and Continuous Monitoring

Development activities in general tend to impact upon natural resources and the environment in various ways. Assessment and evaluation of such impacts helps to minimize the economic and social costs of preventing damage before occurrence as compared to restoring a degraded wetland. In this regard, the following measures and strategies will be taken:

- (a) There will be a requirement that all proposed modifications and restoration of wetlands are subjected to an EIA, the result of which will determine whether such restoration or modification should proceed and if so to what extent.
- (b) All planned new wetland development will be subjected to an EIA process to determine the required environmental controls and mitigations.
- (c) Those that have been subjected to EIA will continually be monitored to assess their impact on the environment and where the impacts cannot be adequately mitigated, Government will require that such development be halted.

An environmental Impact Assessment (EIA) is a detailed technical document, which determines the legally binding environmental management measures to be incorporated into

- (a) Any use of wetlands or wetland resources will have to ensure that they do not lose traditional benefits presently obtained from them.
- (b) Any decision to use wetlands must consider the requirements of all users in the community.

Sustainable use of wetlands is defined to mean utilization which ensures that the products or services derived from that use are available at the same level for the foreseeable future. For example, yields from fishing or harvesting of papyrus should be set at a level that can be maintained for the foreseeable future.

1.6. Conservation of Wetlands

Wetlands are important habitats for a variety of biological resources, some of which depend entirely on wetlands for their survival. In this regard the following measures and strategies will be taken.

- (a) The Government will designate more Ramsar sites for conservation and protection of ecologically important wetlands.
- (b) Government will establish "fully protected wetland areas" of important biological diversity especially with regard to the endemic, threatened and endangered species.
- (c) Government may also establish certain wetlands, which will be used for partial exploitation such as education, research, recreation and regulated tradition use.
- (d) No modification, drainage or other impacts will be entertained for the so-protected wetlands.
- (e) Parts of utilized wetlands will be set aside for conservation and/or protected from modification, drainage or exploitation.
- (f) Riparian communities will be encouraged to conserve and apply wise use principles to wetlands through development of community management plans.

Conservation of wetlands to protect indigenous species of plants and animals is essential for the future biodiversity of Kenya. Many attributes of wetlands remain to be discovered and therefore, complete protection of certain ecologically important wetlands is necessary. Kenya has already designated Lakes Nakuru, Naivasha, Bogoria and Baringo as Ramsar sites, i.e. wetlands of international importance. There are many more that require such recognition.

1.7. Recovery of Previously Drained Wetlands

Many wetlands have been drained or modified throughout the country. This has led to loss of many would be valuable resources before a full assessment has been carried out. In order to restore degraded wetlands the following measures and strategies will be taken.

- (a) Government may require that some wetlands, which have already been drained, be allowed to regenerate. For this purpose, Government aims at restoring the soil hydration so as to re-establish the wetland vegetation as far as it is ecologically possible. Such an operation may range from rehabilitation of wetlands along drainage channels in the case of freehold and leaseholders to full rehabilitation upon delineation of the wetland areas.

Previous Government policies, especially in the colonial and immediate postcolonial eras, allowed nobody to own wetlands, this has led to massive drainage and degradation of wetlands.

1.8. Pollution and Eutrophication

The quality of many water sources in Kenya is declining. This is primarily as a result of salinization and to a lesser extent because of eutrophication and pollution by trace metals and micro-pollutants. Industrial and agricultural activities and sewerage further enhance this. Salinization is a particularly intractable problem, because the only known remedies are dilution with less saline water or very expensive reverse osmosis to remove dissolved salts. On the other hand, eutrophication is the process of nutrient enrichment and an associated increase in primary production. It is often a natural process in aging of wetlands on a geological timescale associated with the natural accumulation of nutrients. However, human activities have greatly accelerated this process in many wetlands in Kenya. This may be seen in the spectacular blooms of the alien floating plant *Eichhornia crassipes* (water hyacinth).

1.9. Implementation Strategies

Rapid population growth and the increasing rate of development require sufficient and steady amount of water supply and discharge of effluent at an affordable cost. Many urban settlements, including Kisumu, Nairobi, Naivasha and Mombasa, are dependent on wetlands for water supply, treatment and discharge of effluent. In this regard the following measures and strategies will be taken:

- (a) Any wetland serving as a source of water supply or receiving effluent, as part of a designated service to any human settlement shall be declared a fully protected wetland from any encroachment, drainage or modification.

Wetlands can preserve the purity of water by their infiltration capacity. One of the important reasons for this policy arises from extensive draining of wetlands for horticulture where these areas also serve as water purification "systems". Such drainage has led to a dangerous situation where farmers and members of the community may come into bodily contact with raw sewage during farming and domestic activities.

1.10. Alien Biota

After habitat degradation, invasive plant and animals represent the greatest threat to the biological diversity of wetlands in Kenya. An invasive species in this context is seen as an alien species or a translocated indigenous species, which, after introduction, has spread unaided into, untransformed ecosystems and may be responsible for causing an imbalance there. Two species of alien aquatic plants have a marked impact on Kenya's wetlands. These are *Eichhornia crassipes* and *Salvinia molesta*.

The major economic impacts of invasive aquatic plants arise from river blockages and interrupted water flows, evapotranspiration losses, difficulties in the treatment of water

to attain portable standards, the development of increased breeding sites for vectors and intermediate hosts of human and stock diseases and an inhabited use of water bodies for recreational purposes.

International movement of plant and animal specimen has resulted to the negative impact to wetlands and native gene pools. Invasions can be viewed from widely different viewpoints and with different objectives. The causes, primarily, are anthropogenic as the activities of man in disturbing natural areas, increase their vulnerability to colonization by invaders and as human deliberately and accidentally serve as agent for transporting specimens from one habitat to another. In this regard the following measures and strategies will be taken. The Government will:

- (a) Take the necessary steps to prevent the introduction of harmful alien species.
 (b) Implement actions that are directed towards the removal and elimination of invasive alien species.
 (c) Develop guidelines, regulations and procedures to control introductions of alien and genetically modified organisms.
 (d) Carry out public education and awareness on the dangers of alien species and integrate all stakeholders in the management of wetlands under threat by invasive species.
 (e) Carry out research on alien species with a view of developing strategies and actions to arrest the spread.

Wetlands are highly vulnerable to invasive species. Introduced species occupy disturbed habitats and seldom establish themselves as a fixed element of natural flora and fauna. One established in the case of plants, they affect water resources adversely by blocking feeder streams and irrigation outlets, wasting water in evapotranspiration, increasing waterborne diseases interfering with fishing and agriculture and clogging drainage systems. Its role in disturbing the water balance cannot be ignored.

1.11. Poverty

Poverty reduction is a national challenge. Despite the planning and implementation efforts made to address national poverty and other social development issues in the past, poverty has remained a key problem. The Government recognizes that the challenges for sustainable development in Kenya are eradication of poverty and the achievement of sustained broad based economic growth. Poverty eradication is viewed not only as a political necessity and a moral obligation but also as an economic imperative for Kenya's development.

Sustainable management of wetlands should take into account that at present, the interaction of the poor and the environment has resulted in undesirable consequences, which have contributed, to loss and/or degradation of wetlands in the country. It is also evident that serious inequalities in resource distribution exist between various income brackets, ethnic groups and between gender. These inequalities also contribute to resource degradation. Poor people who lack access to resources often have no choice but to overuse resources and are often forced to use marginal lands and wetlands for their livelihood.

Natural systems such as wetlands are affected by economic, social and legal systems. All stakeholder groups-individuals, communities, businesses, NGOs and government agencies are motivated by economic, social and legal measures to undertake activities, which either conserve or threaten the diversity and integrity of nature. Poverty, wetlands conservation and equity are interlinked.

On the other hand, wetland ecosystem conservation and management activities affect the distribution of costs and benefits derived from natural resources. Thus, implications for equity, which we must learn to consider and account for in our decisions. On the other hand, it is Government's conviction that poverty reduction and equity are a prerequisite for the long-term conservation and sustainable use of wetlands. In this regard, the following measures and strategies will be taken:

- (a) Development and promotion of sustainable land use practices based on a participatory agro ecological approach.
- (b) Promotion of participation and empowerment of local communities and other stakeholders in the conservation and management of wetlands.
- (c) Develop a framework that has respect of customary tenure law, indigenous systems and sustainable resource use practices.
- (d) Develop local capacities to enforce sound indigenous rights, legitimizing appropriate traditional patterns of local management that enable sound resource use and food security.
- (e) Review and address land-holding system with a few to ensuring that the poor also have access/opportunity for land holding.

As a result of poverty and unsustainable land use practices, the poor engage in activities such as wrong farming practices, draining of wetlands to increase land for farming, cutting of trees to make charcoal among others. These activities have negatively affected wetlands. In essence, immediate survival needs of the population conflict with the long-term conservation and management of wetlands. As a consequence, poverty and issues of maintenance of wetlands are intertwined and need to be addressed simultaneously.

1.12. Limitations of the Study

The study was confined to the areas of lower reaches of Nyando River Basin in Kisumu and Nyando districts, bordering the Winam gulf and Lake Victoria. It was largely based on the three divisions that border the wetlands these were: Kadibo in Kisumu District, Nyando, Lower Nyakach and part of Miwani.

The major wetlands that formed the study sites included: Okana and Ogenya in Kadibo Division, Singida in Nyando Division, Wasare and Komwoga in Lower Nyakach Division. Five administrative locations found in the divisions include East Kochieng', Kanyagwal in Kadibo Division, Kakola in Nyando Division and Rongo and Nyalunya in lower Nyakach Division.

The main focus was to study the wetlands in its entirety and to establish the extent of degradation through various factors such as agriculture, over exploitation, over agriculture, etc. This included highlighting the uses of the wetlands both from Nyando and other surrounding wetlands within the Kenyan portion of Lake Victoria.

Market survey data based on the monetary value of wetlands was also obtained and used to emphasize the economic values and therefore importance of wetlands. The study considered to a considerable depth the biological functions, chemical functions and other related functions of wetlands.

The study was limited to perform ground truthing of certain parts inside the wetlands as these areas were either waterlogged or were inaccessible. The area photographs covering the affected areas were interpreted and without ground truthing.

2. Materials and Methods

2.1. Location and extent

Nyando River wetland is located at the delta littoral wetlands of the Lake Victoria, Winam Gulf of Kenya. It lies about 20 km to the South East of Kisumu City and immediately south of Ahero urban centre. The wetlands lie between longitudes 350 25'E and 350 45'E and latitudes 005'S and 0015'S and has elevation of 1135 above sea level. Nyando wetland is located at the delta of Nyando River and forms the major swamp of Kano and Nyakach plains along the Winam Gulf, Lake Victoria, Kenya. It lies about 20km south east of the City of Kisumu and immediately south of Ahero urban centre. The wetland lies between longitudes 35025'E and 35045'E and latitudes 0005'S and 0015'S with an elevation of 1135 above sea level.

The Nyando River along which the Nyando River wetlands are located originates from the western slope of the Mau Escarpment with the main tributaries originating from Tinderet hills and Kericho highlands. The river flows south west to Lake Victoria through Nandi, Kericho, Kisumu and Nyando districts, a distance of about 142 km while the basin in approximately 3450 km² (JICA, 1992) [5]. The basin forms four sub-river basins known as Awasi, Awach Kano, Nyaitho and Nyando river sub-basin. Awach Kano and Nyando rivere sub-basins form the major portion, what is referred to as Nyando River wetlands in this study and it covers an area of about 276/cm².

2.2. Data Collection Methods

Primary and secondary data were used for the study. Primary data used was obtained from satellite image taken in 1991 and aerial photographs taken in 1961. Photographs were used to record some observations. Secondary sources of data included published, unpublished materials topographical maps and diagrams.

2.3. Mapping Using Satellite Imagery

Satellite data can be obtained in the digital form or analog. The data type to be obtained therefore depended on the method adopted in mapping phenomena. If a digital imagery is obtained then the method for digitizing shall be on screen and further analysis will be done using a computer. However, the methodology used by the author required that a hard copy satellite image scene be obtained. Remote sensing means the acquisition of information about a phenomenon.

Digital data from satellites are usually preprocessed and processed to be useful for particularly mapping of phenomena or for monitoring purposes. As digital analysis systems have become ever more easily available and more capable, so increasing efforts have been made to provide the user with remote sensing data basically in digital form. The fact that analog-to-digital conversion is now carried out in the space craft makes it possible for acquisition of these types of data. Presently, data preprocessing is carried out at central reception and/or archiving facilities and involves data navigation and registration, rectification, cleaning and primary calibration.

Data processing (satellites) includes data manipulation necessary or helpful for later scientific analysis and interpretation, but which the analyst or interpreter does not want to have to perform. Increasingly, data processing is being undertaken by central facilities. The major object of this activity is to present remote sensing data in manageable forms and quantities. Data analysis on the other hand entails inspections of the information content of the data set in its own terms, that is searches for important features and repetitive

patterns inherent in the remote sensing data themselves. Thus, the key element is feature recognition.

Data interpretation covers the assessment of the contents of remote sensing data sets through comparison with the nature and condition of the target, wherever possible assessed also by "in situ" observational information. Appropriate relationships, models and algorithms are often required for meaningful intercomparisons of these two different types of data. Results of interrelations observed in selected test areas for which both remote sensing and ground data are available (i.e. "training sets") are often prepared as the bases for dependent supervised classification of remote sensing data from conventional data-sparse areas.

In the absence of analyst-specified training data, unsupervised classifications are used instead. Here the search is for natural groupings inherent in the remote sensing data themselves, which then may be interpretable in terms of recognizable features or classes of features in the target areas. Two scenes of satellite data for Nyando River wetland areas were obtained. The scenes were found to cover the whole of the study area. The two scenes were joined to provide continuity. These data sets were recorded in February 1991. The hard copy data sets were interpreted using the unsupervised classification.

2.4. Mapping using Aerial Photographs

Hard copy of aerial photographs taken in 1961 was obtained. The photographs were of size 230 X 230 inches and monochrome (black and white). These were used to map the extent of the wetlands. The aerial photographs were interpreted using the methods of photo-interpretation. Mirror stereoscopes were used to aid in aerial photography interpretation and mapping wetland areas and other discernable features.

Preparation of the photographs

Two photographs of the same are taken at slightly different positions or stereo pairs, are required for the purpose of stereo-viewing using the mirror stereoscopes. Therefore two pairs of successively taken photographs for Nyando Wetland area with a forward overlap of 60% and a lateral overlap of 30% were obtained. The first two pairs were worked on so as to obtain the principal points. The principal point is where the drawn lines between opposing collimating marks intersect at the centre of the photograph whereas the collimating marks are those marks which are at the mid-point on each side of the photograph's edges. Therefore, the author joined the two opposite collimating marks by drawing a straight line from one end of the photograph to the other. Similarly, the remaining two collimating marks were also joined. Where the two straight lines intersected each other gave me the principal point of the first photograph.

The first principal point was designated as "A". The next task carried out involved transposing the principal point "A" to the second photograph. The land mark at principal point "A" in photograph one was identified in photograph two. In other words the principal point A' was transposed to photograph two. The land mark in photograph "A" was designated as A' in photograph two.

Viewing the Stereo-pair

The author unfolded the stereoscope and set up the instrument, then adjusted the nearer right leg by screwing it out to give the instrument stability. (This can be screwed in or out). Then the instrument was placed over the stereo-pairs that

had been arranged. The instrument was placed such that the line drawn between the points was seen in the left and right eyepieces without vertical displacement. This indicated that the line was parallel to a line running through optical axes of the eyepieces. Although the photographs should be seen in three dimensionally when viewed through the instrument's eyepieces, the distance between the principal points A and B were adjusted slightly so that the right and left images seemed to coincide exactly. Finally, the instrument was moved parallel to the reference line of the stereo pairs until the required area in the photographs was observed in the field of view. The magnifier knobs were manipulated to place bolt magnifiers into the lines of sight.

Selecting and Delineating Features

A transparent material large enough to cover the right photograph was placed on it and posted. A pencil was used to draw the features selected. The principal that guided the selection included the tone, pattern, shape, size. These were used to map the extent of the wetlands. The aerial photographs were interpreted using the methods of photo-interpretation. Mirror stereoscopes were used to aid in aerial photography interpretation and mapping wetland areas and other discernable features.

The principal point of photograph two was then found using the steps already described above. The principal point on photograph two was designated as B. Then, the principal point B in photograph two was transposed to photograph one and designated as B'. The author then re-arranged the stereo parts so that points A, B, A' and B' were lined up in this order on a straight line with the distance between points A and point A' being about 260mm. A glass proved convenient for this work. The following method may be found convenient too. Fix one end of a string, white string to the left edge of the desk or table which is being used, with the string about 50 cm longer than the top of the desk. Attach a weight to the right end of the string so that it will hang from the high edge of the top surface.

Mark the string, at points about 130mm distance in each direction from the centre of the desk, to indicate 260mm distance between points A and A' coincide the points A and A' to the signs marked on the string and then coincide points B and B' to the string. Tape the aerial photographs so that they will not move. When the stereoscope is already setup the stereo pairs may be arranged against the string, after first aligning the string properly to the mirror stereoscope.

3. Research Materials and Equipment

3.1. Topographical Maps and Aerial Photographs

Existing topographic map sheets were used in this study to aid in both image and photographic interpretation and as a means for orientation and confirmation of the features. The topographical sheet maps also assisted in obtaining actual ground control points and they were at scale 1:50,000 sheet 116/2 and 116/4 (Nyakach). Aerial photographs were also used to map out the Nyando wetlands as it was in 1961. Six photographs were used for this purpose.

3.2. Computer Software and Hardware

GIS software used for digitizing was Catalinx and the equipment for digitizing was an A0 Calcom Drawing Board III configured to work in stream mode. Arc View GIS software was used to compile, analyze manipulate and report the data relevant this study. To digitize the manual option was used and it involved the following procedure.

3.3. Binoculars and Prismatic Compass

While on the study area observation methods was used to ascertain the way wetlands are used. A pair of binoculars was used to observe the areas of the wetlands which were not accessible on foot. An orientation topographical sheet map was used to identify the various locations such as Korowe. A prismatic compass was also used in the field to give the north orientation.

3.4. Topographical Maps

Existing topographic map sheets were obtained and used to aid in both image and photographic interpretation and as a means for orientation and confirmation of the features. The top-sheets were of scale 1:50,000 sheet 116/2 and 116/4 (Nyakach).

3.5. Observation

While on the study area observation methods was used to ascertain the way wetlands are used. Ground photographs were also taken to show the state of the wetlands.

4. Data Analysis and Presentation

Data obtained was converted into digital format through the digitizer. Software used for data imputing included catalinx. The digital data was then exported to arc view where analysis was performed. Geographic Information Systems as a tool for the data analysis was used to obtain the results. Considering the technological methods to obtain satellite imagery and aerial photographs and the equipment and software used it can be concluded that the data used were authentic and that the sowing are unquestionable therefore the results of the study obtained are of high quality and sufficient to fulfil the study objectives.

5. Results and Discussion

5.1. Wetland Areas

Arc View has a module through which one can select and show the desired area from the land cover map and remain with the wetland areas. From the arc cover map already developed, Arc View was employed select the wetland area. The area was then printed out to report visually the area it covers.

Table 1: Land Covers, their Areas and Percentage of the Coverage

Landcover (1991)	Sum-Area (M2)	Percentage
Dykes	706683.93	0.43
Horticulture and cereal cultivation	11948618.23	7.43
Lake Victoria (Water body)	19287705.21	11.85
Nyando Major Wetlands	33307254.30	20.46
Open grassland	3217001.53	1.98
Settlement/Mixed cereal cultivation	80520925.99	49.47
Sugarcane cultivation	7239397.12	4.45
Wetland vegetation	683073.25	0.42
Wetlands	1553185.03	0.95
Wooded grassland	1344543.21	0.83
Horticulture and cereal cultivation	2970543.07	1.82
Total	162778930.87	100.00

6. Conclusion and Recommendations

The study sought to assess the change in size of the RN wetlands between 1961 and 1991. To meet the objective, GIS analysis was performed to make comparison of the two areas

between the two different dates. Remote sensing and GIS techniques provide useful scientific processes to map wetland areas. It was revealed that the wetlands have reduced in size and is continuously reducing. Therefore, the study calls for action in conservation.

The following recommendations are therefore made:

- a) Community participation
All development programmes are best achieved if the community is involved. Therefore all programs aimed at wetlands management should involve the local community who are the nearest to the problem area. The community should be encouraged to embrace the conservation efforts by provision of incentives such as rewarding them with a project such as a dispensary.
- b) Creating a buffer zone
A considerable area to be determined by the community and the authorities should be left to act as a protection to the fragile wetlands. Related to this a given zone should be allocated for the community needs so that the conservation efforts do not shut out the community completely.
- c) Appropriate policies and regulations is already enacted to protect the wetlands because of its values. So far a National Environmental Management Act, 1999 which commenced to be in force on 14th January 2000 is a relief, however a framework for enforcement need to be addressed.

7. References

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