# Stone Cover Effects on Soil Erosion Hazard: A Case Study of the Upper Ewaso Ng'iro Basin

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## Abstract

The influence of stone and rock covers on soil erosion hazard was assessed in the Upper Ewaso Ng'iro North basin of Kenya. Reconnaissance data from 83 sample sites was collected on vegetation cover types and amounts, slope gradients, soil types and percentage stone and rock cover over the area. In addition, topsoil samples were collected for laboratory analysis of texture and organic matter. It was found that although the main factors influencing soil erosion were vegetation cover and topography, stone and rock covers increased soil erosion under each type of vegetation. In addition, stone/rock covers influenced soil erosion on-site and off-site of the affected areas. However, more detailed studies are necessary to determine the processes involved during soil erosion under stone covers, particularly under rangeland conditions.

**Keywords**: Stone cover, soil erosion

## 1.0 Introduction

The manner in which stone cover affects soil erosion hazard is still not well understood. Although it is an established fact that stone cover affects erosion, there are contradictory reports as to whether stone cover increases or decreases soil loss (Bunte and Poesen, 1994). In many cases, stone cover has been associated with reduced soil erosion (Savat, 1982; Collinet and Valentin, 1984). However, Poesen and Ingelmo-Sanchez (1992) suggest that rock fragments increase erosion when embedded, while they decrease erosion when partly embedded or resting on the surface. This has been associated with the effect of the stones on soil porosity. Thus, surface stone cover tends to increase infiltration and retard overland flow, whereas, imbedded stones would have the opposite effect (Bunte and Poesen, 1994). It is common that under natural conditions, stone cover exists partly embedded and partly on the surface. Under such circumstances, it is not clear what role the stone cover has on the inherent soil erosion, under tropical savannah and semi-arid conditions. In addition, data on the impact of stone cover on soil erosion has been scarce, as most of the studies have been laboratory based.

In land use planning, it is common to find that rocky and stony soils are allocated for forestry or rangelands. However, the problem of soil erosion in rangelands has generally received less research attention in comparison with cultivated lands, yet there is growing evidence that erosion is increasing in these regions (Mati, 1999). When rangelands are exposed to excessive grazing, a pattern of soil erosion emerges, mostly related to other factors such as type of vegetation, its management, topography, rainfall characteristics and soil type. The effects of stone cover, which influence soil erodibility, also determine to some extent the type of vegetation that can survive the harsh conditions. Thus, the influence of stone cover on soil erosion under rangeland conditions requires investigation at the field level, as was done in the Upper Ewaso Ng'iro basin of Kenya.

### 1.1 The study area

This study was conducted in the Upper Ewaso Ng'iro North basin of Kenya (or simply Upper Ewaso Ng'iro basin), which forms the upper stream section of the River Ewaso Ng'iro North, covering 15,251 km$^2$ (Fig. 1). It is situated between latitudes 0° 20' south and 1° 15' north and longitudes 36° 10' east and 38° 00' east as defined by the natural topographic divide, lying north of Mt. Kenya and the Nyandarua Range. About 85 percent of the basin is uncultivated, mainly comprising rangelands used as large-scale commercial ranches for beef and dairy cattle, while the drier northern regions are used by the pastoral communities for communal grazing (Thurow and Herlocker, 1993), and a few forests mostly on mountain and hill slopes. It is on the hills and minor scarps that soils having high percentage of stone covers are most prevalent.

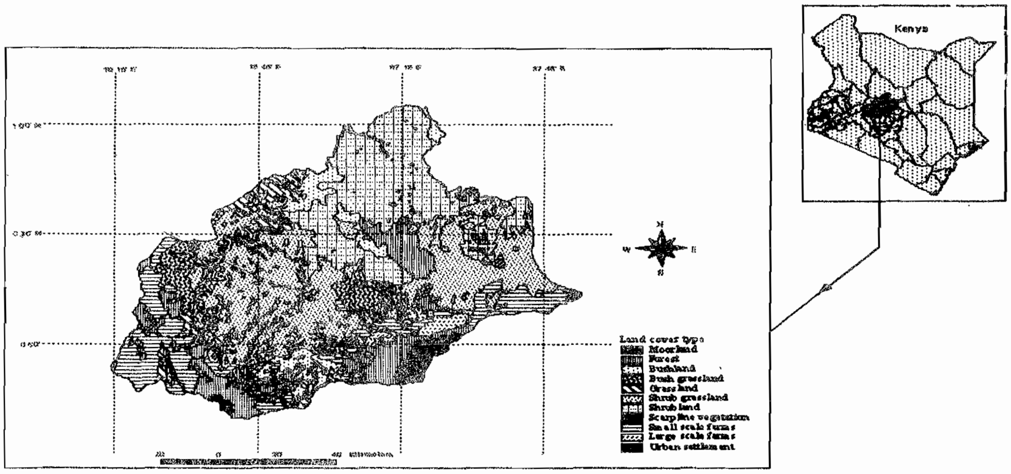


Figure 1. The Upper Ewaso Ng'iro basin showing the major landuse/land cover types

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## 2.0 MATERIALS AND METHODS

The general methodology involved soil sampling and assessment of erosion hazard on 83 sample areas (test sites) whose selection was stratified to include major soil mapping units and the major land use/land cover types in the basin. At each test site, a general description of the soil surface characteristics was made (Kenya Soil Survey, 1987; Landon, 1991). The amounts of stones and gravel on the soil surface were estimated using a meter rule. Large rock cover was estimated visually, by considering 100 by 100 m transects. Top-soil samples were collected with an auger from the top 30 cm, taking three replicates from each site. These were taken to the laboratory for the determination of texture and organic matter contents. In the laboratory, soil texture analysis was done to determine the percentage sand, gravel and stones in the sample by wet sieving, while the percentage silt and clay were determined by the hydrometer method (Kenya Soil Survey, 1987). The organic matter content was determined by the Walkey-Black method (Page *et al.*, 1982).

Soil erosion was assessed in the field using indicators of erosion (Hudson, 1983; Kassam et al., 1991) such as exposed soil surface, interill, rill and gully incidence and deposition. A scoring system was used as shown in Table 1.

**Table 1 Qualitative classification of soil erosion at the test sites**

| Class | Description |
|---|---|
| 1 | No apparent erosion |
| 2 | Slight to moderate erosion, mostly interill erosion |
| 3 | Moderate loss of topsoil generally and/or some dissection by runoff channels or rills. |
| 4 | Severe loss of topsoil generally and/or marked dissection by runoff channels or gullies |
| 5 | Very severe erosion with exposed subsoil and intricate dissection by runoff channels or gullies |

In addition, vegetation cover was assessed based on the system used to classify rangelands in Kenya (Pratt and Gwynne, 1977). At each test site, the vegetation cover was also estimated as catchment cover. This involved pacing quadrants of 20 x 20 m, then counting the number of trees, estimating the percentage canopy cover, height of trees, percentage grass or forbs and vegetation types, including tree names wherever possible. Land slope was also estimated using a clinometer. The data obtained has been summarised and presented in Table 2.

**Table 2. Soil properties, slope and land cover types of some sampled sites**

| Sampled test site | Land use/Land cover | Vegetation cover (%) | Slope (%) | Soil Texture | Organic matter (%) | Stone cover (%) | Erosion Hazard |
|---|---|---|---|---|---|---|---|
| Wuthering Heights | Moorland | 95 | 10 | SCL | 8.9 | 0 | 1 |
| Lobelia forest | Moorland | 95 | 25 | LS | 13.1 | 5 | 1 |
| Teleswani | Forest | 95 | 5 | SL | 6.3 | 0 | 1 |
| Kyegoi (Nyambene Hills) | Forest | 95 | 35 | SL | 11.0 | 0 | 1 |
| Ngobit | Bushland | 90 | 15 | CL | 4.0 | 5 | 2 |
| Karama | Bushland | 80 | 15 | SCL | 1.7 | 30 | 4 |
| Lol Daiga | Bush grassland | 80 | 15 | SCL | 2.8 | 0 | 2 |
| Morijo Estate | Bush grassland | 80 | 20 | SL | 1.6 | 50 | 3 |
| Solio Ranch | Grassland | 80 | 4 | L | 3.8 | 0 | 1 |
| Kifuku farm | Grassland | 90 | 1 | L | 3.2 | 10 | 1 |
| Sweetwaters | Shrub grassland | 85 | 2 | SCL | 3.0 | 0 | 1 |
| Isiolo Qarantine Area | Shrub grassland | 60 | 3 | L | 2.0 | 30 | 3 |
| Lodumei | Shrubland | 40 | 5 | LS | 0.4 | 0 | 5 |
| Ol Donyiro | Shrubland | 60 | 6 | SL | 0.8 | 50 | 4 |
| Archers Post | Shrubland | 35 | 4 | L | 1.7 | 85 | 5 |
| Luisie Gap (scarp) | Scarpline shrubs | 35 | 25 | LS | 1.8 | 70 | 5 |
| Rumuruti | Scarpline shrubs | 35 | 10 | SCL | 2.4 | 80 | 4 |
| Kisima – Timau | Large scale farms | 51 | 5 | CL | 4.2 | 0 | 2 |
| Embori | Large scale farms | 51 | 13 | L | 3.6 | 0 | 2 |
| Sipili | Small scale farms | 49 | 4 | SCL | 1.8 | 0 | 2 |
| Sirima | Small scale farms | 44 | 4 | CL | 2.2 | 0 | 2 |

## 3.0 RESULTS AND DISCUSSION

Of the 83 test sites sampled in the basin, 35 of them had soils covered by appreciable amounts of stone and rock cover. However, it was found that erosion hazard is primarily affected by land cover type, decreasing with increase in percentage vegetation cover (Table 2). This has been demonstrated in earlier work (Mati, 1999; Mati et al., 2000) on erosion hazard mapping in the Upper Ewaso Ng'iro basin using the USLE (Wischmeier and Smith, 1978) and GIS (Geographic Information Systems) techniques. In this study, it was observed that incidences of stone and rock cover were also associated with severe soil erosion. In addition, stone and rock covers happen to occur on hills and minor scarps, where the steeper slope of the land contributes to increased soil erosion as well. Thus, it is difficult to deduce the specific contribution of the stone cover to the erosion process, due to the complexities associated with the nature of the topography, in places where stones are more prevalent.

A regression analysis between percentage stone cover and erosion risk obtained a poor correlation. This was attributed to the fact that soil erosion is a function of several other factors such as vegetation cover and rainfall characteristics, and the simple score obtained may not represent a mathematical relationship. However, by grouping the data according to vegetation cover types, a pattern emerged indicating a relationship between stone cover and soil erosion in the rangelands (Fig. 2). It was found that in each vegetation cover grouping, higher soil erosion had been recorded on stony/rocky soils than those without. From the laboratory studies, it was found that soil texture, especially the proportion of sand content in the soil, influenced the incidence of stoniness and rock cover, as well as erosion hazard. For instance, loamy sands, sandy loams and sandy clay loams had high incidence of stone cover, ranging from 0 to 80 percent, and erosion hazard ranged from moderate to severe.

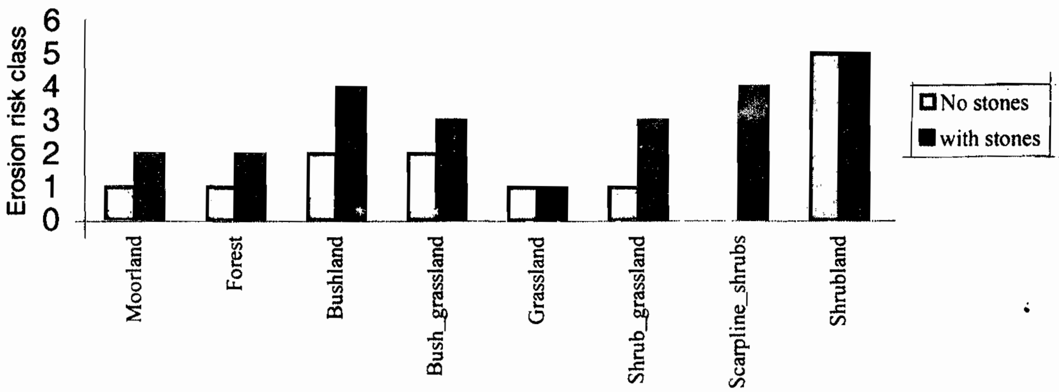


**Figure 2. Stone cover effects on soil erosion hazard for different land use/land covers**

On the other hand, clay, loams and clay loams generally had no or scattered stone covers, averaging less than 20 percent, and erosion risk was low to moderate. The soils with the lowest erosion risk were found on the slopes of Mt. Kenya, the Nyandarua Range and the Nyambene Hills (Fig. 3). These soils also contained no or very few stones. They are developed on volcanic rocks and comprise of chromic-humic Cambisols, humic Andosols and eutric Nitisols (Sombroek et al., 1980) and have a thick humic topsoil, with organic matter content ranging about 4.5 to over 13 percent. These soils have favourable moisture storage capacity, aeration conditions and good structural stability, and erosion risk was found to be minimum under forest and grass covers.

The middle parts of the basin, comprise imperfectly drained, montmorillonitic cracking clay soils (chromic-pellic Vertisols and pockets of eutric Planosols). Although these soils are relatively shallow, they do not contain many stones or rocks on the surface. The vegetation cover is mostly grassland and shrub grassland. Due to the flat gradient of the land, soil erosion is a minimum especially where grass cover has been maintained through good management.

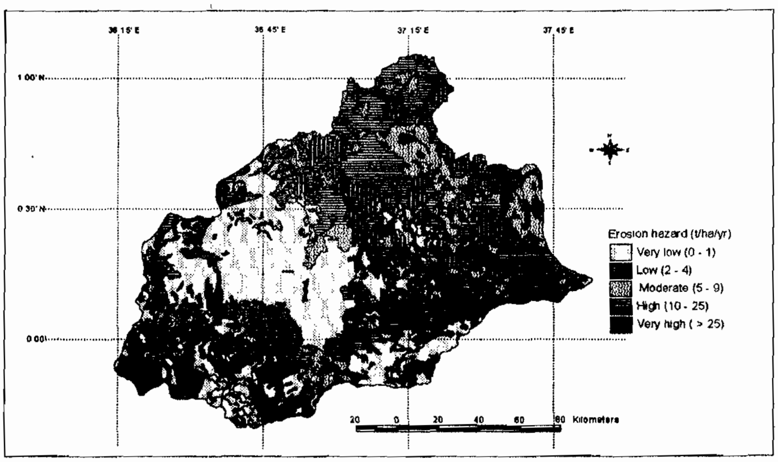


**Figure 3. Stone cover and soil erodibility in the Upper Ewaso Ng'iro North basin**

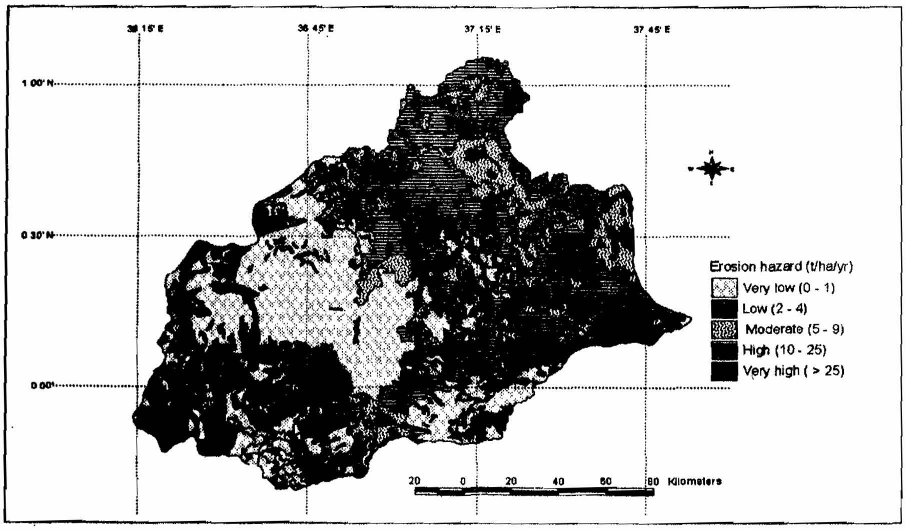


**Figure 4. Soil erosion hazard in the Upper Ewaso Ng'iro North basin**

Stony and rocky surface cover was prevalent in the central and north of the basin. Here, the soils are developed on basement material, and they consist of gravely sandy loams to sandy clay soils (eutric Regosols and chromic Cambisols) on the upper slopes, while on the lower slopes, are dominated by chromic Luvisols. These soils are characterised by low organic matter (less than 1.5 percent) in the topsoil, low porosity and relatively high bulk densities, poor water storage capacity and a tendency to form a strong surface seal, giving them high runoff producing properties. Figure 4 shows the erosion hazard map of the basin as determined using the USLE (Wischmeier and Smith,1978), from a previous study (Mati, 1999). Due to the fact that this map was created from raster GIS files, it is rather congested and was not used to overlay the stones positions, which were instead overlaid on Fig. 3. From both maps and Table 2, it is possible to see that stone covers increased both soil erodibility and the overall erosion hazard.

On the hills and minor scarps, stones and rock outcrops are dominant, exceeding 50 percent of the surface cover. As a result, vegetation cover is sparse and soil depth is shallow showing signs of overland flow. However immediately below these scarps, stone and rock cover decreases or is lacking, but severe erosion with obvious evidence of interill, rill and gully erosion was apparent. It was noted that stone cover had increased the runoff producing properties of the hillside, causing more erosion damage on the outlying land than on the stony hillside itself, indicating an onsite as well as off-site effect on soil erosion. This is in contrast to studies in other regions, where stone cover has been associated with reduced soil erosion (Savat 1982; Collinet and Valentin 1984; Lamb *et al.*, 1950; Mati and Veihe, 2001). However, Poesen and Ingelmo-Sanchez (1992) suggest that rock fragments increase erosion when embedded, while they decrease erosion when partly embedded or resting on the surface. This is because stone cover on the surface protects the underlying soil from raindrop erosion and overland flows, while stones under the surface would reduce infiltration and increase runoff. The soils sampled in this study were mostly partly embedded and partly on the surface. Therefore, any advantage in stone cover on the surface would be counteracted by poor infiltration, and increased runoff. In addition, the presence of the stone cover prevents regeneration of vegetation cover, which enhances the runoff producing properties of the catchment. Although more detailed studies are required to determine the processes that take place in this environment, it appears that the overall effect of the stone cover at the sub-catchment level was increased soil erosion at the field level.

### 3.6 CONCLUSIONS

In general, stony soils and rock outcrops were more prevalent on hills and minor scarps and in the dry areas. Although rangeland erosion was mainly affected by land cover type, management and topography, stone and rock covers increased runoff from the affected hillsides, resulting in severe soil erosion on the flatter outlying land. By a comparison of catchments with similar topography, climate and land cover types, soil erosion was more severe where the catchment contained stone and rock covers, than those without. The results obtained here indicate that in erosion hazard assessments, the influence of stone cover on soil erosion goes beyond the areas covered by the stones/rock outcrops. However, more detailed studies are required to determine the processes involved during soil erosion under rangelands in the Savannah environment.

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