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AN ORDINAL-SCALE CLASSIFICATION OF WATER EROSION INTENSITY

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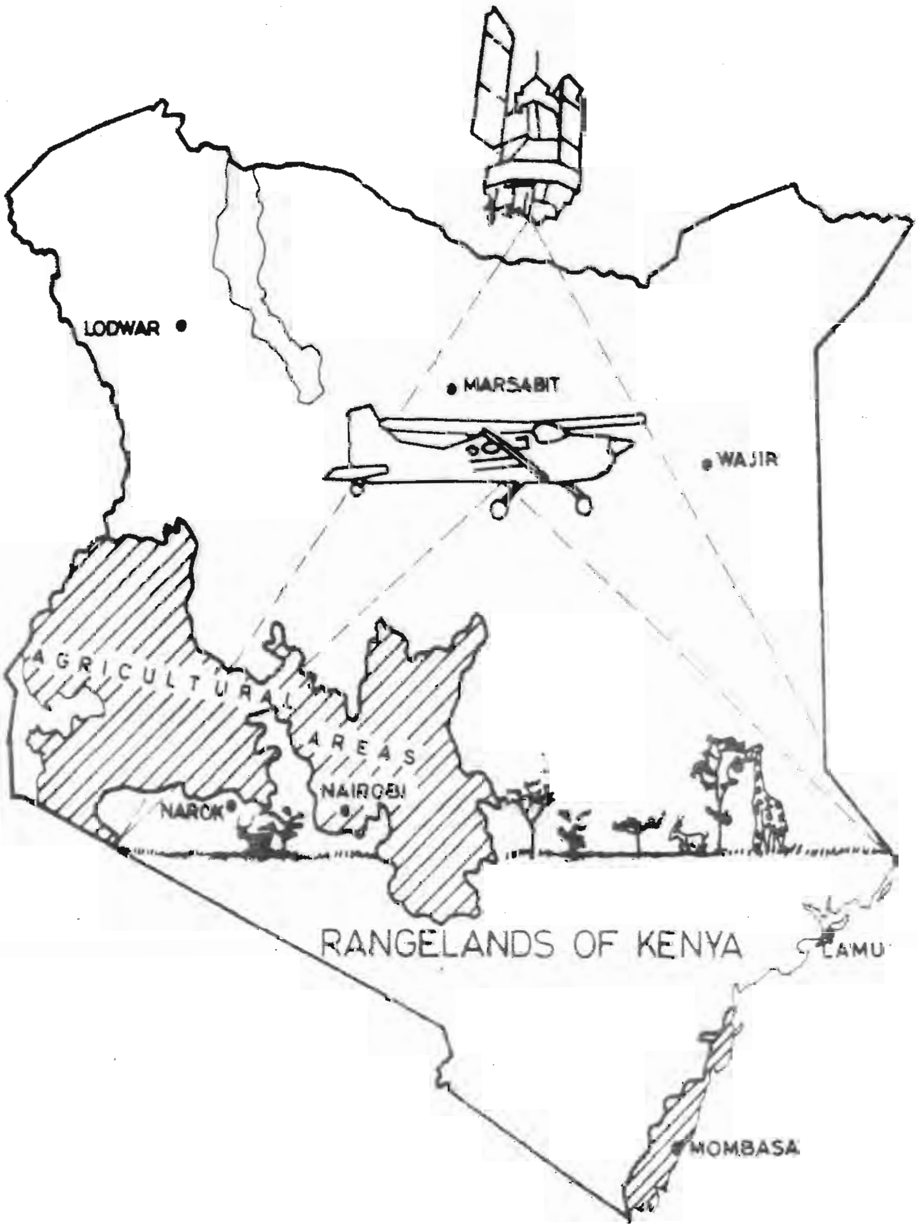

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INTRODUCTION

Soil erosion caused by rainfall and the resulting runoff is an important ecological factor in environmental conservation. The results of soil erosion range from losses of vegetation and fertile surface soil to the extent of ultimate land degradation and environmental damage if erosion control measures are neglected. The reduction of vegetative cover and the alteration of the water-holding characteristics of catchment areas are processes which can seriously affect the ecological character of an area through soil erosion.

Whereas significant efforts have been undertaken to control soil erosion in well-managed agricultural lands, there has been a noticeable increase in erosion in farms and heavily grazed ranches in marginal lands. The practices which contribute greatly to soil erosion are: poorly regulated clear-cut deforestation; submarginal agriculture involving frequent slash and burn as in shifting cultivation, and excessive grazing pressure by stock and game. These practices, if not improved, can result in a razed landscape which is highly vulnerable to soil erosion with far reaching damaging effects on the productive ecological function.

The consequences of soil erosion also affect stream and river siltation. Excessive silt is a major form of water pollution because silt-laden streams have a poor light penetration which often leads to disruptions in normal aquatic ecology and productivity.

In view of the foregoing it would be imperative to measure soil erosion throughout Kenya with a view of monitoring soil erosion on a national-wide basis for the following purposes:

1. To quantify the rates at which soil profiles are being thinned.
2. To quantify the rate at which sediment is entering river channels and reservoirs.
3. To document changes in these rates.
4. To quantify the effects of factors such as climate, vegetation, land use, hillslope gradient and soil type on the rate of soil erosion and sediment production.

Several techniques are available for measuring soil erosion (see Dunne, 1977, for a review), and it is to be hoped that they will be gradually introduced in Kenya for the purposes indicated above. However, these techniques are time-consuming to apply and they require considerable attention to detail in the field as well as personnel trained in the analysis and use of such data.

PURPOSE OF THIS REPORT

Until direct measurements are widely applied, we suggest the use of an ordinal-scale classification of soil erosion intensity, based on systematic field observations of erosion indicators.

This report outlines such a classification system, which we are now testing in the field. We propose it in order to stimulate critical discussion and field application so that the scheme might be improved and applied widely throughout Kenya as a component of agricultural, range or ecological surveys. As data accumulate it should be possible to correlate the erosion intensity in an area with its controlling factors or with the degree of soil deterioration, primary production, or other variables that might be effected by erosion. Mapping of erosion intensity in a drainage basin might also be useful for such purposes as indentifying zones that are the main contributors of sediment to a reservoir, or outlining the parts of an area in which soil conservation is needed most urgently.

BASIS FOR A CLASSIFICATION OF EROSION INTENSITY

Gleason (1953) pointed out that water erosion can be recognized by means of various physical effects, which he termed "erosion indicators". These included: rills; gullies; pebble-capped pedestals of soil; erosion pavement; certain mounds of residual soil around plants; unscorched collars on shrubs; exposed unscorched roots, exposed roots crowns; soil deposits in depressions, behind obstacles on gentle slopes, and above a humus or burned organic layer.

Gleason also proposed indicators for wind erosion, mass wasting, and channel erosion.

Other scientists have used a single indicator more intensively to quantify rates of erosion. In order to calculate the amount of soil lost during a period of deforestation and cultivation, Haggett (1961) in Brazil and Trimble (1974) in the United States measured the A-horison thickness of soils that had been cultivated and of others that had retained a forest cover. In Kenya, we have used the height of tree-root exposures or remnant eroded mounds around datable plants in order to measure erosion rates over the preceding 10-80 years. The method is subject to many potential sources of error, but with careful observations, described by Dunne et al (1978, 1979), some useful results can be obtained.

The most widely used system for classifying erosion intensity qualitatively is that used by the U.S. Soil Conservation Services (1951). The scheme has the following form:

Class 1 : Up to 25 per cent of the original A-horizon, or original ploughed layer in soils with thin A-horizons, removed from most of the area;

Class 2 : Approximately 25 to 75 per cent of the original A-horizon or surface soil lost from most of the area;

Class 3 : More than 75 per cent of the original A-horizon or other underlying layers, lost from most of the area;

Class 4 : The land has been deeply eroded until it has an intricate pattern of moderately deep or deep gullies. Soil profiles have been destroyed except in small areas between the gullies.

In subhumid regions that have been grazed or cultivated for a long time it is usually not possible to recognize the original depth of the A-horizon, and so the classification scheme developed for American agricultural regions is not directly transferable. However, the principle is worth considering for application in a modified form in Kenya.

Such a classification scheme has great utility in the absence of, or as a means of extending results from instrumental observations of erosion. Through the use of an ordinal-scale, erosion intensity can be measured, or at least observed systematically, and can be correlated with its controlling factors such as hillslope gradient, cover density, and land use. Units from a few square metres to about 100 hectares can be classified at once and mapped onto aerial photographs. A score can also be assigned at intervals along sampling transects down hillslope profiles, to define characteristic profiles of erosion rate in a physiographic region. In such cases it may also be useful to extend the classification scheme by adding to the list one or more scores to indicate the intensity of deposition on some footslopes.

The classification system which we propose below for use in subhumid regions is based on surface morphological features rather than soil profiles characteristics which are usually known only vaguely. It also avoids using the density of vegetation cover because this factor can change radically between seasons or years and areas with similar vegetation cover can erode at differing rates depending on gradient, soil type and other variables. Avoiding the direct use of vegetation density also gets around the problem of an observers bias towards assigning a low erosion-intensity score to an area that has a temporary thick cover of annual plants. It is often necessary in such situations to part or remove the vegetation cover on small patches of ground in order to examine the soil surface directly.

Our scale of erosion intensity is the following:

Class 0 : No sign of erosion. Soil surface often rough on the scale of aggregates.

Class 1 : Some signs of weak erosion, such as wash marks on the soil surface, and small erosion mounds or root exposures around trees and bushes.

Class 2 : Erosion mounds and tree-root exposures as in Class 1, but some signs of more intense wash and sediment transport in minor flow concentrations, which may exhibit ripples and a few millimeters of deposited sediment upslope of large stones or dams of vegetation debris.

Class 3 : Well-developed root exposures, sometimes with surviving erosion mounds, and the ground shows general signs of intense washing, such as streaks or armour layers of sand and dark heavy minerals, ripples and redeposited sediment. Root exposure even on some annual plants.

Class 4 : General signs of intense erosion in class 3 but with obvious flow concentrations. The surface has a corrugated form parallel to the strike of the hillslope and the amplitude of the ridges may be upto about 10 cm, but their wavelengths are highly variable. Although the intervening grooves show obvious signs of flow concentration their cross-section tend to be rounded and they typically do not have channels with sharp boundaries.

Class 5 : The hillslope is dissected by rills and small gullies with definite margins. The intervening surface is fairly smooth and gently sloping but shows general signs of intense wash and large erosion mounds or root exposures if suitable plants survive.

Class 6 : The surface is intricately dissected by gullies into a badland topography. The walls of the gullies are steep and frequently rilled. They may also exhibit: erosion pedestals under stones, dry raveling, and soil slumps after the development of tension cracks if the gully margins are nearly vertical.

We have found it useful to classify some sites as being intermediate between two classes by means of scores such as 1.5, 2.5, etc. However, to use a more detailed scoring system would probably lead to a false sense of precision.

On some hillslopes, one can observe small patches of one erosion class interspersed with patches of another. It may be useful to indicate such cases by the notation (e.g.) 3/2, 2/4. etc. with the spatially dominant class being written first.

OPERATOR VARIATION

The three of us visited 26 vegetation stands in KREMU field sampling stations as well as 10 other sites scattered in Rift Valley Province, Eastern Province and Coast Province. The vegetation types include: grassland, bushed grassland, bushland, wooded bushland and forest. Some of the plots were regenerating from heavy cutting and grazing or from shifting cultivation.

We independently classified the erosion intensity, which ranged from Class 0 to Class 5. On only one occasion did the range of estimates exceed one, and in nearly every case the three scores were identical.

Since the operator variation appears to be small, the method could be widely incorporated into agricultural and ecological surveys.

CORRELATION WITH OTHER MEASURES OF EROSION

The rate of hillslope erosion has been measured at a few places in Kenya by a variety of methods. If the areas for which these rates were measured can be classified on our erosion intensity scale, a correlation can be established

The following data are available on erosion rates in Kenya:-

1. Dunne and Ongweny (1976), Ongweny (1978), and Dunne (1979) have computed sediment yields for many areas of Kenya. A number of these areas with more or less homogeneous land use were visited and classified. In most basins, land use and the resulting erosion intensity were so spatially variable that it was not possible to assign a single erosion class for correlation with the basin sediment yield. However, forested highland drainage basins have sediment yields in the range of 20-30 t/km^2 /yr, which is equivalent to an erosion rate of approximately 0.02-0.03 mm/yr. The hillslopes in these basins were classified in the field as zero on the erosion scale.

2. Dunne et al (1978) used datable tree-root exposures to measure erosion rates on hillslopes in Kajiado District. These sites were also classified according to the system proposed herein.

The results of the relationship are presented in figure 1, which indicates a strong correlation between the two forms of measurement. These results are encouraging, and form a basis for careful extrapolation to sites in southern Kenya with the same land-use history for which there are no direct measurements of erosion.

However, it is wise to recognize the following limitations of the procedure:

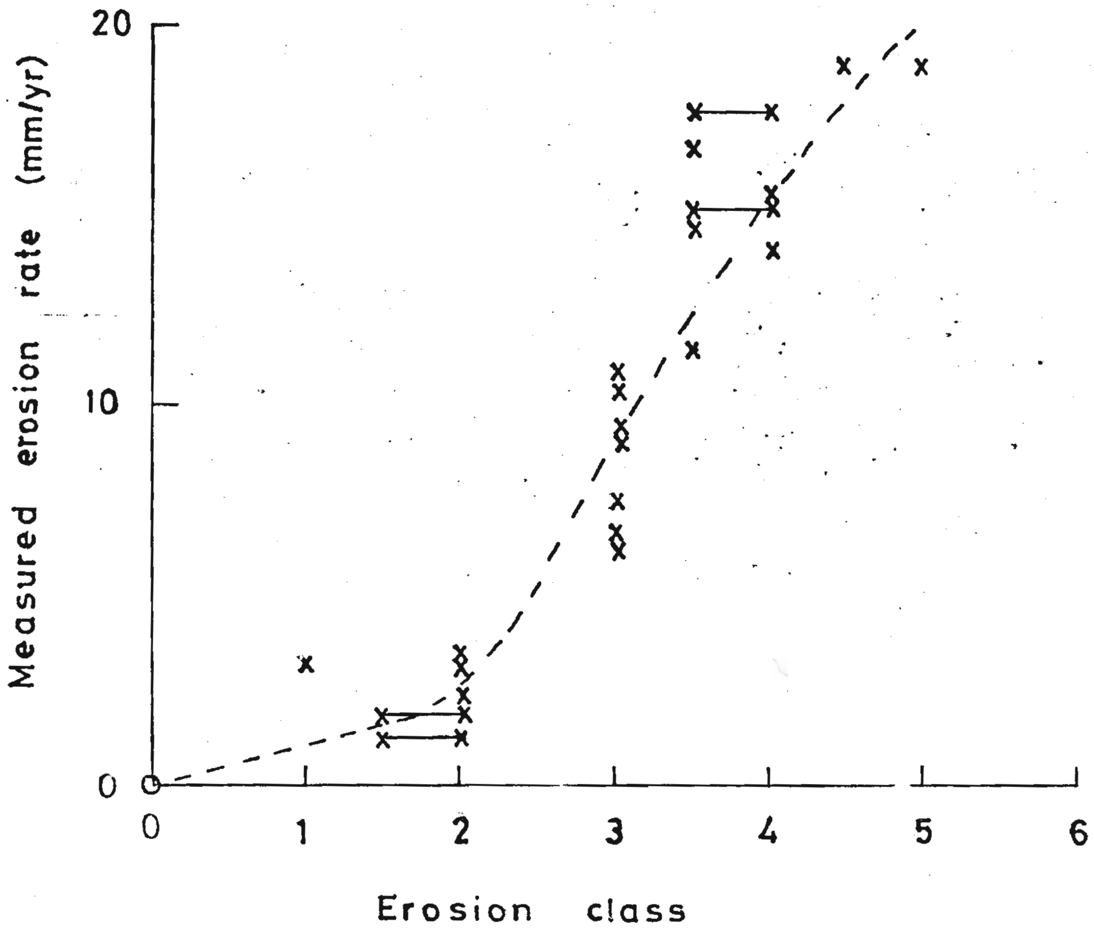

Fig. 1 : Correlation between erosion-intensity class and measured recent rates of erosion in Kenya. The crosses represent measurements made on tree root exposures, and the circle indicates estimates based on sediment yields from forested drainage basins in central Kenya.

1. Before application outside the Kenyan conditions under which it was developed, the classification scheme needs to be checked for relevance to other areas with different climates, physiography, and land use.

2. Within Kenya and similar regions, differences of land use between rangeland and cultivated fields may confuse the classification scheme and it may be necessary to modify the proposed system, which was based heavily on rangeland condition, for use in agricultural regions.

3. The specific relationship in figure 1, is meant only to provide a demonstration that such a correlation is possible. It should not be applied outside southern Kenya.

4. Erosion rates derived from tree roots are subject to many errors and should be considered as approximate values only (Dunne et al, (1978).

5. Erosion rates derived from basin sediment yields also reflect only approximately the average of hillslope erosion within the catchment. In the basins for which we have made computations, there is little or no net aggradation on footslopes or valley floors, indicating that the sediment yield reflects the erosion rate integrated over the catchment. In areas of mixed land use, varied topography, and other conditions, the erosion class should vary dramatically from place to place within a drainage basin. For

example, Dunne (1979) has argued that in the steep, wet highlands of Kenya, an important fraction of the basin sediment yield probably originates from roads, rather than from general erosion of hillslopes or fields. Many roadsides in Kenya are classified into categories 5 and 6 whereas the surrounding areas are in lower classes.

However, it seems likely that a correlation between erosion class and erosion rate can be defined for some regions. Even where such an absolute value cannot be given, the ordinal-scale of erosion intensity still provides a systematic means of comparing sites. Repeated measurements at a location could help resolve arguments about whether soil erosion is accelerating or emeliorating. The erosion classification also provides an objective value that can be used in non-parametric statistical analyses of the factors controlling erosion intensity, if variables such as hillslope gradient, vegetation density, and soil characteristics are measured at the same sites. Thus, incorporation of the classification system into geomorphic surveys of soil erosion or range, agricultural and ecological surveys may produce some useful information.

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