ISSN No:-2456-2165

Assessment of Biophysical Land Degradation in Kerio River Basin, Kenya

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Abstract:- The study was conducted with the main objective to assess the extent of biophysical land degradation in the basin and propose a policy framework for integrated management in Kenya. Degradation have been confirmed to be taking place in the basin with high degradation in the agricultural based areas and bush land areas. The main cause of degradation is clearing of vegetation to pave way for agricultural activities, fuel wood, overstocking and poor cultivation practices.

Although bare lands could be seen as land exposed and susceptible to degradation, it has been confirmed that degradation levels in bare lands is low; therefore it should be noted that degradation is driven by anthropogenic activities as it affects areas mainly with active socio-economic activities. This is a wakeup call to take action and to practice sustainable land use practices.

Assessment of institutional policy framework shows that there is legal and policy framework for land degradation management, however there are shortcomings which have to be addressed for effective policy framework. The main challenge being inadequate coordination between the county and national government which brings about disconnect between county and national government resulting to inadequacy in policy formulation and implementation. There needs to be a clear linkage between the two levels of government. This will go hand in hand towards ensuring a catchment based management of land degradation at basin level, as this will enable close touch with the land users thus ensuring sustainable management of land.

Keywords:- *Degradation; Policy framework; land use management.*

I. INTRODUCTION

Land is a complex resource composed primarily of soil, water and biodiversity. It is a source of sustenance and well-being for human livelihood hence its sustainable use and management; is key for present and future generations (Nkonya *et al.,* 2016). Through global assessment in sub Saharan Africa, it was observed that for every dollar devoted in restoring degraded lands there was a return of 4 US dollars (Nkonya *et al.,* 2016). Sustainable Development Goal 15 on its target number 15.3 on Land Degradation Neutrality (LDN), encourages nations to endeavour for a land degradation neutral world by halting desertification and restoring degraded land by 2030 (United Nations General Assembly, 2015). This is a unique opportunity for countries to halt the growing threats of land degradation and reap multiple socio-economic benefits of land degradation neutrality (Nkonya *et al.,* 2016). Other development agendas such as water security, poverty eradication, economic growth, gender equality and climate change adaptation, solely depends on how land is managed.

Land being the mother resource of all the production, the reduction in the present and prospective land productivity due to natural and other human induced activities describes land degradation (Blaikie, 1987). It has been recognised as a global problem associated with desertification in arid, semi-arid and dry sub-humid zones. The resultant impact is the long-term loss of ecosystem function and productivity which land cannot be able to produce as it was originally producing without extra efforts to improve its productivity (Baartman *et al.*, 2007). Land degradation impacts negatively on sustainable availability of water resources, land productivity and environmental sustainability.

In Kenya land has been defined by the constitution to include soil, water, sea, and all natural resources above and below the land, including the air (Government of Kenya, 2010). In the year 2000, about a third of Kenya's rural population were living in agricultural areas which are susceptible to degradation due to agricultural activities carried out in such areas. A decade later the number grew by 20% increasing pressure on the agricultural areas which increased degradation of the agricultural lands (Nkonya *et al.,* 2016).

Research shows that the state of land use activities whether it is affecting positively or negatively on land degradation plays a significant role on the effectiveness of policies to improve on the socioeconomic livelihood of a community, thus land is the key driver and factor in carrying out measures to improve socio economic development (Government of Kenya Resource Plan, 2016). Land degradation costs about 5% of the country's Gross Domestic Product (GDP), this is estimated to be about 1.5 billion USD (Nkonya *et al.,* 2016). Degradation is more pronounced and critical in the dry areas that comprise about 84% of Kenya's land mass. The humid and sub humid zones which forms the remaining 16% of the landmass is similarly degraded by land disturbing activities which include; poor farming methods, overstocking, infrastructural developments, mining and other extractive processes such as quarrying, limestone mining and de-vegetation (Ministry of Environment and Natural Resources, 2016). Additionally, climate change and variability which results to changing rainfall patterns, with increased intensity and frequent severe droughts is also hastening land degradation (RCMRD, 2014).

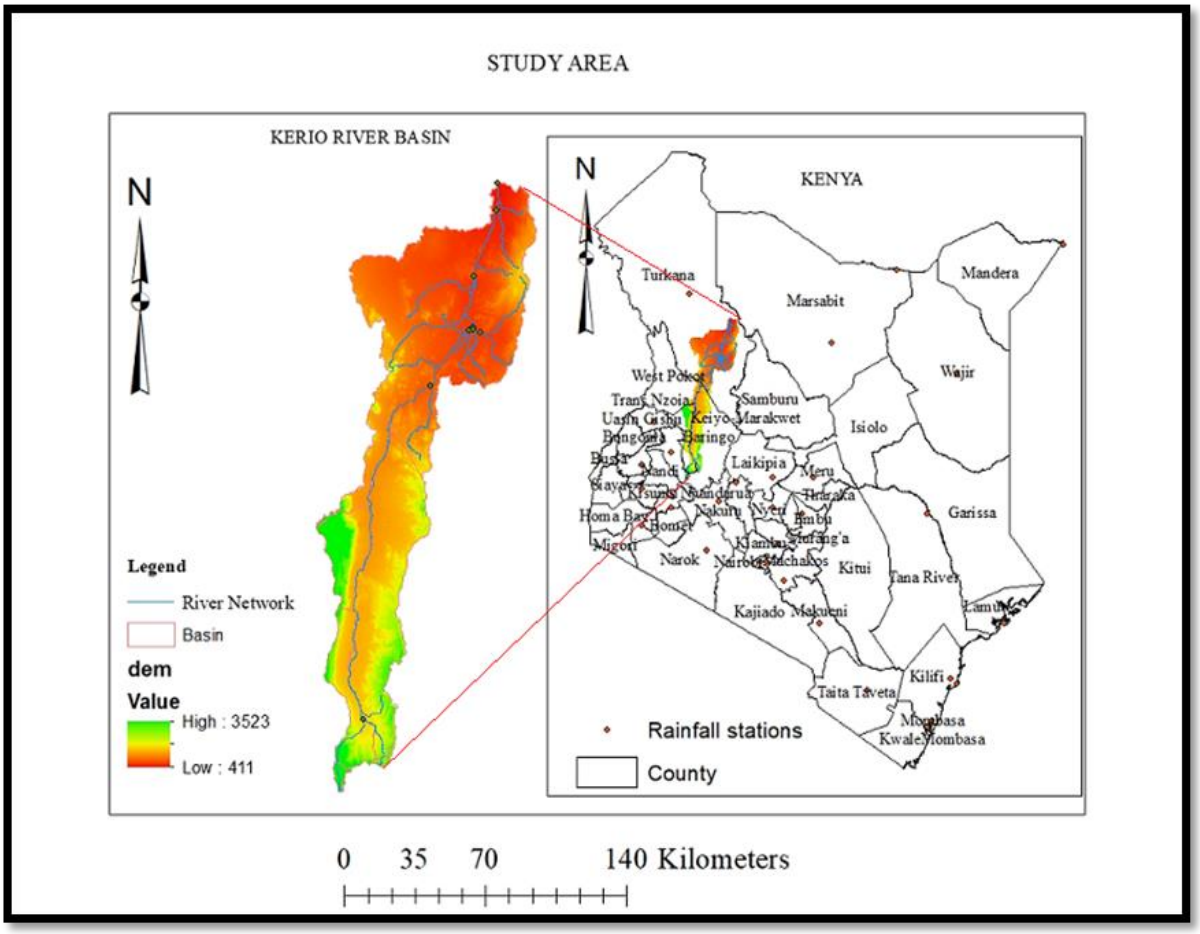
Assessment of land degradation forms a key starting point for taking action against land degradation, further more understanding the structures in place for tackling the

ISSN No:-2456-2165

problem; informs a collective goal towards raising awareness and taking action against land degradation.

II. STUDY AREA

The study area is Kerio Valley. It is situated in a long strip which is approximately 80 km by 10 km wide at its broadest at longitude between $35^0$and 37^0 East and latitude 10^0 and 1^0 North. It is where the Kerio River flows, northwards to Lake Turkana. It lies between the Tugen Hills and the Elgeyo Escarpment. The river originates from the Mau Forest Complex and has a drainage area of about 13,928 km^2 (JICA, 2013).



Map 1: Kerio River Basin Catchment Delineation

III. MATERIALS AND METHODS

A model was conceptualized from RUSLE soil erosion equation to determine the extent of land degradation. This considered five input data; vegetation index, rainfall erosivity, soil erodibility, slope length and population density. ERDAS IMAGINE 2013 and ArcGIS 10.4 was used for data processing and weighted ranking was done to determine the influence each data input on land degradation. The weights were obtained from pairwise ranking using Analytical Hierarchy Process (AHP) based on expert opinions. Degradation hotspots were then identified and SWOT analysis on institutional policy framework was carried out.

To obtain the land degradation index, a weighted overlay based land degradation model is developed in ArcGIS toolbox to process the data inputs. The weighted overlay is used determine degradation index which informs on decision making for management of degraded lands (Jahantab *et al.*, 2017). Figure 1 gives the model outline for obtaining land degradation index as used in ArcGIS.

Pairwise ranking was carried out to determine the influence of the five factors on land degradation. The ranking was done using the Analytical Hierarchy Process (AHP) pairwise ranking, whereby the AHP generated a weight for each factor according to expert's opinion. The expert opinion were done using two groups of professionals from the Department of Land Reclamation and the Water Resource Authority. The higher the weight, the more influence the corresponding criterion on land degradation. The AHP assigned a score to each factor according to the decision maker's pairwise comparisons of the options based on that criterion. The scores were then normalized to obtain the weights for each factor.

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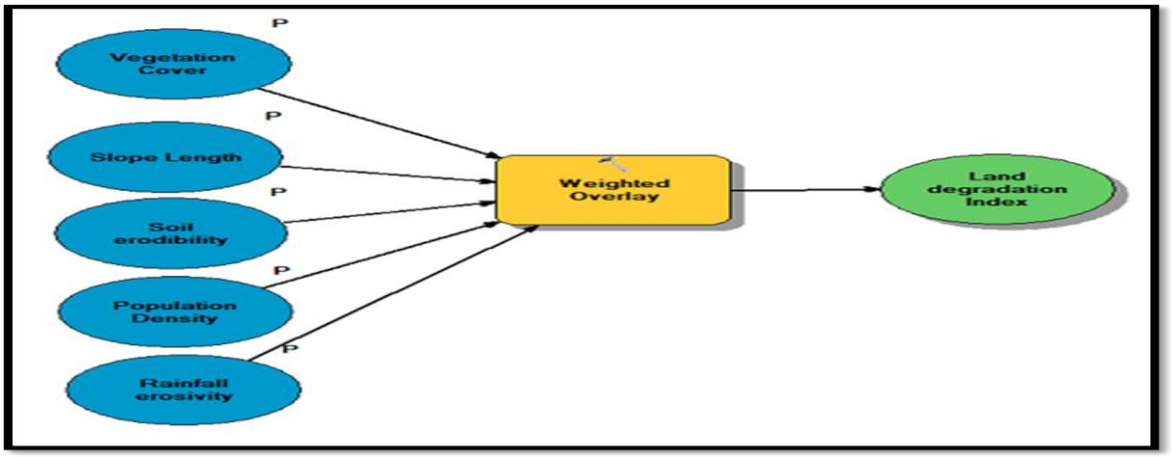

Fig. 1: Land Degradation Model Outline

A. Land Degradation Hotspots in the Basin and Contributing Factors

Degradation hotspots in the basin were identified based on the degradation index map. Areas which degradation index class tremendously changed from one class to another class were observed from the degradation index map. This was done using zonal statistics in ArcGIS spatial analyst tool. The tool calculates statistics on values of a raster within the zones of another dataset. This informed on the degradation index for each land use class. Areas where land use/ land cover were observed to have high degradation index was used as control points for ground truthing both land cover classification and validation of the model degradation index results.

Field visits for ground truthing and validation included observation and description of the site topography to characterize the slope length and steepness of the visited area, population densities within the area, both human and livestock densities, status of the water sources, drying and any other negative impact to be able to characterize the threats to resources which are affected by land degradation. This informed on identifying the major drivers of land degradation in the basin.

B. Assessmentof Institutional Policy and Legal Framework

The institutional policy and legal framework assessment was done to understand management of land degradation. Literature review on policies which govern management of land degradation in the country was done. The national and county level of government have different mandates. Analysis of the roles of the national government and county government was done to propose a policy framework for integrated management of land degradation.

A Strength, Weakness, Opportunities and Threats (SWOT) analysis was done on the institutional policies that operationalize land degradation management at county and national government.

To carry out the analysis the first step is to list all the factors criteria together with the strengths, weaknesses, opportunities and threats for each criteria. The second step is to assign weights to each factor. The weight value is between 0 and 1 (this can be in percentage); Zero means the factor is less important, while one indicates that the factor is most important. The total value of all weights should sum up to one or 100 percent. The third step is to rate the factors, with a value between 1 and 4. This indicates how effective the current strategies are. Rating captures whether the factor represents a major threat or weakness (rating = 1), a minor threat or weakness (rating = 2), a minor opportunity or strength (rating = 3), or a major opportunity or strength (rating = 4).

The fourth step is to assign weighted scores by multiplying weights by ratings. The scores then are used to inform on the strategies to be taken to maximize on strength and opportunities so as to reduce the impacts of threats and work on mitigating the weaknesses (Ommani, 2011).

IV. RESULTS

The results from the study obtained from Weighting of land degradation factors based on expert opinions as seen in Table 2 and Table 4 gave average weights of 44.5%, 26.8%, 13.7%, 9.2% and 5.8% for vegetation index, rainfall erosivity, soil erodibility, slope factor and population density respectively.

	VI	RE	SE	SL	PD
VI	1.00	7.00	3.00	3.00	3.00
RE	0.14	1.00	5.00	7.00	2.00
SE	0.33	0.33	1.00	4.00	3.00
SL	0.33	0.14	0.25	1.00	4.00
PD	0.33	0.50	0.33	0.25	1.00
Sum	2.14	8.98	9.58	15.25	13.00

Table 1: Group 1(Land Reclamation) Pairwise Ranking

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	VI	RE	SE	SL	PD	sum	Weight %
VI	0.47	0.78	0.31	0.20	0.23	1.99	39.74
RE	0.07	0.11	0.52	0.46	0.15	1.31	26.25
SE	0.16	0.04	0.10	0.26	0.23	0.79	15.80
SL	0.16	0.02	0.03	0.07	0.31	0.57	11.42
PD	0.16	0.06	0.03	0.02	0.08	0.34	6.79

Table 2: Normalization

	VI	RE	SE	SL	PD
VI	1.00	3.00	5.00	6.00	7.00
RE	0.33	1.00	3.00	6.00	5.00
SE	0.20	0.33	1.00	2.00	3.00
SL	0.17	0.17	0.50	1.00	2.00
PD	0.14	0.20	0.33	0.50	1.00
Sum	1.84	4.70	9.83	15.50	18.00

Table 3: Group 2 (Water Resource) Pairwise Ranking

	VI	RE	SE	SL	PD	Sum	Weight %
VI	0.54	0.64	0.51	0.39	0.39	2.47	49.31
RE	0.18	0.21	0.31	0.39	0.28	1.36	27.27
SE	0.11	0.07	0.10	0.13	0.17	0.58	11.54
SL	0.09	0.04	0.05	0.06	0.11	0.35	7.05
PD	0.08	0.04	0.03	0.03	0.06	0.24	4.84

Table 4: Normalization

Land degradation index map in Figure 2 shows the degradation indices from very low to very high. The very low, low, medium, high and very high have coverages of 0.37%, 66.14%, 32.29%, 1.19% and 0.01% respectively in 1990 and 1.21%, 50.84%, 45.06%, 2.87% and 0.02% respectively for 2014 respectively. This shows an increasing trend especially for the mediumly degraded, thus implying an active degradation in the catchment. Similarly studies by RCMRD (2014) shows that there has been an increasing trend in land degradation in the country with most of the lands being degraded are the high land areas which have high socio-economic activities. Additionaly, the semi-arid lands have had increased degradation due to vulnerability of the land.

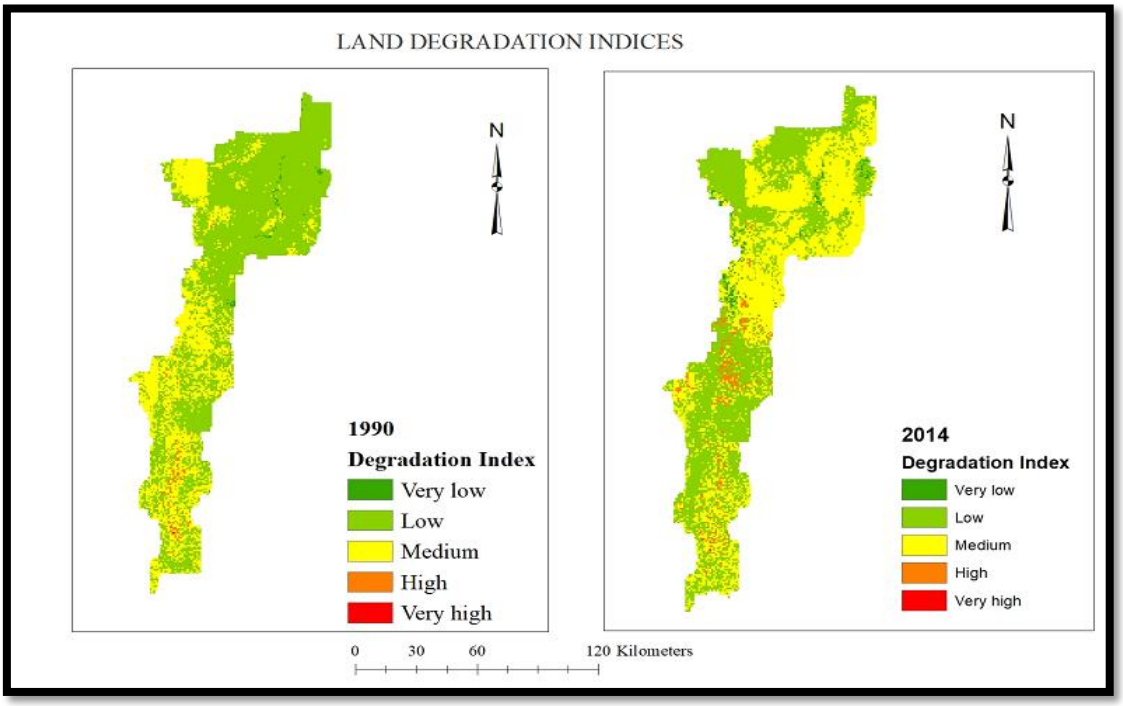

Fig. 2: Land Degradation Indices

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V. DISCUSSION

Vegetation have been given significant weight as it plays a critical role in soil erosion; it intercepts rainfall thus reducing the energy of raindrops which causes compaction of soil, the root systems of vegetation restrain soil particles and binds them from surface runoff. Similarly, the vegetation residues falls on the ground increasing the surface roughness thus reducing velocity of runoff. Vegetation also helps to maintain soil porosity and permeability thus enhancing infiltration of rainfall which in turn reduces surface runoff which causes land degradation as described by a study by Menashe (1998).

The observation from degradation index maps shows that the areas mainly with agriculture activities and bush land cover have very high degradation rate; which implies that there is active degradation taking place in this areas of the basin. They are attributed to the increasing demand for land for agriculture, with communities diversifying their livelihood from full pastoralism to agro-pastoralism; hence increasing cultivation activities. West Pokot indicated a large manifestation of increasing agricultural activities as communities diversified to crop cultivation to cushion them from losses incurred from losing their livestock to cattle rustlers from the neighboring communities of Turkana. However, the topography of land here is steep slopes and cultivating on this areas predisposes land to erosion as manifested by growth of gullies in several places in this part of the catchment.

The agriculture based areas are the areas which are highly degraded whereas the bareland areas are experiencing very low degradation in Figure 3. This is inferred to the kind of agricultural practices that was being practiced in the basin in the past two decades. Study by Adams and Watson (2003) on agriculture and land degradation in the upper part of the catchment shows that they were poor farming practices. The basin being home to the agropastoral communities; this implies that their exposure in terms of agricultural cultivation practices was low during that period coupled with low extension services to capacity build them on best agricultural practices. This explains why there was high degradation in the basin mainly in the agriculture based areas in 1990.

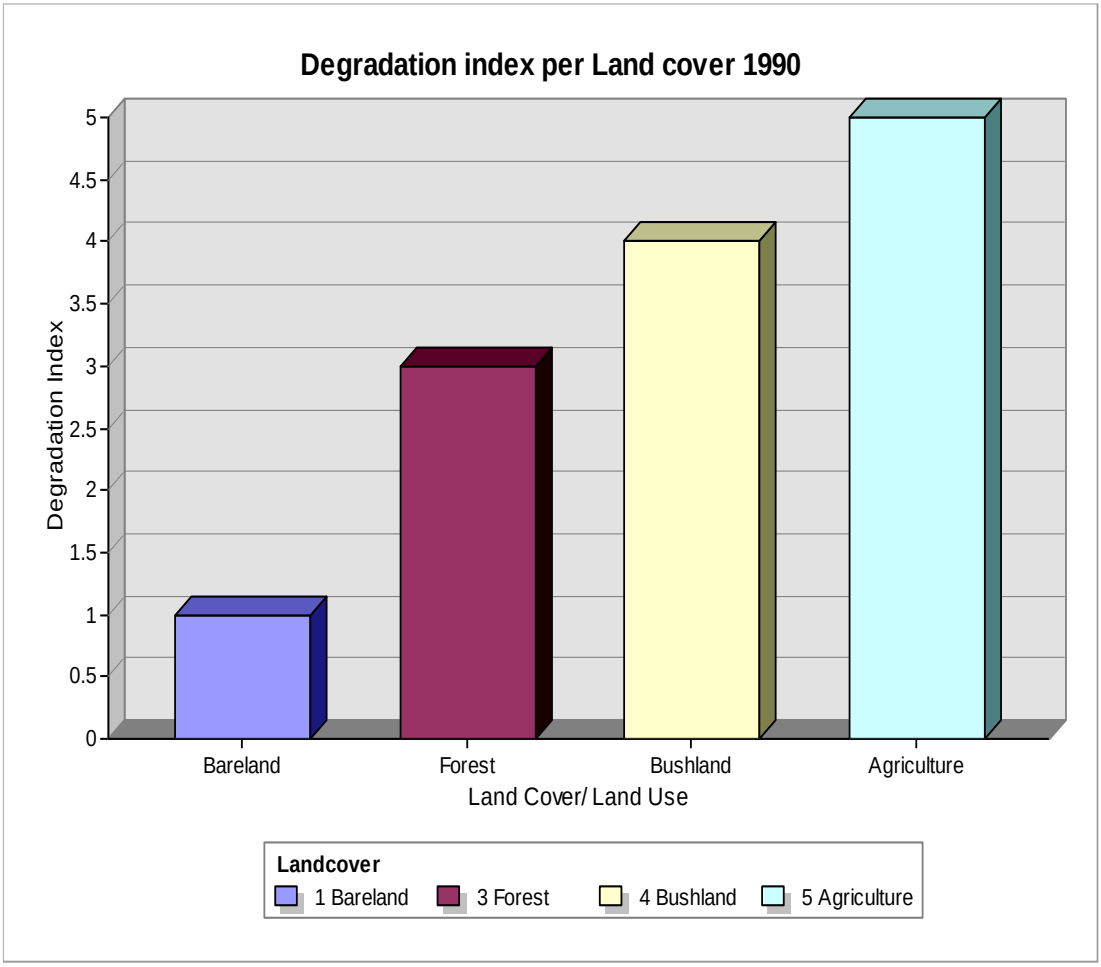

Fig. 3: Degradation Index per Land Use /Land Cover in 1990

In 2014 the degradation index was very high in the bushland as shown in Figure 4. This implies that as the year passed by the communities adapted to good farming practices as increased services from extension officers intensified and their ways of farming improved. However, the increased demand for land for farming led to clearing of bush lands to pave way for farm fields; this explains the high degradation index in the bushland areas in 2014. This is noted in Lokori area in Turkana county where irrigation is carried out along the Kerio River basin.

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The bareland areas are experiencing low degradation, however as much as the land in this areas is exposed with no vegetation cover , the degradation index is low for both the years. This is because the areas are in the lower part of the catchment whereby erosion rate is low, since the slope here is very gentle and the rainfall intensity low hence the degradation rate is low. Similarly, this being the downstream part of the catchment it means most of the sediment from upstream have deposited along the way hence little or no adequate kinetic energy to dislodge soil particles hence low erosion rate at this point. The degradation index in forest land remained medium for the two period of study, this explains why the vegetation cover plays a significant role in degradation. Where there is vegetation degradation is low; despite the fact that forest cover reduced, the degradation rate never increased in the area. Therefore, forest cover plays a significant role in reducing catchment degradation.

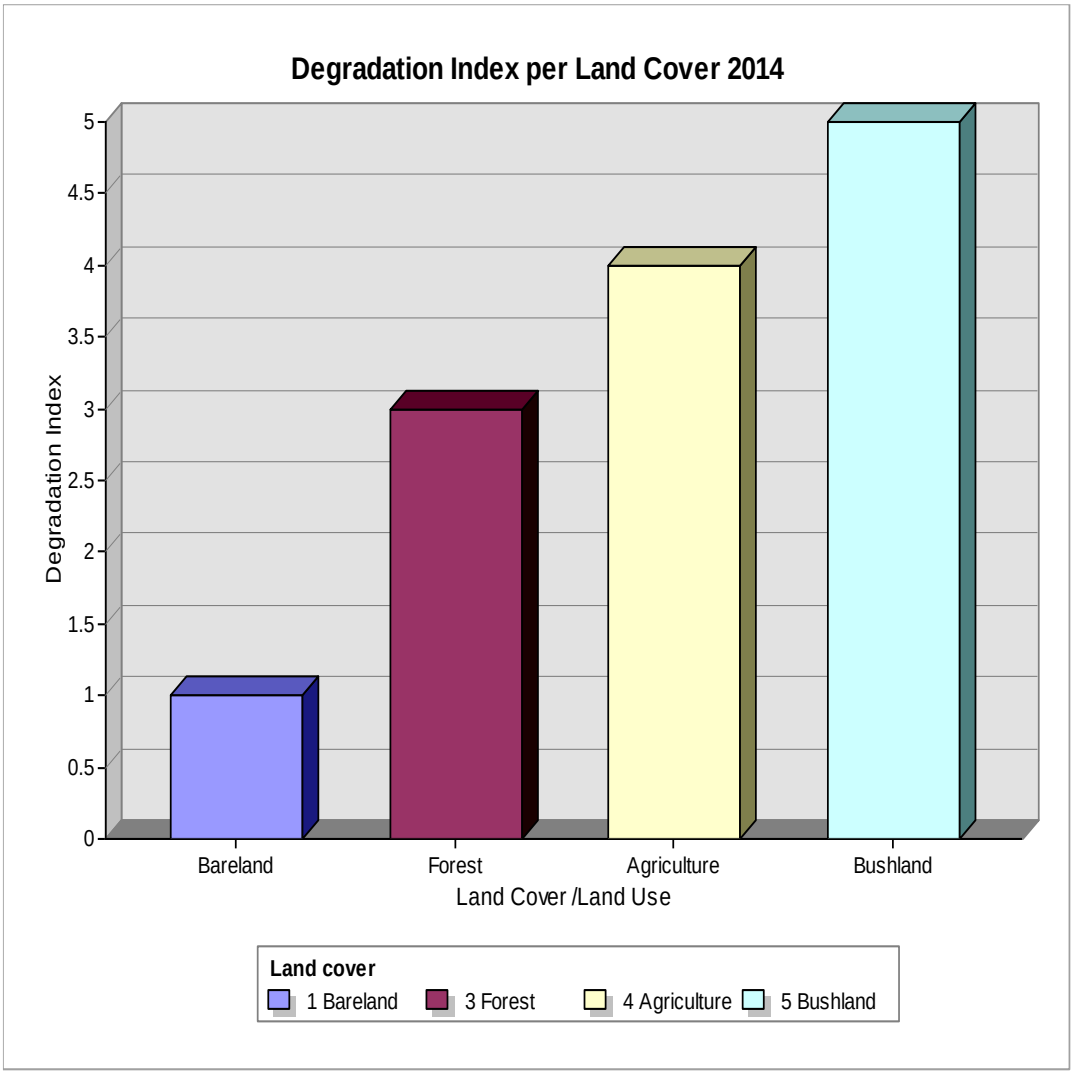

Fig. 4: Degradation Index per Land Use /Land

- **Policy assessment results**
  The study found out that shows that they are several actors playing a role in land reclamation at both national and county level of government. The Table 6 and Table 4.9 shows the SWOT analysis of the institutional policy and legal framework.

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S/No.	Criteria	Strengths	Weaknesses
1	Existence of policies	Presence of policies and strategies governing land and water management for example; (National Environmental Policy, Land Reclamation Policy, National Water policy, Vision 2030, Ending Drought Emergencies, National Water Master Plan	Most of the policies are just drafts hence difficult to implement
2	Political goodwill on policy formulation	Presence of National government which is constitutionally mandated with policy formulation roles for the country	Inadequate support by council of governors on policies which seems not to favor their counties
3	Legal framework	Article 60 of Kenya constitution provision for environment management	Inadequate legislation by county assemblies
4	Existence of by-laws	There are laws on environment and water management example EMCA 1990 Act, Water 2016 Act	Critical bills that touch on land degradation has not been legislated by parliament e.g land reclamation bill
5	Existence of institutions	Existence of key department in the ministry mandated with land reclamation functions	Most county governments have not institutionalized land reclamation in their functions.
6	Research collaboration	Presence of research institutions working on land and water related issues	Lack of collaboration between research and ministry thus a gap on implementation of research findings
7	Stakeholder participation	Constitutional requirement for stakeholder participation and involvement in every development activity	Inadequate awareness raising on critical issues that needs stakeholders inputs
8	Funding mechanisms	Public Private Partnership collaboration to support development agenda	Inadequate budgetary allocation by the government on land reclamation issues
9	Monitoring and evaluation	Clear roles for each level of government have been set by the constitution, the county deals with implementation whereas national government formulates policies	Inadequate coordination between county and national government on monitoring and evaluation framework

Table 5: Strengths and Weaknesses (Internal Factors)

	Internal Factors							
Criteria	Strength	Weight (%)	Rate	Score	Weakness	Weight (%)	Rate	Score
1	S1	15	4	0.6	W1	10	2	0.2
2	S2	15	4	0.6	W2	15	1	0.15
3	S3	10	3	0.3	W3	10	2	0.2
4	S4	5	3	0.15	W4	15	1	0.15
5	S5	15	4	0.6	W5	15	1	0.15
6	S6	10	3	0.3	W6	5	2	0.1
7	S7	15	4	0.6	W7	10	1	0.1
8	S8	10	3	0.3	W8	5	2	0.1
9	S9	5	3	0.15	W9	15	1	0.15
	100		3.4		100		1.7	

Table 6: Internal Factors Analysis

From the scores achieved in Table 1 above, the strength surpasses the weakness, with a score of 3.4 and 1.7 respectively. This implies that the internal policy framework in management of land degradation is good and only some improvement is needed so as to mitigate the negative factors which weakens the institutional framework; in its objective to manage degraded lands.

VI. CONCLUSION

Although bare lands could be seen as land exposed and susceptible to degradation, it has been confirmed that degradation levels in bare lands is low; therefore it should be noted that degradation is driven by anthropogenic activities as it affects areas mainly with active socio economic activities. This is a wakeup call to take action and to practice sustainable land use practices.

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ACKNOWLEDGEMENT

My sincere Gratitude goes to Water-Net for the scholarship and to Ministry of water and Irrigation -Kenya for granting me study leave.

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