Effects Of Physiographic Units On The Relationship Between Cropping Frequency And Level Of Soil Erosion In Nyakach District, Kenya

Maurice O. Kodiwo, Boniface O. Oindo, Francis Ang'awa, Dr. Esnah Kerubo Bosire

ABSTRACT : A number of scholars agree that farms which are cropped more frequently tend to exhibit lower levels of soil erosion than those that are cropped less frequently or left fallow. However, the effects of physiographic units on this relationship are not known. Most methods used to assess land degradation ignore the use of indicators of agricultural land use intensity and land degradation. They are too complex and ignore the role of physiography. This research looked at the effects of different physiographic units on the relationship between the frequency of cropping and the level of soil erosion in Nyakach District of Kenya. The study focused on establishing the relationship between cropping frequency and level of soil erosion in the Plateau, Scarp Slopes, Plains and Valley Bottoms. Purposive and simple random sampling was used to select 384 out of 29,214 farmsteads. Correlation and regression analyses were employed to assess the nature and strength of the relationship between the cropping frequency and the level of soil erosion in the four different physiographic units of Nyakach. Significant relationships occurred in all the four physiographic units with r = -0.347 for the Plateau, r = -0.318 for the Scarp Slopes, r = -0.412 for the Plains, and r = -0.43 for the Valley Bottoms. The researchers concluded that physiographic units have a significant influence on the relationship between cropping frequency and level of soil erosion in Nyakach District. It was therefore recommended that cropping frequency and level of soil erosion be used for assessing land degradation in specific physiographic units of Nyakach District.

Index Terms: Cropping frequency, Soil erosion, Correlation, Physiographic units

1.0 INTRODUCTION

Whereas some researchers have found a positive correlation between land degradation and agricultural land use intensity [1], [2], [3], [4], [5], [6], [7] some have come up with a negative association between land degradation and agricultural land use intensity [8], [9]. The former group *positive correlation theorists* while the latter are *negative correlation theorists*. These two opposing schools of thought require further research while at the same time provide an option for a third distinct school of thought, i.e. *zero correlation theory*. Different effects of agricultural intensification in various types of landscapes are highlighted [10]. There is no research on the assessment of land degradation that uses agricultural land use intensity. In Africa, contrasting results have been obtained. Whereas some scholars found a positive correlation [11], [12], [13], others came up with found a negative correlation [14].

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However, these studies neither take into consideration different physiographic units nor use indicators of the two key variables. In Kenya a number of studies confirm significant relationships between land degradation and agricultural land use intensity. While some scholars found significant positive correlation [15], others obtained a negative correlation [16]. Moreover, no study has been previously conducted in Nyakach District to determine the relationship between agricultural land use intensity and land degradation using cropping frequency and level of soil erosion.

2.0 LITERATURE REVIEW

An old theory of land use intensity hypothesizes that agricultural intensification is reflected in shorter fallow periods and more frequent annual cropping [17]. Crop-fallow cycle has been used to measure agricultural intensity [17], [18] by using following model:

$$F_c = \frac{di}{12};$$

where d_i is the duration of the crop in the field, and F_c is the cropping frequency. Some scholars observe that agricultural intensification involves increased frequency of cultivation [19]. A significant limitation of this method is that it ignores inputs. Moreover, some crops are planted twice or even thrice in a year depending on the prevailing climatic conditions. Others use reduced production cycle (cropping plus fallow period) and cropping frequency per hectare or production cycle (double or triple cropping) [13], [16]. They define land use intensity as the number of continuous cropping cycles – the number of years of continuous cropping multiplied by the number of crops grown per year before putting the land into fallow. This mirrors the use of the R-value (the number of years of cultivation multiplied by 100 and then divided by the difference between the numbers of years of cultivation minus the number of years of fallow period) to measure farming intensity [20]. The length of gully and rill per unit area has been used as a measure of soil erosion index [21] just as the density of gullies has also been used [22]. Universal Soil Loss Equation (USLE) given as

$$E = R.K.L.S.C.P$$

where E is mean annual soil loss in $tac^{-1}y^{-1}$, R is rainfall erosivity, K is soil erodibility index, L is factor of slope length, S is factor of slope steepness, C is crop factor representing the ratio of soil loss under a given crop to that of bare soil, and P is conservation practice factor [23]. This method is too complex for the local farmers. Row crops on steep slopes result in more soil erosion because they provide less cover hence exposing soil to more erosive forces [5]. Land degradation occasioned by slope failure is a common phenomenon in farmed hill slopes [24]. This is often evidenced by increased stream sediment loads [25]. The same situation occurs in Nyakach District [26], but without linking it to agricultural land use intensification. There is no consensus on the measurement of the level of soil erosion [27]. Some scholars propose the use of scoring techniques to quantify soil quality properties [28]. However, this approach lacks scientific basis. Despite the belief that land use intensification leads to land degradation, some scholars show cases where vegetable crop intensification on hillsides lead to increased forest cover [9]. Some even found that soil erosion was either completely eliminated or greatly reduced in most hill slope farms that adopted agricultural intensification [16]. A number of scholars attribute soil erosion in Nyakach District to poor physical characteristics, but ignore the contribution of unsustainable farming practices [26], [29].

2.1 Conceptual framework

The framework given in Figure 1 below was constructed from the literature reviewed in the above section. This research was anchored on 'eco-agro' development as its conceptual framework. The research identified high level of erosion as a major indicator of land degradation arising from increased agricultural land use intensity measured as the cropping frequency. Cropping frequency influences the level of soil erosion which in turn determines the degree of land degradation. However, the relationship between cropping frequency and the level of soil erosion depends on the local physiography.

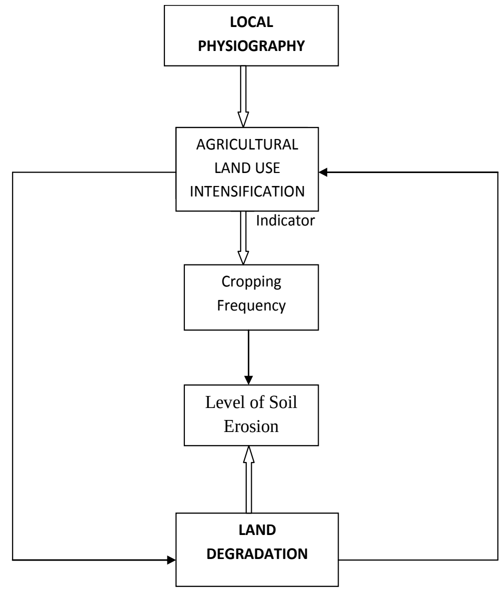

FIGURE.1: Conceptual Framework
Source: Researcher

3.0 RESEARCH METHODOLOGY

3.1 Study area

Nyakach District is located in western part of the Republic of Kenya (Figures 2 and 3).

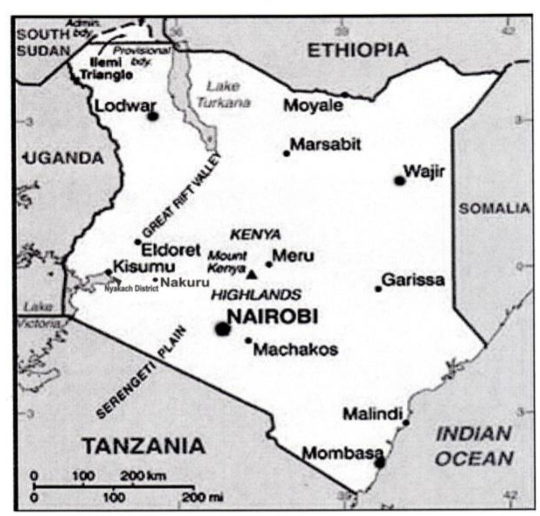

FIGURE 2: Location of Nyakach District in Kenya
Source: Nyakach District Development Office

To the southwest of the district is the small shoreline where it borders Lake Victoria [30]. The district falls within the Lake Victoria Lowlands and Floodplains Region. The four main topographical land formations are the Nyabondo Plateau, the Nyakach Scarp Slopes, the Nyakach Plain and the Valley Bottoms. Agricultural land falls into four categories on the basis of relief, namely high level regions situated on top of Nyabondo Plateau, land on slopes situated on the escarpments surrounding Nyabondo Plateau, plains that encompass the lakeshore, and the valley bottoms situated along rivers Nyando, Awach-Kano and Sondu-Miriu where silt and clay brought by surface run-off are deposited. The district has two extreme climatic conditions – floods and droughts.

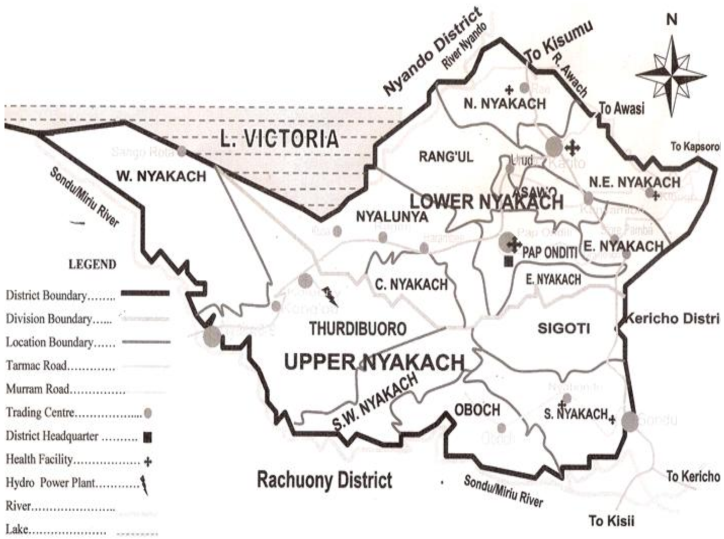

FIGURE 3: Map of Nyakach District

The geology of the district is dominated by relatively flat bedrock in the Nyakach Plain and granitic rock in the escarpment of Nyabondo Plateau [31]. The district has a population of about 133,041 [32]. The main economic activity in Nyakach District is subsistence agriculture which contributes 52% of the household incomes. Major gullies begin at the foot of the escarpment which is about 1500 m above the sea level [33].

3.2 Research design

The type of research used was *descriptive mixed methods research* hinged upon a fundamental principle which states that a researcher should use a mixture of methods that has complementary strengths and non-overlapping weaknesses [34]. The dimension of the study was '*cross-sectional*' [35].

3.3 Study population and Sampling:

Individual farmers were used as the unit of analysis. Household heads of individual farmsteads were interviewed through the use of a questionnaire. A total of 384 farmsteads were selected for the study out of a possible 29,214 farmsteads. A sample size of 96 farmsteads was randomly chosen from each one of the four physiographic units (Plateau, Plains, Valley Bottoms, and the Scarp Slopes) using a list of farmers and computer generated table of random numbers. According to the International Fund for Agricultural Development [36] where the target population is greater than 10,000 a researcher should use the formula below to arrive at the sample size:

$$n = \frac{t^2 \ x \ p(1-p)}{m^2}$$

where n is the desired sample size; t is the confidence level at 95% (usually set at 1.96); p is either the proportion in the target population estimated to possess a given characteristic or simply 0.5 where there is no reasonable estimate; and m is degree of accuracy desired (usually set at 0.05). For the purpose of this research the degree of accuracy was set at 0.05 (5%), that is, 95 per cent confidence level.

3.4 Data collection methods

Primary data was obtained from field surveys through the use field observations, interviews and questionnaire. Secondary data was sourced from existing relevant documentation such as agro-ecological zone maps and topographic maps of the district. Data were collected at farmstead and plot levels through the administration of a questionnaire to farmstead heads. This phase involved interviewing respondents as well as gathering data through field observations and measurements. The level of soil erosion in each farmstead was determined by measuring the average depth of erosional feature(s) such as gully, rill, or sheet. The depth in centimeters of a number of randomly selected cross-sections of the erosional feature was measured for each farmstead using a ruler or a tape measure as was appropriate. The average value of each farmstead was obtained and recorded. The advantage of this system is that it is easy to use and allows for the quantification of a factor which otherwise would remain purely qualitative.

3.5 Data analysis and Results presentation

The data was inspected using frequency tables, measures of central tendency and data spread. Data analysis began by coding questionnaire responses on computer coding sheets. Both quantitative and qualitative analysis methods were employed. Cropping frequency (CROF) was determined using Boserup's model (Boserup, 1965) given as

$$F_c = \frac{di}{12};$$

where d_i is the duration of the crop in the field (refer to Appendix 3), and F_c is the cropping frequency. Statistical analyses involved using Statistical Package for Social Sciences software version 20. Correlation coefficient analysis techniques were used to determine the relationship between, cropping frequency and level of soil erosion [37]. The results obtained were tested for significance using the F-statistic at 0.01 confidence level.

4.0 RESULTS AND DISCUSSIONS

The level of soil erosion was low in the Plateau but high in the Scarp Slopes, Plains and Valley Bottoms. A negative correlation was found to exist between the frequency of cropping and the level of soil erosion in the four physiographic regions. The results are contained Table 1 below.

TABLE1: Relationship between Level of Soil Erosion (LOSE) and Cropping Frequency (CROF)

	Plateau	Scarp Slopes	Plains	Valley Bottoms
Mean LOSE	2.0229	3.1927	4.1031	3.2146
Mean CROF	262.6807	181.9321	189.6221	287.4654
Pearson Correlation	-0.347	-0.318	-0.412	-0.430
Coefficient of Determination	0.120	0.101	0.170	0.185
Adjusted R-Square	0.111	0.091	0.161	0.176
Standard Error of Estimates	0.69141	0.93724	0.54955	0.5651
Calculated F ratio value	12.87	10.557	19.272	21.299
Critical F ratio value	6.91	6.91	6.91	6.91
Significance Level	0.01	0.01	0.01	0.01

Source: Field Data

According to Table 1, the mean level of soil erosion was lowest in the Plateau at 2.0229 but high in the Scarp Slopes, Plains and Valley Bottoms at 3.1927, 4.1031 and 3.2146 respectively. The mean cropping frequency was highest in the Valley Bottoms at 287.4654 but lowest in the Scarp Slopes at 181.9321. Pearson correlation values given in Table1 show a moderate strength in the relationship between cropping frequency and level of soil erosion in all the four physiographic units. The negative sign of the correlation shows that the level of soil erosion decreased as the frequency of cultivation increased. Table 1 shows the coefficients of determination as 0.12, 0.101, 0.17, and 0.185 for the Plateau, Scarp Slopes, Plains and Valley Bottoms respectively. These values imply that the proportions of the variations in the level of soil erosion explained by variations in the cropping frequency were 12%, 10.1%, 17%, and 18.5% for the Plateau, Scarp Slopes, Plains, and Valley Bottoms respectively. The adjusted R^2 values given in Table 1 suggest that the variance in the level of soil erosion explained by the variations in the cropping frequency was 11.1%, 9.1%, 16.1%, and 17.6% for the Plateau, Scarp Slopes, Plains, and Valley Bottoms respectively. Figure 3 below reveals that as cropping frequency increased level of soil erosion decreased. This is demonstrated by high cropping frequency in the Valley Bottoms and the Plateau corresponding to low level of soil erosion in the Valley Bottoms and the Plateau.

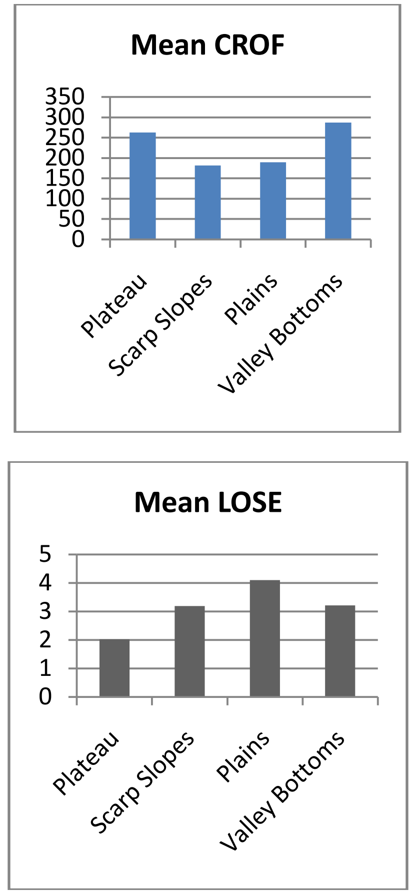

FIGURE 3: Chart for Mean Cropping Frequency and Mean Level of Soil Erosion

The moderate standard errors of estimates given in Table 1 suggest that most of the observed values clustered fairly closely to the regression line. This in turn implies that the regression lines obtained were a fairly accurate fits. The linear regression models for the four physiographic units studied are given in Table 2 below.

TABLE 2: Linear Regression Models for Cropping Frequency (CROF) and Level of Soil Erosion (LOSE)

Physiographic Unit	**Linear Regression Model**
Plateau	y = 2.51484 + -0.001873x
Scarp Slopes	y = 3.7911 + -0.003299x
Plains	y = 4.486 + -0.002019x
Valley Bottoms	y = 3.7638 + -0.002054x

Source: Field Data

According to the regression models shown in Table 2, when the effects of other factors were held constant a change of -0.001873 in the cropping frequency produced a change of 2.5148 in the level of soil erosion in the Plateau; a change of -0.003299 in the cropping frequency produced a change of 3.7911 in the level of soil erosion in the Scarp Slopes; a change of -0.002019 in the cropping frequency produced a change of 4.486 in the level of soil erosion in the Plains; and a change of -0.002054 in the cropping frequency produced a change of 3.7638 in the level of soil erosion in the Valley Bottoms. To test the statistical significance of the above regression models a null hypothesis was formulated for each physiographic unit. Null hypothesis for the Plateau: The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Plateau is not statistically significant. According to Table1, the calculated F ratio of 12.87 was greater than the critical F ratio value of 6.91 at 0.01 confidence level and hence the null hypothesis was rejected. The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Plateau was thus found to be statistically significant. Null hypothesis for the Scarp Slopes: The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Scarp Slopes is not statistically significant. From the results shown in Table 1, a value of 10.557 was obtained from the calculation of the F ratio. This was greater than the critical F ratio value of 6.91 at 0.01 confidence level. The null hypothesis was thus rejected and therefore the linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Scarp Slopes was confirmed to be statistically significant Null hypothesis for the Plains: The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Plains is not statistically significant. A calculated F ratio value of 19.272 obtained is shown in Table 1 above. This was found to be greater than the critical F ratio value of 6.91at 0.01 confidence level. Since the calculated F ratio value was greater than the critical F ratio value, the null hypothesis was rejected at 99% confidence level. The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Plains was therefore statistically significant. Null hypothesis for the Valley Bottoms: The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Valley Bottoms is not statistically significant. Because the calculated F ratio value of 21.299 given in Table 1 was found to be greater than the critical F ratio value of 6.91, the null hypothesis was rejected at 99% confidence level. The linear regression model showing the relationship between the cropping frequency and the level of soil erosion in the Valley Bottoms was confirmed to be statistically significant. These findings are discussed in the paragraph that follows. Cropping frequency and level of soil erosion are strongly related in the four physiographic regions studied because crops provide cover to soil and thus help in maintaining low levels of erosion. The negative Pearson correlation values obtained means that as the cropping frequency increases the level of soil erosion decreases. Increased cropping frequency provides cover for the soil most of the time and hence reduces the chances of soil erosion. Crops act as a cover for the soil, and the more frequently they are grown the less the risks of soil erosion. This relationship is true for farms occupying more or less flat topography. A more level landscape reduces the chance of extreme soil erosion [38]. Scarp slopes are exposed to extreme erosion if they have scarcer cover [39]. The flat topography of the Plateau responds readily to any mechanism that assists in reducing overland flow. A fairly strong correlation found between the frequency of cropping and the level of soil erosion in the Plains may again be attributed to the fact that cropping limits overgrazing as well as providing soil cover and hence reduction in the risks of soil erosion. As such, the more frequently a plot is cropped the lesser the effect of surface run-off on the soil. If the frequency of cropping and the level of soil erosion stand for agricultural land use intensity and land degradation respectively, then the findings of this study are in tandem with those of other scholars [8], [9], [40], [16]. Generally, land degradation decreases along hill slopes as agricultural land use intensity increases [16], [9]. Overgrazing is a common phenomenon in the Plains of Nyakach District. The only time that grazing is restricted is when crops have been planted in the farms. This implies that the more the farms are planted the less the grazing and hence the less the risk of extreme erosion. Since most of the Valley Bottoms are located in the Plains of Nyakach District, overgrazing is a major factor in the Valley Bottoms as well. Grazing is thus restricted only when crops have been planted in the farms. The implication of this situation is that continuous planting of the farms plays a protective role by limiting or eliminating erosion risks posed by livestock grazing. This is corroborated by others who appreciates the significance of raised cropping frequency on soil carbon accumulation and hence the resilience of soil [41]. A negative correlation between cropping frequency and land quality is thus noted by other scholars as well [41], [39]. The findings point to overgrazing as a major cause of soil erosion in the Plains of Nyakach District. When the farms are cropped more frequently, grazing becomes more limited and hence the trampling of the soils. Reduced overgrazing due to cropping and the attempts to protect the soil from erosion could have combined to ensure a moderately strong relationship between cropping frequency and the level of soil erosion in the Valley Bottoms.

5.0 CONCLUSION

Results revealed that the relationship between the cropping frequency and the level of soil erosion was statistically significant in all the physiographic units – $r = -0.347$ for the Plateau, $r = -0.318$ for the Scarp Slopes, $r = -0.412$ for the Plains, and $r = -0.43$ for the Valley Bottoms. Cropping frequency had influenced the level of soil erosion to a moderate extent, accounting for between 10.1% and 18.5% in the variations of the level of soil erosion. Cropping frequency can therefore be used successfully to assess land degradation in the different physiographic units of Nyakach District.

6.0 ACKNOWLEDGEMENT

The authors would like to appreciate the cooperation of Nyakach farmers and the government officers at Nyakach District headquarters who provided vital data during the field survey.

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