ECOLOGICAL MANAGEMENT OF THE MAU CATCHMENT AREA AND IT'S IMPACT ON LAKE NAKURU NATIONAL PARK

M. Gichuhi
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: gichuhimw2@yahoo.com

Abstract
The purpose of this research is to evaluate the impact of human activities in the Mau catchment area and Lake Nakuru National Park. The increase in human population has led to increased pressure and diminishing of natural resources such as forests, grassland and water. This has led to conflicts over these resources. Developments in Nakuru town and other urban centers have contributed to pollution of Lake Nakuru National Park through the disposal of industrial and domestic wastes into the lake. These impacts are manifested through erosion, high silt loads, agro-chemicals, urbanization, degradation, deforestation, encroachment into sensitive habitats and impacts of climate change.

Data collection was carried out using interviews and questionnaires .The population size was 4960 and the derived sample size was 138. The random and purposeful sampling was used for data collection. The Statistical Package for Social Sciences (SPSS) statistical software was used in the analysis.

The results indicated that natural resources were diminishing due to the practiced land-uses and population increase. This has led to an increased demand for the scarce resources leading to overexploitation and to human - human and human - wildlife conflict. This has a negative impact on Lake Nakuru since rivers were drying up due to deforestation, sedimentation, sand harvesting, waste water, storm water drainage, solid wastes which have polluted the lake. Most of the rivers draining into the lake have dried up during the dry seasons due to deforestation of the Mau Catchment area.

There is the need for concerted efforts to manage the Mau catchment area sustainably through conservation initiatives, sustainable farming, reforestation, agro- forestry, energy, and water and soil conservation methods. Farmers should be encouraged to increase tree cover through carbon trading.

Key words: Ecosystem, catchment, natural resources, conservation, re-forestation, waste management, conflicts

1.0 Introduction

The Mau forest complex is Kenya's largest canopy forest ecosystem and the single most important water catchment in the Rift valley and western Kenya. This water tower covers over 400,000 Ha and is the largest of the 'five water towers' of Kenya, (UNEP, 2009). The lake and the catchment area are rich in a variety of habitats. The Upland forest is the main water catchment area; it is rich in forest products, and biodiversity. The catchment has multiple land use types ranging from pastoralism to large-scale commercial farms and ranches in the last 100 yrs. (Erick, *et al*, 2006). The rivers flowing from the catchment area provide a lifeline for major tourism areas including Maasai Maara National Reserve and Lake Nakuru National Park.

There has been land use changes associated with increasing human population, which has led to increased pressure on available natural resources especially illegal logging and settlement in the forest reserve. The decrease in forest cover and increased soil erosion has impacted negatively on rivers and the lake through sedimentation and drying up, (Plates 1, 2, 3). Lake Nakuru National Park has is a unique ecosystem containing a variety of habitats and is home to millions of flamingoes. The lake is alkaline as the catchment rocks contain a high proportion of alkaline minerals that are leached into the lake. It also has the largest Euphorbia forest stand in East Africa and a wildlife rich savannah and highland moist forest.

The lake and the catchment area are rich in a variety of habitats. The Upland forest is the main water catchment area which is rich in forest products and biodiversity. The catchment has multiple land use types such as pastoralism to large-scale commercial farms, Plates 4&5.

The area is in a rich agricultural region with a diversity of agricultural activities. Other types of land uses include urban and industrial centers, ranching, forestry and wildlife conservation. It is a closed basin where the physical and ecological processes are interlinked and interdependent.

Lake Nakuru is linked to its catchment through ecological, hydrological and socio-economic linkages, (KWS, 2002), Fig.1.

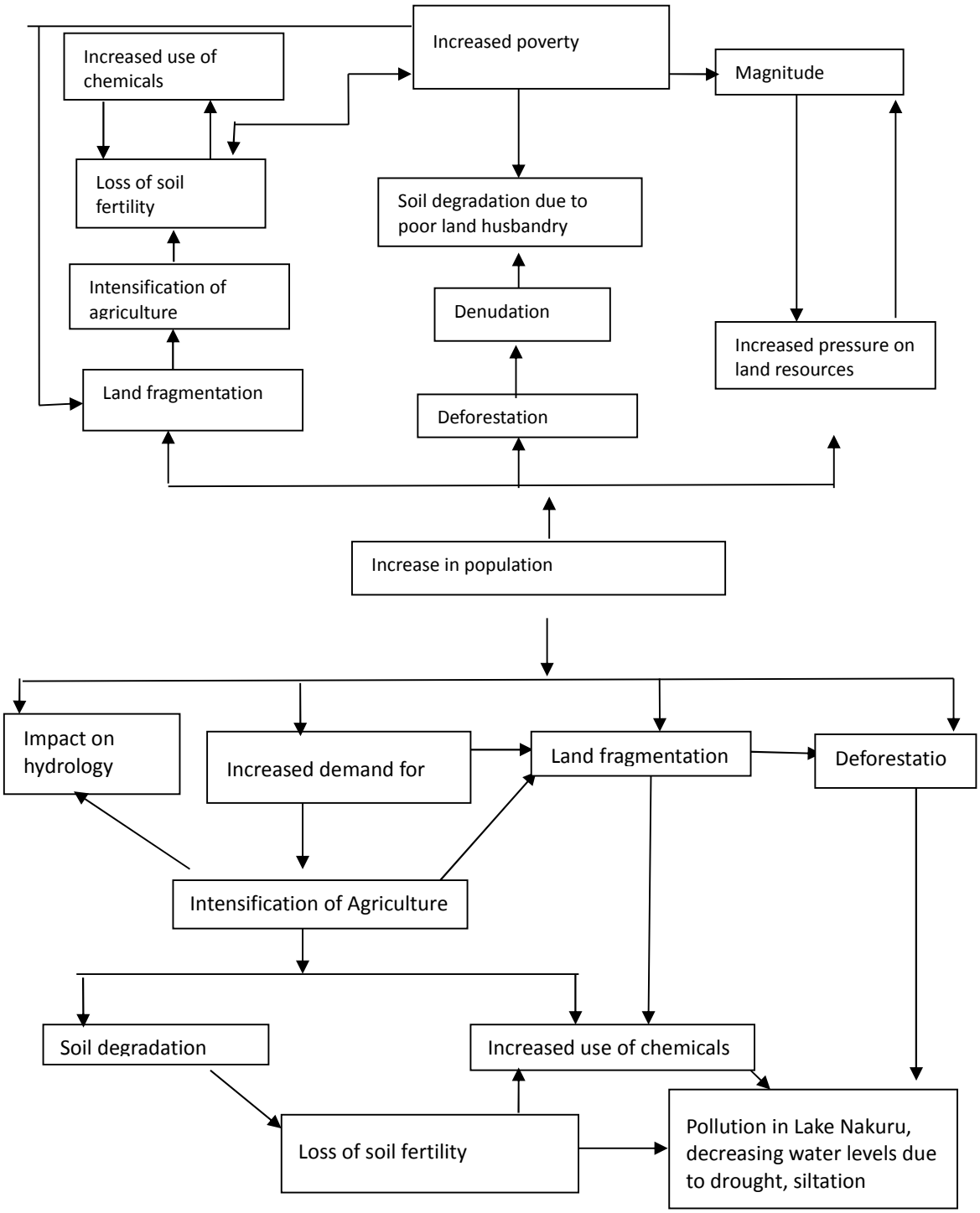

Figure1. Ecological, Hydrological and Socio-economic linkages, Source: KWS 2002

1.1 Study Area

The Mau Forest Complex is the largest closed-canopy montane ecosystem in Eastern Africa.

It encompasses seven forest blocks within the Mau Narok, Maasai Mau, Eastern Mau, Western Mau, Southern Mau, South West Mau and Transmara regions. The area is thus the largest water tower in the region, being the main catchment area for 12 rivers draining into Lake Baringo, Lake Nakuru, Lake Turkana, Lake Natron and the Trans-boundary Lake Victoria. In the past three decades the Mau Forest Complex (MFC) has undergone significant land use changes due to increased human population demanding land for settlement and subsistence agriculture. The encroachment has led to drastic and considerable land fragmentation, deforestation of the headwater catchments and destruction of wetlands previously existing within the fertile upstream parts (Olang and Kundu, 2011).

Lake Nakuru National Park situated in the Gregorian portion of Eastern Rift Valley in Kenya is located between 36 ^{0} 04'-36 07' E and 0 19'- 0 24' S. It is bordered to the north by Menengai Crater, South by Eburru mountain ridges, East by Dundori and Bahati Uplands and to the West by Mau Escarpment. This is the largest of the five "water towers" of Kenya. Its montane forests are important part of water-flow regulation, flood mitigation, water storage, groundwater recharge, water purification, micro-climate regulation, and reduced soil erosion and siltation (UNEP, 2009). It is the source of rivers Makalia, Enderit, Njoro, Larmudiac and Ngosur that discharge into Lake Nakuru (KWS, 2002). The lake is highly alkaline as the catchment rocks contain high proportion of alkaline minerals that are leached into the lake. At the same time high evaporation and low precipitation have turned the lake alkaline and naturally hyper eutrophic. There are a variety of soils in the catchment area ranging from volcanic soils, lacustrine deposits, loams, sandy and clay soils, all supporting different types of vegetation. The lake bottom has been filled with weathered material from the catchment area.

1.2 Hydrology

Lake Nakuru lies at 1,759 m above sea level and it is one of the highest points in the Central part of the Rift Valley. As a result underground inflows into the lake through the fault line system are minimal. The hydrological conditions in Lake Nakuru indicate that water levels are dependent on catchment supply through rivers such as Rivers Makalia, Nderit, Njoro from the Mau catchment. There are also some springs within the park and waste water from Nakuru Municipality. The replacement of forest and woodland by depletive subsistence agriculture has caused massive inflow of sediments into the nearby Lakes. The rising nutrient levels from the sediment have affected the growth of blue-green algae (spirulina platensis), which forms the main food for flamingo birds, known to be a major touristic attraction for Lake Nakuru (Olang and Kundu, 2011).

1.3 Vegetation

The Mau Forests Complex comprises a diversity of forest types and hosts many indigenous plant species. Although the vegetation pattern is complex, there is a broad altitudinal zonation from west to east: lower montane forest below 2,300 metres; mixed Bamboo /forest / grassland vegetation above 2,300 metres; and finally higher altitude Juniperus -Podocarpus - Olea forest near the top of the Mau Escarpment (Prime Minister's Task Force,2009).

The general vegetationof Lake Nakuru National park comprises of montane forests in the upper catchment, grasslands and scrublands at the lower parts of the basin with yellow acacia (Acacia *Xanthophlea*), along the lakeshore and floodplains. Refer to Plate 8. Riverine vegetation along the river courses gives way to dry upland forest in the slopes of the highlands. Major forests in the park include Euphorbia forests, Olea forest (Olive forest) to the South west of the park.

The Mau water tower covers over 400,000 ha and is the largest of the 'five water towers' of Kenya. The forests provide other major environmental services including nutrient cycling and soil formation. In addition, their role in carbon sequestration makes Mau forest globally important for mitigating climate change, Plate 9. The deforestation of this catchment area has led to negative ecological and hydrological changes especially on the water flow regime for Sondu, Mara, Molo,Naishi, Makalia, Nderit and Njoro rivers, (Scott *et al*, 2003). In Kenya, most forest areas are now under the management of the Kenya Forest Service (KFS), which has made substantial steps towards addressing the degradation and deforestation threat to all the major water towers. Among the steps is the new forest policy and law, which were promulgated in 2005 (Olang and Kundu, 2011).

1.4 Climate

Climate ranges from cold to hot and humid weather conditions. There are also arid and semi-arid conditions in the lower parts of the Mau catchment area. The mean annual rainfall averages 750 mm, falling within the periods of November to December and April to May. The total annual rainfall increases and becomes more certain and dependable with increasing altitude.

1.5 Human Activities

The high population in the catchment's area, and the mixed farming practiced have contributed to siltation and pollution of the lake. The continued abstraction of water from rivers and sand harvesting has drastically affected the level of the lake. There is deforestation to clear land for cultivation, construction and charcoal burning. Refer to plates 10, 11 and 12. Nakuru has grown to a large industrial and commercial center with a growth rate of 10%. It produces human, domestic and industrial waste like any other urban centre. Waste handling and treatment facilities have not kept pace with the rate of production leading to environmental pollution. Refer to plates 13 and 14.

2.0 Materials and Methods

The overall respondent data was analyzed using the Statistical Package for the Social Sciences (SPSS 9.0). Summary statistics provided variable frequencies, means, variance, standard deviations and missing entries for the questionnaires. The process of data analysis involved checking of erroneous data and making corrections. In addition, data was transformed by coding, defining variable types, value labels, defining missing values and creating tables for frequencies. This was followed by checking the quality of data using frequency counts, descriptive statistics and measures of associations and relationships.

Primary and secondary data were used in this study. Secondary data was gathered from libraries, research institutions, journals, census data, project proposals, conservation projects and websites. Household data was obtained from the 1999 population census from the Kenya National Bureau of Statistics KNBS (2000) and random sampling and purposeful sampling was used to collect data. Households were used as research units and the head of the household was the main respondent.

Data collection techniques involved the use of questionnaires, interviews, observation and existing secondary data. The questionnaires were structured with closed ended and checklist options for household surveys. Direct observations were used to clarify information from the respondents. Research assistants from the local area were preferred due to their knowledge of the local area. They were subsequently trained on the contents of the questionnaires.

The household questionnaires included closed-ended questions on community characteristics such as sex of head of household, family set up, level of education, marital status and means of sustaining the family. The key themes for resource access and sharing were; type of land use practiced, land ownership, types of resources, sharing of resources and diminishing resources. Equally, the variables on public benefits and costs associated with conservation areas were; problems experienced from wild animals, types of conflicts, type of animal, conservation benefits and expected solutions. Likewise, community involvement in conservation management was assessed using conservation of resources, management of environmental resources, stakeholder input and environmental awareness.

Quantitative method of data collection and analysis was used to analyze primary data. Primary data using questionnaires and interviews was used to assess the communities' opinions on the use of the natural resources. Random and purposeful sampling was used to select respondents in the catchment area and Lake Nakuru Park neighborhood. The population size of the respondents was 4960 cases. Household surveys and sampling formula was as used by Kothari (2004);

$$N = \frac{\frac{P(1-P)}{A^2}}{\frac{Z^2}{}} + P(1-P)N/R$$

N =0.5(1-0.5)

0.05 +0.5(1- 0.5) n = 138

1.96*4960/100%

Sample size = 138

The sample size used was 100 cases derived from random and purposeful sampling. The following variables were used; type of resources, resource conflicts, type of conflict, stakeholder communication, diminishing resources, community welfare, conservancy benefits, best land use, conservation of resources, knowledge of managing resources. The Statistical Package for Social Sciences (SPSS) statistical software was used in the analysis of variables using Pearson's Chi square and Pearson's Correlations. The process of data analysis involved checking of erroneous data and making corrections. In addition, data was transformed by coding, defining variable types, value labels, defining missing values and creating tables for frequencies. This was followed by checking the quality of data using frequency counts, descriptive statistics and measures of associations and relationships.

3.0 Results

3.1 Inferential Statistics using Pearson's Correlation Test

The results of Pearson's Correlation (r) of the following variables; type of conflict and stakeholder communication, diminishing resources, community welfare and stakeholder communication, best land use and conservancy benefits, and conservancy benefits and best land use, stakeholder communication, type of conflict and best land use were as follows indicated that there was no significant correlation noted between the practiced land use and conservation of the environment (r=0.072, p=0.475, n=100). Therefore the Ho: type of practiced land use and conservation of the environment is rejected and the alternative accepted. The respondents do not relate the type of land use they practice and conservation of environmental resources. There is no significant correlation between practiced land use and expected solutions (r=-.067, p=0.509, n=100).There is a significant correlation between practiced land use and the best land use (r=0.345, p=0.000, n=100) at 0.01 level. This is irrespective of whether the practiced land use affects the sustainability of the available environmental resources.

Conservation of the environment and expected solutions had a significant correlation (r=0.396, p=0.000, n=100) at 0.01 level. Best land use also had no significant correlation with conservation of the environment(r=-.019, p=0.853, n=100). Community welfare had no significant correlation with practiced land use (r=-.179, p=0.075, n=100).There is no significant correlation between type of

conflict and the best land use for the area (r=-.128, p=0.206, n=100.) Type of conflict and Stakeholder communication had a significant correlation of (r= 0.219, p=0.028, n=100) at 0.05 significant level. This indicates that if the park management communicates with the community the conflicts would reduce because they will appreciate the park and wildlife as a resource.

Stakeholder communication had a significant correlation with the identification of diminishing resources (r=0.246, p=0.014, n=100) at 0.05 level, and especially the reduction of forest cover with(r=0.53, p=0.000, n=100) at 0.01 level. The type of conflict and know benefits of managing resources sustainably had no significant correlation (r=-.019, p=0.852, n= 100). Conservancy benefits had a significant correlation with the type of conflict (r=-.329, p=0.001, n=100) at 0.01 level. Resource management and know benefits of managing resources sustainably had a correlation of (r=0.398, p=0.000, n=100), at 0.001 level (2-tailed). There was no significant correlation between resource management and conservancy benefits (r=-.142, p=0.162, n=100). The variable on identification of diminishing resources and know benefits of managing resources had a significant correlation noted as (r=0.374, p=0.000, n=100), at 0.01 level. Stakeholder communication and expected solutions r=-.379, P=0.000 and N=100) shows that there is a significant correlation. There is a significant correlation between expected solutions and type of conflict (r=-.229, p=0.022, n=100). There is a significant correlation between conservancy benefits and community welfare (r=0.319, p=0.001, n=100) at 0.01 level.

There is no significant correlation between the type of animal and conservation of the environment (r=-.111, p=0.271, n=100). There is a significant correlation between resource management and practiced land use (r=-.244, p=.0015) at 0.05 level. There is a significant correlation between the best land use and resource management(r=0.369, p=0.000, n=100). There is a correlation between stakeholder communication and conservancy benefits(r=0.230, p=0.021, n=100) at 0.05 level. Conservancy benefits and resource conflicts (r=0.314, p=0.001, n=100) at 0.01 level. Conservation knowledge had a significant correlation with Conservancy benefits(r=0.200, p=0.046, n=100) at 0.01 level.

There is a significant correlation between diminishing resources and know benefits of managing resources(r=0.374, p=0.000, n=100) at 0.01 level. Stakeholder communication had a correlation with benefits of managing resources(r=0.398, p=0.000, n=100) at 0.01 level. Type of conflict and community welfare (r=0.261, p=0.009, n=100) at 0.01 level. Type of conflict and conservation of the environment (r=0.246, p=0.014, n=100) at 0.05 level. Expected solutions and type of conflict had a correlation (r=-.229, p=0.022, n=100) at 0.05 level. Expected solutions and conservation knowledge(r=-.281, p=0.005, n=100) at 0.01 level .Know benefits of managing resources and expected solutions (r=-.304, p=0.002, n=100) at 0.01 level. Conservancy benefits and community view on parks has a correlation (r=0.330, p=0.001, n=100) at 0.01 level.

3.2 Inferential Statistics using Pearson Chi square Test

The following variables were used in the chi-square test to check for the degree of association. The chi square test shows that the best land use can be associated with resource management (x^2=73.200, p-value=0.000<0.005), practiced land use had an association with community view on national parks(x^2=136.600, p-value=0.000<0.005). There was an association between resource conflicts and practiced land use(x^2=136.600, p-value=0.000<0.005), practiced land use had an association with conservancy benefits (x^2=77.100, p-value=0.000<0.005). Practiced land use had an association with conservation of the environment (x^2=5.760, p-value=0.016<0.005).

Benefits of managing resources sustainably has an association with practiced land use (x^2=38.440, p-value=0.000<0.005), type of land use practiced had an association with the type of conflict (x^2=177.800, p-value 0.000 <0.05), practiced land use has an association with the type of animal (x^2 =165.680, p-value 0.000 <0.05). Conservancy benefits and resource management (x^2=77.100, p-value0.000 <0.05),Conservancy benefits has an association with community welfare x^2= 10.240,p-value 0.001 <0.05), Community welfare and stakeholder communication (x^2= 57.980, p-value 0.000<0.05), there is an association between community welfare and visitor facilities (x^2= 79.280, p-value 0.000 <0.05), stakeholder communication has an association with education activities developed for stakeholders (x^2=36.000, p-value 0.000 <0.05). Diminishing resources and type of land use had no association(x^2= 3.240, p-value 0.072 >0.05), Expected solutions and practiced land use had no association(x^2= 73.120,p-value 0.000<0.05),Community view and resource management had an association(x^2= 10.240,p-value 0.001 <0.05),type of conflict had an association with diminishing resources (x^2= 177.800, p-value 0.000 <0.05), Best land use had an association with conservation of the environment (x^2= 73.200, p-value 0.000 <0.05). Best land use had an association with the type of animal (x^2= 165.680, p-value 0.000 <0.05).

4.0 Discussions

20% of respondents in the Mau catchment area practiced farming as a means of livelihood while 53% of the respondents identified grasslands, forests, and rivers as the main types of resources. 81% of the respondents indicated that resources were not well distributed, 59% of the respondents noted a reduction in forest cover. Thirty seven percent of the respondents experienced crop destruction from the wild animals. 53% of the respondents suffered from human - wildlife conflicts. 53% of the respondents preferred compensation for damages caused by wildlife attacks.

The Pearson's Correlation and Chi square results indicate that the communities living in the Mau catchment area noted that population increase and diminishing resources have led to human encroachment into the forest reserve. There was also an indication that communities knew the benefits of managing natural resources sustainably using traditional conservation knowledge. Lake Nakuru National Park

was viewed negatively due to wildlife attacks on people, livestock and crops. The Ogiek living in the Mau forest indicated that they should be allowed to continue living in the forest since they have always used traditional methods of forest conservation.

Several of the variables analyzed had a significant relationship or an association indicating that the communities were aware of the environmental resources and the impact of over-exploiting the same leading to conflicts over the diminishing resources. The results indicated that natural resources were diminishing due to the practiced land-uses and population increase. This has led to an increased demand for the scarce resources leading to overexploitation and human-human and human-wildlife conflict.

5.0 Conclusions

The focus of discussion was on the management of conservation areas, resource access and sharing, and community involvement in conservation management. The increase in human population, type of land use and the scarcity of natural resources has contributed to the misuse and overexploitation of the Mau catchment area. The key findings indicated that farming was the preferred type of land use followed by livestock keeping and commercial activities. There was an indication of high rate of human - wildlife conflicts in form of crop destruction and livestock deaths. The diminishing of the available resources such as forests, grasslands, rangeland, water and wetlands also aggravated conflicts over resources.

The activities in the Mau catchment that affect Lake Nakuru National Park emanate from different land uses and land ownership, land settlement, livestock and crop farming, forestry, urban development and water use. The negative impacts arising from human activities are deforestation, forest excision, farming and settlement in the catchment area. Consequently this leads to siltation due to erosion and rivers drying up downstream during the dry season affecting the park. The overall degree of association indicated that the type of land use practiced in the catchment area and diminishing resources were the key factors that contributed to human - wildlife and human - human conflicts over resources. The respondents also experienced conflicts over grass and water. The conservation area management should immediately compensate communities for crops destroyed by wild animals, livestock and human deaths. Other conflict resolution measures such as sharing of resources could improve the ratings of conservation areas by the communities. The education awareness programs and management plans should be fully implemented.

6.0 Recommendations

There is the need to improve the ecological management of Mau catchment through reforestation, rehabilitation of degraded areas, implementation of sound pollution control methods, controlled sand harvesting, use of scientifically based sound wildlife conservation methods and involve all communities and stakeholders with clear defined roles and responsibilities. Sustainable resource utilization, development and use of alternative and renewable resources should be encouraged. The enforcement of various environmental acts, codes and regulations could lead to environmental protection. The Kenya Government through the relevant Ministries and international conservation agencies should integrate their activities to conserve Mau water tower and Lake Nakuru National Park.

Acknowledgements

I wish to appreciate and thank Mr. Jerome M. Mwanzia of the Kenya Forestry Services for his enormous contribution and support accorded thereto. I also thank Ms. Evelyn Silali of Lake Nakuru National Park for assisting in data collection in the park and the larger Mau Ecosystem.

I also thank the Management of Kenya Wildlife Services and the staff of Lake Nakuru National Park for their assistance and support.

References

Akotsi.E,F.N, Gachanja.M& Ndirangu.J.K.(Nov.2006) *Changes in Forest Cover in Kenya's Five," Water Towers",2003-2005*,UNEP,KFWG,Royal Netherlands Embassy.,pg7.

Honeck.J.H & Smith.W.T, (1992).*Watershed Ecosystem Analysis as basis for multiple-Use Management of Eastern Forests,* USDA Forest Service, North Carolina.

Kenya Wildlife Services,(2002).*Lake Nakuru Integrated Ecosystem Management Plan, 2002-2012,* Pgs 26-47.

Miller.S.N & Shivoga.W, (n.d.).*Sustainable Management of Watersheds,The River Njoro, Kenya*, Egerton University and University of Wyoming.

Nkako.F.M, Lambrechts.C, Gachanja.M, & Woodley.B,(2005).*Mau Forest Status Report*. UNEP, Pgs 5, 14-21.

Olang.O.L & Kundu.P.(2011). Land Degradation of the Mau Forest Complex in Eastern Africa: A Review for Management and Restoration Planning DOI: 10.5772/28532 ISBN 978-953-307-724-6, Published: November 4, 2011 under CC BY 3.0 license

Prime Minister's Task Force, (2009). Report of the Prime Minister's Task Force on the conservation of the Mau Forests Complex, Nairobi, Kenya.

Udhali Thongwe.U, (Nov. 2002).*Participatory Watershed Management for Sustainable Forest Management and Water Resources Conservation.* Royal Forest Department, Bangkok, Thailand.

UNEP,(2009). "*Kenya: Atlas of Our Changing Environment*". Pgs 8-13

UNEP, (May 2008). *Mau Complex under Siege, Values and threats*.

www.gtbay.org, The Watershed Center, Grand Traverse Bay, August, 2011

Appendices

Appendix 1

Acronyms

CBO Community Based Organizations
CSR Corporate Social Responsibility
3Rs' Reduce, Recycle, Reuse
EMCA Environmental Coordination and Management Act
ISO International Organization for standardization
KFS Kenya Forestry Service
KFWG Kenya Forestry Working Group
KWS Kenya Wildlife Service
NGO Non-Governmental Organizations
UNEP United Nations Environmental Program

Appendix 2: Plates

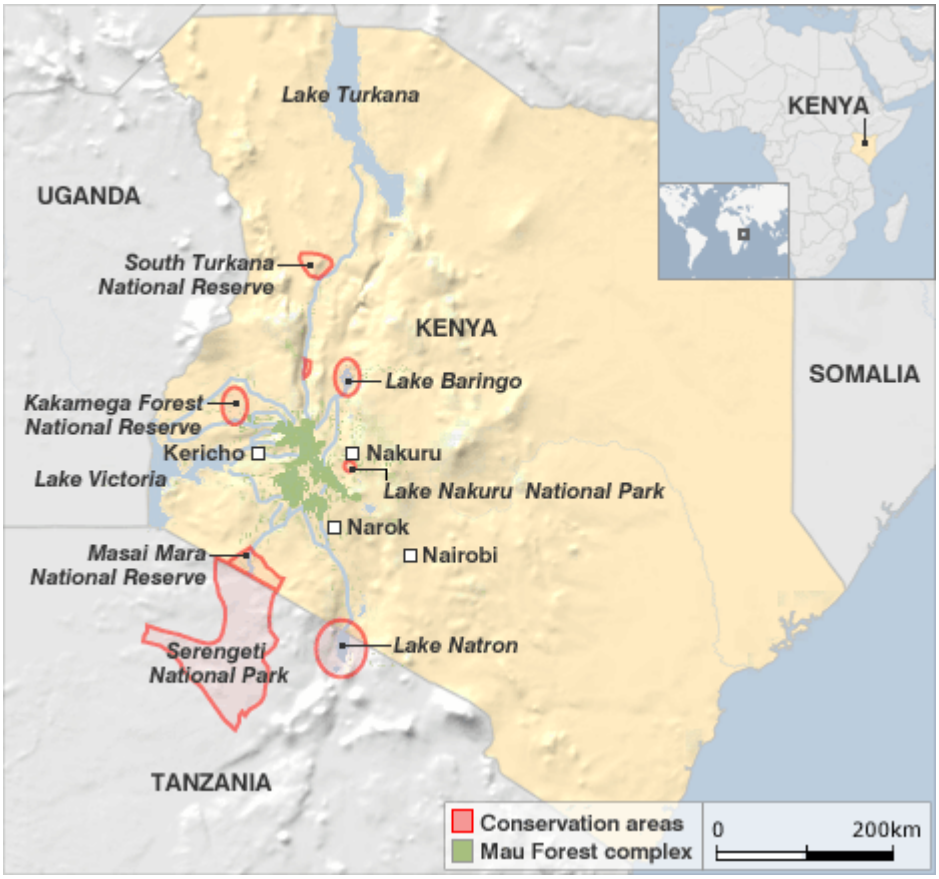

Plate1 Location of Mau Catchment area (Source: BBC News, 2011)

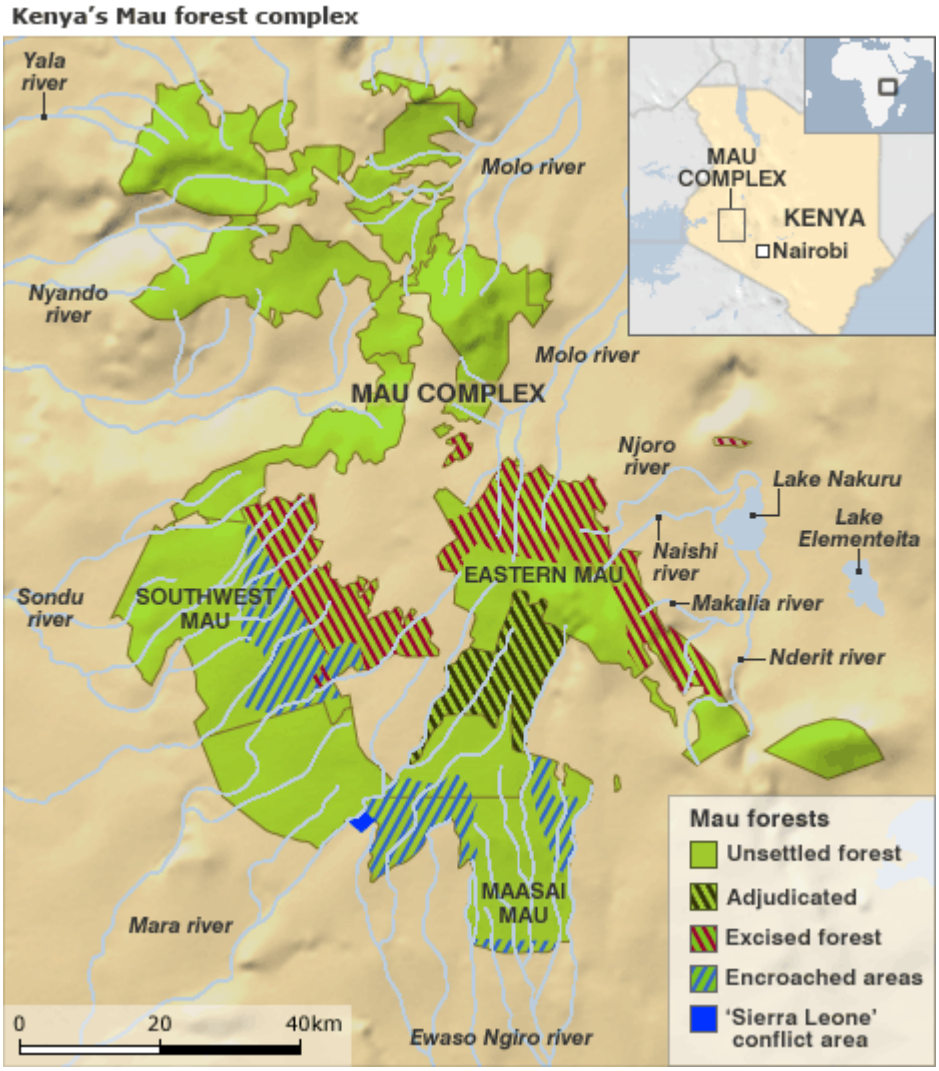

Plate 2: Mau Complex (BBC News, 2011)

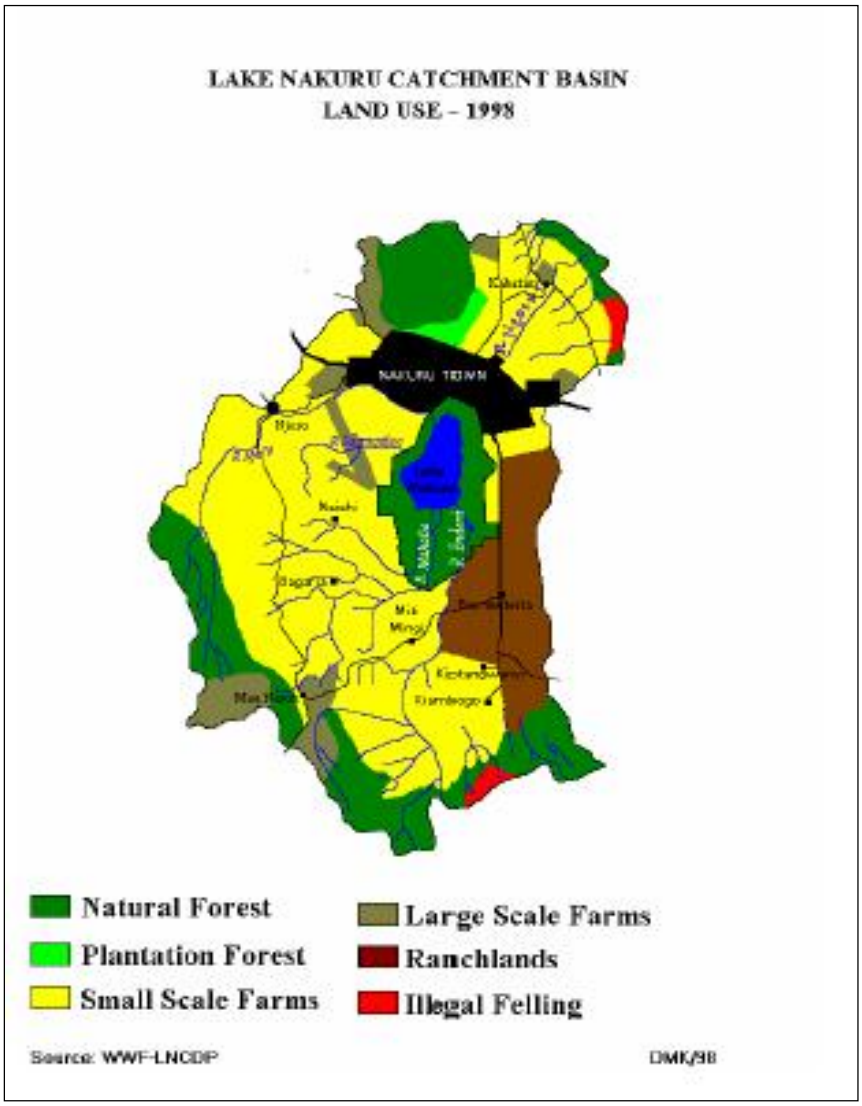

Plate 3: Lake Nakuru Catchment Basin: Land use-1998,(Source: KWS, 2002)

Plate 4: Bird's eye view of Lake Nakuru from Baboon Cliff

Plate 5: Flamingoes in Lake Nakuru

Plate 6: Silting in river Makalia during the rainy season

Plate 7: River Njoro during the dry season, Zebra and Buffalo drinking water in the drying river bed

Plate 8: Acacia Xanthophloea in Lake Nakuru National park

Plate 9: Deforestation of Mau Catchment area

Plate 10: Livestock Keeping and Farming at the Mau Catchment

P*late 11: Illegal Charcoal burning in the Mau Forest*

Plate 12: Sand Harvesting in part of the Mau Catchment area

Plate 13: Sewage and storm water draining into Lake Nakuru

Plate 14: Nakuru municipality Solid waste disposal