1

Effects of Deforestation on Water Resources: Integrating Science and Community Perspectives in the Sondu-Miriu River Basin, Kenya

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1. Introduction

Rivers play a major role as sources of water for both domestic and industrial use in many parts around the world. In developing countries, where infrastructure for water supply has not been fully developed, rivers provide a direct source of water for domestic use with minimal or no treatment at all. For water scarce countries, including Kenya (WRI, 2007), this means that water catchment areas should be managed properly so as to retain their capacity to supply good quality water all year round. Thus, understanding the possible consequences of land use and land cover changes on water resources is a requisite for better water resources management. However, this is not to be as many river catchments are undergoing rapid change mediated by human encroachment.

Africa boosts over 4 million first-order streams that were originally in forested catchments. However, loss of indigenous forests and their subsequent conversion to agricultural use in East Africa, for example, is one of the major threats to surface water quality (FAO, 2010). Major water catchment areas in Kenya have lost their forest cover over the years with the closed canopy forest cover currently standing at a paltry 2.0% (The World Bank, 2007). Most of these forests are montane forests and they constitute the nation's water towers. The Mau Forest Complex, the most important of them, is the source of many rivers draining the Kenyan side of the Lake Victoria basin, with other rivers draining into Lakes Nakuru, Baringo and Natron. The Mau Forest Complex has witnessed considerable land use and land cover changes. For instance, between 1973 and 2000, there was a 32% decrease in forest cover and a 203% increase in agricultural cover in the Mara River basin (Mati et al., 2008). Other river catchments on the Kenyan side of the Lake Victoria basin have also undergone similar changes. Increased intensity of agriculture and

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deforestation have been linked to increasing magnitude and frequency of runoff events and reduced baseflows, increased pesticide contamination, erosion and sedimentation of streams and rivers (Matie et al., 2008; Okungu and Opango, 2005; Osano et al., 2003; Raini, 2009). With the inevitable challenge of climate change amid a rapidly increasing human population, averaging 3% per annum, these problems are likely to be exacerbated jeopardizing environmental management efforts, biodiversity conservation and sustainable social and economic development.

To address the problems of deforestation and land use change in Kenya, a number of approaches have been used; including forceful eviction of settlers from protected forests and catchments and awareness creation among small scale farmers, who make the largest bulk of land owners, for the use of best management practices that include agroforestry and minimal tillage, to minimize the negative effects on water resources. Several studies have been conducted that focus on assessing the effects of land use change on water resources, including water quality (e.g., Kibichii et al., 2007) and water quantity (Mango et al., 2011; Mati et al., 2008). Other studies have also focused on the use of aquatic biota to develop protocols to help monitor changes in water quality in streams and rivers in the basin (e.g., Masese et al., 2009a; Raburu et al., 2009). However, studies that integrate or combine the effects of land use and land use change on water quality and resident aquatic biota are scarce, limiting their use as indicators of surface water quality. The practice of using aquatic biota as indicators of changes in water quality arising from land use practices is a well developed system which gives resource managers a scientific basis for effecting water management guidelines and practices. Since such system does not exist in Kenya and in the wider Eastern Africa region, there is a need to develop biological criteria using aquatic communities as indicators of water quality.

Indigenous knowledge and community perspectives on deforestation and land use change and their effects on water resources have also not been recognized in efforts to conserve and manage key water catchment areas in Kenya. The approach used by the Kenyan Government has been to forcefully evict people from forests and key water catchment areas around the country. However, questions have been raised on the success of this command-and-control approach to environmental conservation (Norgrove and Hulme, 2006; Okeyo-Owuor et al., 2011). This approach also negates the fact that communities that have lived with forests for ages and entirely depend on them for their daily livelihoods have by necessity developed a sense of ownership and systems that conserve the forest for posterity. In the Mau Forest Complex, the Ogiek community has a long history of sustainably living with the forest. As hunters and gatherers the Ogiek have a system of territoriality that prohibits members of one clan or family from invading another's territory for hunting, thus reducing overexploitation of the forest. However, because of immigration, other communities have over the years moved in to clear sections of the forest for farming and settlement. This has led to degradation of the forest and the recent calls for restoration and conservation. This paper discusses (i) the effects of deforestation on water quality and macroinvertebrate communities in streams and rivers draining into the Kenyan part of the Lake Victoria basin; (ii) the Ogiek community's perspectives on land use change and its effects on water resources from an indigenous knowledge point of view.

2. Materials and methods

2.1 Study area

The Sondu-Miriu River Basin is located at latitude 0°17'S and 0°22'S, longitude 34° 04' E and 34° 49' E (Fig. 1). It forms the fourth largest basin of Kenyan rivers that drain into Lake Victoria, covering an area of 3470 km². The main tributaries of the river are the Kapsonoi and Yunith. The river originates from the Mau Forest Complex, an expansive water tower in Kenya where several rivers that drain into Lakes Bogoria, Nakuru and Natron originate. However, forest excisions and the subsequent conversion to agricultural use have reduced its forest cover. The Sondu-Miriu River catchment is characterized by diverse land use types and developments including forestry, large-scale and small-scale agriculture, urban and sub-urban settlements, agro-based industries and hydroelectric power generation. Because of the combined effects of these human activities, and the increase in their scale and intensity over the years, they impose multiple threats to water quality, aquatic biodiversity and general ecology of the river. Evidently, the water quality status in the Sondu-Miriu River has recorded increasing rates of sedimentation over the years (Fig. 2).

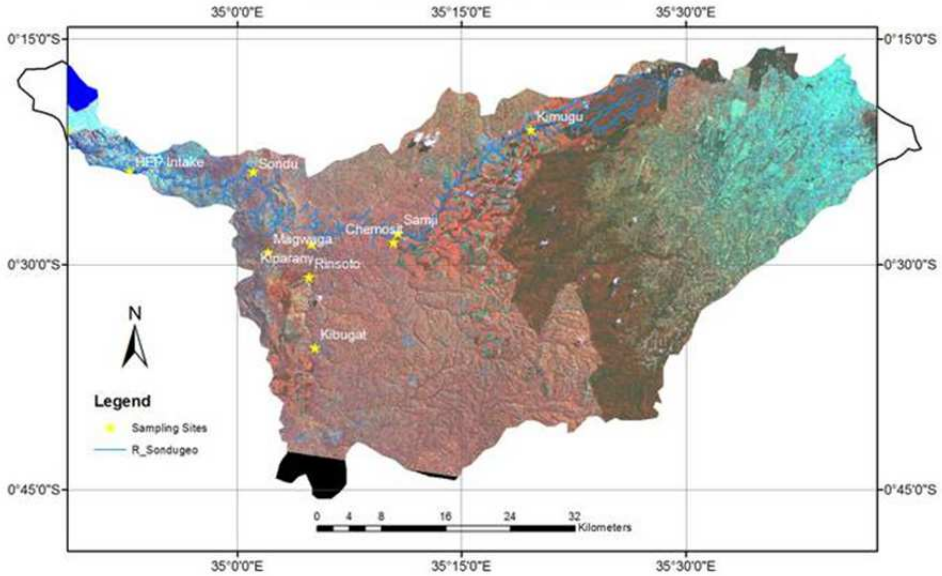

Fig. 1. The Sondu-Miriu River basin indicating sampling sites.

2.2 Study design

The Sondu-Miriu River Basin can be divided into three zones on the basis of altitude and climate. Altitude in the upper zone ranges from 1686 to 2003m above sea level (a.s.l) with humid climatic conditions. The middle zone falls within an altitude range of 1496 to1630 m a.s.l and sub-humid climatic conditions. The lower zone, whose altitude ranges from 1137 to 1394 m a.s.l and falls within the semi-humid climatic regime. The upper part, is mostly covered by forests and woodlands, while the remaining part is under tea, both plantations

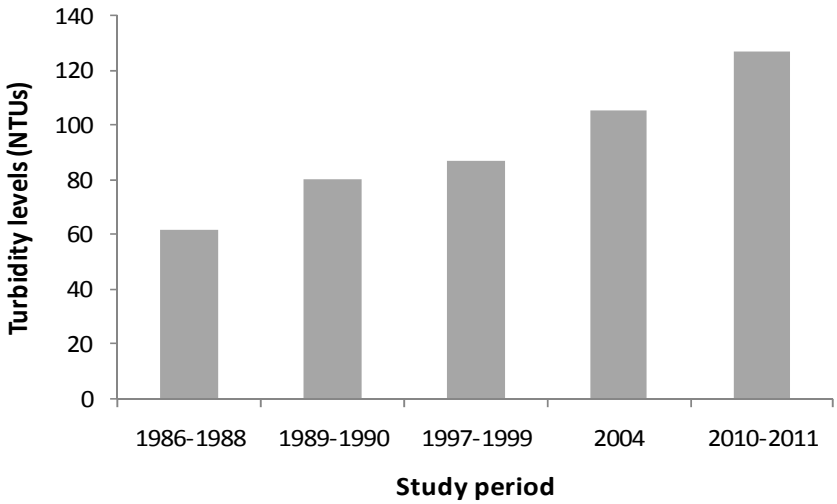

Fig. 2. Historical trends in mean turbidity (NTUs) levels in the Sondu-Miriu River. Sources of data: Ochumba and Manyala 1992; Mwashote and Shimbira 1994; Ojwang 2004 unpublished data, and this study.

and small-holder farms. The middle zone, which is mostly hilly, is covered by herbaceous vegetation. However, most of the natural vegetation has been replaced by exotic tree species, mainly *Eucalyptus* sp., inter-planted with crops. The lower zone is generally semi-arid, with bare soils covered by sparsely distributed shrubs dominated by acacias. This zone is settled by people practicing subsistence agriculture of both crop and livestock. For this study, only the upper and middle zones were considered. A total of 8 sampling sites were selected for the study (Table 1).

2.3 Land cover mapping

The main objective of the study is to determine the relationship between land cover characteristics on one hand and stream flow and aquatic organisms characteristics on the other hand. Land cover characteristics are represented by changes in land cover, mainly the loss of forests and other natural vegetation conditions to farming and settlements, including large scale tea plantation, subsistence farms, homesteads as well as urban and road infrastructure. Land cover changes were obtained by classifying satellite-based remotely sensed data from Landsat TM images acquired in January 1986 and January 2009. Stream flow characteristics analyzed were water quality and stream discharge parameters. Aquatic organisms are represented by diversity and abundance of macro-invertebrates found along the river.

A field survey identified ten main land cover classes including water, natural forests, plantation forests, woodlands, bushlands, bare surfaces, tea plantations, subsistence farms and built environments (homesteads, urban areas and roads). Due to inter-class similarity and intra-class variability in spectral characteristics, the study area was defined into three zones namely upper, middle and lower. However, because of obvious differences brought

about by a waterfall in the lower sections of the river, only two zones, the upper and middle, were included in the water quality and macroinvertebrates data.

2.4 Sampling and sample analysis

Sampling was done from September 2009 to April, 2011 to capture both dry and rainy seasons. In each sampling station, electronic meters were used to measure conductivity, temperature, pH and DO *in situ*. Alkalinity and water hardness were determined colorimetrically on site immediately after sampling. Triplicate water samples were collected, fixed with sulphuric acid to below pH 2 and transported to the laboratory for nutrient analysis using standard procedures (APHA, 1998).

2.4.1 Macroinvertebrate assemblages

Triplicate samples of macroinvertebrates were collected from pools, riffles and runs using a dip net. They were placed in polyethene bags and immediately preserved using 75% ethanol and shipped to the laboratory where they were sorted, identified to lowest taxon level possible and counted. Assemblage attributes were determined for each site using diversity and richness measures and the relative abundance of various taxa. Potential macroinvertebrate metrics for IBI development were categorized by their relationship to community structure, taxonomic composition, individual condition and biological processes (Table 2) using groups previously used in riverine ecosystems in the ecoregion (Kobingi et al.; 2009, Masese et al.; 2009a; Raburu et al., 2009; Aura et al., 2010). A ''metric'' is an attribute that changes in some predictable way in response to increased human disturbance and that has been included as component of a multi-metric IBI (Karr and Chu, 1999). Testable hypotheses for these classes of attributes were proposed regarding the direction (increase, decrease, no change) of change to increasing levels of human disturbance (Table 2). Twenty-two metrics were selected *a priori* based on their demonstrated ability to evaluate environmental condition in rivers in the region (Aura et al., 2010; Kobingi et al., 2009; Raburu et al., 2009) and evaluated to identify key ones that responded to changes in macroinvertebrate condition in the Sondu-Miriu River Basin.

2.5 Indigenous knowledge about deforestation

In December 2008 a comprehensive study was undertaken to incorporate indigenous knowledge in the mapping of the critical areas within Mau Forest Complex. During this survey indigenous knowledge data were collected from the communities living within and around the forests using structured questionnaires, Focused Group Discussions (FGD) and Key Informants Interviews (KII).

2.6 Data analysis

To describe the variation in environmental variables, means of all measured environmental variables were calculated for all sites. One-way ANOVA was used to detect differences among different physico-chemical parameters, land uses variables and macro-invertebrate attributes. Metrics were evaluated for responsiveness to changes in water quality and land use by correlation analysis. Summary statistics on indigenous knowledge are presented in tables and charts.

Biophysical Characteristics	Sampling sites and thir attributes							
	Upper Zone				Middle zone			
	Kibugat	Chemosit	Jamji	Kimugu	Sondu Bridge	Magwagwa	Rinsoto	Kiparanye
Altitude	1686	1701	1709	2003	1496	1567	1591	1630
Topography	Steep slopes	Undulating hills	Undulati ng hills	Undulating hills	Flat surrounded by hills	Gentle undulating hills	Steep slopes	Rolling hills
Natural land cover	Woodland				Woodlands	Shrubland with planted woodlands	Woodland	Planted woodlands
Major land use	Tea and	Tea plantations	Tea plantatio ns	Tea plantations	Subsistence farming	Subsistence/smal l-holder tea	Tree and tea plantations	Subsistence/small holder tea
Level of degradation	Little evidence	Little evidence	Little evidence	Little evidence	No evidence	Reduced water levels	Little	Little evidence, clear water

Table 1. Site physical characteristics in the upper and middle zones of the Sondu-Miriu River Basin as characterized in this study.

Metric	Metric definition	Predicted response
Number Ephemeroptera taxa	Total number of mayfly taxa	Decrease
Number Plecoptera taxa	Total number of stonefly taxa	Decrease
Number Trichoptera taxa	Total number of caddisfly taxa	Decrease
Number Ephemeropter-Plecoptera-Trichoptera genera	Total number of taxa from mayfly, stonefly and caddisfly orders	Decrease
Total number of taxa	All different taxa at a site	Decrease
Percent EPT individuals	% individuals from mayfly, stonefly and caddisfly orders	Decrease
Percent non-insect individuals	% of individuals no belonging to the insect orders	Increase
Percentage Diptera individuals	% midge individuals	Increase
EPT: Diptera individuals ratio	Ratio of individuals belonging to mayfly, stonefly and caddisfly orders to that of midges	Decrease
Percent Coleoptera individuals	% of beetle individuals	Decrease
Shannon diversity index	Value of Shannon diversity index	Decrease
Number intolerant taxa	Total number of taxa belonging to pollution intolerant taxa	Decrease
Percent intolerant individuals	% of individuals in pollution sensitive taxa	Decrease
Percentage tolerant individuals	% of individuals in pollution tolerant taxa	Increase
Percentage filterer individuals	Filter fine organic material	Increase
Percentage scraper individuals	Feed on epiphytes	Decrease
Percentage predator individuals	Carnivores- scavangers, engulf or pierce prey	Decrease
Percent Shredder individuals	Feed on leaf litter	Decrease
Percentage gatherer individuals	Collect fine deposited organic material	Increase

Table 2. Metrics for macroinvertebrates that were considered for development of an index of biotic integrity for the Sondu-Miriu River Basin and the predicted responses to pollution.

3. Results

3.1 Land use/ cover characteristics

The ISODATA unsupervised classification algorithm was used to create 12 spectral classes for each zone for both 1986 and 2009. These classes were combined into 3-5 major land cover types using field data (Tables 3 and 4). Based on initial spectral analyses of representative signatures, only 3 of the 7 Landsat TM which had high inter-class separation were used. These are TM bands 2, 3 and 5. Class statistics for the two time periods were computed and compared for each zone.

Land use/ cover type	1986 (Ha)	2009 (Ha)	Change (1986-2000)	Change (%)
Forests	19486	15452	-4034	-20.7
Bushlands	11850	10627	-1223	-10.3
Farms and settlement	11141	16398	5256	32.1

Table 3. Land use/ cover areas in the upper Sondu-Miriu River basin- Kimugu Sampling Site.

Land use/ cover type	1986	2009	Change (1986-2000)	Change (%)
Water	8409	7006	-1403	-16. 7
Woodland/ Wetlands	24332	18458	-5874	-24.1
Sparse	8213	6992	-1221	-14.9
Bare	13452	11888	-1564	-11.6
Farms/ settlement	21439	31501	10062	46.9

Table 4. Land use/ cover areas for the lower Sondu-Miriu River Basin- River-Mouth Sampling Site.

3.2 Water quality

The changes in physico-chemical water quality parameters and nutrients downstream are given in Table 5. With the intensification of human activity downstream, corresponding with the increase in the land area under agriculture, changes in the water physico-chemical parameters were also observed. For instance, temperature, turbidity and TSS values were higher at the lower reaches.

Site	Turbidity (NTUs)	Conductivity (µS/cm)	DO (mg/L)	Temperature (°C)	TN mg/L	TP mg/L	TSS mg/L
Kimugu	64.3±32.6	63.4±25.2	7.0±0.3	16.5±0.7	2.6±0.25	0.4±0.18	31.4±20.6
Jamji	76.2±24.3	103.7±18.8	7.40.2	17.2±0.5	2.1±0.18	0.4±0.14	25.8±15.3
Chemosit	118.4±32.6	43.0±25.2	6.9±0.4	19.5±0.7	1.9±0.25	0.7±0.18	21.8±20.6
Kibugat	173.3±28.1	79.0±22.9	6.9±.03	21.5±0.6	2.5±0.23	0.3±0.17	32.6±18.8
Kipranye	90.9±23.1	95.6±17.8	7.1±0.2	19.5±0.5	2.0±0.17	0.4±0.13	30.2±14.5
Rinsoto	192.8±29.8	90.5±22.9	6.8±0.3	21.6±0.7	2.6±0.23	0.4±0.17	64.8±18.7
Magwagwa	163.1±29.8	58.8±23.0	6.6±0.3	21.7±0.7	2.2±0.22	0.5±0.17	43.0±18.8
Sondu Bridge	117.03±24.3	128.7±18.6	7.1±0.3	20.3±0.5	1.8±0.18	0.3±0.13	42.6±15.3

Table 5. Physico-chemical characteristics and nutrient levels at the various sites along the Sondu-Miriu River.

3.3 Macroinvertebrate assemblages

A total of 16 orders, 47 families and 49 genera were encountered during the study period. Whereas their distribution was varied with a few predominating upstream, mid-stream and downstream reaches, many of the macroinvertebrates displayed basin-wide distribution. Some of these included odonates belonging to Genera *Gomphus* sp. and *Agrion* sp., plecopterans *Nemoura* sp and *Neoperla* sp., hemipterans *Belostoma* sp. and *Gerris* sp., the pulmonate *Sphaeriun* sp., dipterans *Tipula* sp and *Chironomidae* and the ephemeropterans *Baetis* sp, *Afronurus* sp., *Caenis* sp. and *Adenophlebia* sp. and lastly the trichopteran *Hydropsyche* sp. Table 6 summarizes the species richness and diversity indices of the macroinvertebrates found along the river system. Taxon richness was low in the uppermost stations in both the Yurith and Kipsonoi sub-catchments, increasing significantly downstream with the mid stations registering a relatively high number of taxa at Kipranye, Magwagwa and Sondu Bridge Stations.

		Macroinvertebrate Diversity Measures			
Station	**Number of taxa**	**Dominance**	**Shannon Index**	**Evenness**	**Simpson Richness (1/D)**
Kimugu	25	0.26	2.51	0.32	8.89
Jamji	22	0.24	1.91	0.35	7.31
Kipranye	26	0.18	2.25	0.37	5.67
Sotik	19	0.25	1.66	0.34	4.1
Kibugat	18	0.11	2.41	0.39	9.09
Rinsoto	16	0.17	2.02	0.35	6.04
Magwagwa	22	0.12	2.45	0.45	6.71
Sondu Bridge	24	0.16	2.28	0.35	5.15

Table 6. The diversity measures of macroinvertebrate communities at the study stations along the Sondu-Miriu River.

3.3.1 Index of biotic integrity

Table 7 show metrics that qualified for the determination of the macroinvertebrate Index of Biotic Integrity (MIBI) and the scoring criteria derived from the data collected in Sondu-Miriu during the study period.

	Scoring criteria		
MIBI metrics	**5**	**3**	**1**
Number Ephemeroptera genera	≥ 6	3 - 5	≤ 2
Number Plecoptera genera	2	1	0
Number Trichoptera genera	≥ 5	3 - 4	≤ 2
Total number of genera	> 40	20 - 40	< 20
Number intolerant ganera	≥ 10	5 - 9	≤ 4
% EPT-BCH individuals	> 40	18 - 40	≤ 18
% Non-insect individuals	< 10	10 - 16	> 16
% Tolerant individuals	< 31	31 - 70	> 70
% Gatherer individuals	< 5	5 - 35	> 35
% Predator individuals	> 30	15 - 30	< 15

Table 7. Ten component metrics of the macroinvertebrate Index of Biotic Integrity (MIBI) and metric values corresponding with scores based on the 1, 3, 5 scoring system.

3.4 Community perspectives on deforestation

A total of 76 households were randomly sampled in two administrative Divisions namely Elburgon and Keringet. A typical household in the two divisions had 7 members with the majority having at least primary school level of education (Figure3). Most of the respondents were also elderly (Figure 3).

In Keringet Division, which was the main focus of the survey , about 88.2 % of the respondents were farmers with a minority (11.8%) engaged in small scale business as their primary source of livelihood. It was also reported that 62.5% and 37.5% of the respondents are engaged in business and agriculture as secondary source of income, respectively. Some of the respondents interviewed in Keringet Division have been resident in the area since 1918.

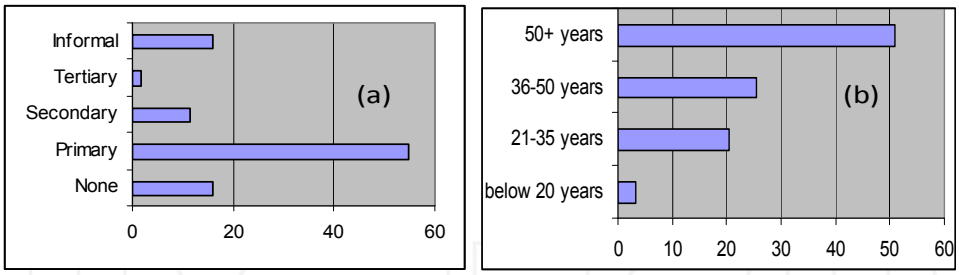

Fig. 3. Demographic characteristics of respondents in this survey: (a) level of education and (b) age distribution.

3.4.1 Value of Mau Forest in Keringet Division

The Mau forest is valuable to residents as acknowledged by a majority (94%) of the respondents during this survey. Control of soil erosion, rainfall, source of building materials and firewood are the most important uses (Figure 4). The Mau Forest has been a source of medicinal plants to the resident Ogiek community which they use to treat many ailments. In addition, communities graze their livestock and farm millet and pumpkin within the forest. Other uses include gathering of honey, fruits and hunting.

3.4.2 Water resources

The Mau Forest is an important source of streams and rivers in Keringet Division that are relied upon by the local community for water supply. Other streams and rivers mentioned by the community include Kiplapo, Cheptemet, Buchechet, Kiphoobo, Anguruwet, Oinetopilongotisiek, Oinetoptiepoison and Oinetoptieposere. Many of the streams are protected by the community by discouraging grazing of livestock within the forest, discouraging cutting of trees at their sources and discouraging cultivation at the water catchment areas. However, some streams, like Oinetopkongotisiek and Oinetopmogireri, have dried up. Some have also experienced changes because of deforestation.

3.4.3 Changes in climatic and weather parameters

The Keringet area has witnessed some changes in weather patterns in the past 20 years as reported by respondents in this survey. Before 2001 when large sections of the Mau Forest were cleared to create room for farming and settlement, the Keringet section of Mau Forest experienced moderate fluctuations in weather patterns as opposed to the current irregular state depicted in Figures 5 and 6.

During focus group discussions and key informant interviews, community members indicated that the status of the catchment area of most streams and rivers has changed. The elderly from among the Ogiek community narrated that the changes in the vegetation cover of the Mau Forest started in the 1970s when exotic commercially viable tree species were extensively introduced in the section of the forest at the expense of indigenous woody perennials. The peak of the changes occurred in 1996 when community settlement schemes began prior to the official government degazattement of sections of the forest in 2001.

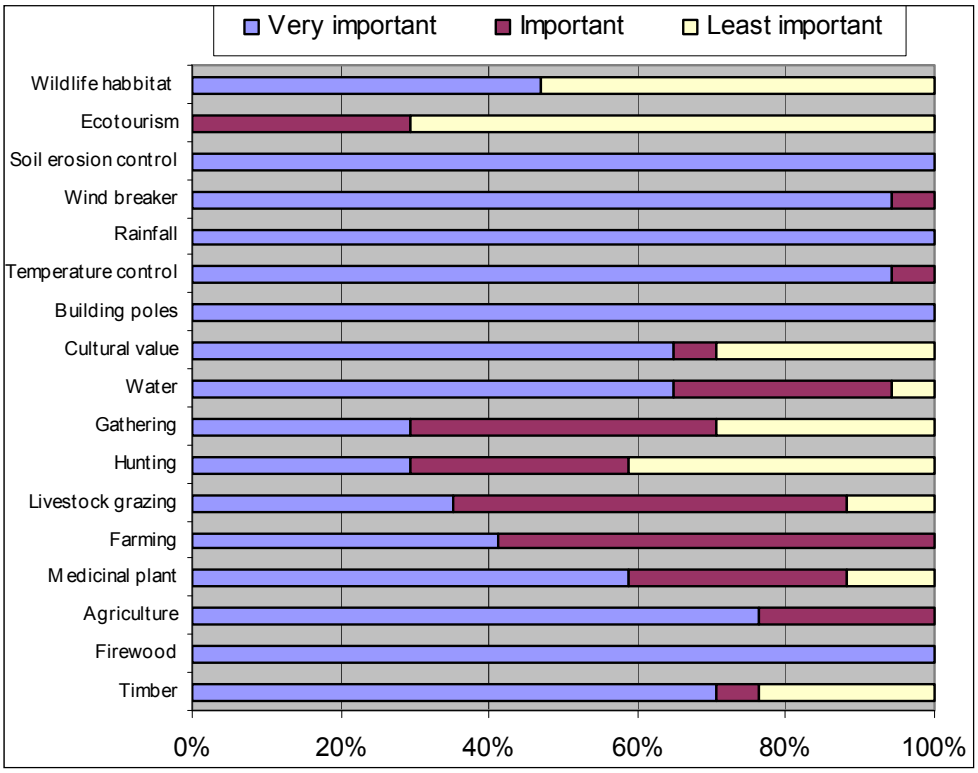

Fig. 4. Community perspectives on the importance of the Mau Forest.

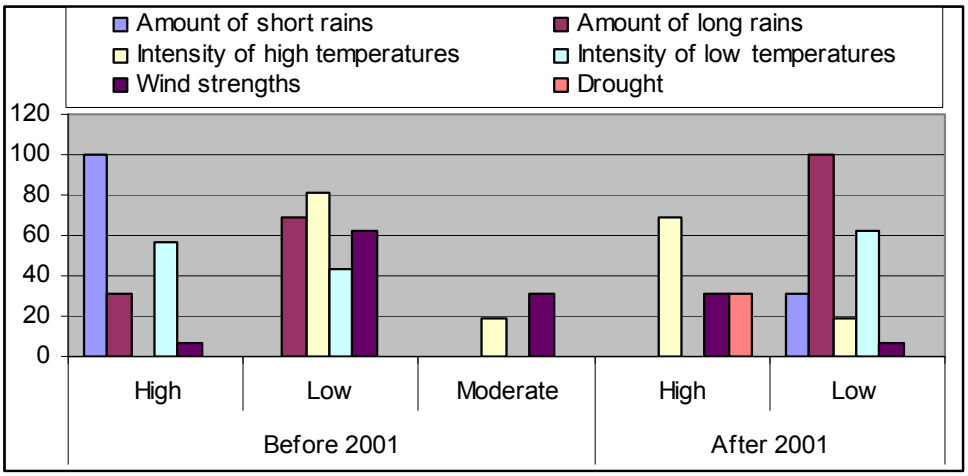

Fig. 5. Community perception on the changes in weather parameters in Keringet Division.

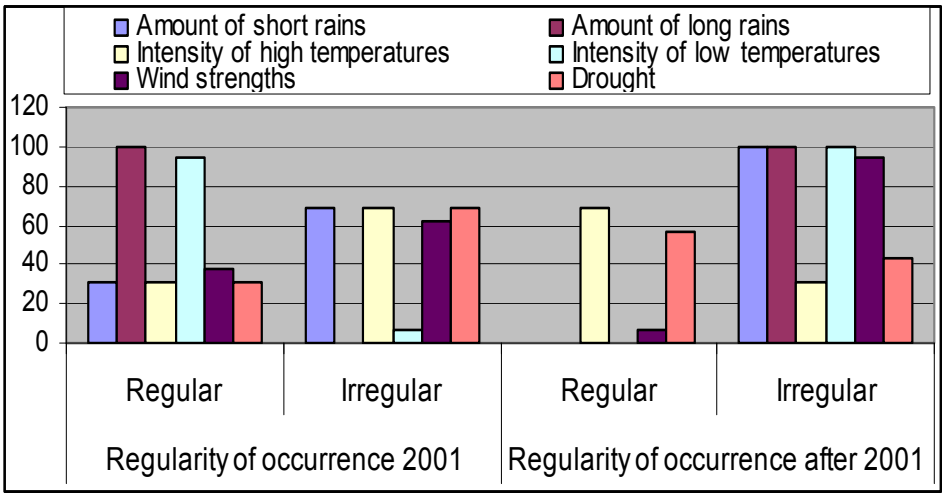

Fig. 6. Community perceptions on climatic parameters in Keringet Division.

The informants narrated how the changes have occurred gradually since the 1970's. Prior to this, the Mau Forest was rich in indigenous woody perennials with highly predictable and reliable weather patterns as opposed to the current situation. Stream flows were also regular and the water in streams and rivers clearer. Changes in quantity and quality of streams from Mau Forest became apparent in 1984 resulting in some sections of the streams gradually drying up. The land bordering the Mau Forest was initially very productive with farmers not using commercially supplied fertilizers. However, this phenomenon has changed and farmers have to apply fertilizers on their farms. Other changes include the rise in temperature levels, which has shortened the growing season of maize by about 4 months. The water table has also been going down with some springs and wells around the forest drying up.

3.4.4 Challenges to forest conservation

Lack of awareness amongst the members of the community on the environmental significance of the Mau Forest emerged as the greatest hindrance to the conservation of the Mau Forest. Nonetheless, it also emerged that the Ogiek community had a socially structured system of protecting the greater Mau Forest Complex. For example, they had a territorial management system that prohibited a member from a certain clan or family from invading another's clan or family's territory. For example during hunting, one was to seek permission from a territory leader to pursue his/her prey. Charcoal burning and cutting of trees were also prohibited. An elder of the Ogiek community who has lived in the area since 1929 gave greater insights into the changes in the forest and the way of life of the Ogiek. It was learnt that before the excision, the Ogiek community was living and zealously protected the forest along the Mau Narok, Buret and Nandi Forests, since they were hunters and gatherers harvesting only honey and wild meat. However, in 1976 their livelihood strategies started changing. They were taught how to plant maize, potatoes and other crops by the immigrants. The ensuing clearing of forests for agriculture led to degradation and mass migration of wildlife that the Ogiek depended upon.

4. Discussion

The longitudinal deterioration in water quality in the Sondu-Miriu River reflects the cumulative effects of human activities both on the riparian and in the catchment areas. This phenomenon has been reported in a number of studies conducted to investigate the influence of land use on water quality in rivers in the region (Kibichii et al., 2007; Masese et al., 2009b; McCartney, 2010). Turbidity increases downstream mainly originated from agricultural areas and erosion from unpaved roads. Previous studies in the river have also indicated that the water quality has been deteriorating (Figure 2) as a result of the intensification of agricultural activities and clearing of forests, as also corroborated by community members living in the upper reaches of the Sondu-Miriu River basin.

Macroinvertebrates assemblages encountered along the Sondu-Miriu River are typical of riverine communities in the region (Raburu et al., 2009). However, there were variations in composition and distribution and this is explained by tolerance to poor environmental conditions exhibited by the various taxa. The non-insect taxa gained more diversity and abundance as one moved downstream. This could be explained by their tolerance to pollution and higher turbidity levels. Other groups that were abundant, both in terms of taxon richness and abundance were soft bodied macroinvertebrates like oligochaetes, especially in sites receiving organic pollution. These groups are considered to be among the most tolerant to organic pollution in the Lake Victoria Basin (Kobing et al., 2009; Masese et al., 2009b). Other tolerant species include *Chironomus* sp. and *Lumbricus* sp. which are found in degraded sites because they possess high glycogen content and display reduced activity which allows them to withstand increased conductivity levels. In contrast, high abundance of Ephemeroptera, Plecoptera and Trichoptera dominated stations at the upper reaches where per cent land use under forestry is higher than in the middle and lower reaches. These sites are also less impacted by organic waste and general human disturbance. This confirms their utility as sensitive indicators of poor water quality (e.g., Masese et al., 2009a; Raburu et al., 2009).

The macroinvertebrate-based index of biotic integrity developed in this study had previously been used in the basin. Thus, the sensitivity of the metrics included in the final index has already been proven. Their use in this study was, however, to test their utility in detecting the effect of land use change of forestry to agriculture, which is a major problem in many of the river catchments in the region (e.g., Mango et al., 2011; Raini, 2009).

4.1 Integrating science and community perspectives

It was clear from the survey that the Ogiek Community has traditionally utilized the forest sustainably with well structured systems that guard against over-exploitation and conflicts. However, during interviews and discussions with community members it emerged that majority of the forest uses identified by the community as important are all consumptive in nature. This poses a great challenge to management given that their livelihoods are closely linked to the forest. However, by virtue of their long history of living with forests, the Ogiek Community had a good record of events and changes that have taken place in the forest over the years and this can be used as a basis during restoration and conservation efforts. This is more pertinent considering that not many studies have been previously conducted in the forest to assess the status of water quality and other forest resources.

There was congruence in the views held by the community and what has emerged in most studies in land use studies about the main reasons for some streams in the forest drying up. This is a good score on part of a community whose presence in the forest has been perceived as destructive. With awareness creation among these communities on the importance of forests, their participation in conservation efforts can be enhanced. Forceful evictions of communities from the forests where they have lived for generations has not been well received by residents living within and in areas adjoining protected areas (Norgrove and Hulme, 2006; Okeyo-Owuor et al., 2011). This has further entrenched, negative feelings further jeopardizing conservation efforts. There is a feeling among local communities that their interests should be given priority allowing them free access to forest resources. Their exclusion leads to the loss of ownership, making them adopt more destructive practices of forest exploitation practices in protest, instead of the traditional ones which are often more sustainable in nature (Norgrove and Hulme, 2006).

5. Conclusions

In the management of aquatic resources in Kenya, biological assessment has not been widely used to evaluate the level of degradation of streams and rivers. In the Lake Victoria basin, this is largely attributable to lack of long-term monitoring programs that can generate reference data sets for the initial development and subsequent evaluation and refinement of biological criteria and indices. However, this paper makes a significant first step towards developing a tool for monitoring human induced influences on river water quality at the catchment level. Following its effectiveness, there is the potential for developing similar indices for basin-wide and national monitoring of streams and rivers as a cost-effective means of maintaining the integrity and sustainability of our national water resources.

This study also indicates that indigenous knowledge by communities living in conservation areas can be used to identify critical areas for restoration. Their knowledge of local forest resources such as tree species and streams become useful during mapping. Their recording of events and changes in the structure and functioning of the forest can be used to benchmark restoration efforts and also to assess their success. The capacity of the communities also needs to be enhanced by offering adequate awareness creation on the significance of forests and the need for their conservation. Community representation in various groups and committees concerned with forest conservation and management should be enhanced to dispel feelings of exclusion. Meaningful restoration efforts must genuinely involve community members and their leaders.

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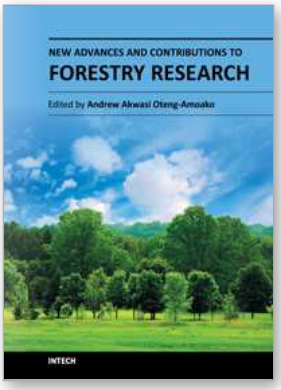

New Advances and Contributions to Forestry Research

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New Advances and Contributions to Forestry Research consists of 14 chapters divided into three sections and is authored by 48 researchers from 16 countries and all five continents. Section Whither the Use of Forest Resources, authored by 16 researchers, describes negative and positive practices in forestry. Forest is a complex habitat for man, animals, insects and micro-organisms and their activities may impact positively or negatively on the forest. This complex relationship is explained in the section Forest and Organisms Interactions, consisting of contributions made by six researchers. Development of tree plantations has been man's response to forest degradation and deforestation caused by human, animals and natural disasters. Plantations of beech, spruce, Eucalyptus and other species are described in the last section, Amelioration of Dwindling Forest Resources Through Plantation Development, a section consisting of five papers authored by 20 researchers. New Advances and Contributions to Forestry Research will appeal to forest scientists, researchers and allied professionals. It will be of interest to those who care about forest and who subscribe to the adage that the last tree dies with the last man on our planet. I recommend it to you; enjoy reading it, save the forest and save life!

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