ASSESSMENT OF ENVIRONMENTAL DEGRADATION AND WATER QUALITY IN SOUTHERN VIHIGA HILLS

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Abstract

Southern Vihiga hills present a case of an intriguing history of land degradation in Kenya that has over the years defied all efforts to address. In 1957, as a measure to curb environmental degradation in southern Vihiga, the colonial government through the legal notice number 266 of the Kenya gazette supplement number 28 established Maragoli Hills Forest without the acceptance by the local communities. The forest was over time degraded, and completely destroyed in 1990s. Efforts to rehabilitate the forest have continually been frustrated by the local community. The study set out to determine the extent of environmental degradation; and establish water quality in streams originating southern Vihiga hills. Data for the study was collected using GPS surveys; photography; high temporal resolution satellite imagery; and interviews. Data on environmental degradation was analyzed through ArcGIS 10.3.1. Analysis of biological and physiochemical parameters of water was undertaken at the government chemist in Kisumu. The study found total loss of forest cover on Edibwongo Hill (Maragoli forest), with extensive areas of bare surfaces, and gulleys. The study also found very high population of Coliform and E.Coli in water in all the three streams sampled in both dry and wet seasons; and very high turbidity; water color; and iron (Fe) concentrations in water from the sampled streams. The study recommended adoption of incentive based strategy, use of environmental co-operatives in rehabilitation of Maragoli forest, and prioritization of water treatment and supply in southern Vihiga to reduce direct consumption of water form streams, which could pose a threat to life and health.

Key Words: Environmental Degradation, Water Quality

Background

Southern Vihiga hills present a case of a complicated history of land degradation in Kenya that has over the years defied all efforts to address. Since colonial period, high population pressure, settlement in hilly areas of Southern Maragoli and intense cultivation triggered environmental degradation leading to general soil fertility decline and extensive soil erosion in Maragoli hills. Verma (2001) observed that as early as 1930, the problem of environmental

degradation had caught the attention of the colonial government which sought to arrest the problem through legislative measures to compel residents in the region to conserve the environment.

In enforcing environmental conservation, the colonial government carried out campaigns on agricultural practices for maintaining soil fertility, besides forceful conscription of people to carry out reforestation and terracing in heavily degraded areas of Maragoli and Bunyore (Mwangi, 2003). Further, the colonial government passed the 1957 Motion on Forest Policy for Kenya based on which, they started discussions with communities in Maragoli with view of establishing a forest in the area.

Through the legal notice number 266 of the Kenya gazette supplement number 28 of 1957, the government by order established Maragoli Hills Forest without the acceptance by the local communities. As noted by Mwangi (2003), the African District Council entrusted with responsibility of protecting the forest opposed the idea of establishing Maragoli hills forest, making the forest department unable to demarcate the forest boundary for gazetement. Further afforestation initiatives between 1957 and 1964 were resisted, however, in 1964, to protect from further degradation, the government declared 1318.8 acres of Maragoli Hills Central Government Forest through the Legal Notice number 174.

Like the colonial government, independent Government of Kenya as well as the present devolved government have failed to win the local community's support, continued destructive activities and sabotage of government's re-afforestation efforts has been reported (Nekesa, 2003; Dareel, 2013).

The deforestation and human settlement within Maragoli hills forest has resulted in serious environmental degradation reaching alarming levels. River drainage from the catchment have been highly impacted and declining water quality and heavy sediment loading due to heavy soil erosion have been reported. Destructive sand harvesting practices are slowly emerging downstream the river banks, further complicating conservation efforts. The Vihiga County Government, in its Integrated Development plan for 2013-2017, acknowledged the degradation in the area as grave, an opinion also advanced by Ochanda (2014). This study, therefore, found it necessary to investigate the extent of environmental degradation following the loss of forest cover, and how the degradation has impacted on water resources in the area.

Statement of the Problem

Kenya has suffered alarming rate of loss of forest cover which portends serous socio-economic consequences for the population in the affected areas. National Environmental Management Authority (NEMA, 2012) in the Kenya State of Environment 2011 noted that Kenya had 5.9% of land areas under forest cover, which was 4% below the requisite percentage cover, that the main forests cover in had suffered rampant destruction through extensive, irregular and ill-planned settlements and illegal forest resource extraction. NEMA (2011) also noted Kenya country's forests and woodlands were increasingly under pressure from the growing human population, with the greatest loss involving montane forests. In the Kenya State of The Environment 2011, NEMA (2012), development and implementation of restoration and afforestation programmes, were recommended. Further, need to inventorize, map and document all environmentally significant areas was also recommended.

While the degradation in the five major water towers in Kenya is well documented and efforts to rehabilitate them put in place, scientific studies on forest loss and environmental degradation in hilly areas of southern Vihiga County are,

nonetheless, scanty. It is in view of this reality that the researchers set out to investigate environmental degradation in southern Vihiga hills and the water quality in streams originating from the hills in the area.

Research objectives

The objectives of the study are to:

1. To determine the extent of environmental degradation in southern Vihiga Hills using GIS technology
2. To analyze water quality in streams originating from southern Vihiga hills

Research questions

1. What is the extent of environmental degradation in southern Vihiga Hills?
2. Does the water quality in streaming with sources in hills in southern Vihiga County meet the standards for human consumption?

Justification for the study

This study was found necessary because in the Vihiga District Environmental Action Plan 2008-2013, catchment destruction had been noted as a problem facing Vihiga district at the time (NEMA, ND) (NEMA 2008). Further, Vihiga County government in its 2013-2017 County Integrated Development Plan had identified protection of all water catchment as its immediate objective in its environmental protection sector. The study was thus necessary in establishing the achievements of the County Government of Vihiga in rehabilitating the degraded areas of Vihiga Hills.

The Constitution of Kenya 2010 under article 68 (1) (a) obliges the state to ensure sustainable exploitation, utilization, management and conservation of environment and natural resources among other provisions. Further, under article 68 (1)(b), the state is obliged to work to achieve and maintain a tree cover of at least 10% of the land area of Kenya, implementation of which are functions of county governments. Besides, Kenya identified issues of environment and water as key in the realization of Vision 2030 and this included identification rehabilitation of degraded water catchments areas.

The study was also necessary considering the importance attached to environmental issues in the UN 2030 Agenda for Sustainable Development which Kenya is a signatory. Specifically, Goal 6 and 15 commits members of international to ensure availability and sustainable management of water and sanitation for all and to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Thus, this study was found necessary for generating information and awareness about the degradation process in the southern Vihiga hills; and provide insight on new strategies that could be adopted to achieve community acceptance and participation in rehabilitation and protection of forests and conservation of environment.

Study Methodology

Study area:

The study was carried out in Vihiga Hills in Southern parts of Vihiga County. Vihiga County, lies between longitudes 34°30' and 35°0' E, and latitudes 0° and 0°15' N. The county covers a total area of 531.0 Km^2 (figure 1). Southern Vihiga hills are characterized with several steep sided hills with huge granitic rocks, and a very a rugged topography. The altitude for the area ranges between 1750 -1950 metres above sea level (NEMA, 2009). The area experience high rainfall well distributed throughout the year with an average annual precipitation of 1900 mm, with long and short rains experienced in March - May and September – November, respectively. The area experiences warm temperatures with mean of 23^0C, with an average humidity of 41.75 %.

Due to high rainfall and high altitude, Vihiga hills form an important water catchment with several streams radiating in different directions. The study area has a population density of 1044 persons per km^2, and is rated as one of the highest population density in Kenya (Republic of Kenya, ND)

Data collection

Data was collected using GPS surveys; photography; high temporal resolution satellite imagery; and interviews. The GPS survey was done in late 2015 and a validation survey in mid-August 2016. During the GPS surveys, other collection techniques like photography, interview and observation were also used. The satellite images were supplied as georeferenced *.tiff* formatted files and covered the years 1988, 1990, 1995, 2008, 2011 and 2015. The base maps used were downloaded from online sources and included Kenyan administrative boundaries, and river density. Topographic maps were obtained from the Regional Mapping Centre in Kenya. During the study, water samples were collected from three streams draining from the catchment.

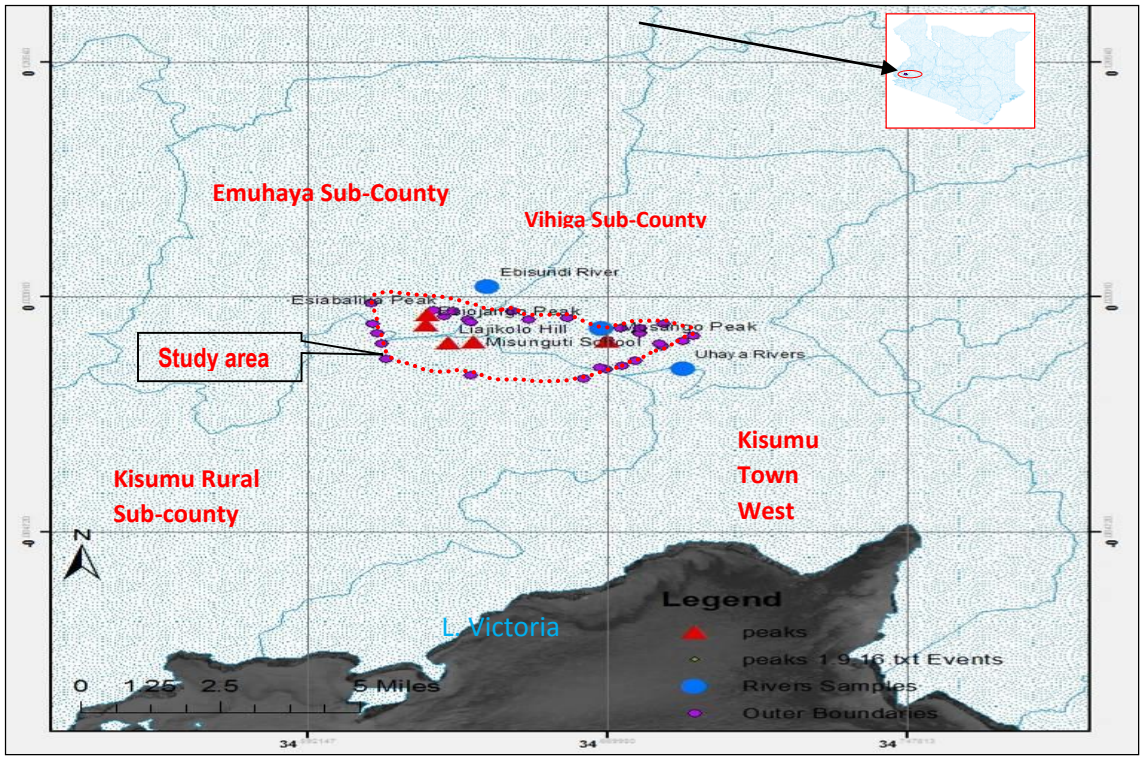

Figure 2: Map of the study area

Data analysis

The GPS data collected from the field surveys was organized in excel and formatted as delimited text files for use in ArcGIS software. The maps were sorted for clarity, relevance and resolution and GIS analysis achieved through ArcGIS 10.31. The spatial data collected (coordinates & images) were imported as shapefiles layers, then overlaid on the base data map in the software from where changes in the catchment status were observed from the temporal resolution images, analysis of change and areas were performed. The draw tool in the toolbar was used in determining the surface area which was marked as polygons. The coordinates were plotted to show key boundary areas and important points in the study area like hill peaks, water collection points, eroded spots etc.

Water analysis was undertaken at the government chemist facility in Kisumu, Kenya and a number of parameters were tested. The deviations of the findings from the World Health Organization (WHO) standard were analysed and presented in the tables below to give impressions of the conformities and non-conformities. Other statistical analyses were accomplished in MS excel. The Data analyzed was presented as map outputs, table summaries and figures. Pictures taken from the area were also included as outputs.

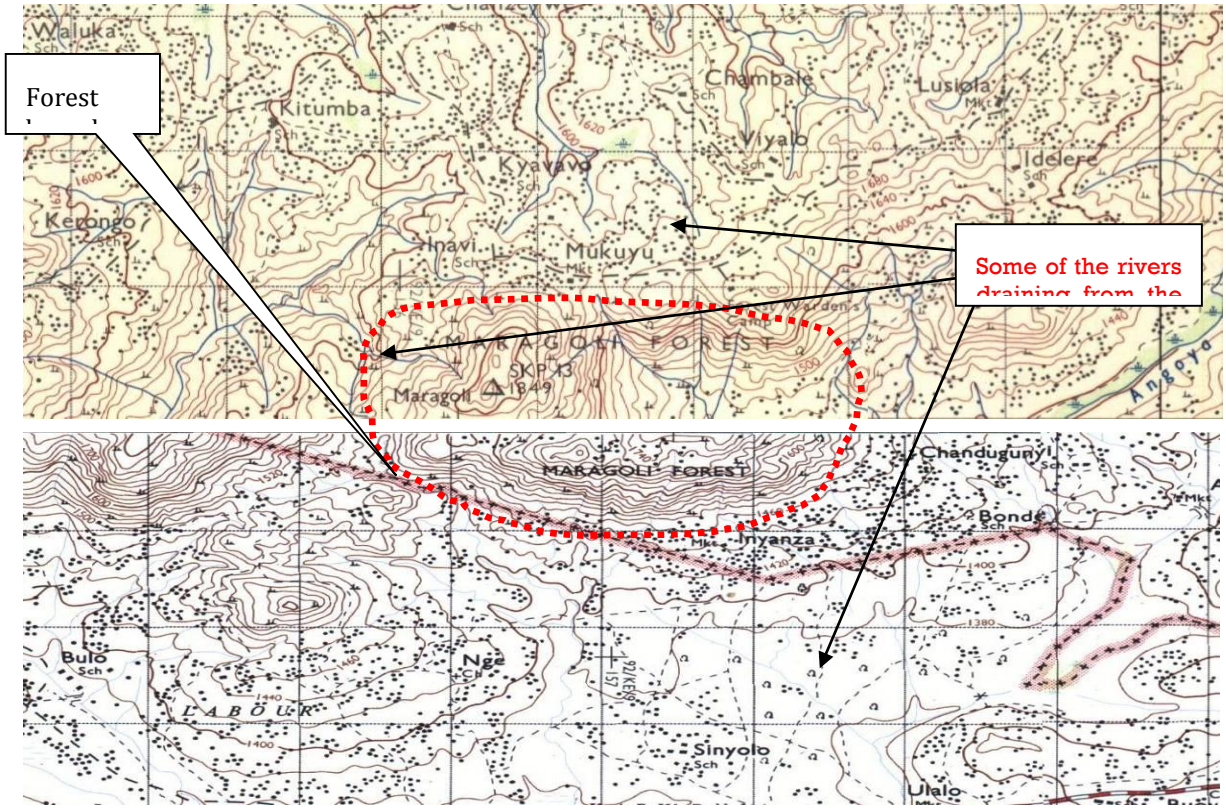

Figure 2: Topographical Maps showing Maragoli forest catchment

Results and Discussion

Environmental Degradation

The first objective of this study was to determine the extent of environmental degradation in South Vihiga Hills. Environmental degradation was analyzed in terms of changes in vegetation cover, changes in landscape and changes in catchment characteristics in the area over time. Analysis of environmental change involved use of GIS analysis. Analysis of earlier topographic maps and Landsat images of the catchment under study found that southern Vihiga Hill was forested, with Edibwongo Hill designated Maragoli Forest with forest protection facilities such as forest camp and wardens (See figure 2). Analysis of temporal changes in forest cover carried out between 1988 and 2016 detected extensive degradation (see table 1). Content analysis from documents on Vihiga County confirmed Maragoli Forest as 100% degraded. The NEMA in Vihiga District Environment Action Plan for 2009-2013 indicated the state of Maragoli forest as 100% degraded. Similarly, in Vihiga County Integrated Development Plan for 2013-2017, Maragoli Forest status indicated Maragoli forest as having been destroyed by human activities, and identified hilltop restoration as one of the key priorities in the forest sub-sector.

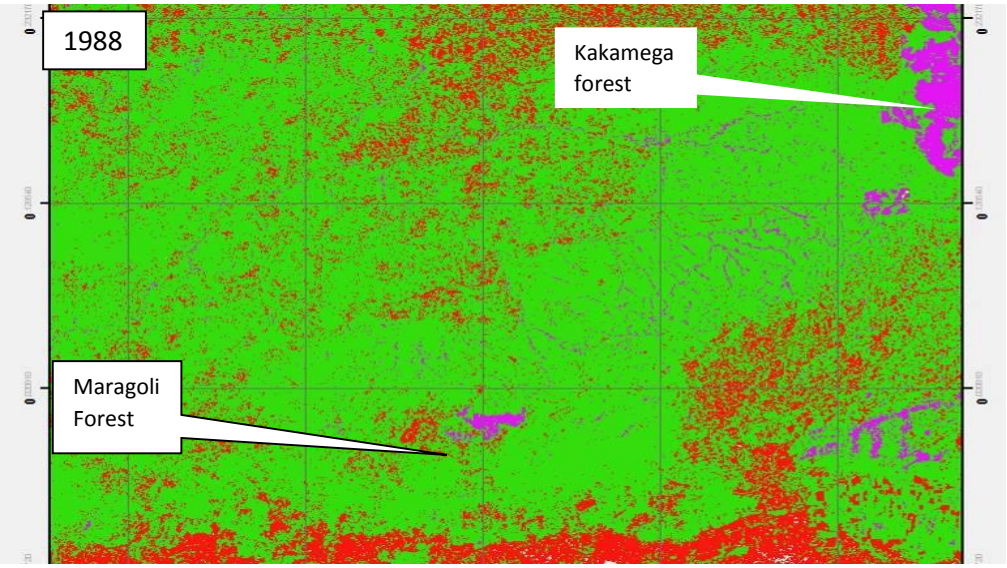

Figure 3: Classified land sat image of the study area in 1988 showing Maragoli forest under forest cover

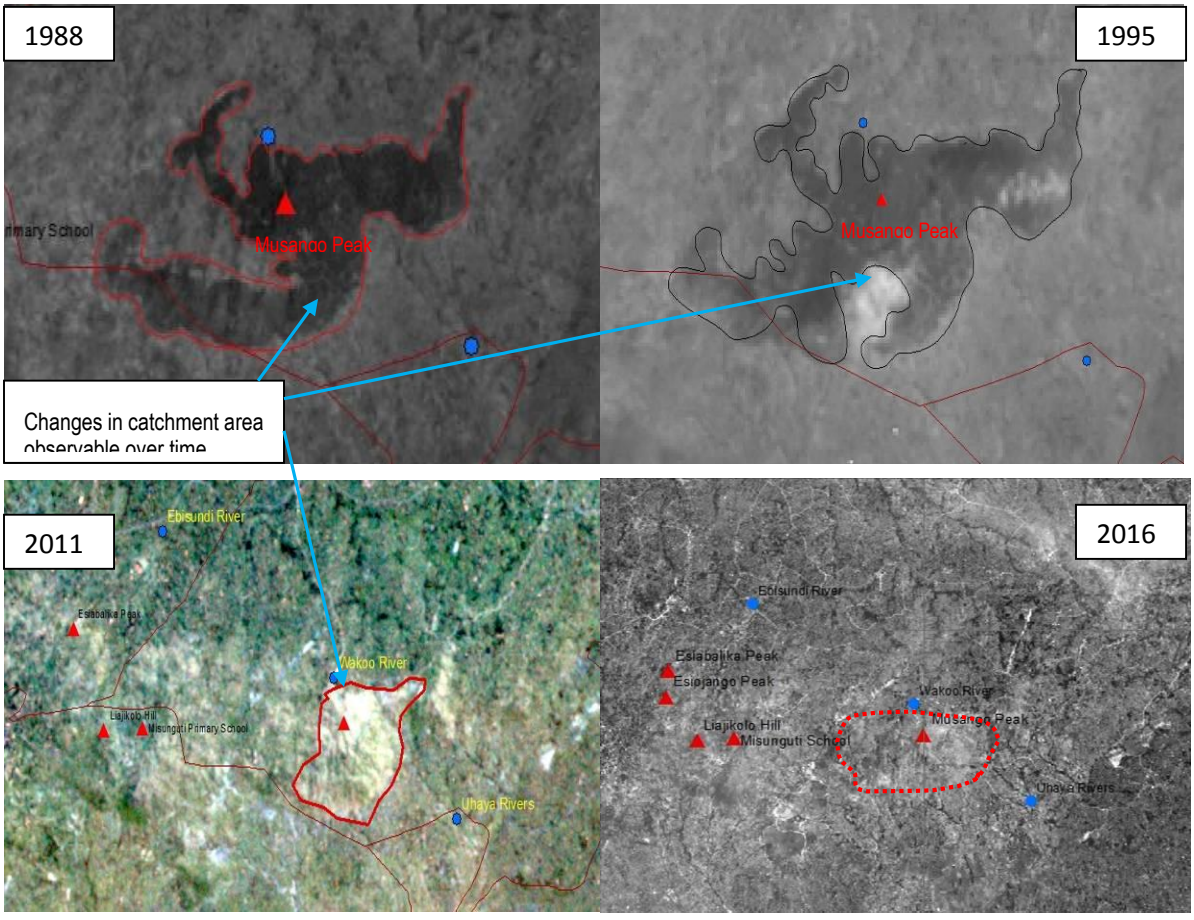

Figure 4: Observable change in catchment area between 1988 and 2016

Field surveys carried out in southern Vihiga hills in August 2016 confirmed that Maragoli Forest was 100% degraded, providing grazing fields for animals (plate1). The field survey found evidence of deep galleys in sections of Maragoli forest area, which was undermining the stability of hill slope with risk of hill collapse. Field Survey in Emusunguti hills also established a case of heavy erosion with deep galleys and collapse of hill slope in several areas and heavy sand harvesting activities in streams as a result of erosion in hilly areas (plate 1). From interviews with elderly residents in the area of study the study established that all hills in southern Vihiga hills had thick vegetation cover up to 1970s. Residents indicated that from 1970s population pressure lead to clearing of vegetation in Maragoli Hills and in Bunyore Hills. Residents in Bunyore hills confirmed that members of the community had frustrated initiatives to plant a forest extending from Maragoli hills to all Bunyore Hills.

Table 1: Landsat Imagery Analysis on Catchment Degradation on Maragoli Forest

	Change in catchment area calculated from satellite imagery		
Year	**Area (sq.km)**	**Chnange (sq.km)**	**Percentage change**
1988	4.822798	0	0
1990	4.49114	-0.33166	6.9
1995	3.915938	-0.90686	18.8
2011	0	-4.8228	100
2015	0	-4.8228	100
Total Loss area			**100**

Water analysis

The second objective of the study was to analyze water quality in streams with sources in southern Vihiga hills. Water quality in streams and rivers is vital for human populations, especially, in rural areas where there is high dependence on river water supplies. The catchment under study is one of the most populated areas in Kenya, with high population settlements along the stream originating from the catchment under. Thus the quality of water in the streams and rivers in the area directly affects the lives and livelihoods of the people in the area. Water quality was analyzed in terms of biological and physiochemical parameters of water samples collected from Ebisundi and Wakoo stream important tributaries to the major rivers that join River Yala, and Uhaya stream which join river Muguruk which drains into Lake Victoria.

Biological water quality

Biological water quality is the amount of impurities of biological origins present in water. Biological water quality was analysed in terms of the percentage counts of *Coliform* and *E.Coli* bacteria in the water. The presence or absence of *Coliform* and *E.Coli* bacteria in water indicates the health of water. Analysis of samples collected from three (Wakoo; Ebisundi; and Wahaya), found the populations of *Coliform* and *E.Coli* in waters to be very high (TNTC-too numerous to be counted in sample) both in wet and in dry seasons (table 2). The high concentration of *Coliform* and *E.Coli* in water sample in the dry and wet seasons was interpreted to suggest a catchment that has lost its potential on water purification as noted by Farrell-Poe (2000). The two indicators *Coliform* and *E.Coli* in water sample were way above the recommended standards by the WHO thus making the water from the streams in which the sample were collected to be technically unfit for domestic consumption.

Plate 1: Evidence of heavy erosion and hill collapse on Emusunguti Hilll and sand harvesting

The high biological contamination further indicates, perhaps, heightened biological activities in Maragoli Forest area from which streams originate, which may include increased grazing activities leading to increased faecal matter on the catchment, but also may be suggestive of increased human presence/settlement in the catchment and widespread open defecation and bad waste disposal mechanisms.

Table 5: Biological Water Quality Results From Three Rivers in Dry and Wet Seasons

Season	River	Coliform count/100ml	E.Coli count/100ml
Dry Season	Uhaya	TNTC	TNTC
	Wakoo	TNTC	TNTC
	Ebisundi	TNTC	TNTC
Rainy Season	Onzoore	TNTC	TNTC

	Wakoo	TNTC	TNTC
	Ebusundi	TNTC	TNTC
WHO/KEBS standards		**100/100**	**NIL/100ML**

*TNTC – Too numerous to be counted

Considering the social and economic activities dependent on the streams from which samples were collected, continued use of water from the three streams should be taken as a point of great concern. While some microbial populations in water pose little threats to life, presence of biological organisms to levels found in water samples in the three streams sampled may pose serious threat to health when consumed.

Physiochemical Water Analysis

Physiochemical water quality was analysed in terms of pH; Total Dissolved Solids (TDS); Nitrate Concentrations; turbidity; colour; and iron (Fe) concentrations of samples collected from three streams with sources in southern Vihiga Hills: Wakoo; Ebususndi; and Uhaya. In analysis of the water parameters, the results of each parameter analysed was compared with WHO standards for water quality.

Table 6: Summary of selected water analysis results

Parameter	WHO/KEBs	River	Season	Results	Deviation from WHO/KEBs
Turbidity	10 NTU	Uhaya	Dry	31.1	21.1
			Rainy	184	174
		Wakoo	Dry	10.2	0.2
			Rainy	524	514
		Ebusindi	Dry	52.5	42.5
			Rainy	319.1	309.1
Color	15 Hazens Units	Uhaya	Dry	74.6	69.6
			Rainy	980	965
		Wakoo	Dry	57.1	42.1
			Rainy	1400	1385
		Ebusindi	Dry	164.8	159.8

			Rainy	1100	1085
Fe	0.1mg/L	Uhaya	Dry	0.78	0.68
			Rainy	0.78	0.68
		Wakoo	Dry	0.52	0.42
			Rainy	1.48	1.38
		Ebusindi	Dry	0.73	0.63
			Rainy	5.9	5.8
TDS	1500	Uhaya	Dry	45	-1455
			Rainy	25	-1475
		Wakoo	Dry	31	-1469
			Rainy	30	-1470
		Ebusindi	Dry	40	-1460
			Rainy	14	-1486

KEY: - Above WHO standards

+ Within range of the WHO standards

Turbidity

The high turbidity and poor colour indicators (table 3) reveal higher sediment and other suspended solids loads in the water, further suggesting increased cases of soil erosion and vegetation degradation. The parameters also show varying trends over the rainy and dry seasons. Analysis of turbidity found Wakoo stream with the highest turbidity of 450 in rainy season, but the lowest turbidity of 50 in dry season compared to other rivers (table 3). Except for the Wakoo River in dry seasons, the turbidity of the three rivers was found to be above the recommended standards by the WHO for domestic use (10NTU).

Water colour

Analysis of colour found above threshold water color during the rainy season. This was more pronounced in Wakoo where it was >1400 in rainy seasons as compared to Uhaya and Ebisuni rivers (850 and 1000 Hazen units respectively). During the dry season, Ebisundi had the highest visibility, which is still above the allowable standards (15Hazens

Units). During the dry seasons, turbidity decreases and the water becomes clear as can be seen in the colour indicators (table 3).

Iron (Fe)

Iron toxicity was a concern for all streams; Ebisundi had highest concentration of rainy season having 5.9mg/L which gradually drops to 0.7mg/L in the dry season. The rainy season Fe concentration is higher both in Ebisundi and Wakoo, but for the Uhaya stream, which flows south, the concentrations remain the same in dry and rainy seasons. Iron concentration in water suggested a highly eroded rock landscape and is often associated with underground erosion of iron rich minerals and rocks (Farrell-Poe, 2000). Higher iron concentration in the waters may affect the solubility equilibrium for other elements like Phosphorus. Iron also has a net effect on the pH balance of the water, thus affecting the oxidation reduction balance. The iron content of River Ebisundi was found to be of concern considering that the river flows through an area with dense human settlement. The pH of the water was relatively stable and below the minimum danger thresholds set by WHO/KEBS.

TDS and Nitrates

TDS indicates the extent of dissolved actions and anions in the water which has bearing on the conductivity of the water solution. As can be seen (table 3) the level of TDS is normal bellow standards. The level of nitrates are also fairly stable, actually nitrates in solutions are part of the TDS and as such will contribute to the amount of TDS in solution.

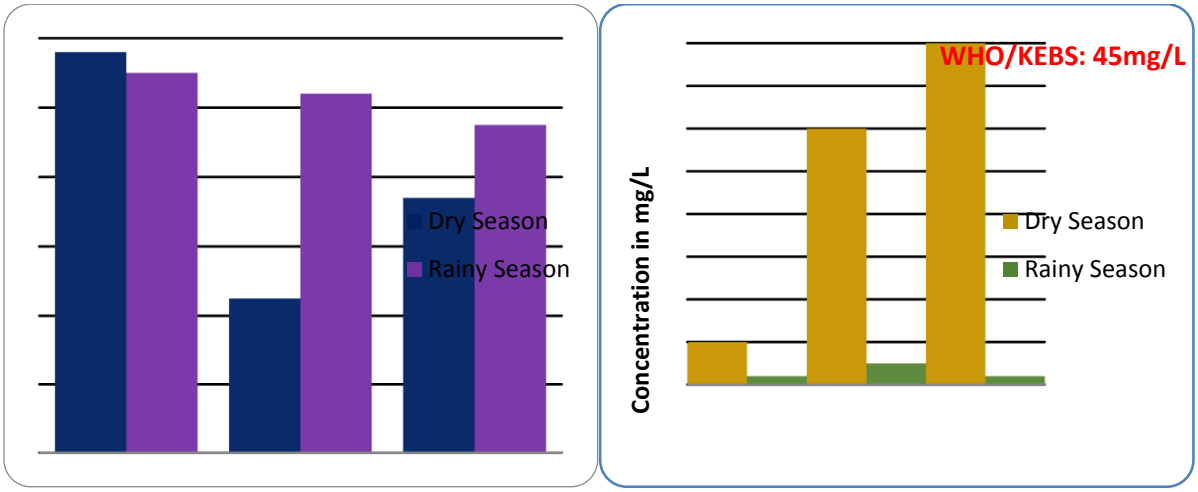

Figure 4: pH and Nitrate concentration

Conclusions and Recommendations

Satellite imagery and ground survey of Maragoli Hills found total loss of forest cover on Edibwongo Hill (Maragoli forest), with many huge areas of bare surfaces, and galleys. On Musunguti hill, similar findings of scars of erosion,

bare land surfaces and gulleys on the on steep hill slopes, with sections of the hill slopes having collapsed, these pose risk of hill collapse and related disasters. Again, water in the streams was high in *Coliform* and *E.Coli* in all the three streams sampled in both dry and wet seasons. The study also found the level of turbidity; water colour; and iron (Fe) concentrations above the recommended levels. The water is therefore be deemed unfit for human consumption. On the basis of the findings, the recommended the following; 1) adoption of an incentive based strategy for rehabilitation of Maragoli forest, 2) prioritization and investment in of water treatment and supply by the Vihiga County Government and finally 3) mapping and zoning of all hilly areas within the jurisdictions of County governments in Kenya.

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