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Analysis of Spatial Variations of Agricultural Land Use Intensity and Land Degradation in different Physiographic Regions

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ABSTRACT

This article looks at spatial variations and the relationship between land degradation and agricultural land use intensity in Nyakach District, Kenya. The main objective was to determine spatial variations and the relationship between land degradation and agricultural land use intensity in forested areas, hill slopes and river banks. Digital Elevation Model (DEM) was used to identify various land uses which acted as indicators of land degradation and agricultural land use intensity in the three physiographic regions. Digitized maps generated from the topographical maps of the three areas under study were in turn used to generate land use statistics. The results show highest land degradation on the steep slopes and lowest land degradation along the river banks. Agricultural land use intensity was highest along the river banks and lowest in forested areas. The findings imply that land degradation can be arrested by intensifying agricultural land use along the river banks and steep slopes of Nyakach District as well as other regions of the world. However, the situation in forested areas remains more complex and requires further investigation.

Key words: spatial variations, land degradation, agricultural land use intensity, physiographic regions

1. Introduction

Land degradation and agricultural land use intensity have a complex relationship and their spatial variations are not easy to predict. This complex nexus has elicited considerable scientific discussions and research thus raising worldwide concern (Tilman 2009; Dent & Bai 2008; Scherr 2007; Thang *et al* 2007; Maddox 2006; Borjeson 2004; Ostberg 2004; Widgren 2004; Widgren &Sutton 2004; Obiero 2003; Tiffen *et al* 1994; Unwin 1981; Kitching 1980; Leys 1975). In 1991 Food and Agricultural Organization (FAO) reported that annual arable land loss was between 5 to 7 million hectares. Recently United Nations Environmental Programme (UNEP) reported that topsoil is eroding faster than it forms on approximately one third of the world's cropland. Moreover, according to UNEP (2007), 27 per cent of land in Africa is degraded leading to reduction in per capita food production by about 12 per cent since 1981. Sub-Saharan Africa suffers from serious soil degradation and nutrient depletion (World Agroforestry Centre 2008). Gachene and Kimaru (2003) aver that farmers in eastern Africa reap a mere one-quarter from their fields compared to what they can actually harvest if soil quality is improved. Land degradation problems such as soil erosion, nutrient depletion and poor vegetative cover are widespread in Kenya. According to Kenya (2005) and UNEP (2007), 23 and 8 per cent of the total land area in Kenya is severely and very severely degraded respectively. A look at the FAO/ Land and Water Development Division (AGL) soil degradation map of Kenya confirms that Nyakach District falls within very severely human-induced soil degradation region (FAO/AGL 2005). Food situation in the district has been deteriorating over the years. In 2003 the district had a 26 percent food deficit. In 2008 the district could only manage to supply 1.5 bags per capita per annum instead the minimum 2.5 bags. The disconnect between agricultural land use intensification and land degradation in the district prompted this research.

2. Literature review

In this section the authors review what other scholars have written about spatial and temporal variations in land degradation and agricultural land use intensity in forested areas, hill slopes and river banks.

2.1 *Forested areas*

Butter (2012) records that agriculture in rainforests is not sustainable as the soils lose their nutrients just within a short period of cultivation. The implication is that any attempt to intensify agriculture in forested area would result in increased land degradation. Ogunleye *et al* (2004) in their study to examine the impact of farming activities on the vegetation in a forest reserve found very low diversity indices where farming intensity was high and concluded that farming in the reserve had resulted in impoverished secondary forest, bare ground and degraded land. This supports the finding by Butter. FAO (2003) and Gudger & Barker (1993) also contend that forested areas are too fragile to sustain intensive cultivation and grazing.

2.2 *Hill slopes*

Marsh and Grossa (1996) argue that land degradation occasioned by slope failure is a common phenomenon in farmed hill slopes. This fragility is often evidenced by increased stream sediment loads (Fellmann *et al* 2008). Slopes are prone to water erosion where cultivated slopes are steeper than 10 to 30 per cent (FAO 2003). Intensive cropping of hill slopes leads to soil erosion and other forms of land degradation (*ibid*).The same trend had been noted in Nyakach District by Waruru *et al* (2005), but without linking the land degradation to agricultural land use intensification. Moldenhauer & Hudson (1988) also note that steep slopes experience soil fertility problems in addition to sparse vegetation cover. According to Gopal *et al* (2002), agricultural activities on steep hill slopes cause heavy erosion and river siltation. Contrary to what these scholars propose, Scherr points out cases in East Africa and Central America where vegetable crop intensification on hillsides have led to increased forest cover on steep slopes. The same relationship is advanced by Phillips-Howart and Lyon (1994).

2.3 *River banks*

Lee *et al* (2004) argue that as population densities increase the bottomlands become more intensively cultivated. FAO (2012) found that the introduction of water melon and sweet potatoes along river banks in Kapilvastu has led to reduced land degradation. However, a study by Gopal *et al* (2002) along most river valleys of India concludes that intensive agriculture and grazing has almost completely eliminated all natural riparian vegetation and intensified erosional forces together with pollution from agricultural chemicals.

The fundamental critique of the works reviewed above is the extent to which they fail to clearly expose the causal relationship between agricultural land use intensification and land degradation in different physiographic areas. They are not specifically explicit about the relationship between these two principal components of human livelihood – agriculture and land.

3. Research methodology

3.1 *Research Strategy and Design*

The research adopted *mixed methods research*. The choice of this approach was influenced by the fact that: (i) there was need for triangulation, i.e. looking for convergence, corroboration and correspondence of results obtained using the different methods; (ii) there was need for complementarity, i.e. trying to elaborate, enhance, illustrate and clarify the results from one method with the results from the other method; and (iii) there was need for expansion, i.e. extending the breadth and range of inquiry by using different methods for different inquiry components. According to the philosophy of pragmatism, researchers are encouraged to use a mixture of approaches that works best in real world situation. This study opted for '*cross-sectional*' design research. This approach was found suitable because was suitable because variables were collected concurrently, quantifiable data had to be collected and patterns of associations between them determined, and a cross-sectional study provides good evidence for the absence or presence of a relationship.

3.2 *Sampling*

Purposive sampling was used to select three areas - Nyabondo, Nyadero, and Nyamarumbe. Nyabondo Area is in Upper Nyakach and has different physical and socio-economic characteristics that contrast well with Nyamarumbe Area in Lower Nyakach. Nyadero Area is administratively found in Upper Nyakach but shares the characteristics of both Upper and Lower Nyakach. Topographical maps of the three areas were used to identify forested areas, hill slopes and river banks. In each area twenty farmers were randomly selected from each physiographic region.

3.3 *Data Collection Instruments*

Structured and unstructured interviews were used to collect data from household heads. Observation was used in determining the approximate plant cover loss or bare ground. Both structured and unstructured questions were shared by experts before embarking on data collection. Several consultations were made during the analysis.

Primary data was obtained from field surveys through the use of oral interviews, questionnaire and field observations. Interpretation of topographical maps also provided some primary data. Data collection was divided into phases I and II. Phase I consisted of interpretation of topographical maps sourced from Kenya Surveys. Phase II consisted of ground activities for the purpose of verifying data collected from topographical maps.

3.4 *Data Analysis Procedure*

Terrain Analysis was accomplished by the use of GIS package called ILWIS. ILWIS was used to run simple filter operations on already existing Nyakach contour map. This was done for the different areas in this study, i.e. Nyabondo, Nyamarumbe and Nyadero. In modeling Digital Elevation Models (DEMs) were created from the contour maps of Nyadero, Nyabondo and Nyamarumbe areas using the technique called interpolation. For accuracy purposes, the grid size, scale and resolution were taken into account. In contour map data, the average grid size is determined by the length of the contour lines. A map with the greatest length of contour lines was chosen as a blue print for the rest of the areas. The study areas were selected and their grid sizes extracted from the larger map. The grid sizes were therefore chosen as an estimate. The grid resolution was given by the following formula:

$$p = \frac{A}{2 . \sum l}$$

where A is the total size of the study area and $\sum l$ is the total cumulative length of all digitized contours.

Creating a DTM in ILWIS involved (1) digitizing contour lines from existing topographic maps and subsequently (2) interpolation between the contour lines to obtain a rasterized surface of topography. The contours were digitized from a segment map which contained coordinate data. Due to lack of proper digitized maps for analysis, the process of creating accurate DEMs involved the use of Golden Software Didger which provides a straight forward approach to digitizing the topographical maps. Once Didger is installed and started, a new project was started and the image map imported. The imported image map was vectorized. The software analyzed the map and created polygon lines which represent the contour lines shown on the topographic map.

ILWIS tools were then used on digitized topo maps to enhance, filter and evaluate the data. In this step the slopes in each of the maps were calculated to find out the coverage of high altitude terrain and how they affect land use. The slopes and aspects were calculated from the DEMs at each pixel using the gradient of the slope. The filters *Dfdx* and *Dfdy* are gradient filters in the X and Y coordinates respectively that yield the altitude differences in these directions on a pixel by pixel basis. Calculating the slope is a two-step process: first the two filtered maps for the gradient in X and Y direction were calculated and used to obtain slopes. The map slopes were created using the formula shown below.

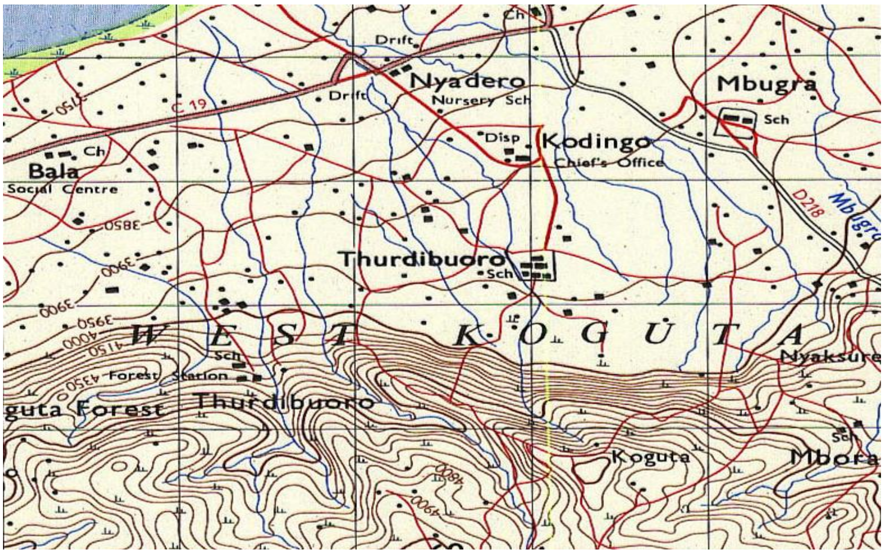
Slope = ((hyp(Dx,Dy))/50) x *100*

4. Findings and discussions

4.1 *Nyadero area*

The contour maps of Nyadero, Nyabondo and Nyamarumbe areas shown in Plates 1, 2 and 3 below were subjected to Digital Elevation Model (DEM) technique using interpolation. This process created the polygon lines shown in Plates 4, 5 and 6 which are digitized maps. In the digitized maps the points marked in blue represent water bodies.

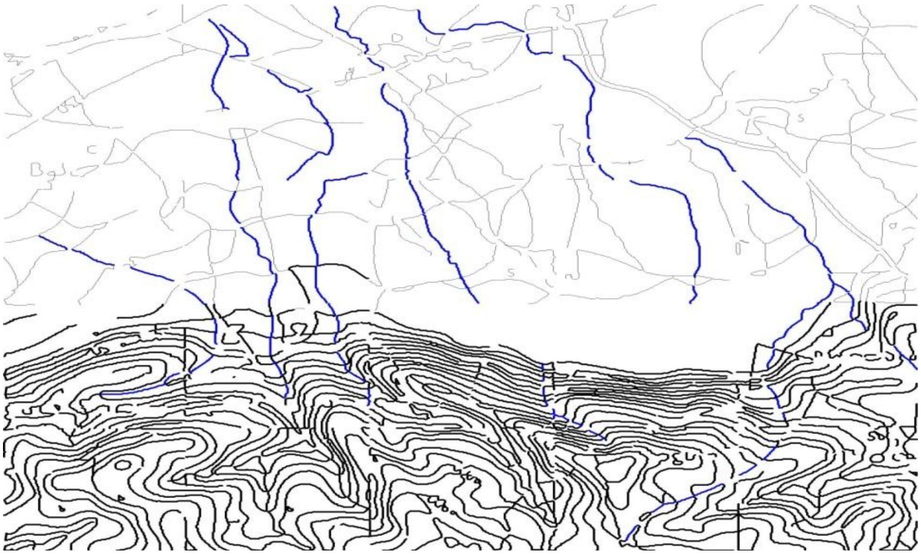
PLATE 1: NYADERO TOPO MAP



Source: Kenya, Republic of (1982)

Plate 1 above produced Plate 2 below after the digitization process.

PLATE 2: NYADERO DIGITIZED CONTOUR MAP



Source: Kenya, Republic of (1982)

Results obtained from digitization of the topographical (contour) map of Nyadero are summarized in Table 1 given below.

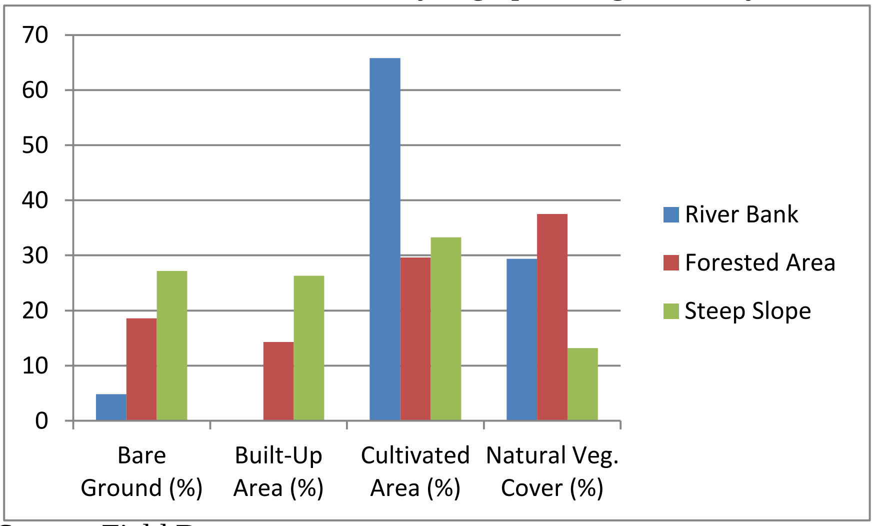
TABLE 1: Land Uses in different Physiographic Regions of Nyadero

	Bare Ground (%)	**Built-Up Area** (%)	**Cultivated Area** (%)	**Natural Veg. Cover** (%)
River Bank (Area 7802)	4.8	-	65.8	29.4
Forested Area (Area 4590)	18.6	14.3	29.6	37.5
Steep Slope (18358)	27.2	26.3	33.3	13.2

Source: Field Data

The tabulated results above are graphically represented on Figure 1 below.

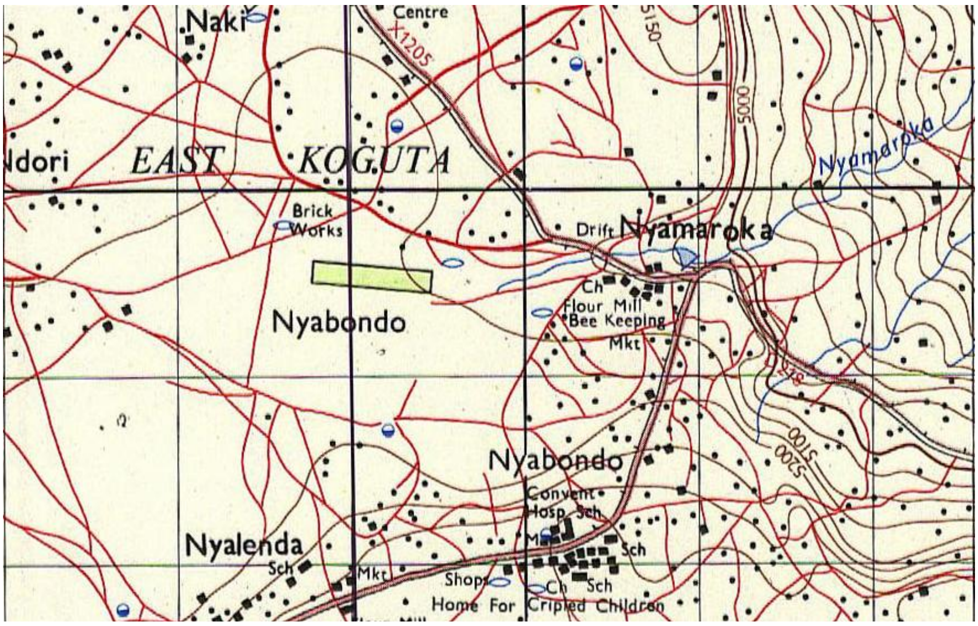
FIG.1: Land Uses in different Physiographic Regions of Nyadero Area



Source: Field Data

4.2 *Nyabondo area*

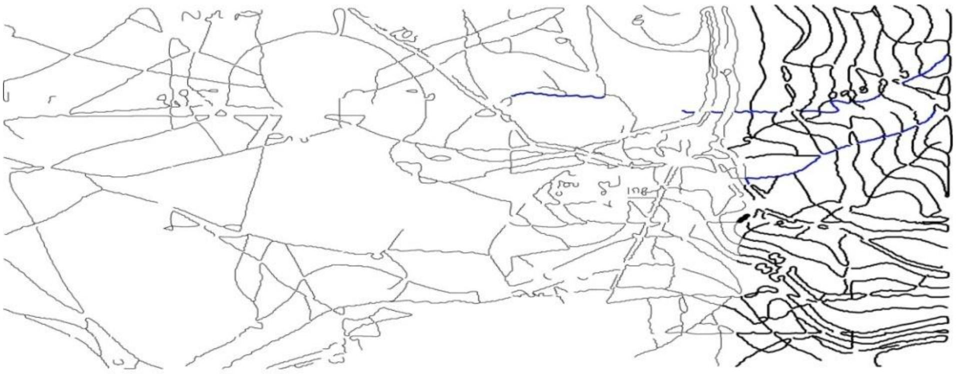
PLATE 3: NYABONDO TOPO MAP



Source: Kenya, Republic of (1982)

Plate 3 above generated Plate 4 below after digitization process.

PLATE 4: NYABONDO DIGITIZED CONTOUR MAP



Source: Kenya, Republic of (1982)

Results obtained from digitization of the topographical (contour) map of Nyabondo are summarized in Table 2 given below.

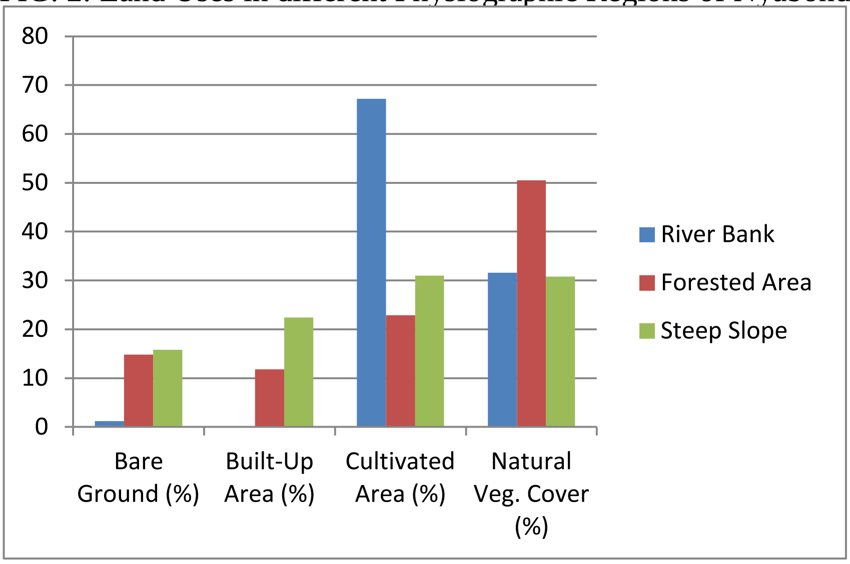
TABLE 2: Land Uses in different Physiographic Regions of Nyabondo

	Bare Ground (%)	**Built-Up Area** (%)	**Cultivated Area** (%)	**Natural Veg. Cover** (%)
River Bank (Area 7325)	1.2	-	67.2	31.6
Forested Area (Area 8953)	14.8	11.8	22.9	50.5
Steep Slope (8139)	15.8	22.4	31.0	30.8

Source: Field Data

The results in Table 2 above are given in a graphical form in Figure 2 below.

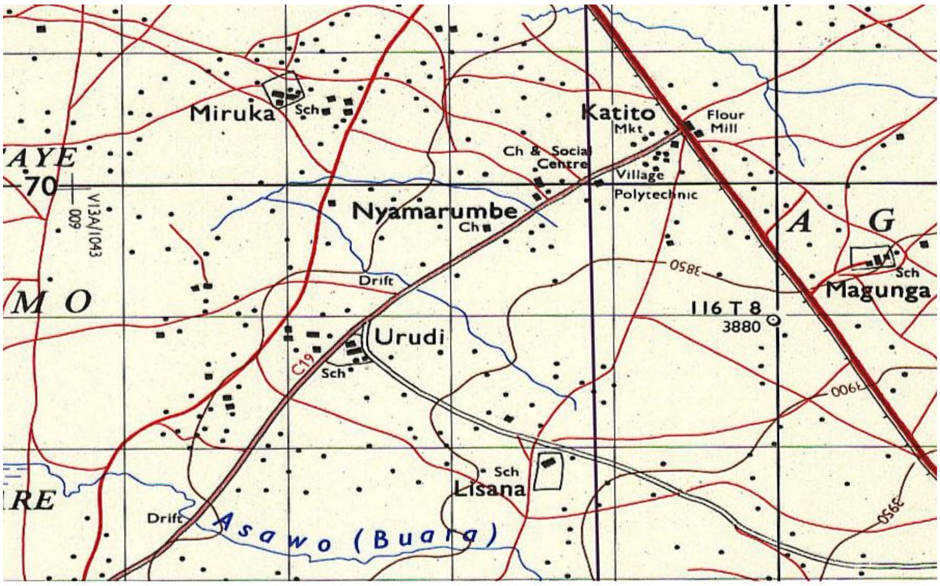
FIG. 2: Land Uses in different Physiographic Regions of Nyabondo



Source: Field Data

4.3 *Nyamarumbe area*

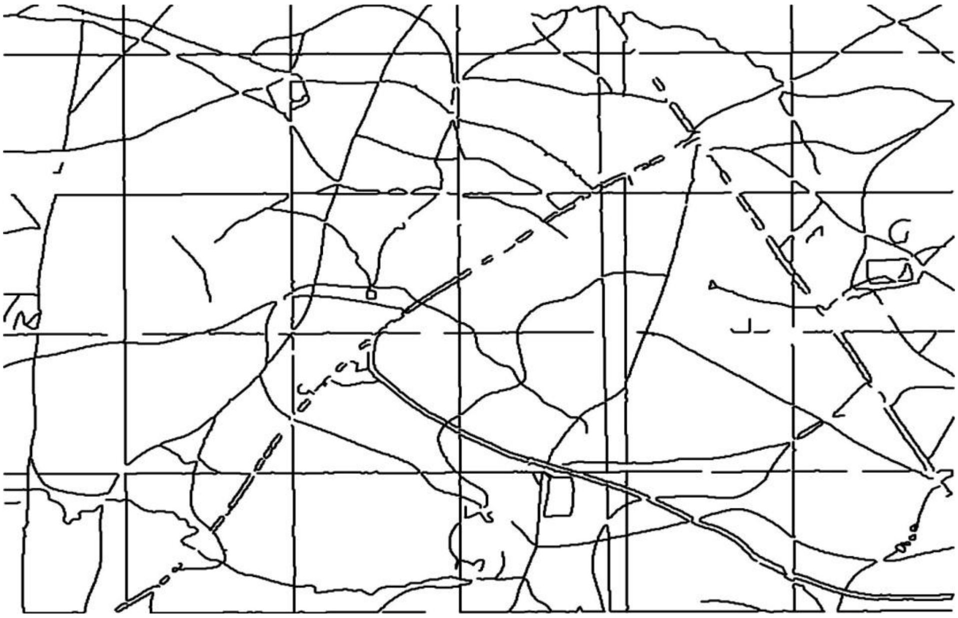
PLATE 5: NYAMARUMBE TOPO MAP



Source: Kenya, Republic of (1982)

Plate 5 above produced plate 6 below after digitization process.

PLATE 6: NYAMARUMBE DIGITIZED CONTOUR MAP



Source: Kenya, Republic of (1982)

Results obtained from digitization of the topographical (contour) map of Nyamarumbe are summarized in Table 3given below.

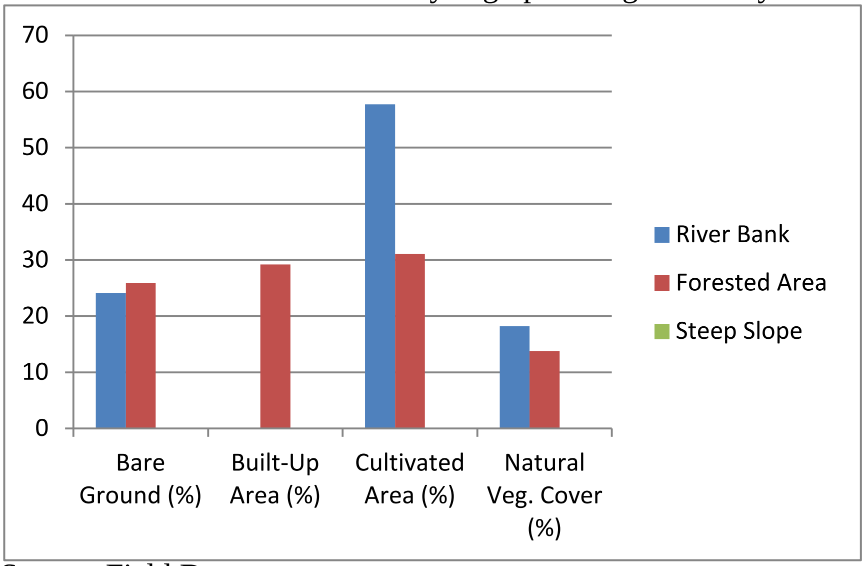
TABLE 3: Land Uses in different Physiographic Regions of Nyamarumbe

	Bare Ground (%)	**Built-Up Area** (%)	**Cultivated Area** (%)	**Natural Veg. Cover** (%)
River Bank (Area 2827)	24.1	-	57.7	18.2
Forested Area (Area 707)	25.9	29.2	31.1	13.8
Steep Slope (0)	-	-	-	-

Source: Field Data

Figure 3 below was generated from Table 3 above.

FIG. 3: Land Uses in different Physiographic Regions of Nyamarumbe



Source: Field Data

4.4 *Nyakach District*

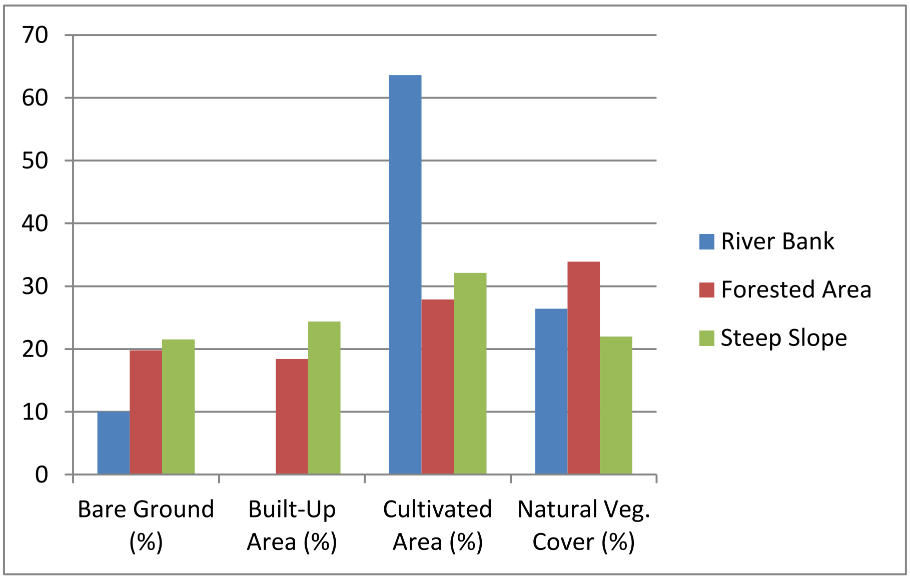
Table 4 below shows average values for Nyakach District. The data is graphically presented in Figure 4.

TABLE 4: Land Uses in different Physiographic Regions of Nyakach District

	Bare Ground (%)	**Built-Up Area** (%)	**Cultivated Area** (%)	**Natural Veg. Cover** (%)
River Bank (Area 2827)	10.0	-	63.6	26.4
Forested Area (Area 707)	19.8	18.4	27.9	33.9
Steep Slope (0)	21.5	24.4	32.1	22.0

Source: Field Data

FIG. 4: Land Uses in different Physiographic Regions of Nyakach District



Source: Field Data

4.5 *River banks*

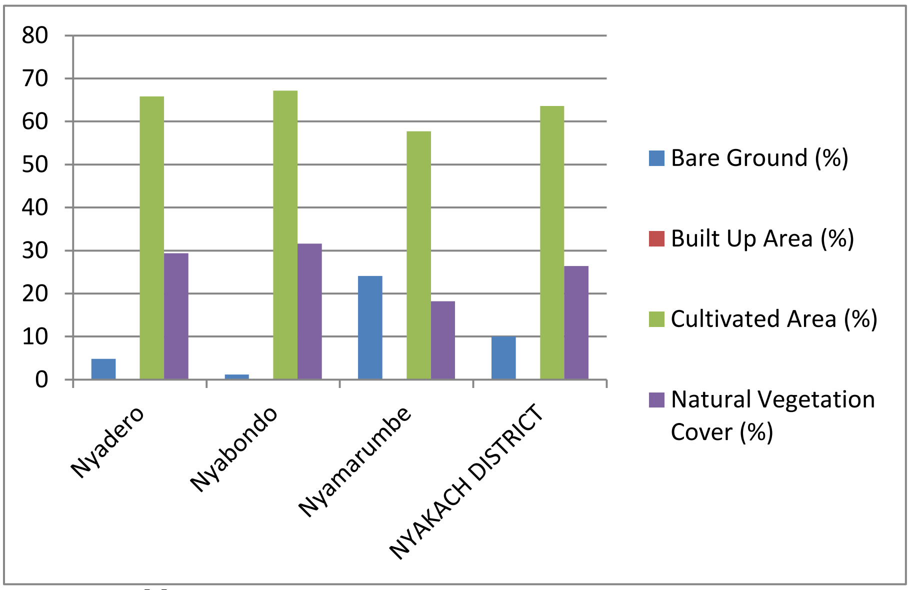
Table 5 below represents percent coverage of various land uses captured along the river banks in the three areas studied and also the average for the district. Figure 5 that follows graphically portrays the results in Table 5.

TABLE 5: Different Land Use Coverage along River Banks

	Nyadero	Nyabondo	Nyamarumbe	NYAKACH DISTRICT
Bare Ground (%)	4.8	1.2	24.1	10
Built Up Area (%)	-	-	-	-
Cultivated Area (%)	65.8	67.2	57.7	63.6
Natural Vegetation Cover (%)	29.4	31.6	18.2	26.4

Source: Field Data

FIG. 5: Different Land Use Coverage along River Banks in Different Areas



Source: Field Data

Table 5 and Figure 5 above reveal that the proportion of bare ground along the river banks was smallest in Nyabondo area (1.2%) followed by Nyadero area (4.8%). However, it is large in Nyamarumbe area where it is 24.1 per cent. The average for the entire district is 10 per cent. The fraction of cultivated area along river banks is much higher in Nyabondo at 67.2 per cent than it is in Nyadero and Nyamarumbe where it is 65.8% and 57.7% respectively. The average for the district is 63.6 per cent. The percentage of natural vegetation cover along river banks varies between the three areas with Nyabondo area recording the highest (31.6%) followed closely by Nyadero area (29.4%) and Nyamarumbe area showing the least (18.2%). The average for the district is 26.4 per cent.

4.6 *Forested areas*

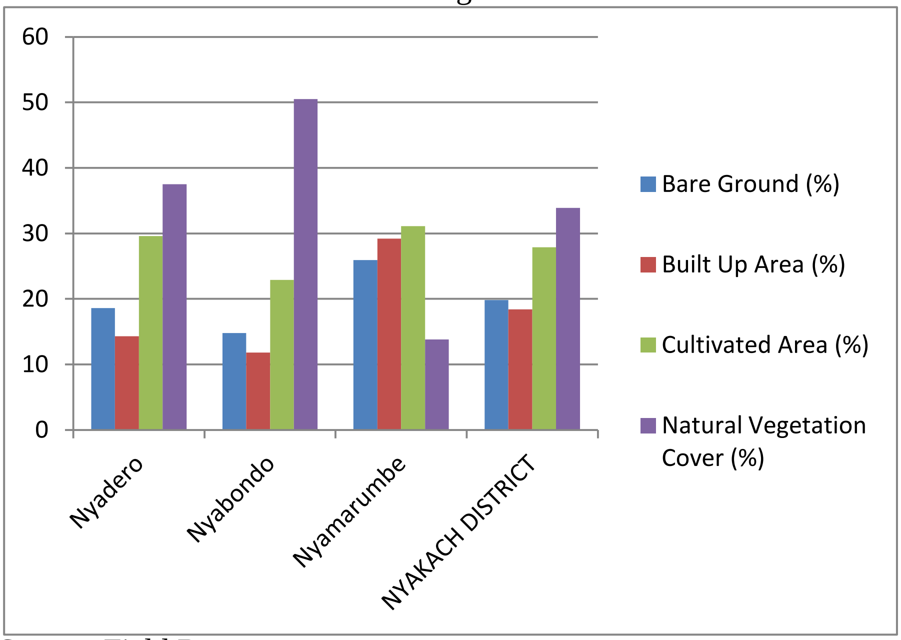
Table 6 below represents percent coverage of various land uses captured in the forested areas in Nyadero, Nyabondo and Nyamarumbe as well as the average for the district. Figure 6 graphically shows the results in Table 6.

TABLE 6: Different Land Use Coverage in Forested Areas

	Nyadero	Nyabondo	Nyamarumbe	NYAKACH DISTRICT
Bare Ground (%)	18.6	14.8	25.9	19.8
Built Up Area (%)	14.3	11.8	29.2	18.4
Cultivated Area (%)	29.6	22.9	31.1	27.9
Natural Vegetation Cover (%)	37.5	50.5	13.8	33.9

Source: Field Data

FIG. 6: Different Land Use Coverage in Forested Areas



Source: Field Data

Table 6 and Figure 6 above reveal that the proportion of bare ground was significant in all the three areas studied. Nyamarumbe recorded the highest percentage at 25.9 followed by Nyadero at 18.6 and finally Nyabondo at 14.8. The district average was 19.8 per cent. The percentage of built-up area in forested areas was also significant with Nyamarumbe registering 29.2%, Nyadero had 14.3% while Nyabondo had the lowest at 11.8%. The average for the district was 18.4 per cent. The forests were also cultivated although at a much lower intensity. Nyamarumbe had the highest proportion of cultivated forested area (31.1%), followed by Nyadero (29.6%) and finally Nyabondo (22.9%). The district had an average of 27.9 per cent. Nyabondo led with 50.5% of natural vegetation cover within its forested areas. It was followed by Nyadero with 37.5%, while Nyabondo was last with only 13.8%. The average for the district was 33.9 per cent of natural vegetation cover.

4.7 *Steep slopes*

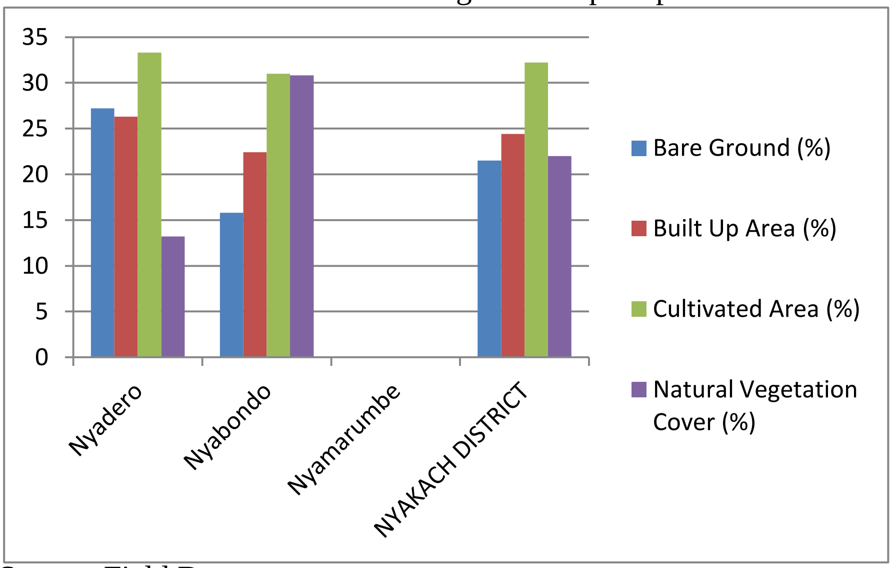
Table 7 below represents percent coverage of various land uses captured on the steep slopes in Nyadero, Nyabondo and Nyamarumbe as well as the average for the district. Figure 7 graphically represents the results in Table 7.

TABLE 7: Different Land Use Coverage on Steep Slopes

	Nyadero	Nyabondo	Nyamarumbe	NYAKACH DISTRICT
Bare Ground (%)	27.2	15.8	-	21.5
Built Up Area (%)	26.3	22.4	-	24.4
Cultivated Area (%)	33.3	31	-	32.2
Natural Vegetation Cover (%)	13.2	30.8	-	22

Source: Field Data

FIG. 7: Different Land Use Coverage on Steep Slopes



Source: Field Data

There was no steep slope in Nyamarumbe area. Nyamarumbe area is found within the Nyakach Plain hence its near-flat topography. Bare ground is larger in steep slopes than in forested areas and river banks. However, the percentage is higher in Nyadero (27.2%) than in Nyabondo (15.8%). The average for the district was 21.5 per cent. Likewise, the proportion of built-up area is higher on steep slopes than in forested areas. Nyadero had higher proportion of built-up area (26.3%) than Nyabondo (22.4%). The district average was 24.4

per cent. Cultivated area on steep slopes is less than along river banks but higher than in forested areas. However, Nyadero exhibited a higher proportion (33.3%) than Nyabondo (31%). Natural vegetation cover was found to be lowest on steep slopes compared to river banks and forested areas. Nyabondo had higher proportion of natural vegetation cover on steep slopes (30.8%) than Nyadero (13.2%).

Regression analysis revealed that the relationship between agricultural land use intensity and land degradation was strongest along the river banks (72.9% of the variations in land degradation were explained by agricultural land use intensity), moderate in the steep slopes (56.3% of the variations in land degradation were explained by agricultural land use intensity), and low in the forested areas (only 19.1% of the variations in land degradation were explained by agricultural land use intensity). The coefficient of determination (R-Square) was 0.729 in the river banks, 0.536 in the steep slopes, and 0.191 in the forested areas. Table 4.20 given below shows a summary of the regression statistics.

TABLE 8: Summary of Regression Statistics for ALUI versus LADEG

	R	**R-Square**	**Adj. R-Square**	**Significance Level**
River Bank	0.854	0.729	0.723	0.00
Forested Area	0.437	0.191	0.162	0.02
Steep Slope	0.732	0.536	0.524	0.00

Source: Field Data

5. Summary, conclusions and recommendations

5.1 Summary

5.1.1 *Land Use Coverage along River Banks*

The results mean that land degradation along the river banks, as indicated by bare ground, is highest in Nyamarumbe but fairly low in both Nyadero and Nyabondo. This may be partly due to overgrazing along the river banks in Nyamarumbe and partly because of high erosion prevalent in Lower Nyakach in general. Sand mining along the river beds in Nyamarumbe area has worsened land degradation problem. The problem of soil erosion in Nyakach District is well documented by a number of scholars who have done research in the region (Waruru *et al* 2005and Sjors 2001).

There are no built-up areas along the riverbanks. Nyakach District is prone to flooding and as such people choose to settle on higher ground off the river valleys which are usually more severely affected during the annual floods. Moreover, people tend to reserve more fertile areas along the river banks for farming and they establish their homesteads in less fertile land away from the river banks.

River banks are more intensively cultivated due to high soil fertility. Fluvial processes deposit silt along the river valleys which enriches the soil. Moisture content of the soil is also higher on the valley bottoms. This finding is in agreement with the work done by Institute of Geographic Sciences and Natural Resources Research (2011) in which land with better quality was found to be used more intensively. Similarly, Lee *et al* (2004) note that as population densities increase the bottomlands become intensively cultivated due to higher production returns that accrue from them. They point at the semi-arid zones of India where the bottomlands are intensively cultivated. Yet intensive cultivation of the river banks does not necessarily lead to heightened land degradation. According to FAO (2012), the introduction of water melon and sweet potato cultivation along the river banks in Kapilvastu District in Nepal, South Asia has led declining degradation of land. The climate of Nyabondo is more suitable and hence agricultural land use intensity is higher than it is in Nyadero and Nyamarumbe and it still retains a higher proportion of natural vegetation cover. The spatial differences in cultivated area between the three areas can also be partly attributed to differences in population densities. This explains why Nyabondo leads in the percentage of cultivated land in the river banks.

Overall, river banks are better watered and hence retain more natural vegetation cover than areas far away from the water sources. Despite this, areas that are more severely degraded or those that have more unpleasant weather conditions exhibit smaller coverage by natural vegetation. Hence Nyamarumbe is less favoured while Nyabondo is more favoured with natural vegetation.

Forested areas have fairly low proportions of bare ground in both Nyabondo and Nyadero (14.8% and 18.6% respectively). However, the proportion of bare ground in forested area is much higher in Nyamarumbe at 25.9 per cent. The percentage of built-up area is significant in all the three areas under consideration with Nyabondo area recording the lowest at 11.8%, Nyadero has 14.3 while Nyamarumbe area stands out at 29.2 per cent. The percentage of land under cultivation in the forested areas also varies from one place to another. In Nyabondo it is 22.9%, in Nyadero it is 29.6 while in Nyamarumbe it is 31.1 per cent. An inverse relationship is exhibited between cultivated area and natural vegetation cover – the latter being 50.5% in Nyabondo, 37.5% in Nyadero, and 13.8% in Nyamarumbe forested areas.

Comparison of the three areas of Nyadero, Nyabondo and Nyamarumbe in terms of land use was made difficult by the fact that there were no steep slopes in Nyamarumbe (refer to Plates 5and 6). However, for the two areas of Nyadero and Nyabondo, it was found that steep slopes in Nyadero had more bare ground (27.2%) than those in Nyabondo (15.8%). Likewise, there are more settlements (built-up areas) on the steep slopes in Nyadero (26.3%) than those in Nyabondo (22.4%). Cultivation on steep slopes is higher in Nyadero (33.3%) than it is in Nyabondo area whose steep slopes are 31 per cent cultivated. On the other hand, natural vegetation cover on steep slopes is higher in Nyabondo area at 30.8% than in Nyadero area at 13.2%.

According to Table 5 above, utilization of river banks in Nyakach District is such that 10 per cent of the land is bare ground, 63.6 per cent is cultivated and 26.4 per cent of the land is covered by natural vegetation. Forested areas are mainly covered by natural vegetation (33.9%) while 19.8 per cent of the ground is bare and 18.4 per cent covered by buildings. Some 27.9 per cent of the forested areas are under cultivation. While 32.1 per cent of the steep slopes are cultivated, a significant portion (24.4%) is used for buildings. A good proportion (22%) is covered by natural vegetation while 21.5 per cent is bare ground. Figure 4.32 given below graphically represents this information.

5.1.2 *Land Use Coverage in Forested Areas*

The proportion of bare ground in forested areas of Nyakach District is significant because the majority of farmers plant trees in barren land that is rocky in most cases. As it is noted in ASB (2011), farmers plant trees if land is not a limiting factor than when it is scarce and has to be cultivated more intensively. The proportion of built-up area followed the same trend with Nyamarumbe leading at 29.9% followed by Nyadero at 14.3% and finally Nyabondo at

11.8%. The district average for built-up area in forested areas was 18.4 per cent. These significant values suggest that integration of trees into farming systems in the form of agroforestry has gained momentum in Nyakach District. This may be attributed to the realization by farmers of the need to mitigate land degradation. Scherr (1995) while working in Western Kenya noted that there is usually an increase in tree cultivation when ecological degradation threatens to cancel any gains accruing from land. The figures for cultivated area are also relatively high – suggesting the adoption of agroforestry systems in the district. The figures for cultivated area show a spatial positive correlation with land degradation level. Figures for natural vegetation cover are negatively correlated with land degradation level.

5.1.3 Land Use Coverage on Steep Slopes

Steep slopes are severely eroded where land management efforts have not been fully adopted hence high proportion of bare ground, especially in Nyadero. Steep slopes have more settlements than forested areas. Due to thin soils, steep slopes have lower agricultural potential compared to forested areas and river banks. Scarcity of agricultural land has driven people to set homes on steep slopes and spare the gentle slopes for cultivation. However, the steep slopes are more intensively cultivated than forested areas. The percentage of natural vegetation cover comparatively low compared to river banks and forested areas. This may be partly due to the thin soils that cannot support dense growth of natural vegetation. Moldenhauer & Hudson (1988) contend that steep slopes have soil fertility problems on top of sparse or nil vegetation cover during long dry seas

5.2 Conclusions

Land degradation is highest on steep slopes, moderate in forested areas and lowest along the river banks. It therefore varies spatially from one physiographic region to another. Agricultural land use intensity also varies spatially according to the physiographic region. It is highest along the river banks, moderate on steep slopes and lowest in forested areas.

A negative correlation exists between land degradation and agricultural land use intensity along the river banks. The higher the agricultural land use intensity, the lower the land degradation. In forested areas land degradation and agricultural land use intensity are positively correlated – land degradation increases with increasing agricultural land use intensity. The same relationship is also found on the steep slopes of Nyakach District.

5.3 Recommendations

More intensive agricultural land use that combines soil conservation techniques, increased use of capital on labour and farm chemicals as well as farm implements, and high cropping intensity holds the key to mitigating land degradation on steep slopes and river banks of Nyakach District and other regions of the world. However, forested areas are more fragile to increased agricultural land use intensity. Such ecosystems should be left in their current status or the coverage of trees may be increased.

References

ASB (2011). Why smallholders plant native timber trees away from forest margin: Lessons from Leyte, the Philippines. [Online] Available www.theredddest.org/sites/default/files/resources/pdf/2012/asb_-pb24.pdf

Barring, l. (1988)*"Aspects of Daily rainfall Climate Relevant to Soil erosion in Kenya"* Department of Physical Geography, University of Lund, Sweden.

Borjeson, L. (2004) The History of Iraqw Intensive Agriculture, Tanzania: in Widgren, M. & J.E.G. Sutton (2004) Islands of Intensive Agriculture in Eastern Africa; (pp 68-124) E.A.E.P Nairobi.

Butter, R. (2012) The Impact of Industrial Agriculture in Rainforests. [Online] Available mongabay.com/0811.htm

Dent, D.L. & Bai, Z.G. (2008) Assessment of Land Degradation Using NASA GIMMS: A Case Study in Kenya; GLADA Report; ISRIC – World Soil Information. [Online] Available rd.springer.com/chapter/10.1007/978-1-4020-8592-5-21

FAO (2012) Bagar Farming (Baluwa khati) in river banks of Nepal. [Online] Available teca.fao.org/es/read/7376.

FAO (2003) Agriculture and the environment: changing pressures, solutions and trade-offs. [Online] available www.fao.org/docrep/005/y4252e/y4252eOO.htm#TopOfPage

FAO (1991) Sustainable Development and Management of Land and Water Resources. [Online] Available www.fao.org/docrep/V5406e/v5406e06.htm

FAO/AGL (2005) National Soil Degradation Map. [Online] Available http://www.fao.org/agll/glasod/glasodmaps.jsp

Gachene, C.K.K. & Kimaru, G. (Eds) (2003) Soil Fertility and Land Productivity. RELMA Technical Handbook No. 30 - Nairobi, Kenya.

Gopal, B., Goel, U., Chauhan, M., Bansal, R. & Khuman, S.C. (2002) Regulation of Human Activities along Rivers and lakes. [Online] Available www.nieindia.org/Yamuna/RRZ-Background-Report-Dec2002.pdf

Gudger, W.M. & Barker, D.C. (1993) Banking for the environment. [Online] Available www.fao.org/docrep/T0719E/t0719eOO.htm

Institute of Geographic Sciences and Natural Resources, Chinese Academy of Sciences (2011) *Agricultural Land Use Intensity and Its Determinants in Ecologically-Vulnerable Areas in North China: A Case Study of Taipusi County, Inner Mongolia Autonomous Region*, Journal of Resources and Ecology 2(2):117 – 125.

Jaetzold, R., Schimdt, H., Hornetz, B., & Shisanya, C. (2009) Farm Management Handbook of Kenya Vol. II – Natural Conditions and Farm Management Information - Part A West Kenya Subpart A2 Nyanza Province. (2nd ed.). Nairobi: Ministry of Agriculture.

Kenya, Republic of (2011) Ministry of Livestock Development: Livestock Production Development. Nairobi: Nyakach District Annual Report.

Kenya, Republic of (2010) 2009 Kenya Population and Housing Census Vol. 1B Kenya National Bureau of Statistics. Nairobi: Government Printer.

Kenya, Republic of (2009) Nyando District Development Plan 2008-2012: Ministry of Planning; Government Printer; Nairobi.

Kenya, Republic of (2005) Achieving Millennium Development Goals in Kenya: A Needs Assessment and Costing Report: Government Printer; Nairobi.

Kenya, Republic of (2003) Nyando District Development Plan 2004-2008; Ministry of Planning; Government Printer; Nairobi.

Kitching, G. (1980) Class and Economic Change in Kenya: Yale University Press, London.

Lee, R.E., Arthur, W.B., Kelley, A.C., Rodgers, G. & Srinivasan, T.N. (Eds) (2004) Population, Food, and Rural Development; Clarendon Press; Oxford.

Leys, C. (1975) Underdevelopment in Kenya: The Political Economy of Neo-Colonialism. EAEP, Nairobi.

Maddox, G.H. (2006). Sub-Saharan Africa: An Environmental History: ABC-CLIO; California.

Moldenhauer, W.C. & Hudson, N.W. (Eds) (1988) Conservation Farming on Steep Lands; Ankeny, Iowa.

Obiero, O. (2003) Lake Victoria and its Environs: Resources, Opportunities and Challenges; 2nd Ed. Africa Herald Publishing House; Kendu Bay, Kenya.

Ogunleye, A.J., Adeola, A.O., Ojo, L.O. & Aduradola, A.M. (2004) Impact of Farming Activities on Vegetation in Olokemeji Forest Reserve, Nigeria. [Online] Available www.gnest.org/journal/Vol6_No2/Ogunleye9620131-140.pdf

Ostberg, W. (2004)*"The Expansion of Marakwet Hill-Furrow Irrigation in the Kerio Valley of Kenya''* in Widgren, M. & J.E.G. Sutton (2004) Islands of Intensive Agriculture in Eastern Africa. E.A.E.P

Scherr, S.J. (2007) *"Soil Degradation: A Threat to Developing Country Food Security by 2020"*. Washington D.C.: International Food Policy Research Institute – Food, Agriculture and the Environment Discussion Paper No. 27.

Sjors, A.B. (2001) Erosion History of Ragen and Nyalunya Area, Nyando District, Kenya: Committee of Tropical Ecology; Uppsala University, Sweden.

Thang, C.C., Euimnoh, A., Shivakoti, G.P., & Clemente, R. (2007) "*Spatial Modeling for Land Degradation Assessment Using Remotely Sensed Data and Geographic Information System: A Case Study of Daungnay Watershed, Magway District, Myanmar*".

Tiffen, M., Mortimore, M. & Gichuki, F. (1994) More People, Less Erosion: Environmental Recovery in Kenya; Wiley, Chischester.

Tilman, D. (2009) *"Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices"* in the Proceedings of the National Academy of Sciences of the United State of America.

UNEP (2007) Global Environmental Outlook 4: Flagship Report; Nairobi, Kenya.

Unwin, D. (1981) Introductory Spatial Analysis. Methuen & Co. Ltd, London.

Waruru, B.K., Wanjogu, S.N. & Maina, J.K. (2005) *"The Influence of Soil Moisture and Related Soil Physical Properties on Gully Development in the Nyakach Area, Nyando District, Kenya"*; LVEMP Dar es Salaam.

Widgren, M. (2004)*"Towards a Historical Geography of Intensive Farming in Eastern Africa"* in M. Widgren & J.E.G. Sutton (Eds) Islands of Intensive Agriculture in Eastern Africa; East African Educational Publishers; Nairobi.

Widgren, M. & Sutton, J.E.G. (Eds); (2004) Islands of Intensive Agriculture in Eastern Africa: East African Educational Publishers; Nairobi.

World Agroforestry Centre (2008) "*Transforming Lives and Landscape*" in Strategy Report 2008-2015.