DRIVERS OF GULLY EROSION: CASE STUDY, NAROK COUNTY, KENYA

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Abstract

Soil erosion is a serious issue in Arid and Semi-Arid lands and affects community livelihoods and soil conservation efforts. The objective of this paper is to assess drivers of gully in Narok County, Kenya. The driving forces of soil erosion can lead to gradual loss of the adaptive capacity of the soil and its ecosystem.Agricultural intensity without soil conservation measures is linked to greater water erosion. Overgrazing is one of the main drivers of gully erosion in rangelands. Global warming puts more regions at high risk of gully erosion in the future. The projected scenario (2030) showed an increase in the area under shrubland, cropland and close natural forest and a decrease in grasslands and open natural forest in Narok County. This indicates overgrazing and deforestation will reduce vegetative cover resulting in increased runoff in the County.Further research in land use changes such as change in scale and intensity needs to be done particularly in the arid and semi- arid areas. More soil erosion studies that take into account socioeconomic factors are required. Projected land use and land cover change and climate scenarios are also needed particularly in relation to gully erosion.

Keywords: Drivers, Gully Erosion, Agriculture, Grazing, Climate Change, Narok County

1. Introduction

Gully erosion is a process whereby runoff water accumulates over short periods, and removes the soil to considerable depths (Poesena*et al*., 2003). Globally, about 1.1 billion ha of land is affected by erosion (Pathak *et al*., 2006). It is estimated that 80% of the current degradation on agricultural land in the world is caused by soil erosion due to water (Sharda*et al*., 2012). Erosion by water is a primary agent of soil degradation at the global scale, affecting about 1094 million hectares, or roughly 56% of the land experiencing human induced degradation (Nasri*et al*., 2009). The United Nations Environmental Program reported that crop productivity is reduced by about 20 million ha/year due to soil erosion and degradation (Lim *et al*., 2005). In Iran, soil erosion rates in agricultural lands vary between 7.6 and 32 ton/ha/yr and 4.3– 22 ton/ha/yr in rangelands (Samani*et al.,* 2009). Research conducted in Imo, Abia and Anambra States, Nigeria shows that gully erosion generate between 4.2 and 10 m^3/ha/year of sediments, which constitute about 45–90% of total sediment production from agricultural lands (Ogbonna*et al.,* 2011). Gully erosion contributes to 50% to 80% of overall sediment production in drylands. Global sediment yields constitute 12.1 in Ethiopia, 3.4 Kenya, 32 Niger, 16.1 Portugal, 64.9 Spain and 36.8 ton/ ha/yr in the USA (Frankl, 2012), hence affecting large areas that could have been put to productive use.

According to Van-Camp *et al*., (2004) soil erosion is severe in Romania (6.7 million ha), Bulgaria (4.8 million ha), Poland and Hungary (4.7 and 3.8 million ha respectively). Current rates of soil erosion documented in Ethiopia range from 16-300 tons/ha/year (Itanna*et al.,* 2011).With a very slow rate of soil formation, any soil loss of more than 1 t/ha/yr can be considered as irreversible within a time span of 50-100 years (Van-Camp *et al.,* 2004). In Africa about 29 million ha of land is affected by gully erosion (Pathak *et al*., 2006). It is estimated that cultivated and degraded land generates 10–20 times more runoff than do forests; thus, expanding cultivation can drive soil degradation unless the land is well managed (Moges*et al.,* 2009). Gully development is believed to spread from upslope to downslope, and the rate of soil loss has been estimated to range from 11 to 30 t/ ha/yr in Ethiopia (Moges*et al.,* 2009) through gully erosion. According to Kodiwo*et al.,* (2013), 23 and 8 per cent of the total land area in Kenya is severely and very severely degraded respectively. Gully erosion is more often linked to the vulnerability of the landscape and the land use/cover changes (Frankl*et al*., 2011).

The driving forces of soil erosion are social, economic, ecological and physical but they act in an integrated way (Van-Camp *et al.,* 2004). Soil erosion is driven by the forces of climate (energy of wind and rainfall), and also when vegetation and upper soil horizons have their storage and regulation functions impaired or diminished under the influence of human actions. Pollution, cultivation and land leveling can lead to the gradual or sudden loss of the adaptive capacity of the soil and its ecosystem to retain water and sediment on a slope. According to Van-Camp *et al.,* (2004)thedriving forces for erosion include land use changes such as change in scale and intensity, abandonment, and desertification, forest fires, land levelling and soil displacement by tillage, climate change (change in frequency and magnitude of events), which is the case in the arid and semi-arid areas. Therefore the identification of driving forces in gully erosion is important for effective rehabilitation.

Socioeconomic variables are important determinants of soil erosion (Udayakumara, *et al*., 2010), since human actions are drivers of erosion processes. Most soil erosion studies do not take into account socioeconomic factors of soil erosion (Udayakumara, *et al*., 2010), and this aspect therefore needs to be investigated. If there was more awareness and concern by government and local communities about the consequences of soil erosion, in terms of the irreversible loss of capital and future opportunities for its productive use (Van-Camp *et al.,* 2004), then every effort would be put in addressing the driving forces and pressures on fragile lands.

Some of the driving forces have been studied and reveal strong increases in gully erosion as a consequence of land use changes, in combination with extreme rainfall events and further induced by socio-economic changes. In Ethiopia erosion is estimated to range from 1,248 - 23,400 million ha per year from 78 million ha of pasture and range lands and cultivated fields (Itanna*et al.,* 2011). The organic matter loss associated with the removal of surface soil ranged from 15-1000 kg/ha/year which amounted to 1.17-78 million ha of organic matter lost per year from cultivated and grazing lands in Ethiopia (Itanna*et al.,* 2011). According to Titilola*et al.,* (2008), soil loss through erosion prompted by poor land use practices could be as much as 15 tons per hectare per year on a bare ploughed soil in Western Nigeria. About 850,000 hectares of land are badly affected annually or rendered useless for agricultural purposes and human settlement (Titilola*et al.,* 2008). Therefore the consequences of soil erosion are severe and every effort should be put to prevent it.

Gullies not only occur in marl (clay + lime) and mountainous or hilly regions but also more globally in soils subjected to loess (European belt, Chinese Loess Plateau, North America) and sandy soils such as the ones that are dominant in the study area in Suswa and Sahelian zone, north-east Thailand (Shahrivar*et al.*, 2012), hence further accelerating the driving forces and pressures of gully erosion. Therefore, the rate of gully erosion depends on the run-off-producing characteristics of the watershed: the drainage area; soil characteristics; the alignment, size and shape of the gully; and the gradient of the gully channel (Geyik, 1986). Gully erosion studies have also shown increasing concern for off-site impacts of soil erosion. Increased exploitation of land resources in upper parts of catchments results in increased sediment yield and elevated nutrient loads in runoff that reduce water quality and availability to downstream users (Poesena*et al.,* 2003), hence the need to study the effects of gully erosion on communities.

2. Factors affecting gully formation and development-Case Study

Changes in various types of land use in Kenya from 2005-2008 are shown in Table 1. Eighty percent of Kenya's land area is arid or semi-arid (ASALs) supporting 50% of livestock and 80-90% of wildlife resources. Twenty percent of the remaining arable land area has over 80% of the population living in these areas. Twelve percent of the land area was originally covered by forests and have been reduced to 1.7% of its original size, due to population pressure for settlements, infrastructure, demand for wood products and conversion to agriculture. Forest cover is therefore lower than the recommended threshold of 10% (National Environment Management Authority-NEMA (2011). This indicates a worrisome trend in land use and land cover change in Kenya.

Table 1: Changes in various types of land use in Kenya from 2005-2008

Categories of land use type	**Areas ('000 ha) in Year-2005**	**Areas ('000 ha) in Year-2008**	**Remarks**
Indigenous closed canopy forests	1165	1165	Decreased forest cover (25 000 ha) due to human interference in Cherangani, Samburu and Mau forests

Mangroves	54	54	Located in Kilifi , Malindi, Lamu (coastal areas).
Industrial plantation Forests	134	107	This is in additi on to 16000 ha of the unplanted designated areas
Private plantation Forests	83	90	Increasing trend due to accelerated commercial planting by private sector and farmers
Subtotal closed canopy Forests	1532	1 406	2.4 per cent of Kenya's total area
Woodlands	2075	2 050	Spread mainly in the ASALs
Subtotal of forest Areas	3496	3 456	5.9 per cent of Kenya's total area
Bush-lands	24570	24 510	In ASALs and medium rainfall areas
Grasslands	10350	10350	Mainly in the savannah
Settlements	8152	8 202	
Tree on farmlands	10320	10 385	Mainly in high and medium rainfall areas
Inland water bodies	1123	1123	
Total area	58037	58037	

Source: National Environment Management Authority –NEMA (2011)

Table 2: Land cover change in Narok County

Category	**Total Area (ha) 1970s**	**Total Area (ha) 2000s**	**% change (1970s-2000s)**	**% change 2030 (ha)**
Woodland	444 079	49231	-88.9	Substantial
Shrubland	374 202	785890	52.4	53.0
Bareland	59 242	804	-98.6	-

Cropland	42388	328 104	87.1	94.0
Open natural Forest	390 871	189050	-51.6	-60.2
Close natural Forest	-	103 174	100.0	100.0
Grassland	201 223	55752	-72.3	-74.3
Total (Ha)	1 512 005	1 512 005		

Source: National Environment Management Authority- NEMA (2011)

The projected scenario by 2030 in (table 2) shows an increase in the area under shrubland (53.0 %), cropland (94.0 %) and close natural forest (100 %) and a decrease in grasslands (-74.3 %) and open natural forest (-60.2 %) in Narok County. This indicates overgrazing and deforestation will reduce vegetative cover resulting in increased runoff in the County. Gully erosion is linked to land use and land cover changes. Land use and land cover changes include cultivation, forest clearing and livestock grazing and are discussed next.

2.1 Effect of cultivation on gully erosion

Agricultural practices can promote erosion through soil compaction, reducing water holding capacity and increasing soil erodibility. A high degree of agricultural intensity without adequate soil conservation measures can be directly linked to greater water erosion in the high-risk areas. Slopes are however prone to water erosion when cultivated and are steeper than 10 to 30 per cent (Kodiwo*et al.*, 2013). Cultivation in steep slopes is widely practiced in Kenya, hence higher likelihoods of soil erosion.Conventional cultivation techniques (compared to no-till or minimum-till), expose bare soil to rain, which is more serious in arid and semi-arid areas. Kimigo et al., (2008) in Sasumua catchment showed that land management practices such as intensive cultivation of horticultural crops, overgrazing of pastureland and farming on steep areas were contributing to soil degradation. Therefore land use management affected soil health in the Kenya.

During dry years, farmers will generally have reduced cropping seasons (Frankl, 2012), therefore timing of cultivation is critical. Farming practices associated with some crops encourage runoff and erosion. For example, cultivation of potatoes in rows and ridges channel runoff (Boardman *et al.,* 2003). According to Forsyth (2007) erosion from rain-fed rice had the highest rates of erosion, 60 tons per hectare per crop cycle. Maize and beans were least erosive with median soil losses of 19 and 10 tons per hectare per crop cycle respectively. Erosion in cabbage fields lay in between these two extremes. Therefore crops have varying impacts on runoff, thus affecting land use planning.

The movement of cultivation onto steeper slopes as a result of more powerful farm vehicles encourages runoff. Larger machines have been developed for farming but, the result has been a significant increase in axle loads not always matched by reductions in ground contact pressures to prevent or minimize compaction (Van-camp *et al.,* 2004), which could be the case in the arid and semi-arid areas. After levelling by farm machines, land is in a vulnerable condition and a few storms can easily cause severe soil losses. Soil compaction therefore occurs when soil is subject to mechanical pressure through the use of heavy machinery or dense stocking with grazing animals, especially in wet soil conditions, which could be the case in the arid and semi-arid areas. In a study by Klaus *et al*., (2014) in Souss Basin Morocco on land levelling, results showed that on levelled study sites, runoff was 1.4 times higher than in undisturbed areas. Sediment production was even 3.5 times higher under the influence of land levelling. Hence, the erosive impact was increasing along ploughing rills and gullies. Disturbances on the land therefore results in high amounts of water runoff and sediment erosion.

In mountainous regions, annual cropping has been reported as intensifying rill and gully erosion processes. Studies show that irrigation water flowing without control over bare abandoned fields can also trigger serious gully erosion, as shown in the oasis of San Pedro de Atacama in northern Chile (Valentin *et al*., 2005). Gully erosion has been observed in the sandy Sahelian soils of West Africa when soil crusts develop during fallow periods as a result of dust deposition (Valentin et al., 2005). Soil crusting has resulted in abandonment of communal cultivated fields in South Africa, in fields that have been associated with gully initiation and intensification. Soil crusting has an effect on gully development and is a problem in the loess belts of China, Europe, Spain, New South Wales, South Africa and North America (Valentin et al., 2005). Due to the scarcity of vegetation, soils of the arid and semi-arid regions such as Suswa are subjected to crusting and thus runoff production and gully erosion.

Research by Turkelboom*et al* .(2008) in Northern Thailand showed that land-use changes at Pakha led to the concentration of agriculture in certain areas of the catchment, increase of (semi)-permanent agriculture, change in crop types, increase of tillage operations, and the expansion of paths and irrigation infrastructure. The earlier natural hydrological equilibrium at the DzeDonglo catchment became severely disturbed during this transition, and led to landscape instability and the acceleration and emergence of different land degradation processes. Land use changes can therefore accelerate gully erosion processes. Mugagga*et al.,* (2010) in Mount Elgon, Eastern Uganda showed that slash and burn is a very common and continuously increasing practice in the non-irrigated marginal cultivated uplands of the Mt. Elgon catchment area. As a result various forms of erosion (including rills, gullies and sheet) were observed in the fields that have been prepared using this method. Slash and burn is common in the arid and semi-arid areas of Kenya and is therefore of concern.

In a study by Farhan *et al*., (2014) in the WadiKufranja catchment northern Jordan, results showed that the average soil loss from “mixed rainfed” cultivation across the watershed is much higher when compared with forest area, and open rangeland, and bare soils. Hence, the expansion of cultivated areas, and intensified use resulting from reduction and almost complete abandonment of fallow system, led to intensified soil degradation and sediment loss. Therefore land use planning should be of high priority in order to effectively reduce soil loss. Young *et al*., (2014) in the Midwest, U.S.A results showed that one-half of the fertile topsoil in Iowa has been lost through erosion during the last 150 years of farming, and erosion continues today at a rate of about 30 t/ ha/ yr because of the topography and the type of agricultural practices. Therefore agricultural practices result in long term soil loss. In a study by Zhang *et al*., (2010) in Yongding river basin, northwest of Beijing results showed that regions where erosion risk had increased by more than three levels were in the gentle slope, were easily cultivated. These sloping cultivated lands were created by destroying natural vegetation and hence exposed as bare areas without crop residue cover because of one cropping in a year. By identifying areas in most need of conservation measures to address soil erosion, this will facilitate the planning of future erosion conservation actions based on priorities.

2.2 Effect of livestock grazing on gully erosion

Overgrazing is one of the main drivers of gully erosion in rangelands. Grazing intensity, duration, and frequency, as well as timing of grazing relative to vegetation availability, has been identified as a factor affecting ecosystem and rangeland health (Veblen *et al*., 2014). Poor rangeland health may point to historic grazing intensity which is the case in the Kenya. Grazing intensity must be closelymanaged to maintain a ground cover of perennial grasses at 60% or higher. If the grasscover drops below this value, a key biophysical threshold is surpassed with potentially dire consequences involving reductions in grass cover, increase in bare soil, decrease in infiltration, increase in soil erosion and further reductions in grass (Sannwald*et al.,* 2006).

According to Valentin *et al.,* (2005) research showed that gullying rates exceed 190 mg/ ha/year due to sheep grazing on Easter Island (Rapa Nui, Chile), which over time may contribute to gully formation. Livestock grazing reduces pasture and shrubs and is therefore of concern. Research among the Gabbra and Samburu pastoral community, Marsabit sub-county by Okoti*et al,* (2006) showed that there is increased gully erosion, especially near the mountain areas and near settlements due to animal trampling and cutting of vegetation and also in some places where people have settled. The eroded places hardly grow any vegetation, which is of concern to the local community. Gicheru*et al.,* (2012) in Sasumua Catchment observed that overgrazing, intensive cultivation, and erosion by water affected soil quality. Amman *et* al., (2004) in Narok observed that high livestock levels resulted in degradation, especially during critical periods of drought.

Research in Zaka's Ward 5, Zimbabwe by Makwara*et al.,*(2012) showed that crop residue is either removed for storage as dry season fodder or it gets cleared by freely moving livestock from May to mid-November. Therefore it comes as no surprise that over 25% of the area is seriously eroded. In a study by Hillerislambers, *et al*., (2001), their spatially explicit model showed that an increase in the level of herbivore lead to transitions from a state with a closed vegetation cover, to a state with spatial vegetation patterning, to a state with bare soil. Results also showed vegetation changes are reversible if herbivore decreases, which is important for soil conservation. In a study by Yannelli*et al*., (2013) in Argentina results showed that grazed fields and abandoned crop fields were much more susceptible to potential gully erosion. Therefore understanding how long it takes to recover these ecosystems is crucial in order to then define whether they will recover on their own or whether it is necessary to apply active restoration techniques.

Johansson*et al.,* (2002) in the semi-arid catchment of Lake Baringo showed that the change from cattle to goats has resulted in the goats eating much more bushes and twigs and therefore survive in much harsher conditions. But on the other hand this leads to an even harder pressure on the remaining vegetation. The animals both eat up the vegetation and break the lower vegetation and root system by their trampling. The trampling is often the initiation of gully erosion, which is common in the arid areas.

2.3 Effect of forest clearing on gully erosion

Research shows that 40% vegetation cover is considered critical, below which accelerated erosion dominates on sloping land (Van-Camp *et al*., 2004), which could be the case in arid and semi-arid areas. In the Chinese loess plateau studies showed that an increase in grassland and forestland by 42% and a corresponding decrease in farmland by 46% reduced sediment production mainly due to gully erosion by 31% in the catchment (Valentin *et al.,* 2005).In the Chinese loess plateau research also showed that sediment production declined by 49% for a terraced hill slope and by 80% for a vegetated hill slope compared with a cultivated hill slope (Valentin *et al.,* 2005). This therefore demonstrates the effectiveness of terracing and vegetation cover in controlling sediment production, and could be useful in land use planning in the arid and semi-arid areas of Kenya.

Research by Johansson*et al.,* (2002) in the semi-arid catchment of Lake Baringo showed that the clearance of the forest has resulted in a larger proportion of the rainfall forming surface runoff. Findings by King, (2008) in Baringo District showed that ground cover (*Aloe secundiflora* shrubs) prevented erosion, reduced surface water flow velocities and wind speed. This study also showed that over four growing seasons of *Aloe secundiflora* shrubs generated successional response similar to that seen when grazing intensity was reduced (King, 2008). Therefore, shrubs can retain soil in their immediate vicinity hence they are effective for gully rehabilitation. Gicheru*et al.,* (2012) in Narok observed that the loss of land cover (grass, bushes and trees) further reduced pasture availability for livestock, resulting in increased exposure of the soil to erosion. In the Luangwa valley on Zambia's eastern border results showed that areas with plenty of grass and trees had rates of erosion around 5 t/ha/yr while areas with poor vegetation cover had erosion exceeding 100 t/ha/yr (Makwara*et al.* 2012), further highlighting the effectiveness of vegetation cover for soil conservation.

In a study by Tesfahunegn*et al*., (2014) in the Northern Ethiopia catchment, results showed that the highest rates of soil detachment occurred in marginal lands, and subsoil exposed soils having low soil resistance to detaching forces. The lowest was observed in forest land, protected plantation areas, and farm lands with high soil quality regardless of the slope steepness. This study showed that the rate of soil loss increased with an increase of detaching forces. Therefore increasing vegetation cover can be part of the solution for reducing the amount of soil loss. In a study by Omuto*et al*., (2011) in Somalia, results revealed that about one-third of the country was degraded because of the loss of vegetation cover, topsoil loss and decline of soil moisture. Overgrazing, excessive cutting of trees and poor agronomic practices in agricultural areas are the primary drivers of land degradation in Somalia. These drivers therefore encourage soil loss hence sustainable land use planning should be a priority. In a study by Phillips*et al*., (2013) in France and New Zealand, results showed that an increase in vegetation cover in the last 150 years is closely coupled with a decrease in the sediment yield at the outlets of revegetated catchments. Field measurements show that the fine sediment yield is 220 times less in the Brusquet catchment, which has an 87% vegetation cover, compared with the Laval catchment which has only a 32% vegetation cover. This therefore demonstrates that vegetation can help reduce soil erosion and runoff.

Kabanza*et al.,* (2013) working in South-Eastern Tanzania on land-use/cover dynamics, results showed that as annual crops increased, natural vegetation lost large proportions of land, mostly bush land, wooded grassland or woodland, and which had been converted to cashew orchards. Therefore land-use/cover change led to an overall reduction of natural vegetation, a driver of soil erosion. In a study by Fentahun*et al*., (2014) to examine the trend of land use and land cover changes in Bantinaka watershed Southern Ethiopia, results showed that the expansion of cultivated land was at the expense of forest land. Furthermore cultivated lands were extended into fragile areas due to the shortage of land, resulting in soil erosion. Land use and land cover changes can therefore aggravate soil loss. Maloney *et al*., (2008) in Chattahoochee and Muscogee counties, Georgia, USA on historical land use and stream conditions, showed that after 55 years of recovery from landscape disturbance, many forest patches are in successional stage. This is also the time when soils have largely recovered from prior agricultural practices. Land use history therefore helps to give information in disturbed catchments, enabling accurate assessment of reference conditions for restoration.

In a study by Bangash*et al*., (2013) in the Mediterranean river basin, results showed that the amount of sediment retained is two orders of magnitude higher than that exported, and most of the sediment produced in the basin is retained by existing vegetation. Therefore vegetation helps to reduce runoff and should be adopted for soil conservation. In a study by Colmenero, *et al*., (2012) in the Henares River basin southeast of Madrid, Spain, results showed that the planting of vegetative cover crops between the rows of vines in sloping vineyards resulted in greater infiltration, and consequently, a four- to six-fold reduction in erosion compared with conventional tillage. Therefore vegetative cover can reduce losses from erosion and improve the infiltration of water for farming. Xin *et al*., (2010) in China's Loess Plateau showed that 60% loess and 10% vegetation cover were important thresholds for the relationship between sediment yield and runoff. The spatial pattern and intensity of sediment yield are therefore related to the distribution and proportion of vegetation cover. The thresholds of vegetation cover may provide valuable indicators for gully rehabilitation.

Zhou *et al*., (2009) in Shaanxi province China, showed that a 1.2% conversion to forest per year may lead to a 10% or more yearly reduction of the annual sediment volume delivered to the main rivers. In a study by Renison*et al*., (2010) in Central Argentina results showed that degradation of forests and their soils is triggered by domestic livestock rearing. Therefore land use should always be considered in soil conservation efforts, with an emphasis on the need to manage livestock adequately, especially in susceptible areas. Li *et al*., (2010) in China's Loess Plateau Region, showed that the total area of forestland and grassland increased from 27.4% to 34.2%. These cumulative changes resulted in a 3.6–35.3% reduction in overland flow. These results suggest that the land-use changes gave rise to a mean erosion reduction of 38.8%. Thus, ecological restoration efforts can effectively mitigate the soil loss and thus contributed to the improvement of the ecological conditions.

In a study by Duvert*et al*., (2010) in the Mexican Central Highlands, results showed that traditional cropping practices with cattle grazing could lead to severe soil degradation in the Cointzio basin. Thus the formation of gullies in Huertitas and Potrerillos was triggered by those practices. This therefore demonstrates that human-induced land use changes are major drivers of soil erosion. Favreau*et al*., (2009) in southwest Niger, showed that land clearing increased surface runoff volume by a factor close to 3 (runoff volume), with a 2.5-fold increase in gullies. Therefore demonstrates how land use cover change can increase soil erosion.

2.4 Effect of climate change and climate variability on gully erosion

Global warming associated with the extension of grazing and cropping areas puts more regions at high risk of gully erosion in the future, with a particular threat on the semi-arid areas (Valentin*et al.,* 2005) including Kenya. During drought, vegetation decays leaving large areas unprotected from rainfall splash, resulting in runoff which tends to promote gully erosion. A drier climate in the semi-arid zone is thus expected to foster rill and gully development. Changes in rainfall patterns will increase the probability of storms after long dry periods in the arid and semi-arid areas, which have a direct impact on water erosion. Studies show that gully erosion occurred in the indigenous forest catchments of Raparapariki and Mangapoi Rivers in New Zealand after a severe cyclone in 1988 (Parkner*et al*., 2007), further highlighting the impact of climate change on erosion processes. Research also shows that soil losses of 20 to 40 t/ ha/yr in individual storms, may happen once every two or three years, and are measured regularly in Europe with losses of more than 100 t/ ha/yr in extreme events (Van-Camp *et al.,* 2004). Research shows that the Mediterranean region is particularly prone to erosion because it is subject to long dry periods, followed by heavy bursts of erosive rain, falling on steep slopes with fragile soils. Land use change is expected to have a greater impact on gully erosion than climate change (Valentin *et al.,* 2004).

Climate data provide the context for interpreting vegetation and livestock grazing information. Grazing information, coupled with climatic data, can be used to examine appropriateness of stocking rates. Yearly rainfall amounts have a direct bearing on impacts of a given grazing intensity, timing of grazing and also determines how grazing affects plants. Long-term trends in vegetation cover would be affected by lengthy drought periods, both with and without grazing. Research shows that assessments of long-term relationships between grazing and climatic patterns could provide insights into how rangelands might respond to future climate scenarios and suggest whether grazing intensities may need to be adjusted to cope with altered climate patterns (Veblen *et al.,* 2014). This remains an active area of research due to the challenge of quantifying climatic factors across complex landscapes, with sometimes limited historical climate data. Literature shows that in the Masai-Mara Ecosystem (Nyariki*et al.,* 2009) rainfall affects the seasonality and quantities of water available. As human population rises, so does the need for more water, both for the people and their animals. Limited supplies of water lead to overgrazing and trampling by cattle with a serious negative environmental impact, which is the case in the Kenya.

In a study by Kathumo*et al.,* (2012) on effects of land use on climate change on hydrological processes in River Gucha, results showed that total stream flow increases with expansion of agricultural and residential lands and reduction of forest cover. Stream flow therefore showed a higher relationship with the land use and land cover changes than with the temperature and rainfall. Ahigh correlation of land use and land cover with stream flow was also observed, which could either be due to expansion of agriculture and reduction of forest cover hence reducing evapotranspiration which causes soils to be wetter and therefore more responsive to rainfall, or lack of good land husbandry which reduces infiltrability of the soil surface, or prolonged exposure of topsoil to raindrop impact.This could lead to increased soil erosion and land degradation and flooding in the lower parts of the catchment. Control measures against increased runoff need to be applied, where agricultural land has to be given priority with emphasis on proper farming practices; where less land would produce more crop yield rather than the opposite. The extra land could then be utilised to plant trees suited to the area.

Land use changes induce emissions of carbon as carbondioxide into the atmosphere which result in global warming. Land use and land management options which enhance carbondioxide emission include deforestation, tillage and excessive grazing (Lal 2004).Therefore land use changes in Catchment should be controlled and well managed.

3.Conclusions and Recommendations

The driving forces of soil erosion whether social, economic, ecological act in an integrated way. Therefore land use changes such as abandonment, desertification, forest fires, land levelling, soil displacement by tillage and livestock and climate change are driving forces in gully erosion and are therefore important for effective rehabilitation. Further research in land use changes such as change in scale and intensity needs to be done particularly in the arid and semi- arid areas. More soil erosion studies that take into account socioeconomic factors are also required. Projected land use and land cover change and climate scenarios are also needed particularly in relation to gully erosion.

REFERENCES

Boccoa G., Vela´zquez A&Siebec C. (2005). The case of ruralindigenous communities in Michoacan, Mexico.Catena 60, 239–253.

Erktan, Amandine and Freddy Rey (2013). Linking sediment trapping efficiency withmorphological traits of Salix tiller barriers on marly gully floors under ecological rehabilitation. Ecological Engineering, 51,212–220.

FranklAmaury., Jan Nyssen., Morgan De Dapper., Mitiku Haile., JozefDeckers and JeanPoesen (2011). Trends in gully erosion as evidenced from repeat photography (NorthEthiopia). Landform Analysis, 17,47–50.

FranklAmaury (2012). Gully development and its spatio-temporal variability since the late19th century in the northern Ethiopian Highlands. Afrika Focus. 25,121-131.

Forsyth Tim (2007). Sustainable livelihood approaches and soil erosion risks.International Journal of Social Economics.34: 88-102

Giménez Eric Holt. (2002). Measuring farmers' agroecological resistance after HurricaneMitch in Nicaragua: a case study in participatory, sustainable land managementimpact monitoring. Agriculture, Ecosystems and Environment, 93,87–105.

GrellierSéraphine., Kemp Jaco., Janeau Jean-Louis., Florsch Nicolas., Ward David., BarotSébastien., Podwojewski Pascal., Lorentz Simon and Valentin Christian.(2012). Theindirect impact of encroaching trees on gully extension: A 64 year study in a sub-humid grassland of South Africa. Catena,98, 110–119.

Ghosh Sandipan and MajiTithi (2011). PedoGeomorphic analysis of soil loss in the lateritic region of Rampurhat I block of Birbhum district, West Bengal andShikaripara block of Dumka district, Jharkhand. International Journal of Environmental Sciences

ItannaFisseha., Mats Olsson and Karl Sta (2011).Effect of Land Use Changes on SoilCarbon Status of Some Soil Types in the Ethiopian Rift Valley.Journal of the Drylands, 1, 289-299

Jenny Johansson Jenny and SvenssonJakob (2002).Land degradation in the semi-aridcatchment of Lake Baringo, Kenya.Earth Sciences Centre, Goteborg University,Sweden.

KathumoV.M., Gachene C.K.K., Gicheru P.T and Kariuki P.C (2012). Effects of land useon climate change on hydrological processes in River Gucha, Kenya. E. Afr. agric.For. J. 78,113-118.

Katz Alexander Harry., Daniels Michael and Ryan Sandra (2013). Slope-area thresholds of road-induced gully erosion and consequent hillslope–channel interactions. EarthSurface Processes and Landforms DOI: 10.1002/esp.3443.

King E.G (2008). Facilitative effects of Aloe secundiflora shrubs in degraded semi-aridrangelands in Kenya. Journal of Arid Environments, 72, 358–369.

Kodiwo Maurice O and Okere Francis A (2013).Analysis of Spatial Variations ofAgricultural Land Use Intensity and Land Degradation in different Physiographic Regions.Asian Journal of Humanities and Social Sciences (AJHSS).

Lamelas, M.T., Hoppe A., Riva J. de la and Marinoni O (2009). Modelling environmentalvariables for geohazards and georesources assessment to support sustainable land-use decisions in Zaragoza (Spain), Geomorphology,doi:10.1016/j.geomorph.2008.10.021

Lim, Kyoung Jae Lim., MyungSagong., Bernard A. Engel., Zhenxu Tang., Joongdae Choi & Ki-Sung Kim, (2005). GIS-based sediment assessment tool.Catena,. 64, 61–80.

Long H. L.,Heilig G. K., Wangi J. X. B. LI Luo, M., Wu Q X. Q. and Zhang M.(2006).LandUse and Soil Erosion in the Upper Reaches of the Yangtze River: Some Socio-Economic Considerations on China's Grain-for-Green Programme. Land Degrad. Develop.17,589–603.

Maeda Eduardo Eiji., Pellikka Petri K.E., Siljander Mika and Clark Barnaby J.F. (2010).Potential impacts of agricultural expansion and climate change on soil erosion in the Eastern Arc Mountains of Kenya.Geomorphology 123, 279–289.

MaedaEiji., Petri K.E. Pellikka., Mika Siljander and Barnaby J.F. Clark (2010). Potentialimpacts of agricultural expansion and climate change on soil erosion in theEastern Arc Mountains of Kenya.Geomorphology. 123, 279–289.

Makwara E.C and Gamira D. (2012). About to Lose all the Soil in Zaka's Ward 5, Zimbabwe: Rewards of Unsustainable Land Use. European Journal of SustainableDevelopment 1 (3) 457-476

Martin Michael., Peters Briannes and Corbett Jon (2012). Participatory Asset Mapping in the Lake Victoria Basin of Kenya. Journal of the Urban and Regional Information Systems Association. 25 (2): 45-56

MogesAwdenegest and Holden Nicholas M (2009). Land Cover Change and Gully Development Between 1965 and 2000 in Umbulo Catchment, Ethiopia.Mountain Research and Development, 29(3):265-276

Mugagga F., Buyinza M and Kakembo V (2010). Livelihood diversification strategies andsoil erosion on Mount Elgon, Eastern Uganda: A socio-economic perspective. Environmental Research Journal 4(4): 272-280

NasriMasoud., Sadat Feiznia., Mohammad Jafari and Hasan Ahmadi (2009). Using Field Indices of Rill and Gully in order to Erosion Estimating and Sediment Analysis (Case Study: Menderjan Watershed in Isfahan Province, Iran)

NEMA (2009).Narok District Environment Action Plan 2009-2013. Nairobi.

Nyariki, D.M., Mwang'ombe A.W and Thompson D.M (2009). Land-Use Change andLivestock Production Challenges in an Integrated System: The Masai-MaraEcosystem, Kenya. J Hum Ecol, 26(3): 163-173

Nyssen J., GetachewSimegn A.C and NurhussenTaha (2009). An upland farming system under transformation: Proximate causes of land use change in Bela-Wellehcatchment Wag, Northern Ethiopian Highlands. Soil & Tillage Research. 103: 231–238

Okoti Michael., Keya G. A., Esilaba A. O. and Cheruiyot H (2006). Indigenous TechnicalKnowledge for Resource Monitoring in Northern Kenya. J. Hum. Ecol., 20(3): 183-189

Parkner Thomas., Page Mike., Marden Mike and Marutani Tomomi (2007). Gully systems under undisturbed indigenous forest, East Coast Region, New Zealand. Geomorphology 84: 241–253

ParveenReshma, Uday Kumar (2012). Integrated Approach of Universal Soil Loss Equation(USLE) and Geographical Information System (GIS) for Soil Loss Risk Assessment In Upper South Koel Basin, Jharkhand. Journal of Geographic Information System,4:588-596

Pathak P., Wani SP and Sudi R (2006).Gully Control in SAT Watersheds.SAT eJournal.2 (1): 1-23

Poesen Jean (2011). Challenges in gully erosion research. Landform Analysis, Vol. 17: 5–9

Poesena J., Nachtergaelea J., Verstraetena G and Valentinb C (2003). Gully erosion and environmental change:importance and research needs. Catena 50: 91– 133

Sakthivel R., Jawahar Raj N., Pugazhendi., Rajendran S and Alagappamoses A (2011).Remote Sensing and GIS for Soil Erosion Prone areas Assessment: A case studyfrom Kalrayan hills, Part of Eastern Ghats, Tamil Nadu, India. Archives of AppliedScience Research, 3 (6):369-376

SamaniAliakbarNazari., Ahmadi Hassan., Jafari Mohammad., Boggs Guy., Ghoddousi Jamal and MalekinArash (2009). Geomorphic threshold conditions for gully erosion inSouthwestern Iran (Boushehr-Samal watershed). Journal of Asian Earth Sciences 35:180–189

Sannwald Elisabeth Huber., Maestre Fernando T., Herrick Jeffrey E. & Reynolds James F.(2006).Ecohydrological feedbacks and linkages associated with land degradation: a case study from Mexico. Hydrol.Process.20: 3395–3411

Shahrivar, A and Christopher, T.B.S. (2012). The effects of soil physical characteristics ongully erosion development in Kohgiloyeh& Boyer Ahmad Province, Iran. Advances in Environmental Biology 6(1): 367-405

Shit P K, Maiti R. (2012). Effects of plant root density on the erodibility of lateritic topsoil bysimulated flume experiment.International Journal of Forest, Soil and Erosion,2(3):137-142.

Stavia I., A. Perevolotskyb and Y. Avnic (2010). Effects of gully formation and headcutretreat on primary production in an arid rangeland: Natural desertification in action.74 (2): 221–228

Sulieman Hussein M and Ahmed Abdel Ghaffar M(2013). Monitoring changes inpastoral resources in eastern Sudan: A synthesis of remote sensing and localknowledge. Pastoralism: Research, Policy and Practice 3:22

TitilolaTunji S. and Jeje L.K. (2008). Environmental Degradation and Its Implications for Agricultural and Rural Development: The Issue of Land Erosion. Journal of Sustainable Development in Africa 10(2): 116-146

Turkelboom F., Poesen J and Trébuil G (2008). The multiple land degradation effects causedby land-use intensification in tropical steeplands: A catchment study from northernThailand Catena, doi:10.1016/j.

Udayakumara ,E.P.N., R.P Shrestha., l. Samarakoon, and D. Schmidt-Vogt. (2010). People'sperception and socioeconomic determinants of soil erosion: A case study of Samanalawewa watershed, Sri Lanka. International Journal of Sediment Research 25: 323-339

Vågen Tor-G ., Winowiecki Leigh A. ., AbegazAssefa and HadguKiros M. (2013). Landsat-based approaches for mapping of land degradation prevalence and soil functional properties in Ethiopia. Remote Sensing of Environment 134: 266–275

Valentin C., J. Poesen J. and Li Yong (2005). Gully erosion: Impacts, factors and control.Catena 63:132–153

Van-Camp.L., Bujarrabal, B., Gentile, A-R., Jones, R.J.A., Montanarella, L., Olazabal, C.and Selvaradjou, S-K.(2004). Reports of the Technical Working Groups Establishedunder the Thematic Strategy for Soil Protection.EUR 21319 EN/2, 872 pp. Office forOfficial Publications of the European Communities, Luxembourg.

Veblen Kari E., Pyke David A., Aldridge Cameron L., Casazza Michael L., Assal Timothy J. and Farinha Melissa A. (2014). Monitoring of Livestock Grazing Effects onBureau of Land Management Land. Rangeland Ecology & Management, 67(1):68-77

Wu Yongqiu., Zheng Qiuhong., Zhang Yongguang., Liu Baoyuan ., Cheng Hong and WangYanzai (2008). Development of gullies and sediment production in the black soilregion of northeastern China.Geomorphology 101: 683–691

Xu X.Z., Xua Y., Chen S.C., Xu S.G. and Zhang H.W. (2010). Northeast China: a retrospective study. Environmental science & policy 13: 793–800