Assessment of the Extent of Land Degradation in the River Loboi Watershed of Baringo County, Kenya

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Abstract: ***Increased human population pressure and climate change constitute the global underlying root causes of accelerated and devastating land degradation processes in the Arid and Semi-Arid Lands (ASALs). River Loboi watershed, located at the lower part of the Lake Baringo Catchment, is not an exception. The area is characterized by severe vegetation degradation that has resulted in extreme soil deterioration. This study aimed to determine the extent of land degradation in the watershed with specific objectives of determining the vegetation cover and composition, observing signs of accelerated soil erosion as well as assessing the socio-economic status of the inhabitants in the watershed. Tools for data collection included structured questionnaire, observation schedules and oral histories. The measured variables were analysed using a one-way ANOVA (α =0.05) and correlation analysis. The results indicated that the whole watershed is degraded with 87.5% of the watershed being highly degraded and the remaining 12.5% moderately degraded. The overall vegetation cover was 59.6%. The middle section (Simotwe location) was the worst hit and recorded the least vegetation cover of 51.4%. In addition the watershed indicated signs of transformation towards a shrubland. The results demonstrate the urgency of developing and establishing more effective and scientific ways to curb and monitor land degradation processes in the watershed.***

Keywords: Land degradation, extent, assessment, ground methods, vegetation alterations, watershed

1. Introduction

In Kenya, Arid and Semi-Arid lands (ASALs) cover 80% of the country (Sutherland *et al*., 1990). With the current rapid increase in population and the associated demand for land in the high potential areas, people are migrating to the ASALs. This has resulted in severe land degradation (Johansson and Svensson, 2002, Akuja *et al*., 2005). The River Loboi watershed in Kenya is undergoing land degradation through accelerated soil erosion and vegetation loss. The main causes of land degradation in the watershed are overgrazing, poor watershed management, poor farming practices and indiscriminate cutting of trees for fuel. The degradation has resulted in off-site effects like sediment accumulation in Lake Bogoria and Kiborgoch swamp. As a result the Kiborgoch swamp, formerly known as the greater Loboi swamp, has greatly reduced in size. In addition, the swamp has transformed from an expanse of tall cattail (*Typha domingesis)* to a complex mosaic riddled with different species of *Acacia* trees. The consequences of such changes include loss of organic matter, erosion, loss of biodiversity and habitat change for many plant and animal species.

Based on the immense effects associated with land degradation together with the fact that the ASALs are now the only areas still available for agricultural expansion, there is need for improved management of ASALs. For instance, integrating watershed management concept onto soil and water conservation measures will result in increased annual yield of usable water for downstream users and reduced run-off volumes and peak discharges for moderating floods-increasing land productivity and environmental conservation. Estimates of the extent of land degradation provide sound basis for identifying areas most affected by land degradation and monitoring the consequences of rehabilitation actions (Campell *et al*., 2003) as well as assist in the planning and designing of appropriate mitigation measures (Adeel *et al*., 2005). The ground surface characteristics (vegetation cover and composition and the visible erosion type) that were assessed are discussed in this study. The socio-economic investigation of the inhabitants in the watershed was also important given that any action programmes always require support from and implementation by the local community.

2. Study Methodology

2.1. Study Area

The study area constituted the upper seasonal section of Majimoto River as commonly known by the locals. River Loboi originates at an elevation of 1850-1700m above sea level and descends in a northeastern direction terminating at the Loboi/ Kiborgoch wetland with an elevation of 1411m above sea level. The mean annual rainfall in the area ranges between 700-800mm per annum and an average temperature of 30^{0}C. The potential evaporation exceeds 2500mm per year. The soils in the study area are described as soils of deep faulted floor of the rift valley developed on tertiary basic igneous rocks. They are well-drained, moderately deep dark reddish brown to reddish brown friable to firm and slightly smeary, boulderly and stony clay loam to clay, and in other places calcareous. When they occur in valley bottoms, they are imperfectly drained clay soils of varying calcareousness, salinity and sodicity.

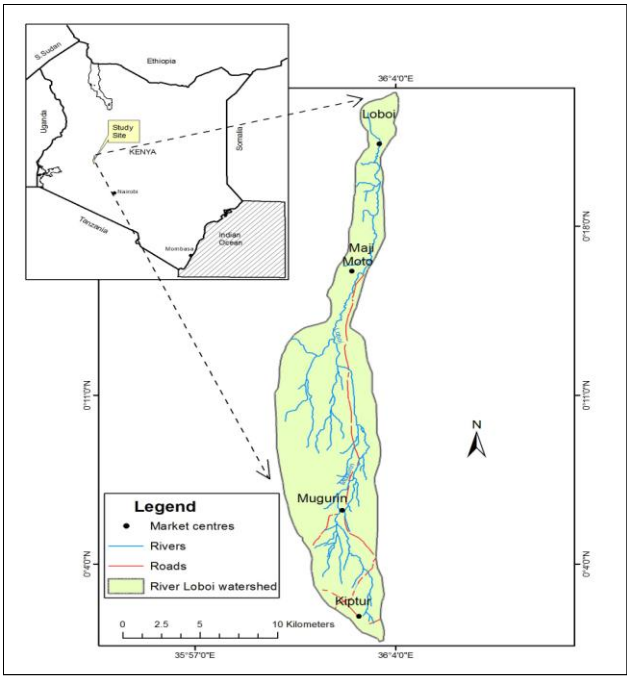

Figure 1: River Loboi watershed

The vegetation in the watershed is predominately woody. Grasses are mainly found around the Loboi/ Kiborgoch swamp. The rearing of indigenous livestock i.e. cattle, sheep and goats together with and subsistence cultivation, constitute peoples` way of life. Inadequate water supply and pasture has rendered cattle, sheep and goats rearing a difficult undertaking. However, whereas heavy losses of goats during the dry season are reported, they are more resilient than cattle and sheep.

2.2 Socio-economic conditions

The socio-economic indicators were assessed using a semi-structured questionnaire. Using systematic random sampling, 40 households were sampled. The household heads were chosen as respondent based on the assumption that they had the historical and widest access to information regarding their homes especially on land degradation menace. The indicators assessed were house type, the land size, livestock number and rearing system and household head educational level (Lyamchai, 1998). These factors were assigned scores and computed to obtain low, medium and high economic categories. A low economic category corresponded to a score of 4 to 9, medium from 10 to 13 and high from 14 to 17.

2.3 Vegetation sampling and Land degradation classification

Ground sampling locations were selected using stratified random sampling approach. The watershed was stratified into three blocks (10km by 10km) based on the topographical features. Within each block, transects (4km in length) were located. Four sample plots (30m by 30m) were systematically located along each transect for the measurement of vegetation parameters and observation of signs of accelerated erosion. Cover and species composition were measured using step point and line-intercept methods. Cover estimate was determined from the number of hits and distance intercepted. Individual cover was used in the determination of dominant species. Plant species with more than 15% cover was considered dominant, subdominant constituted that with 6% to 14% cover while that with less than 5% was categorized as minor. Observed type and signs of soil erosion as well as the dominant plant species within the plot were recorded in the observation schedule. Additional information on plant diversity was obtained by interviewing the key informants, who included: Environmental committee members, community elders and chiefs. An index of the extent of land degradation was developed by the use of cover, dominant species and signs of accelerated soil erosion as shown in table 1.

Table 1: Land degradation classification parameters

Indicator	Class 2 (Low)	Class 2 (Moderate)	Class 3 (High)	Class 4 (Very high)
Cover	> 70%	55-70%	45-55%	< 45%
Visible erosion	None/ sheet	Sheet	Rill	Gully
Dominant species	Graminiod	Herbaceous (indigenous species)	Shrubs/ trees	Exotic/ invading species

2.4 Data analysis

All data on vegetation and household economic characteristics collected was tested for normality and then cleaned, validated and edited for accuracy, uniformity, consistency and completeness. The data was then analysed using Statistical Packages for the Social Sciences (SPSS) employing both descriptive and inferential statistics. Differences between vegetation cover and species richness within the three blocks/locations were determined by one way Analysis of Variance (ANOVA) technique and means separated using Duncan's Multiple Range Test (DMRT). A 0.05 level of significance was maintained in all computations. Correlation analysis was performed to explore the relationship among different cover estimates under different vegetation types and sampling locations. Significant relationships were determined using Pearson-Product correlation coefficient.

3. Results and Discussion

3.1 Household socioeconomic characteristics

Families in the watershed are young and large; an average household consists of seven persons. Survey results indicate that most (72.5%) of the household heads are married men with the remaining 27.5% being single and widowed women. Men are believed to be most influential people and decision makers at both village and household levels. They have more access to information on land degradation control and to land and other resources (Lyamchai *et al.*, 1998). However, it was not the case in the river Loboi watershed as the education status of most household heads is generally low. Forty five percent of the household heads have primary school education, 12.5% have secondary school education and 22.5% are without any formal education. Similarly, 97.5% of the respondents in the river Loboi watershed admitted that lack of knowledge was a constraint in their attempts to control land degradation on their farms.

Therefore, they have limited knowledge to the modern Soil and Water Conservation (SWC) technologies and continue with traditional practices such as stone terraces. Tenge *et al*. (2004) have indicated that the adoption of SWC technologies increases with higher level of education.

The major livelihood activity is agro-pastoralism. On average, each household keep 33 animals. Most animal herds are dominated by goats. The fairly large land holdings per household (over 90% of the households own more than five acres of land) promote the unrestricted animal movement over large areas in such of water and pasture. The locals have no/ less economic capital available to them given that off-farm economic opportunities are minimal. They greatly depend on the natural resource base (land) hence degrading it. Many studies indicate that poverty and low purchasing power leads to poor lifestyle and subsequent overexploitation or irresponsible uses of resources whose result is serious environmental degradation (Cunnigham *et al.*, 2005). The findings of this study illustrate that the land resource in the watershed is highly degraded making it difficult to efficiently support the people as well as their livestock. The inhabitants, therefore, continue to experience increased poverty levels. In 1997, the Welfare Monitoring Survey estimated that 35% of the population in Baringo County lived below the food poverty line. With the land degradation havoc, this figure may increase drastically.

3.2 Vegetation cover

The overall vegetation cover estimate was established to be 59.6±2.3%. The results also depicted a gradual increase in rock cover downstream; from 3.75% upstream to 40.8% downstream. Vegetation cover estimates for Kapkechui location and Koibos location did not differ statistically. Similarly, cover estimates in Simotwe and Koibos locations were not significantly different. However, vegetation cover in the middle section of the river Loboi watershed is significantly different with that in the upper section of the watershed. Baringo County is described as one of the most dependable sources of grain with water and grass available all year round (Sanyu, 2001), implying cover was significantly sufficient in the early 1900's. By analysis of satellite images, Johansson and Svensson in 2002 recorded a bush cover of 77% for the Semi-Arid catchment of Lake Baringo, of which river Loboi watershed is part. This illustrates that within a decade, vegetation cover has declined by 17.4% while bare ground has increased from 13% to 16.3%. It was also observed that there was no riparian cover along the Loboi river hence the river bank is prone to serious soil erosion. Bossio and Geheb (2008) indicate that such riverbank erosion eats into productive land while increasing incidences of siltation and flooding downstream. During the rain season, flooding is a common phenomenon downstream especially near Kiborgoch swamp.

Plate 1: Riverbank erosion along the Loboi river (March, 2013)

Figure 2 below illustrate the general trend for vegetation cover in the river Loboi watershed. The upper section (Kapkechu location) of the watershed recorded the highest cover of 71.5% (Metibelion/ Kapkundul and Kibomui villages). The cover seemed sufficient in providing adequate protection to the soil in the area. There were few incidences of visible erosion in the location and of great environmental significance was the seasonal spring at Chepchukukto. People fetch water from the spring. The spring is almost 3km from the main source of river Loboi where the locals hold that there was once a spring. As is the case with most water sources, such as lakes Baringo, Bogoria and Nakuru, in the rift valley, quantity of water in the spring has increased in the last three years.

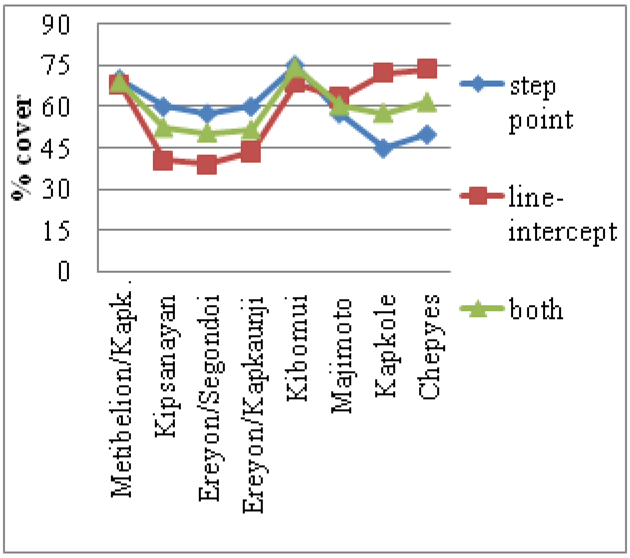

Figure 2: Cover along each transect/ village

Stoddart *et al*. (1975) indicated that a >70% basal cover provides an adequate protection to the soil in the rangelands and forage for livestock production. Based on field observations and cover results of Kapkechui location, this study affirms the figure for river Loboi watershed. Cover is a key factor in combating land degradation. The middle section (Simotwe location) of the watershed was found to be most hit in terms of cover degradation. The location recorded the least cover of 51.4%. Transect 3 and 4 (Ereyon/Segondoi and Kapkaunji villages) recorded the least covers (50.36% and 51.54%, respectfully). The two transects constitute the priority areas for future vegetation cover rehabilitation. Cover in lower section of the watershed (Koibos location) was 59.8%. Koibos location is rocky and it was observed that the rocks were so large that at some points there was no vegetation at all. More crown cover was recorded in the location compared to the middle section and upper section. The high crown cover can be attributed to the many trees recorded in the location especially the *Acacia species.*

The main driving force for the observed decline in cover in the watershed can be explained by continuous pressure from human disturbances for agro-pastoral activity. The action of animal hooves, especially the small cloven hooves of sheep and goats extremely damages vegetation cover (Taddese, 2001). In addition, reduced cover can also be attributed to wood harvesting for charcoal burning. The results of this study established that 87.5% of the respondents do burn charcoal with 37.4% of them burning charcoal on a daily basis. With 87.5% of the respondents burning charcoal, only 2.5% of the respondents agreed that charcoal burning is harmful and is contributing to the observed land degradation in the watershed. This demonstrates that their focus is on their immediate needs rather than the long term benefits of environmental conservation. Cunnigham *et al*. (2005) too recognized similar observations. Low cover can also be explained by the poor soil condition. Soil is a base to produce vegetation and its degradation corresponds to the restriction of vegetative activity (Uchida, 1995; Fasching, 2003).

Many studies have shown that decline in cover leads to decline in both surface and ground water levels. Studies by Squires and Ahmed (1998), Wild (2003) and Bossio and Geheb (2008) affirm this cover-water relationship. Based on this relationship, the resilience of the seasonal spring at Chepchukukto in Kibomui village as well as the durability of sand dams along the river Loboi will, therefore, increase upon improved vegetation cover. The spring at Chepchukukto may with time become a first-order stream in the watershed.

3.3 Vegetation Composition

The results of this study indicated that the flora of the watershed contains 42 plant species belonging to 34 genera. As indicated in the previous section; vegetation cover has declined and this may be as a result of reduced number of plant species in the watershed. Probably, some species have disappeared from the watershed due to the poor soil condition. Some of these species include *Boscia anguistifolia* (Lito), *Acacia drepanolopium* (Ingowe) and *Osyris compressa* (Marimarwe). On average, 7±3 plant species were recorded per plot. This implies that the watershed ecosystem is less diverse and this may be contributing to its inefficiency in withstanding environmental stress. Species richness in the three locations was almost uniform. The climax vegetation in the watershed was probably that of a tropical Savanna (Stoddart *et al.*, 1975). Results of this study demonstrate a shift from the Savanna vegetation to shrubland as most of the dominant plant species currently are classified as shrubs (Figure 3).

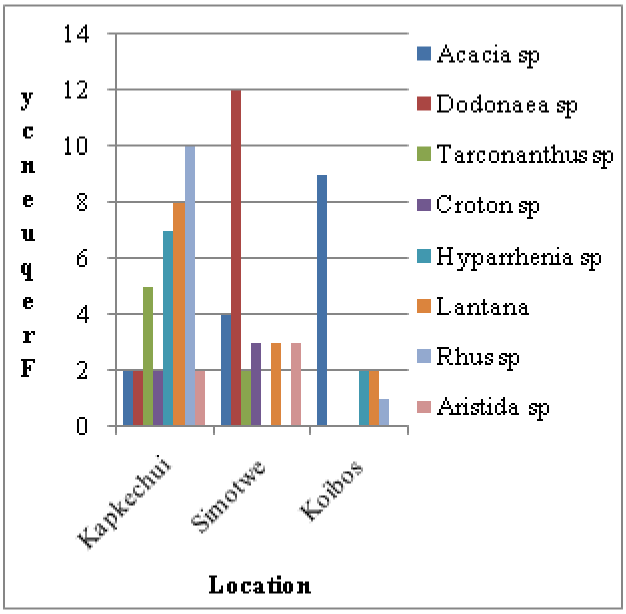

Figure 3: Cover of some dominant plant species in the river Loboi watershed

Locals believe that the growth of different plant species that were not part of the initial 'climax' vegetation started in the 1970s. Stoddart *et al*., (1975) revealed that in 1970s, the *Acacia species* and *Combretum species* constituted the dominant indicator tree species while *Panicum species*, *Aristida species* and *Hyparrhenia species* were the dominant grasses. This study registered the presence of these species but established that except for the *Acacia species*, all the others no longer constitute the dominant vegetation. Their abundance/ occurrence have greatly reduced to the point that some of these species were classified as minor. As for the *Acacia species*, they are largely supported by ground water and have limited sensitivity to seasonal rainfall, which, however, dramatically affects ground/basal vegetation.


Plate 2: *Dodonaea viscosa* (March, 2013)


Plate 3: *Tarchonanthus camphoratus* (March, 2013)

Various explanations can be given for the observed plant species alterations. Historical information indicates that fire was used to enhance the palatable (decreaser) species. This practice might have tampered with the regeneration capacity of the native species through the destruction of seeds and seedlings. Lack of seeds hinders natural regeneration of native/indigenous vegetation (Islam *et al.*, 2001). Probably, the current charcoal burning activities may be worsening the situation. The dominance of *Dodonaea viscosa* in the watershed can be attributed to its great powers of withstanding fire as well as its ability to regenerate very freely, even in dry rocky localities (Dale and Greenway, 1961). Inhibiting regeneration of native species increases the chances of invasive species growing in the area. For instance, it was established that the dominance of *Lantana camara* cut across the three locations compared with other native flora such as *Rhus species*, *Croton dicogamus* and *Tarconanthus camphoratus*.

Heavy grazing also contributes to vegetation composition deterioration. This study affirms this notion. The current dominant species in the watershed are all less palatable. The most palatable species have been grazed or/ and browsed upon to the extent that their natural regeneration capacity has been exceeded. The perception of the locals on overgrazing is however different. Like in the charcoal burning, only 7.5% of the respondents admitted that overgrazing is detrimental. As mentioned earlier, the dominant vegetation type in the watershed is shrub vegetation. Studies have shown that shrubland in ASALs exacerbates soil erosion (Adeel *et al.*, 2005). This study indicated that there is a strong positive correlation (r=0.82) between cover and vegetation type at 0.01 significant levels. This implies 67% of cover can be explained by the type of vegetation. As a plant species increases in size, cover too increases. Tall vegetation, in spite of its cover, is not efficient in protecting the soil from the rain drop impact as compared to the herbaceous vegetation, especially grasses. In addition the unpalatable shrub species have a wide resprouting capability and are highly adaptable in poor site conditions. *Acacia mellifera* was also considered as dominant with 20.3% cover. Although *Acacia mellifera* is considered a good forage tree, the locals believe that no grass grow underneath it. This was confirmed during field observations. However, the truth in this conviction is yet to be established.

3.4 Land Degradation Characterization

Excellent cover (> 70%) dominated the whole watershed with Koibos recording the highest at 18.7% followed by Kapkechui location at 12.5% and Simotwe recording the lowest at 9.4%. Overall, 40.6% of the watershed recorded excellent cover while 31.2% of the area recorded fair cover (45-55%) and 18.8% good cover. There were no portions of poor cover in Kapkechui. Based on this cover class system, vegetation cover in the watershed seems sufficient. The situation is different when using absolute/ straight numbers as indicated in the previous section. The cover class system has the problem of slight errors at the margins of cover classes. For instance, choosing between 30-60% and 60-100% cover classes for a 59.5% cover may lead to huge differences in the overall estimation.

Evident from the results is that the dominant vegetation across the three locations is shrub/tree type. As mentioned earlier, there are more shrubs than trees in the area. The results indicate that 84.4% of the watershed is dominated by shrub/tree vegetation. Grass was found to be the least dominating vegetation with 3.1%. The dominance of herbaceous (forbs) vegetation species was 6.2% twice that of grass. This is a threat to the major livelihood (livestock production) given that most of the dominant shrubs are unpalatable. Poor soil condition and overgrazing are the major factors for the observed trend.

Signs of erosion were recorded during vegetation sampling and household economic survey. The results reveal that no portion of the watershed is free from erosion. Rill erosion is the most prominent type of water erosion in the watershed. There were less gullies (25%) observed near homesteads compared to those further in the fields (34.4%). Sheet erosion dominated in the farms (42.5%) while it was least observed in the fields (15.6%).

The differences in the proportion of erosion recorded in the land cover form and that of the questionnaire can be attributed to the fact that farms near homesteads are taken care of as compared to those further away. One expects to see no/less rills and gullies near homesteads and vice versa. Similar observations have been recorded by Tenge *et al.*, (2004). Sheet, gully and rill erosion were prominent in Kapkechui, Simotwe and Koibos location, respectively (Figure 4).

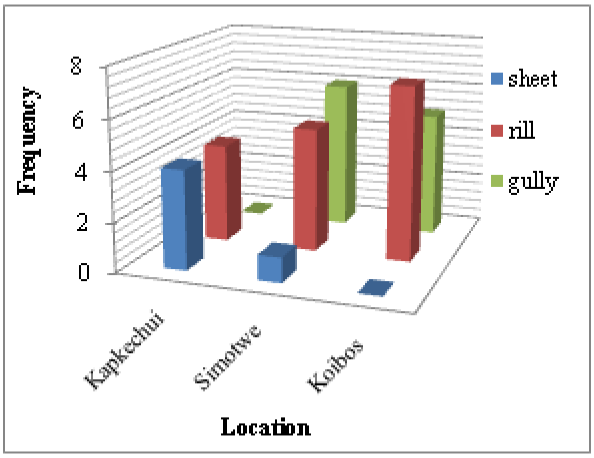

Figure 3: Visible erosion in the three locations

The erosion scenario in the middle section can be explained by the less vegetation cover. The other contributing factor is the low organic matter content which makes the soil aggregates more unstable and susceptible to erosion. In spite of the good crown cover recorded in Koibos location, rills and gullies are outstanding in the location. Rill and gully formation in the lower section of the watershed can be attributed to the high rock cover and the cumulative effect of increased surface runoff from the upper and middle sections of the watershed. In addition trees and shrubs are not effective in protecting the soil.

In general, the results reveal that the whole watershed is degraded. Only 12.5% of the watershed is experiencing moderate land degradation but the rest 87.5% is highly suffering from land degradation. Simotwe location is the most affected region in the watershed.

4. Conclusion and Recommendations

The findings of this study indicate that river Loboi watershed is highly degraded. Vegetation deterioration especially plant species alterations is not only exacerbating the soil degradation processes but also threatening the livelihoods of the locals. The vegetation cover in the river Loboi watershed was established to be 59.6% with *Dodonaea viscosa*, *Tarconanthus camphoratus*, *Lantana camara*, *Acacia mellifera*, *Acalypha fruitcosa* and *Croton dicogamus* being the dominant species. The current vegetation can neither protect the soil nor provide forage for livestock production. The middle stretch of the river Loboi watershed is the worst hit.

It was also established that lack of knowledge and finances is constraining the locals reaction toward this ecological challenge of land degradation. Therefore, the study demonstrates the need for developing and establishing more effective and scientific ways to curb and monitor land degradation processes in the watershed. In addition keystone plant species that are important for the health and survival of many other native vegetation species in the watershed need to be identified and their dynamics understood.

5. Acknowledgements

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