

Land Use Effects on Lake Ol'bolossat Watershed Conservation, Nyandarua County



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Abstract

Despite their importance, wetlands have remained unprotected and they are exploited beyond what they can endure. The main objective of the study was to establish the land use effects on conservation of the Lake Ol'Bolossat watershed. The study was conducted in 10 villages, by systematic random sampling of 60 households and purposive sampling of key institutions such as KWS, KFS, NEMA and KALRO. Household questionnaires were issued to sample households, while interviews were held to establish environment issues in the study area. Direct observation transects walks and photography revealed that there was human encroachment, crop and livestock production and quarrying in the basin. Lake and runoff water were analyzed for both physical and chemical parameters. The samples were analyzed for pH, Mn, COD, TDS, TSS, K, P, Nitrates, EC, Total Nitrogen and Ammonia.

The results showed that runoff water was polluted before it flowed into the lake. The concentration of minerals in lake water was lower than that of the runoff water, an indication that contamination originated from surrounding farms. Water usage and proximity from the lake were significantly different at 95% confidence interval, hence most members of the community near the watershed rely directly on lake. Interviews indicated that the wetland degradation such as water pollution was based on land utilization. The study established that watershed conservation is affected by land use by the neighboring communities. Agrochemicals (30%), clearing vegetation (7%), water abstraction (16%), quarrying (3%), land fragmentation (12%), population growth (11%), poverty (12%) and others (9%) impacted the lake negatively. Water abstraction, drying of bore holes and land use were significantly different at 95% confidence interval. It is recommended that conservation of the lake ought to be enhanced through community participation and other stakeholders to manage, restore and preserve Lake Ol'Bolossat catchment.

Keywords: Conservation; Land use; Water quality and Watershed

Introduction

Globally, the wetlands cover about 26% of the earth's surface and in Kenya, they cover about 2-3% of her land surface, [1]. Seemingly small geographic extent, wetlands provide some of the most critical ecosystem services to many communities in the rural areas and are indispensable to the very survival, health and welfare of human beings and biodiversity. They are crucial in attainment of the MDGs and the vision 2030 goals. They control floods by soaking up and storing excess water [2]. The wetlands have been recognized as world heritage sites since the convention on wetlands was adopted in 1971 in Iranian city of Ramsar. Wetlands are areas of marsh, fen, peat, or water, whether natural or artificial, permanent or temporal, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceed 6metres [3].

Wetlands are highly productive ecosystems being only second to the tropical rainforests. Wetlands perform many func-

tions that maintain the ecological integrity of the systems and provide many vital services that are important for the general public such as agriculture, tourism, industry, and biodiversity conservation, social economic and cultural activities. Kenya has a variety of wetlands that stretch from coastal and marine wetlands to inland freshwater lakes, rivers, dams and swamps as well as the saline lakes of the rift valley system, constructed wetlands in irrigation schemes and sewerage treatment systems and the mountain bogs, peat and glacier lakes (EMCA).

However, due to lack of effective management mechanisms and proper appreciation of their true worth, wetlands have been subjected to severe pressure and through rapid unsustainable activities, conversion and over-exploitation of their resources at an alarming pace. The pressures to wetlands have been exacerbated by catchment degradation and pollution leading to proliferation of invasive species. The results have been detrimental

and even catastrophic in some areas of the country. For example, flash floods in western Kenya have become more common, severe and destructive as there are no wetlands to hold back any massive overland flow, leading to loss of property, destruction of infrastructure and damage to crops [4]. The Kenya government has recognized the importance of wetlands and their contribution to her gross domestic product.

The original inhabitants of the study area were Masaai pastoralists and the land belonged to the community as there was no individual land ownership. Crop farming was done on very small scale without use of chemicals. The pastoralists used live-stock for meat and did not harm wild animals [5]. The rules were centered on the preservation of sacred areas for traditional rituals and not for commercial benefits [6]. Currently, the dominant community members are the Kikuyu and they have converted part of the wetland into agricultural farms. Lake Ol'Bolessat is a high altitude wetland located in Satima escarpment where streams and springs that feed lake, flow from the Aberdare Ranges through Satima escarpments and pass across farms. The farming practices lead to Lake Siltation and landslides. Soils eroded from the neighboring farms reduces the water storage capacity of the lake. The lake water is moderately saline but fresh water from springs and streams dilute the water before it is discharged into Ewaso Narok River which exits the lake in the north. Kenya has an obligation to regulate land use for sustainability of wetlands, G.O.K (2009). However, through county environmental action plan (CEAP), National Environment Management Authority is making policies in collaboration with community to conserve the Lake.

Despite their valuable functions, wetland resources are often regarded as wasteland and are degraded through conversion to agricultural, settlement and industrial development, hence deterioration of the environment quality and little or no concern has been shown in conservation of the same. Sustainability of Lake Ol'Bolessat is threatened by the land use transformation resulting to loss of ecologically important species such as pollinators and biological control agents, [2]. The state of equilibrium between various entities has been disturbed and disharmony has resulted from lack of integration between conservation and utilization of natural resources, ACCORD (2002).

There is an urgent need, therefore, to step up management interventions in order to reverse the negative trends. The study sought to reveal the negative land use impacts in the area and hence a critical need for improved land uses planning to curtail further decline of Lake Ol'Bolessat. Although watershed degradation processes may occur without human interference, Stocking & Niamh (2000), accelerated degradation is commonly caused as a result of human intervention in the environment. Human induced factors causing deterioration of watersheds (are such as population growth and urbanization, poverty, overgrazing, pollution, biodiversity, erosion and land use changes) [6-8].

Socio-economic factors, including poverty, land fragmentation; low standard of living and earning are cited as drivers con-

tributing to an increased risk of watersheds, [9] due to differences in land uses. Land ownership influences socio-economic and political position of different groups of people. Land issues and conflicts occurs and are related to poverty, inequality and land reformation processes. Contestations over land are most noticeable among the poor, who lack alternative means of supporting their livelihoods, UNDP (2006), therefore lack of resources conservation. Transition from forest to another agricultural use leads to significant impact on topsoil resistance and resilience [10]. For most wetlands, soil erosion by water is the most common process causing sedimentation. There is a distinct linkage between erosion and watershed conservation, and these are accelerated by deforestation, overgrazing, and the cultivation of unsuitable land [11].

Lake Ol'Bolessat watershed has been affected by anthropic disturbances [12]. In the headwater catchments of the central Kenya, a prevalent cause of land degradation is unplanned deforestation to allow for human settlements and subsistent agriculture. In the highlands of Nyandarua, the ubiquitous land-use changes are believed to be the major cause of the dwindling volumes of Lake Ol'Bolessat, which has recently been declared an endangered water body by the regional government of Kenya. So far, few studies have been carried out on the spatio-temporal lands cover changes possibly affecting the size of Lake Ol'Bolessat largely hence lack of reliable in-situ data. The largest herbivores in the basin are the hippopotamuses. The cattle grazing in the basin are abundant in the dry season. Hippopotamus population density is 3.6 animals per Km². which is the highest in Kenya. The grazing activities influence the structure and composition of the natural vegetation which supports many herbivores and grasshoppers. Continued overgrazing maintains a low grass biomass. Trampling by animals affects ground nesting birds negatively. The other water animals include waterfowls, ducks and geese which are indicators of environmental quality. The areas with high concentration of different species of birds are also rich in diversity of other animal species as well.

Human activities affect the water availability by increasing storage capacity and by draining wetlands, [13]. The natural input to sub surface water is from rivers and streams. Basic household water requirement is estimated at solicitors/person/day. The environmental usage is non-consumptive, but it reduces water availability for other purposes. Recreation water is mostly found in reservoirs and it is required in small amounts. The Ol'Bolessat catchment area includes springs and streams which feed the lake and support livelihoods, but the lake is characterized by freshwater scarcity supposedly due to climate change and high evapotranspiration [14]. Accumulated of organic matter and silt from the surrounding farmland has contributed to water pollution. The water level fluctuates from zero to 2.5metres depending on the rainfall, surface run off and seepage from the basin. There is domestic and agricultural pollution due to unsustainable farming practices which lead to occurrence of waterborne diseases [5].

According to the forest Act 2005, KFS has the responsibility of managing Kenyan Forest. The law allows for collaboration and participation of the local community living adjacent to the forest in conservation of the forest in question. In return the community earns a living through extraction of non-wood products. The use of agrochemicals has led to bioaccumulation in fish and pose health risk to human as well as fish death and causes extinction of some species. In 1992 the Fisheries department established that turbidity of Lake Ol' Bolossat was not suitable for fresh water fish though mud fish could do well in those conditions. Habitat loss and degradation ruin the fisheries through water abstraction, removal of vegetation for development and agriculture. Communally owned resources experience problems when being shared such as unequal sharing of resources, dissimilar priorities, location of the resource, dissimilar cultures and unequal representation in the management [15].

Generally, the region of Lake Ol' Bolossat has a history of colonial settlements when the major land uses were large scale livestock rearing and crop production. In the recent past however, the area has gone through considerable land use transformations under the national settlement fund trustees, resulting into significant land subdivision and fragmentation, especially after 1993. Presently, the majority living in the area are small scale farmers who grow subsistent crops and rear domestic livestock on land parcels ranging from 0.5 to 8 acres. The human population density of the area is approximately 202 per Km².

General Objective

It was to establish the land use effects on conservation of the Lake Ol' Bolossat watershed.

The specific objectives were:

- i. To identify the key land uses by the community affecting Ol' Bolossat catchment area conservation
- ii. To analyze the water quality of the lake
- iii. To suggest the possible preventive and resolution options for the conservation of the watershed.

Research Hypothesis

The land uses in the study area do not affect lake Ol' Bolossat conservation

- i. All land uses in Ol' Bolossat catchment area are not causing toxicity.
- ii. The conservation activities in the study area are not affected by land uses.
- iii. There are no preventive and resolution options for land use effects in Ol' Bolossat catchment area.

Research Methodology and Materials

Study Site

Lake Ol' Bolossat is bordered by Ndaragwa, Ol kalou and Ol joro orok sub counties. It is situated in a wedge-shaped Rift val-

ley floor sloping eastwards and northwards, known as Ongata Pusi. Lake Ol' Bolossat is approximately 195 Km north of Nairobi. It lies between latitudes 0o 09'S and longitudes 36o 26'E in Nyandarua county in the central part of Kenya (Figure 1). The lake has a surface area of about 43Km² and lies at an average altitude of 340M above sea level. The entire catchment area of Lake Ol' Bolossat, covers 4800Km², encompassing Nyandarua ranges, Satima Escarpment and Ndundori Hills, NEMA (2007). The water flows northwards through Thompson Falls into the northern part of Ewaso Nyiro River. In the lake basin it is dominated by vertisols, NEMA (2007).

There is seasonal inflow of water from streams in the eastern side and there are underground springs that replenish the lake in the west. The lake is fed by streams from Satima escarpments on the eastern side. There is seasonal water recharge in the south and the lake supplies water to river Ewaso Nyiro in the north NEMA, (2007). The mean annual rainfall of the area is about 980mm and increasing southwards and westwards. Rainfall is bimodal, with long peaks between April and June and the shorter peaks between October and November. The mean temperature is 23.50C with little monthly variations.

Methods

Field research was conducted between November and December 2015. The research methods used included actual sampling and laboratory analysis of Lake Ol' Bolossat water and runoff water. A questionnaire, informal discussions, direct observation and focus group meetings were used to explore land uses activities and farmers' perceptions of effects related to land uses.

The samples, of both lake Ol' Bolossat and runoff water, were collected during morning hours (650F, mostly cloudy, wind, N at 4mph and humidity 100%) and evening hours (600F, light rain showers, wind, NE at 0mph and humidity 100%), of the rainy season of the project area.

Lake Ol' Bolossat and runoff water samples

Water samples were collected from different selected points in the lake and other samples from runoff flowing towards the lake. The following assumptions were made during water sampling:

- i. Water samples would adequately represent the situations on site
- ii. Sampling during the morning and evening hours would cater for variation in pollution
- iii. A minimum of two sampling points per site (lake and flowing runoff) in different hours would take care of spatial variation in pollution.

The samples were transported to the upper kabete laboratory (UON) in 500ml plastic bottles. At the upper kabete laboratory (UON), a general water characterization was carried out following procedures described in a manual of standard methods for examination of water samples [16]. The parameters studied in-

clude nutrients (Nitrates, Phosphates and Potassium), pH, Electrical Conductivity(EC), Total Suspended Solids, Total Dissolved Solids, Potassium, Manganese and Chemical Oxygen Demand (COD). The water samples collected contained particulate organic matter, requiring pretreatment or digestion before spectroscopic analysis. The water samples were digested using 5ml nitric acid (HNO₃) for testing phosphates and 3.5ml sulphuric acid for testing Chemical Oxygen Demand (COD). The sample was brought to a slow boil and then evaporated to almost dryness (9 lowest volume possible-about 15 to 25 ml) on a hot boiling tube. Heating was continued until digestion was complete which was indicated by a light colored clear solution, followed by Flame Atomic Absorption Spectrophotometer (FAAS).

Land use and their effects Sampling, on Watershed Conservation

Since Lake Ol’Bolossat is narrow and lies in a north-south direction, it appears to form boundary between west and east. To assess the community perception of impacts associated to land use on wetland, a survey was conducted in 5 villages, 30 households respectively on both eastern and western side of the lake using individual household questionnaire. The sample size was randomly selected systematically, using an interval of twenty based on how they lie in the basin and near the lake. Purposive sampling of institutions was used to gather information from officers in NEMA, KALRO, KFS and KWS about the land use around the watershed and their effects. Interviews were used to collect relevant information from key institutions and conservation groups. Observations and photographs collected information guided by checklist. Data collected from the FGD and questionnaires was treated with utmost confidentiality.

Data Analysis and Presentation

Data collected was sorted, organized, conceptualized, refined and interpreted using methods drawn from the constant comparative analysis techniques. The strategy involved comparing data, some of which were similar and others different in order to develop conceptualizations of the possible relations between various pieces of data. Data was analyzed using Statistical Package for Social Sciences (SPSS) software and excel. Various data sets such as land uses, quarrying, sources of income and other variables were fed to the package. This information was generated in form of percentages and presented using tables, graphs and charts, upon which conclusions and recommendations were based on.

Results and Discussion

(Figure 1) shows gender of respondents in percentage. The household interviews revealed that there was almost equal gender distribution since the sample comprised of 58%, females and 42% males as shown in Figure 1 below. This gender distribution was attributed to the fact that the study area is relatively newly settled with land being occupied by both genders as landowners. Gender empowerment and promulgation of Kenyan constitution 2010 contributed to the almost equality in gender distribution.

According to [17], watersheds and gender has taken a proactive approach to women’s greater involvement in water management. (Table 1) From Table 1 participants had their ages distributed from 20years old to over 52 years old. For easy presentation, ages were grouped into classes of intervals of 15 years. It was established that majority were aged between 20 to 35 years, while the class of above 52 had lower frequency. This was as a result of unemployment of youths therefore involving themselves with activities such as quarrying and subsistence fishing in the lake. Most of them who were involved in conservation complained that they do not find any tangible benefits from their conservation efforts (Figure 2).

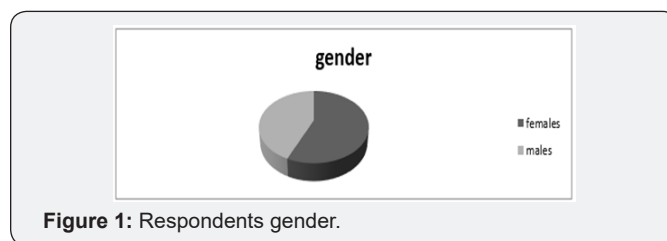


Figure 1: Respondents gender.

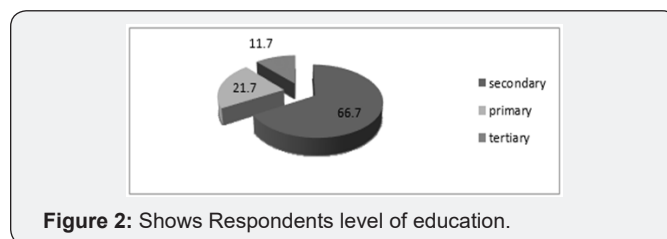


Figure 2: Shows Respondents level of education.

Table 1: Respondents age frequencies.

Age in years	Frequency	Percent
20-35	30	50
36-51	20	33.3
above 52	10	16.7
Total	60	100

Table 2: Showing relationship of education and gender.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.174	1	0.174	0.524	0.472
Residual	19.226	58	0.331		
Total	19.4	59			

Literacy levels of formal education considered in this study area were primary, secondary and tertiary education. Most of the respondents in the study area had secondary level of education with frequency of 66% as shown in Figure 2. This ascertains that most of the residents have formal education and it is expected they understand all those activities that contribute to degradation within the basin and hence they are expected to practice the possible conservation measures. Low levels of education and high levels of illiteracy are usually associated with little knowledge on the importance of conservation and hence little or no adoption of the various recommended conservation methods. Ignorance is also associated with illiteracy whereby, due to low

levels of education residents are ignorant of the recommended conservation measures as highlighted by the government policies on catchment conservation (Table 2). Education level and gender were not significantly different at 95% confidence interval Table 2.

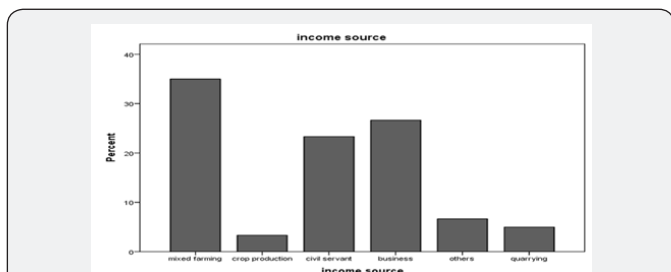


Figure 3: Respondents sources of income.



Plate 1: Shows quarrying near the lake; photograph taken 11th February 2016.

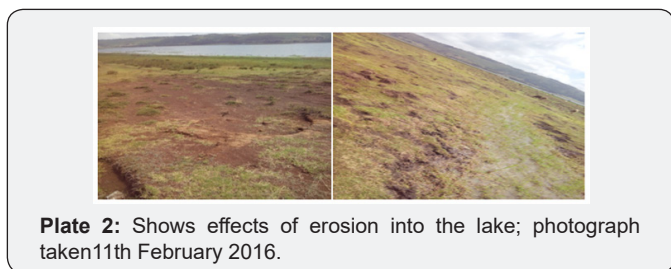


Plate 2: Shows effects of erosion into the lake; photograph taken 11th February 2016.

Therefore, the two variables did not affect each other, meaning the respondents had knowledge of the conservation of the lake irrespective of their education level and gender. Figure 3 shows different sources of income for the participants. Most people in this area were farmers i.e. mixed farming and crop production (22% and 3% respectively). This was a result of benefits of wetland supporting agriculture such as water abstraction, forage for the animals. As these people intensively got involved in farming it was established that a great proportion (3%), also did quarrying around the basin. However, accessibility of wetland resources made most members of the community to rely on watershed for their livelihood. The survey also established that the natures of daily activities undertaken by the respondents were also contributing to the catchment degradation (Plate 1). As these people intensively got involved in farming it was established that a great proportion (3%), also did quarrying around the basin. This was an evidence of unemployment in the country. However, accessibility of wetland resources made most members of the community to exploit the resources for income.

The study established that the farming methods embraced within the study area were intensive and resulted to topsoil

eroded during runoff causing gullies within the catchment (Plate 2). This erosion has also been evident on the boundaries of the lake causing sedimentation and siltation hence reducing its water holding capacity. This is evident as majority of the respondents complained that the lake water usually changed color during rain seasons as compared to dry spells. Settlement and the development of agriculture can enhance erosion on the surfaces of the watersheds [18].

Factors Contributing to Lake Ol'Bolossat Degradation

The study established that various human activities had led to degradation which included agrochemicals, clearing vegetation, water abstraction, quarrying, land fragmentation, poverty, population growth and other combined problems (Figure 4).

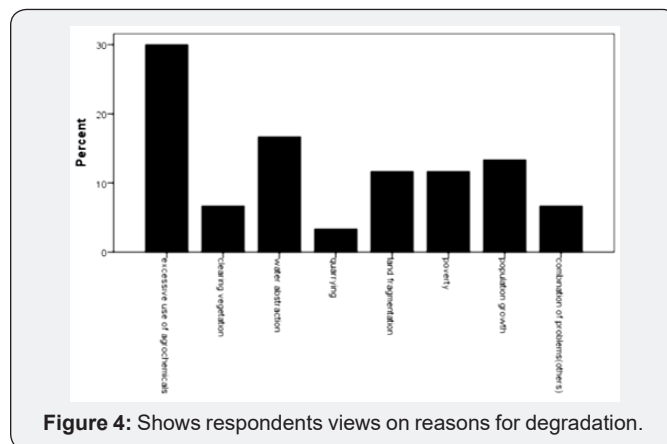


Figure 4: Shows respondents views on reasons for degradation.

According to respondent's response on what they felt caused degradation 30% said that excessive use of agrochemicals was the major cause of degradation as it had impact on water quality due to sphere erosion. 16% of the respondents were of opinion that water abstraction was also a threat to the lake riparian ecosystem, which was practiced along the lake. Excessive agrochemicals were as a result of intensive farming from the surrounding farms. Several studies have demonstrated strong associations between agricultural land use and alteration to wetlands [19]. In addition to nutrient transport, the loss of suspended sediment in agriculture runoff is a major threat to water quality as particles may carry pesticides, pathogens and other pollutants [20].

Table 3: Shows water usage by respondents in proximity to the lake.

Distance from lake	Frequency	Percent
less than 1km	38	63.3
2-3km	17	28.3
above 4km	5	8.3
Total	60	100

Agricultural (agro ecosystem) sources of disturbance can increase loading of total nitrogen and phosphorous which affect watershed [21,12]. Land was not used according to its suitability. Current patterns of agriculture will continue to result in damage to both quantity and quality of water resources [22]. Conversely, watershed with abundant human activities that increase the

export of nutrients will more rapidly degrade water quality in the receiving lake [23]. Population pressure in natural resources remains a key driver [24]. The responses and observations indicated that the community near the wetland is unprepared for dry periods (Table 3). Hence most of them relied more on wetland for water supply. They have no storage facilities for harvesting rainwater, hence they fetch water from water points that they share with livestock.

Table 4: Shows relationship distance and water usage from lake.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Water use from wetland	0.725	0.147	0.543	4.922	0.036

Water usage and proximity from the lake were significantly different at 95% confidence interval; hence most members of the community near the watershed rely directly on lake (Table 4). Most of respondents near the Lake were dependent on it for source of water therefore most of them did not have water storage facilities. Hence, affecting Lake's capacity to function due to excessive abstraction of water.



Plate 3: Water abstraction from the lake for agriculture; photograph taken 11th February 2016.

Plate 3 shows irrigation in the eastern side contributed to pollution of the lake. This was as a result of poor irrigation methods which involved excessive water supply on the farm hence resulting to water overflow. However, leading to excessive abstraction of water from the Lake.

Land Use

Table 5: Shows relationship of land use to water abstraction and drying of boreholes.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
abstraction of water	1.454	0.641	0.371	2.269	0.027
Drying of boreholes	0.9	0.449	0.458	2.007	0.04

The survey established that the major land tenure activity was agriculture i.e. mixed farming, crop production and livestock production. Water abstraction, drying of bore holes and land use

were significantly different at 95% confidence interval (Table 5). Therefore, land use contributed to watershed degradation as a result of excessive water abstraction for agricultural activities.

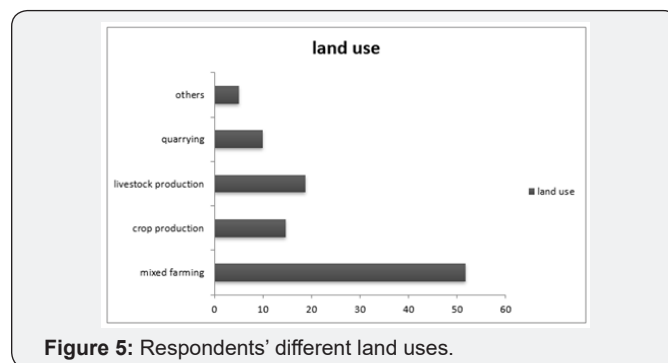


Figure 5: Respondents' different land uses.



Plate 4: Livestock grazing on the basin; photograph taken 11th February 2016.

Of the respondents 14.7% were involved in crop production, as compared to 51.7% who used their land for both crop and animal production (Figure 5). This land use ventures were found to seriously affect the wetland for some farmers grazed on the riparian zone of the lake (Plate 4) hence affecting the water quality and quantity. The activities on the land surrounding Lake Ol'Bolossat were attributed by the ecosystem services provided by the watershed. Most of them who were involved in conservation complained that they do not find any tangible benefits from their conservation efforts.

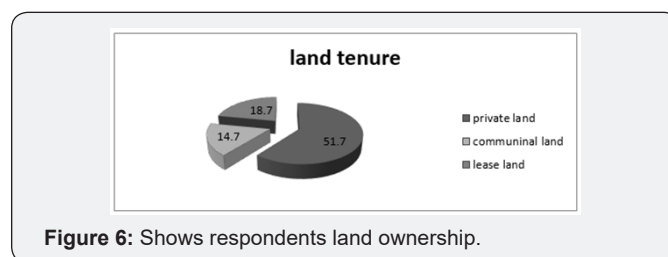


Figure 6: Shows respondents land ownership.

Livestock grazing practices can cause erosion and bank destabilization as shown in Plate 4 [25]. However, eutrophication can be as a result of nutrients accumulation from livestock manure. According to the sub county agricultural officer the type of land tenure was also a contributing factor to the high rate of destruction on the catchment (Figure 6) and this required an urgent attention in order to address it. The survey established that 51.7% of the land within the catchment was privately owned as a result owner had a higher stake in determining the type of farming to be undertaken. This affected the wetland and fragile ecosystem.

Water Quality



Plate 5: Cattle dip near the watershed; photograph taken 11th February 2016.

Water quality is a term used to describe the chemical, physical and biological characteristics of water, generally in terms of suitability for a particular use. The respondents indicated that crop production was insufficient and intensive cultivation has therefore been employed in order to increase crop production by use of pesticides and chemical fertilizers. The agricultural practices have negative impacts on the wetland by polluting water. Water pollution can interfere usage of a wetland. The water quality in the catchment area has declined over years. For instance,

there are cattle dips near the lake. Surface runoff was collected from water channels flowing towards the lake at different day hours. Plate 5 shows cattle dip which could be a source of pollution through chemical leaching and runoff, therefore contaminating the watershed. The lake water was found to be highly contaminated and unfit for domestic use. The concentration of nitrates, total suspended solids and total dissolved solids in the lake water was lower than that of runoff water (Table 6). This indicates that the concentration originated from activities associated with the land use from the surrounding such as quarrying, intensive farming, livestock grazing (Plate 1 & 2) but once it enters the lake it's diluted by clean water from streams and springs. Livestock grazing practices can cause erosion and bank destabilization, Borman et al. [20]. Freshwaters are degraded by increasing inputs of silt, nutrients and pollutants from agriculture [26]. Moreover, the irrigation in the eastern side curtails flow of water into the lake, therefore contributing to pollution of the lake. The ground water is slightly saline due to the nature of rocks [27-30].

Table 6: Shows monitored water quality parameters in both lake and runoff water samples; for domestic use.

Parameter	Units	Laboratory Results	Observed	Max. drinking water quality guideline Source: WHO	Methods of Estimation
pH	pH scale	M1 -7.18	R1-7.88	6.5-8.5	Electrometric
		M2- 7.25	R2-7.84		
Manganese (Mn)	Mg/L	M1 -0.001	R1-0.22	0.1	Atomic absorption spectrophotometry
		M2-0.0	R2-0.20		
COD	Mg/L	M1- 48	R1-96	50	
		M2-32	R2-80		
TDS	Mg/L	M1-174.9	R1-192.6	1200	
		M2-177.8	R2-185.3		
TSS	Mg/L	M1- 143.9	R1-165.4		Used 10ml aliquot
		M2-115.4	R2-156.1		
Potassium(K)	ppm	M1 - 19	R1-26		Flame spectrophotometry
		M2-21	R2-28		
Phosphates(P)	Mg/L	M1 - 0.48	R1-1.42		Atomic absorption spectrophotometry
		M2-0.53	R2-0.97		
Nitrates	Mg/L	M1- 1.21	R1-1.34	10	Colorimetric method
		M2-0.61	R2-1.06		
Electrical conductivity(EC)	µs/cm	M1- 318	R1-368	1500	Used conductivity bridge at 20°C
		M2-394	R2-418		
Total Nitrogen	Mg/L	M1-0.042	R1-0.01		
		M2-0.014	R2-0.0068		
Ammonia	Mg/L	M1 - 0.465	R1-0.27	0.5	Nesslerization after distillation
		M2-0.354	R2-0.18		

Key: M1-lake water in morning hours
M2-lake water in evening hours

R1-Runoff water in morning hours
R2-Runoff water in evening hours

Conclusion

The study did an in-depth research and established that there was serious degradation; this destruction has negatively

impacted the lake thus leading to water decrease on the catchment. The lake has been unable to perform its functions efficiently. This has allowed grazing in the basin of the lake. Farming has

also been going on along the riverine which has led to loosening of top layer of the soil which is eroded during runoff on rainy seasons. Moreover, water quality has been affected negatively. Privately owned land has been used for intensive cultivation and to some extent abstraction of water for irrigation hence leading to decline in water quantity. The study concluded that Lake Ol'Bolossat requires urgent measures to restore, conserve and manage the watershed.

Recommendations

The study suggests various strategies towards restoration, conservation and management of Lake Ol'Bolossat. Sustainable land use practices and farming technologies such as organic farming to minimize agro pollution and drip irrigation to avoid water wastage. Oxidation ponds could be constructed to deal with nutrients in the runoff water from farms; nutrients flow into the lake will be reduced. The local community should be sensitized on the various advantages of conservation of the watershed through capacity building by training conservation groups and Rainwater harvesting should be improved in order to provide alternative sources of water for irrigation instead of abstracting direct from the lake. Riparian reserves and buffer zones need to be provided to remove people on the catchment and allow restoration, such as massive livestock grazing. However, the Water resource management authority needs to protect Lake Ol'Bolossat from degradation by locating the cattle dips far away from water sources in order to reduce pollution.

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