AN ANALYSIS OF SOIL EROSION POTENTIAL:THE CASE OF SONDU BASIN, WESTERN KENYA

by

BILLY MARK MENYA KARIAGA

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ABSTRACT

The objective of this thesis is two-fold. Firstly, it aims to identify areas of high potential of soil erosion by water within Sondu Basin, western Kenya. Secondly, it attempts to determine the dominant factors of soil erosion in those areas of high potential. A review of literature pertaining to water erosion of the soil is presented. In this study, a simple method of factor analysis to obtain a composite model of soil erosion potential is employed. The principal factors selected for analysis are soil erodibility, rainfall erosivity, slope gradient, vegetation cover and human influences. A new Geographic Information System computer package, Map Analysis Package (MAP), is used in the analysis of data. This technique enables the mapping of soil erosion risk, the identification of areas of high erosion potential, and the determination of dominant factors of erosion in the latter localities. A letter-annotated map, revealing the association of dominant factors in various areas of high soil erosion potential, is produced. Findings of the study reveal that there is a general tendency for soil erosion potential to be high in the central and western parts of Sondu Basin, especially on the western Kericho Plateau and in the Kisii Highlands. Vegetation cover and human influences are found to be almost invariably major causes of high soil erosion potential. With respect to human influences, particularly vegetative cover modification, cultural practices such as land clearing, tilling, burning, planting and weeding are revealed as the major causes of soil erosion. Slope gradient is found to be a dominant factor of erosion potential in the Kisii Highlands, whereas rainfall erosivity is significant on the western Kericho Plateau. Soil erodibility is not a crucial determinant of soil erosion potential in the Sondu Basin, except where Vertisols and Planosols occur. It is recommended that agronomic measures which maintain a protective vegetative cover be employed, and that controlled livestock grazing be practiced to reduce soil erosion risk.

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Chapter I

INTRODUCTION

Kenya's population increase of about 4% per annum is one of the highest in the world and is placing greater demands on the nation's physical environment. Few areas exist in Kenya where landscapes are completely void of human impact. Today human activities are augmenting the changes brought about by geomorphic erosive agents. In particular, human impact upon unconsolidated materials, such as soils, is potentially large as these materials have low erosion thresholds with respect to surface removal by running water or wind, a geomorphic effect commonly referred to as "soil erosion".

Clearing of vegetation in order to increase food supply is increasing in most areas of Kenya. Dunne (1979) has pointed out that much of the natural vegetation of Kenya has been removed to promote cultivation, pasture growth, and manufacture of charcoal. This is especially critical from an erosional point of view in areas of steep slopes or on land considered marginal for cropping.

In addition, the altering of traditional land use patterns increases the likelihood of accelerated soil erosion, unless conservation practices are initiated simultaneously. The severity of soil erosion in a given area depends upon the interaction between cultural practices and physical factors, as well as upon population pressure. Some of the critical determinants of soil erosion are farming technology, soil properties, terrain morphology, vegetative cover, and precipitation characteristics.

1.1 SOIL EROSION IN THE KENYAN SETTING

1.1.1 Population and traditional farming

A recent phenomenon occurring throughout rural Kenya is the increasing area of land used for food production. A growing population requires more food, and this is usually met either by bringing good quality forested land under cultivation or by cultivating marginal land. In both cases this usually results in a decrease in the density of vegetation cover for at least a portion of the year, and soil erosion increases seasonally.

Traditionally in Kenya shifting cultivation and rotational bush fallow have been practiced (Ojany and Ogendo,1973). The common practice in both systems is a period of cropping, during which the nutrient reserves of the soil are exploited, followed by a period of fallow during which the nutrients are again recycled and replenished (Greenland,1974). This was a sound practice that required minimal investment when there was a relatively stable population. Today, with increased population growth and food demand, these traditional farming techniques place severe pressure on the soil resource. Productivity using these techniques can only be increased by reducing the fallow period or by cultivating new lands. Maintenance of current agricultural output is achieved at the expense of decreasing soil fertility and continual clearance of more land. Thus, the soil erosion potential increases.

The seriousness of the problem is now recognised by the public in many areas as food prices increase and shortages occur. In response to this, the government is becoming ever more involved in agriculture and food supply problems. Governmental assistance is currently growing in a sector of the economy that traditionally has been an area of modest state investment (Garst, 1974).

1.1.2 The Physical Environment

The physical environment in many areas of Kenya is degenerating due to the growing soil erosion problem resulting from the breakdown in the traditional relationships between population, farming practices, and natural environmental factors. In the tropics, rains are generally more erosive than those in the middle latitudes. This is due to the generally large water drop size in tropical rains and the high rainfall intensities and, consequently, high kinetic energy of the precipitation (Lal, 1976). Furthermore, tropical rains are often accompanied by high intensity winds which further increase their aggressiveness (Ahmad and Breckner, 1974). With land clearance these rainfall characteristics all interact positively to accelerate soil erosion. Traditionally, long periods of fallow were a major strategy for minimizing precipitation impact. However, increase in food production required by Kenya's growing population necessitates, among other things, shorter fallowing, thereby diminishing this strategy.

Under natural conditions an equilibrium exists between soil formation and soil erosion. When the vegetation cover is removed by grazing or cultivation, the crucial change to bare soil results in exposure to the direct impact of rain. Soil aggregates in Kenyan soils are generally too large to be directly transported by runoff (Sombroek et al 1982). However, tropical rains break up these aggregates by raindrop impact where bare soil exists, and the resulting fines are easily eroded by surface runoff.

Today in Kenya, there is a rapid shrinkage of forest cover by clearing. The natural forest is being replaced by a variety of secondary formations, depending on the depletion of its fertility, and topography. The density of woody growth in these vegetation formations varies inversely with intensity of cultivation. Often it decreases as land is farmed more frequently and cultivation methods become modernised. The decrease in Kenya's vegetation cover results in an ever increasing area of potential soil erosion.

1.1.3 Historical Background

Soil erosion in tropical Africa commanded attention as early as the 1930s when the first runoff plots were built in Tanganyika by Staples (1933). Although soil erosion is an important problem for tropical agriculture, very little research on this hazard on African farmlands had been undertaken until recently. Case studies are comparatively few and mostly descriptive. While many of the studies in Africa contain maps and information on the general nature of erosion, only a few measurements of soil erosion on actual farmlands or in drainage basins are available (Roose,1967; Hudson, 1959; Lundgren, 1980). In East Africa, studies indicate that higher soil erosion levels result from the combination of high intensity of agriculture and its mismanagement (Dunne, 1979). In Kenya, the intensity of soil erosion was first determined on the basis of land use and soil conservation studies (Champion, 1933). Champion found that after an initial clearing of the bush and cultivation for two to three years, a further eight to twenty years are generally required to restore fertility. However, in Kenya increasing food demands in the 1950s required the inhabitants to extend cultivation into less favourable areas. The potential for soil erosion has thus been increasing in recent years, also in part because of the employment of traditional land use techniques. New soil conservation techniques are required if these marginal lands are to remain in continuous food production.

1.2 OBJECTIVES OF THE STUDY

This thesis research investigates the potential for soil erosion in Sondu Basin, western Kenya. The major objectives of the study are : a) to locate regions of high erosion potential within the Sondu drainage Basin b) to determine the principal physical and human factors responsible for the high erosion potential in these regions.

1.3 STUDY AREA SELECTION

Sondu Basin was adopted as the area within Kenya for this thesis research for the following reasons:

1. The literature review indicated that few studies of soil erosion have been made in Kenya, and none has been undertaken in Sondu Basin.
2. Sondu Basin is familiar to the author, and in view of the limited funds available for this study, provided easy accessibility for data acquisition and field reconnaisance.
3. The population of Sondu Basin has increased substantially in recent years; most of the

inhabitants are farmers, and the growing intensity and extent of agricultural land have a bearing on the soil erosion potential.

4. A large part of Sondu Basin was originally tropical rain forest, which was cleared for the establishment of large tea estates and subsequently for small-scale subsistence and commercial agriculture. Maize is now widely grown in the Basin as a subsistence as well as a commercial crop. This crop has been identified as providing high soil erosion potential (Morgan, 1979). Furthermore, the Kipsigis, the Luo, and the Kisii people who live in the Basin keep livestock, and possible overgrazing might have augmented erosional problems.

5. Sondu Basin lies within both the Lake Victoria region and the Kenya Highlands, which are areas of high annual rainfall and, according to Moore (1979), high erosivity.

1.4 PERCEPTION OF SOIL EROSION

The extent to which the general public perceives soil erosion as a hazard is very important in its control. The co-operation of the total population is needed if soil conservation measures are to succeed. Ironically, what constitutes soil erosion has not been agreed upon, even among scientists, and this has been a stumbling block to educating the general public about this problem in many parts of the world. Mather (1982) has described the changing perceptions of soil erosion in New Zealand among its scientific personnel and among its farmers. Here scientists could not agree among themselves whether off-site damage, in the form of excess sedimentation in streams, was a consequence of normal geological erosion or man-induced soil erosion. The relegation of human factors determining soil erosion in New Zealand is exemplified by Mosley (1980):

> "Some well established beliefs regarding the supply of sediments to river systems might be erroneous, sediment supply appears to be controlled by geomorphic and geologic factors, and human interference with the ecosystem has had minor effect on the rate of supply" (P.85).

On the other hand, there is growing evidence among some scientists in New Zealand that soil erosion rates have been increasing as a result of man's activities. For instance, Cunningham (1978) has demonstrated the erosional impact of introduced feral animals in forested mountains of North Island.

More remarkable is the difference in perception between experts and farmers as regards the soil erosion hazard. Batie (1983) has referred to one survey in Nebraska, USA, in which experts classified 82% of the farms as having a major soil erosion problem while only 2% of the farm operators and none of the landlords classified their farms similarly. Moreover, 54% of the farm operators and 55% of the landlords indicated either no or few erosion problems; yet experts classified only 4% as having no problem.

Batie has suggested that these differences in perception come partially from different perspectives. She indicated that scientists classify erosion problems in terms of soil movement. Operators, however, classify problems in terms of difficulties caused by erosion, the visibility of soil movement and the short run effect of erosion on the economic, physical and operational aspect of farming.

External stimuli influence the way in which both scientists and the general public perceive an environmental phenomena such as soil erosion. In several parts of the world, including New Zealand (Mather, 1982), Kenya (Moore, 1979), and Australia (Williams, 1979), soil erosion was first perceived as a significant problem during the 1930s as a result of publicity given to American problems and responses culminating in the U.S.Soil Conservation Act of 1935. Mather (1982) asserted that "outside" publicity influences not only the scientific community but the general public at large, or at least its better informed and influential members.

Williams (1979) has indicated that the degree to which a natural process like soil erosion is perceived as a hazard depends upon the the density of human settlement and its proximity to the area affected. Working in Australia, Williams noticed that soil erosion is gradual and consequently went on unnoticed, thereby affecting its perception as a hazard.

In Kenya many people are unaware of the degree and extent to which soil erosion is taking place. This is because soil erosion is often imperceptible or subtle unless gullies are formed during the process. However, the general public is aware of the intensification of food shortages, the growing shortage of firewood, and the mass exodus of the people from rural areas to the city, all of which are problems that may be indirectly related to soil erosion. In Kenya research into soil erosion lags behind other agricultural research such as that on crop diseases, the use of chemical fertilizers, weed control, and breeding of high yielding crop varieties. The impact of these technological improvements on the soil resource remains unstudied. Thus the need exists to investigate the effects of these improvements.

1.5 EXPECTED BENEFITS FROM THE STUDY

Findings from this study should identify areas in Sondu Basin where soil erosion potential is high. In addition, the principal causes of soil erosion in these areas of high potential will be ascertained. These findings should be useful to all those concerned with development in Sondu Basin. A knowledge of areas of high erosion hazard should benefit farmers who earn their living by cultivating the soils in the Basin, and should encourage them to incorporate soil conservation methods in their agricultural activities. Knowledge of the principal causes of soil erosion should help the farmer identify which particular conservation strategy to adopt. Government agricultural scientists and extention workers, who advise the farmers on various strategies for soil conservation, should benefit from the findings of this research. The latter should also be useful to planners, especially those who are concerned with resettlement of people or agricultural development. Environmentalists, geographers, geomorphologists, and others concerned with man-land relationships, should also gain from this study.

Chapter II

LITERATURE REVIEW

2.1 FACTORS AFFECTING SOIL EROSION

Soil erosion, according to Morgan (1979), is the removal of surface material by wind or water, and involves the detachment of particles from the soil mass and their transport. This thesis only studies soil erosion by water, because wind is not an important soil erosion agent in Sondu Basin.

Processes involved in soil erosion by water include rainsplash, infiltration overland flow, subsurface flow, saturated overland flow, rilling, gullying, and piping (Thornes, 1980). Soil erosion rates are mainly dependent on climate, vegetation cover, soil characteristics, topography, and human interference. The major human activities are associated with agriculture, forestry, and urbanisation, each of which produces distinctively different erosional responses.

Climatic elements that influence soil erosion are rainfall, wind, and temperature. Of these, rainfall is the most important factor, especially in the humid tropics where it is intense and highly erosive. Rainfall erosivity is the ability of rain to cause erosion of the soil, and is the driving force behind the process. It is, in turn, dependent upon the intensity and duration of the rain storm and its work potential, as determined by the size and velocity of raindrops. At the ground surface, the dissipation of a raindrop, depending on its momentum, causes fracturing and detachment of soil particles. Large raindrop sizes are partly responsible for high intensity rains in the tropics (Lal, 1985). Measurements in tropical Africa (Kowal and Kassam, 1976; Aina et al. 1977) have shown that rains with a median water drop size greater than 2.5mm are common.

When rainfall intensity exeeds the soil's infiltration rate, surface runoff occurs, and detaching soil particles are carried away in the flowing water downslope. In the wet and dry tropics, where high intensity rains alternate with dry periods, potential erosion is greater than in areas where rainfall is uniformly distributed throughout the year. This is because the soil in the humid tropics is continuously protected by a vegetation cover that absorbs the raindrop impact. In addition, the continuous supply of plant matter (by leaffall) on the ground provides a mat of decaying vegetation that increases infiltration rates and minimises surface water flows. In the wet and dry tropics, especially at the advent of the rainy season, both the ground cover and natural vegetation provide only partial protection against rainsplash, and often infiltration rates are exeeded due to compaction or baking of the soil.

The most important topographic variables affecting soil erosion are slope angle, shape, and length, because the velocity and quantity of runoff passing over a piece of ground are strongly controlled by these slope properties. All other things being equal, as slope angle increases runoff increases, and a greater amount of soil is washed from the slope (Wischmeier and Smith,1965)

A vegetation cover helps to retard the fall of raindrops, reducing their kinetic energy and ability to cause erosion. The interception of raindrops is achieved mainly by living plants and by the layer of dead leaves on the ground. As much as 70% of rainfall can be intercepted by different parts of trees, shrubs, mosses, and grasses (Birot, 1966). Vegetation is perhaps the most important factor in minimising soil erosion, because plants protect the ground surface from raindrop impact, reduce the velocity of runoff, and increase the infiltration capacity. The ground surface roughness, owing to dead leaves, twigs, etc, retards and divides water flow into many small fractions, and correspondingly inhibits the concentration of runoff. Plant roots tend to keep the soil *in situ*, by binding the soil particles and increasing the soil's resistance to erosion, hence reducing the amount of surface wash.

The most important soil factor affecting erosion is its erodibility. Soil erodibility is the resistance of the soil to both detachment and transport by water. It is a function of the physical and chemical properties of the soil, including particle size distribution, presence of organic matter and permeability conditions.

Human use of the land almost always increases the erodibility of the soil. In humid and subhumid regions the vegetation cover often protects the soil against erosion. When the vegetation cover is removed, one crucial geomorphic change is the exposure of bare, erodible soil to the direct impact of rain. The common practice of land clearing for farming in many tropical developing areas, synonymously known as slash and burn, shifting cultivation, and rotational bush fallowing, with no remedial measures, has been well documented by Ruthenberg (1971) and Okigbo (1975). In these tropical areas current land management practices are neither related to the rugged terrain, nor to the high rainfall erosivity, nor to the erosional susceptibility of some of the soils. Arable lands are undergoing increasing pressures to produce more food to meet growing domestic food demands. But all too often the transfer of technology from the developed world to meet these demands results in increased soil erosion, thus limiting the success of new machinery, seeds, water works, and other agricultural practices. Besides the latter, urban development, mining, and highway construction have considerably increased soil erosion and sedimentation.

Need exists for erosion studies in tropical areas where inappropriate agricultural practices often result in increased erosion. In these areas the livelihood of people, and at times nations, are threatened by the soil erosion problem. In most of the developing world, little data and inadequate understanding of the soil erosion process exist. There is need to improve the data base to understand soil erosion under the constraints operating in the developing coutries in order to predict and minimise the erosion problem.

2.2 APPROACHES TO SOIL EROSION STUDIES

Soil erosion results from the imbalance between weathering rates on one hand and erosional rates on the other hand, with the latter process being faster than the former.

An awareness of the soil erosion problem in a geomorphic context first occurred over 100 years ago through experiments made by a German soil scientist, Ewald Wollyn between 1874 and 1895 (Baver, 1938). The extent of soil erosion in the United States was determined for the first time in a nation-wide survey in 1934. This detailed survey showed that approximately 775 million acres of land had become severely eroded and required erosion control measures to become productive again (Beasley, 1972, p. 7).

The soil erosion problem in Africa is particularly serious. As noted by Okigbo (1975), the concern about the problem dates back to the early 1950s. Green (1951) and Gillaume (1951) surveyed soil erosion in many African colonies in order to describe measures which could be taken to check and control the problems. Important findings of these surveys included: widespread deforestation resulting from shortening the fallow interval in cycles of cropping and fallowing; migration of people to areas where their traditional methods of agricultural production are unsuitable for the existing environmental conditions; and overgrazing, resulting from increased livestock populations and stocking rates.

While erosional problems date back probably to the beginning of agricultural and pastoral livelihood systems, modern research extends back only to about 100 years, and most of the applied research has been undertaken in the United States. In modern research, four major approaches have emerged for predicting soil erosion and determining the relative importance of the various factors affecting its magnitude. These are causative process studies, empirical models, deterministic models and factorial surveys.

2.2.1 Causative Process Studies

This approach examines the interaction of the various physical factors responsible for soil erosion. Relatively few field studies have used this approach, probably because of the difficulty in modelling field situations or the areal magnitude of most erosional systems. When this approach is used, often it is limited to small scale and site studies.

2.2.1.1 Infiltration and Overland Flow Studies

The earliest and most exhaustive studies using this approach were those of Horton (1933, 1945). Horton emphasised the importance of infiltration capacity, as the maximum rate at which a given soil in a given condition can absorb water. He considered that a soil's infiltration capacity is the maximum value of infiltration that can be sustained under specifed conditions. When this capacity is exceeded by rainwater supply, then surface detention and runoff will occur.

Rainwater infiltrates into the soil, at a rate determined by soil structure, soil texture, vegetation cover, biotic activity, antecedent soil water conditions, and land management practices. Soils with dense vegetation covers have higher infiltration capacities than those with less dense covers or bare areas, since the ground is protected from raindrop impact and the vegetation mat provides a high infiltration medium. Horton (1933) hypothesised that, normally, surface runoff will result in rill formation, initially developing rapidly with some rills enlarging faster than others until a simple pattern developed. Rilling is common only in relatively vegetation-free areas, such as semiarid regions or cleared arable areas. Vegetation is therefore a critical variable in rill formation. When present, a plant mantle minimises rill formation by increasing the infiltration rate, promoting a thicker soil cover, improving soil structure, and breaking raindrop impact on the surface. Where a dense vegetation is established surface runoff is unusual. Subsequent studies to Horton's, however, have shown that the infiltration rate is more important than the infiltration capacity in terms of soil erosion inducement.

2.2.1.2 Throughflow (Subsurface Flow)

Kirkby and Chorley (1967) emphasised the movement of water downslope through the upper soil horizons which they called subsurface flow, or throughflow. Water moving vertically through the soil may be deflected laterally. This lateral movement may be either diffused or concentrated along seepage lines. The important controls of this process are soil characteristics, distance downslope, slope angle, and rainfall intensity. Moisture in deep soils concentrates along seepage lines and at heads of streams and depressions.

Where throughflow is the main source of runoff, discharges tend to be lower than those from overland flow, as most of the rainwater is stored in the soil and only released slowly to contribute to streamflow. Whereas overland flow seems to be the dominant producer of insoluble surface sediments, throughflow is capable of transporting solutes and, if concentrated when emerging at the surface, can initiate gully development. Throughflow processes have been measured in the tropics; they often occur in forested areas with deep permeable soils. Throughflow rarely occurs in the wet-dry tropics, but it is important in the wet tropics (Morgan, 1972).

2.2.1.3 Saturated Overland Flow

The surface emergence of water resulting from a rising water table recharged by throughflow is termed saturation overland flow (Kirkby, 1969),) now commonly known as saturated overland flow. In areas of high rainfall intensities, rates of saturated overland flow are greater than elsewhere, but still less than the overland flow. But according to Dunne and Leopold (1978), only a portion of the catchment contributes to saturated overland flow, that is, those hillslopes that are saturated during rainfall. The process is therefore localised in nature, and characteristic of forested areas having soils with high infiltration capacities, much organic matter and high root densities.

2.2.1.4 Process Studies in the Tropics

In the tropics saturated overland flow over catchment areas has been observed qualitatively and quantitatively in a number of locations in the following regions; West Africa (Thomas, 1974; Roose and Lelong, 1976); South East Asia (Ruxton, 1967; Morgan, 1972); Latin America (Lewis, 1974,1975; Walsh, 1980); Brazil (Tricart, 1972). Thomas believes saturated overland flow only occurs on steep slopes because of the rapid infiltration of the intense rain into the deep kaolinitic soils which prevent surface flow. Ruxton points out that the open canopies due to tree-fall caused by mass movements create less protection from rainfall on the forest floor, making sheet and splash erosion more effective. At the same time, stem flow on trees may add to saturated overland flow. None of the above writers however, were able to provide quantitative evidence for these observations.

In studying overland flow in a wet-dry tropical setting, Roose and Lelong (1976) found that on naturally vegetated areas, cultivated land, and bare soil, overland flow is prevalent in the open savanna, whereas it is significant only during intense rainstorms in the dense savanna and forested areas. Lewis (1974) has pointed out the widespread nature of soil creep in both the humid and semi-arid parts of Puerto Rico. There is an absence of overland flow in the humid areas, but soil creep and slow subsurface flow in localised valley bottoms are the principal displacements of soils under natural conditions. In contrast, the semi-arid areas, despite intense rainfalls, have low soil creep but widespread overland flow. Walsh (1980) studied throughflow and overland flow in different localities in the Dominican Republic. Widespread overland flow occurs in the montmorillonite soils in the wet-dry areas, because of the characteristic shallow topsoil and impermeable subsoil. Rapid shallow throughflow is dominant in the extreme wet podzols because of deep permeability. Tricart (1972) accounts for the absence of overland flow in wet tropical areas because of their very permeable soils that allow high infiltration to occur.

2.2.1.5 Critique of Erosion Process Studies

Results from previous studies indicate that, in the wet-dry tropics, saturated overland flow is widespread because of high rainfall intensity, shallow topsoil, and intense human activity. In temperate areas, however, only a small portion of the drainage basin is contributing to saturated overland flow, namely, lowline depressions of hillsides that become saturated during either a rainy or a snowmelt season. Hewlette and Hibbert (1967) developed the variable source area concept, in which saturated overland flow may be generated in small but variable areas of catchment. This concept appears inapplicable to the undisturbed wet-dry tropical environment of N.E.Australia. Bonell and Gilmour (1978) found that saturated overland flow is not a localised phenomenon as asserted by the concept, but is a widespread process, attributable to the high rainfall intensity and deep permeable kaolinitic soils which prevent much surface flow. Saturated overland flow is probably the main soil erosion process under natural conditions in the wet-dry tropics.

Considerable controversy arises concerning the applicability of both the Hortonian (infiltration) and saturation overland flow concepts to various process studies, especially in humid regions under forest cover. Generally, it is accepted that the Hortonian overland flow process prevails in areas where vegetation cover is limited and on cultivated soils, whereas saturated overland flow prevails in densely vegetated areas, especially along drainage line margins. The latter process is therefore more variable in space and time than the Hortonian one, depending on the infiltration capacity as well as storm intensity and duration. Even though the Hortonian concept has generated controversy, one important feature of Horton's work is that it clearly identifies the variables that determine runoff and erosion; these include rainfall intensity, infiltration capacity, length of overland flow, and slope and surface roughness.

One crucial issue that can be generally raised from all these studies is whether erosion actually increases with distance from the divide as Horton (1945) and Kirkby (1969) suggested. Studying runoff processes in a semi-arid area, Yair and Klein (1973) found that runoff and sediment load collected were highest on the divides - Horton's belt of no erosion. Furthermore, an inverse relationship was found between slope angle and slope erosion, and this was attributed to the spatial variation in surface soil texture. Likewise, Lewis (1980) found no correlation between sediment loss and slope length, even though thick weathered soil materials existed on all slopes.

Hampered by the complexity of runoff processes, investigators have paid more attention to determining variations in erosion rates in limited areas. These studies often employ field techniques such as erosion pins and stakes (Schumm, 1956; Gleason, 1957; Leopold et al. 1966; Haigh, 1979). From such observations, average erosion rates are computed and related to geomorphic characteristics of the hillslope and drainage basin. One disadvantage of this method is that due to the great soil variability over a large area, soil is not washed uniformly over the entire exposed surface. Secondly, the pins may cause unnatural conditions on the slopes and create local departures from the norm when overland flow occurs.

2.2.2 Empirical Models (Regression and Simulation)

Empirical models are based on a researcher's own observations and data collection regarding soil erosion at particular locations over a period of time. They are too site specific to be transferable to other hydrologic regions (Morgan, 1979). Empirical models give insight into the physical processes in action but they fail to specifically identify them. Two types of model have been extensively used: sediment yield and erosional plot analyses.

2.2.2.1 Sediment Yield

The total amount of eroded material which completes its journey from source area to downstream channel control point is known as sediment yield. It is normally expressed in tonnes/km^2/annum, and is a function of the size of the contributing area. With the use of multivariate statistics, particularly multiple regression analyses, attempts are made to relate sediment production to a diversity of morphometric, climatic, hydrologic, and land use parameters. Detailed studies, based on field measurements, have been made of continental-scale sediment yield (Langbein and Schumm, 1958; Fournier, 1960; Douglas, 1967), and of sediment yields of regional or drainage basin scale (Anderson, 1954,1970 ; Branson and Owen, 1970).

Langbein and Schumm (1958) evaluated sediment yield from drainage basins in the United States, using suspended sediment and reservoir fill data. These data demonstrated a variation of sediment yield with effective precipitation, the latter defined as the amount of precipitation required to produce the known amount of runoff. Langbein and Schumm(p.1082) demonstrated that vegetation bulk increases as some power of annual precipitation:

$$V \propto px$$

where V = weight of vegetation (pounds/acre)

p = annual precipitation (inches)

x = number greater than one

Sediment yield increases with increasing annual effective precipitation until the latter reaches 300 to 360mm per year. Larger amounts of effective precipitation are associated with a reduction in sediment yield due to increasing vegetation cover as one goes from semi-arid to subhumid (grasslands) and further to humid (forests) regions (Figure 1). Semi-arid areas have the highest sediment yields because of the sparseness of ground cover, leading to low infiltration rates and high soil erosion rates. In wetter areas, sediment yields are lower because a complete vegetation cover occurs there under natural conditions. If there is a complete vagetation cover, increased precipitation results in very little change in sediment yield.

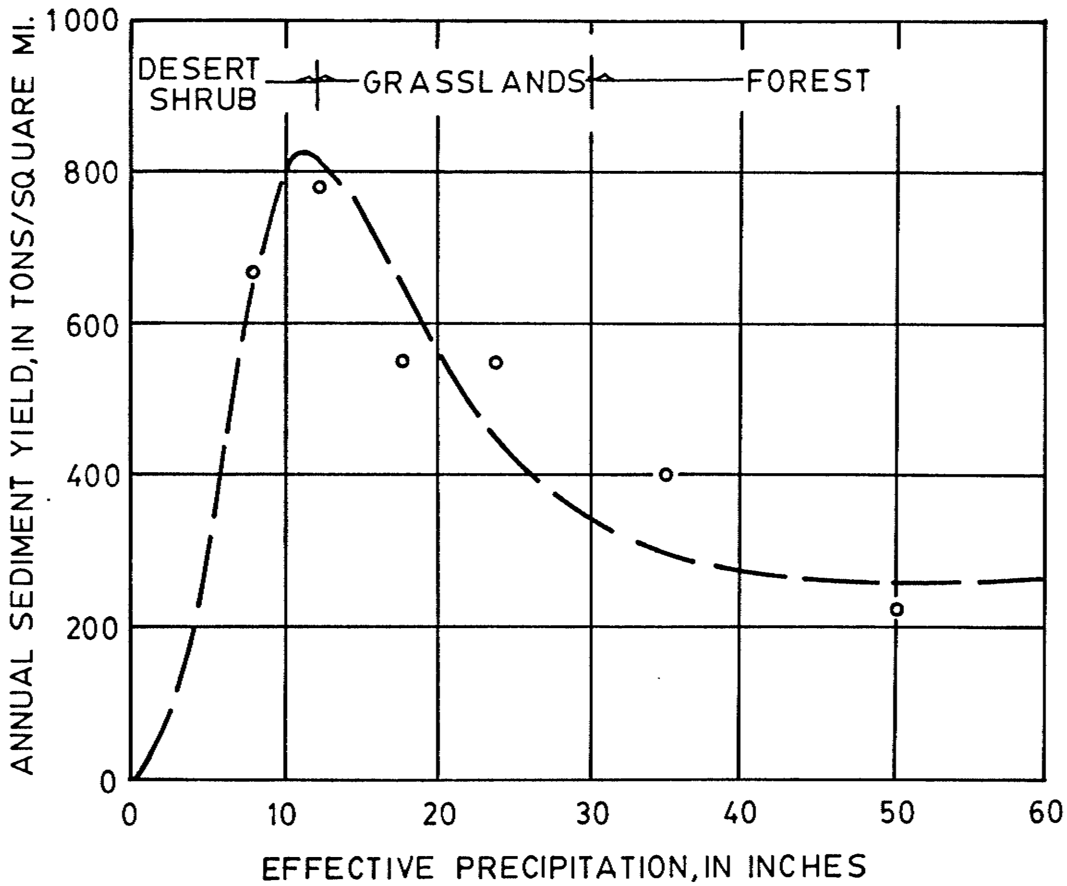


Figure 1: Climatic Variation of Sediment Yield with Effective Precipitation (after Langbein and Schumm, 1958)

Douglas (1967) has examined the relationship between annual suspended sediment yield and annual runoff in semi-arid environments of the USA and in other areas of the world, including north-eastern Australia (Figure 2). From figure 2 it seems that the sediment yields in the USA (upper curve) are significantly greater than would be expected in terms of runoff; in particular, human activity has greatly modified semi-arid areas of the USA, and soil erosion rates are higher than those in northern Australia. Furthermore, generally an inverse relationship exists between sediment yield and basin size.

As reviewed by Stoddart (1969), Fournier (1960) studied suspended sediment yield in 78 basins ranging in size from 0.0025 to 1.06 X 10^6 km^2. He correlated sediment yield with the climatic parameter p^2/P, where p is the rainfall of the rainiest month in the year and P the mean annual rainfall. Fournier derived a general empirical equation that he used for predicting sediment yield when climatic and relief parameters for a drainage basin are known:

$$\text{Log } E = 2.65 \log(p^2/P) + 0.46 \log \bar{H}.\tan\varnothing - 1.56$$

Where:

E = suspended sediment yield ($tons/km^2/yr$)

p = rainfall in the rainiest month(mm.)

P = mean annual precipitation(mm.)

$\bar{H}$ = mean height of the basin(M.)

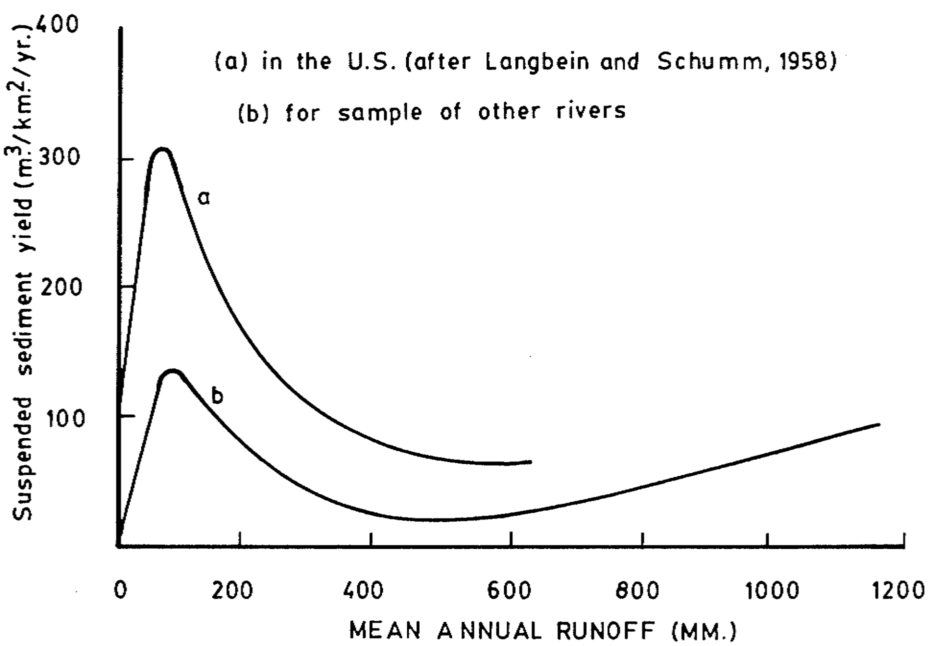


Figure 2: Relationship Between Suspended Sediment Yield and Runoff (a) in the United States(after Langbein and Schumm, 1958) and (b) for a sample of other rivers (after Douglas, 1967)

$\bar{\emptyset}$ = mean slope in basin.

If the mean height $\bar{H}$ and slope $\bar{\emptyset}$ are not readily available, erosion may be calculated from a regression equation for one of four classes of basins identified by Fournier (1960); the classes are depicted as curves on a graph plotting sediment yield against rainfall characteristics (p^2/P), figure 3.

Fournier mapped the distribution of erosion in the world based on sediment yield data (Figure 4). Drainage basins were classified according to relief and climate: (i) Low relief and temperate climate; (ii) Low relief, and tropical/sub-tropical /semi- arid climate. (iii) High relief and humid climate. (iv) High relief and semi-arid climate (Figure 3) From the map, maximum rates are found in the wet-dry tropics;lowest rates occur in arid regions, where the total amount of runoff is low. Fournier's index is better correlated with erosion in the tropics than in the temperate areas. The applicability of Fournier's index is limited by the fact that the vegetation mantle is not a parameter determining sediment yield (Lal, 1976).

Whereas Fournier's map and Langbein and Schumm's graphs are based on data from areas where human activities significantly increase erosion rates, Douglas (1967) derived an equation for sediment yield and precipitation, with world wide applicability in undisturbed environments. Employing

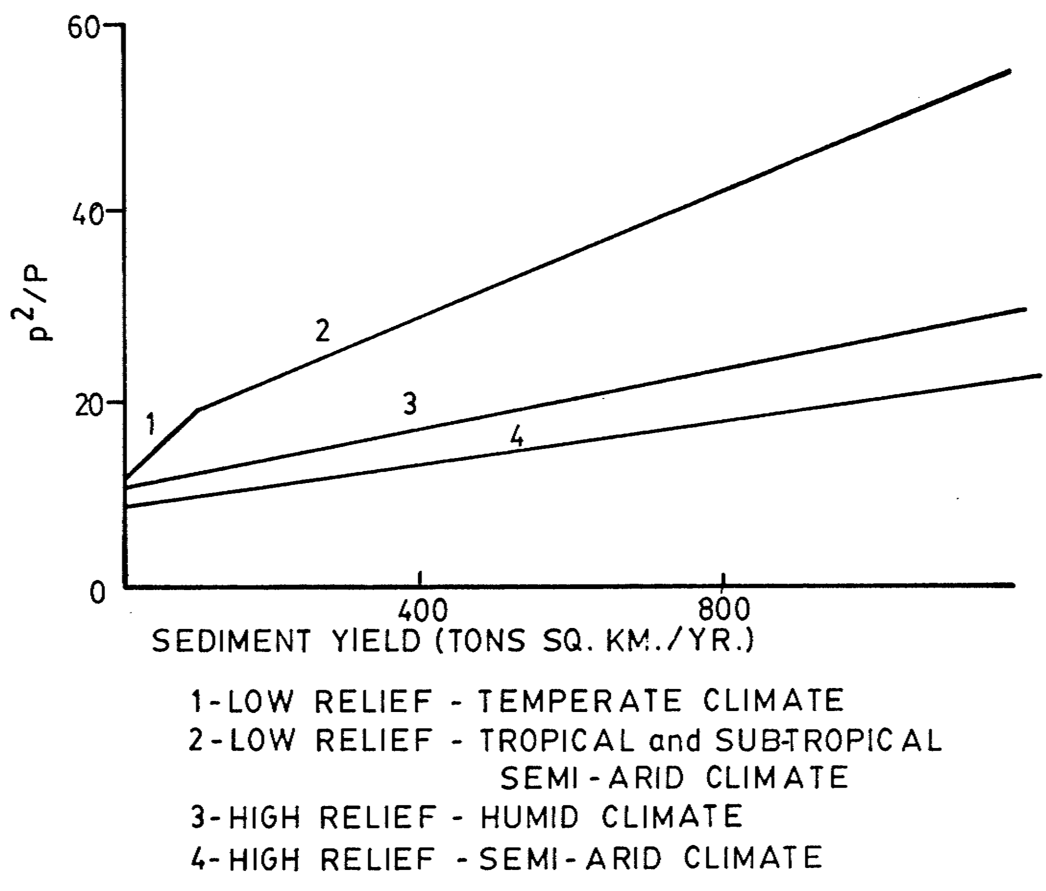


Figure 3: Relationship Between Climate and Suspended Sediment Yield, vertical scale = p^2/P (after Fournier, 1960)

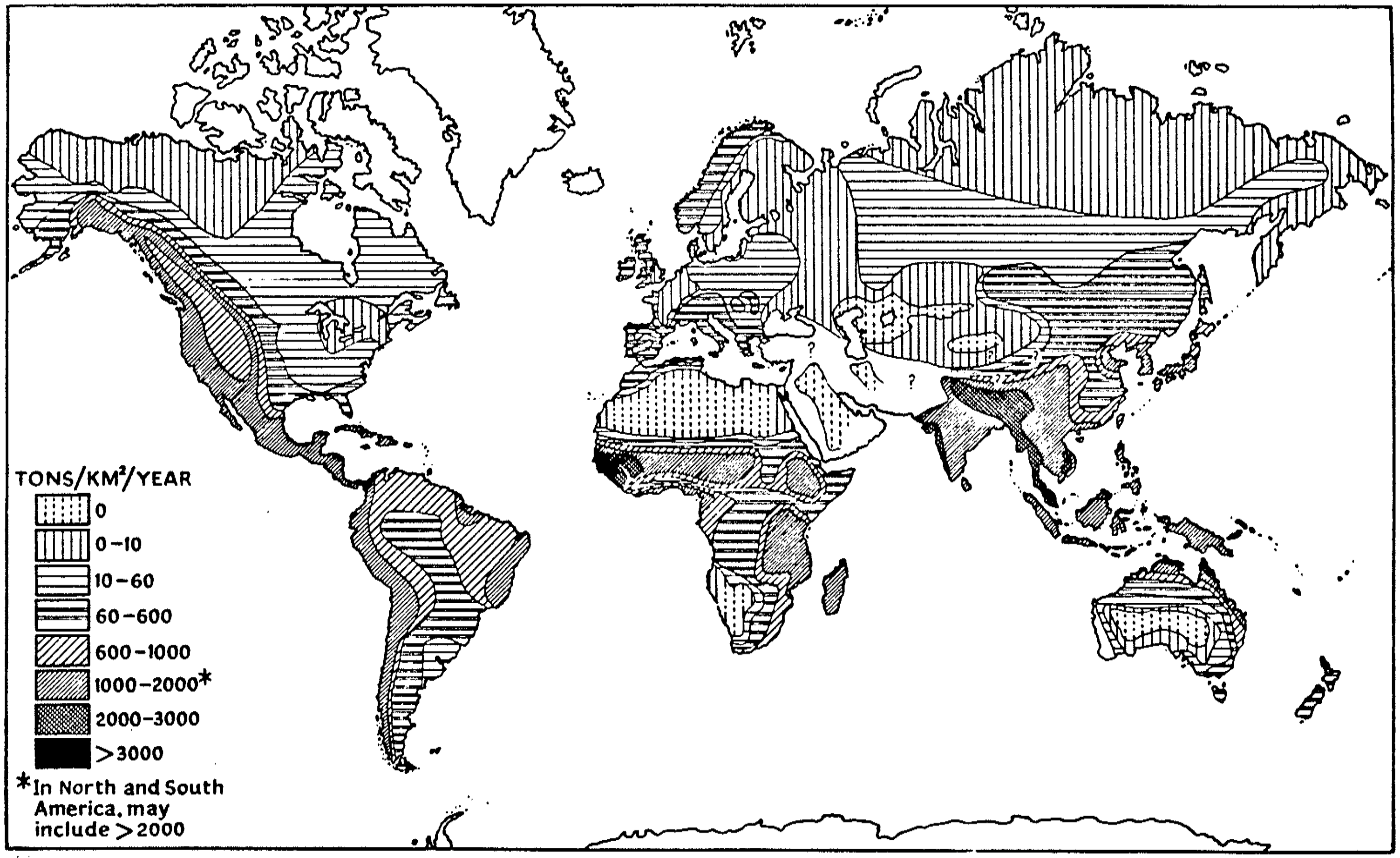


Figure 4: World distribution of Erosion Rates (after Fournier, 1960)

rainfall data for selected river basins in Australia and Asia, Douglas (1967, p.927) related mean annual suspended sediment yield to effective precipitation:-

$$S = \frac{1.631(0.03937\ P)^{2.3}}{1+0.0007(0.03937\ P)^{3.3}}$$

Where:

S = annual suspended sediment yield in $m^3/km^2/yr$

P = effective precipitation (mm).

The numerator in this equation represents the erosive influence, whereas the denominator represents the vegetation protection factor. Based on this equation, Douglas's curve depicting suspended sediment yield in relation to mean annual runoff reveals that as mean annual runoff increases above 600mm, there is a progressive increase in sediment yield (figure 2). In wet and dry tropical areas, where intense seasonal rainfall causes soil erosion and where drought during another season prevents growth of a dense vegetation cover, sediment yields will be high even under natural conditions.

These empirical methods of estimating sediment yield provide a useful means of examining erosion rates on a worldwide or regional scale. Practically, however, soil erosion studies require a close examination of the factors within well-defined smaller areas, preferably specific drainage basins. In a study of 29 drainage basins, ranging in size from 69 to 7280 sq, miles (179 to 18,855km^2 respectively) in western Oregon, and employing morphometric, climatic and hydrologic parameters, Anderson (1954) developed relationships with sediment yield in which a land use parameter was also included in the equation. He found that sediment yield increased with increases in the number of roads, the length of eroding channel banks, the area of recent cutover forest (in the last ten years) and the areas of row crops and small grains. His equation took the form of:

$$\log SS = -3.721 + 0.116 \log A + 1.673 \log FQP\ 1.244$$
$$\log MAq + 0.401 \log S + 0.0486\ SC + 0.482$$
$$S/A + .0280BC - 0.0036OC + 0.942R + 0.0086RC$$

Where:

SS = suspended sediment discharge in tons/sq. mile/year.

A = area of watershed in sq. miles(=2.6km^2)

FQP = discharge peakedness - a unitless measure

MAq = mean annual runoff in cfs/sq.mile(=0.01m^3km^2)

S = slope of streams of one mile mesh length in feet/mile(0.19m/km)

Sc = silt and clay in top six inches(15cms) in percentages

BC = bare cultivation

OC = portion of watershed in cultivation other than bare cultivation in percentages

RC = recent cut over forest during past ten years in percentages

Other researchers have developed regression equations relating sediment yields to various independent variables for localised areas. Branson and Owen (1970) initially examined several geomorphic and hydrologic variables, as well as vegetation cover, to investigate the determinants of sediment yield. Eventually they developed an equation, with a multiple correlation coefficient of 0.86, which identified the most important pair of variables.

$$\hat{Y} = 40.87X_1 + 0.03X_2 - 1.27.$$

Where:

$\hat{Y}$ = sediment yield in acre feet per sq. mile

X_1 = relief ratio

X_2 = percent bare soil

The above studies have two common features. They are used for specific purpose in localized areas, consequently extrapolations to other areas are limited. Moreover, a greater diversity in topography exists in larger drainage basins which might hamper the development of sediment yield equations. Flatter slopes, bottomlands and swamps within valleys provide sites for deposition of colluvium which do not often directly reach the stream. As such, this temporary sediment storage is only accounted for in terms of long-run averages in the gross erosion. Secondly, there is a limited areal extent of individual rainstorms that produce erosion and runoff; thus, in a single storm event eroded material is often transported only a short distance and then redeposited.

2.2.2.2 Erosion Plot Analyses

Experimental plot studies, in which measured amounts of soil loss are correlated with physical and cultural factors, are the main basis of soil erosion research on agricultural lands (Zingg, 1940; Ellison, 1945; Musgrave, 1947; Barber et al. 1979; Dunne, 1977; Moore et al 1979.). Two groups of these studies of soil erosion have been identified. There are those which are carried out at permanent research or experimental stations and those which are designed to assess erosion at a number of sample sites over an area. The first group consists of bounded runoff plots of known area, slope steepness, slope length and soil type from which both runoff and soil loss are monitored. The second group involves the installation of soil collecting gutters or troughs on unbounded plots across the slope at different slope lengths. A typical example of this technique is the Gerlach Trough (Morgan, 1979)

The topographic variables of slope length and steepness are important in soil erosion studies. Zingg (1940), summarising experiments carried out at five experimental stations of the U.S. Soil Conservation Service, indicated that soil losses increase exponentially with slope steepness, with an exponent close to 1.4. He proposed the following exponential relation between soil loss and slope steepness:

$$Xc = 0.65S^{1.49}$$

Where:

Xc = the total soil loss(in tons per acre)

S = percent slope

Observations made by Fournier (1969) in Zimbabwe indicated that erosion was severe on slopes of 1-2% gradient with high rainfall energy, indicating that the latter was more dominant than gradient in causing erosion. From his studies in the region, Hudson (1971) suggested an exponent of 2 rather than 1.4 to account for the stronger effect of slope on erosion in the tropics.

Based on a series of erosion plot experiments, Musgrave (1947) developed an empirical aquation which showed that soil loss varied according to meteorologic, pedologic, topographic and vegetation conditions. Musgrave indicated that soil loss can be expressed by the following equation:

$$E = Is.C.S^{1.35}\ L^{0.35}\ P_{0.5}{}^{1.75}$$

Where:

E = soil loss

Is = inherent erodibility of the soil

C = vegetal cover factor

S = degree of slope

L = length of slope

$P_{0.5}$ = maximum half-hour amount of rainfall within a two year frequency(in.)

This equation yields gross sheet erosion and enables calculation of long-term average sheet erosion. It enables prediction of soil moved from its original source within a field plot. However, it cannot discriminate soil erosion and temporary deposition within a field plot. The experimental determination of soil loss from plot studies cannot reliably indicate the soil loss from a sizable drainage basin because of diverse physical conditions and human modifications of the environment.

A major advance in soil erosion studies was the development of the Universal Soil Loss Equation (USLE) in which a human factor is included (Wischmeier and Smith, 1978). The USLE is

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

Where:

A = the annual soil loss per unit area

R = rainfall erosivity factor

K = soil erodibility factor

L = slope length factor

S = slope steepness factor

C = cropping management factor

P = support practice factor such as terracing, strip cropping and contouring, are compared in terms of soil loss with straight-row farming up and down the slope.

The main sources of values for USLE factors are charts and tables developed from forty years of previous research and meteorological data. The rainfall erosivity factor, R, is determined by the following relationship, as reported by Wischmeier and Smith:

$$R = \frac{KEi}{100}$$

Where:

KE = storm kinetic energy (ft/tons/acre/in.)

i = maximum 30 minute intensity

KE is kinetic energy related to rainfall intensity, and the R factor can be determined from existing rainfall data for a region. The soil erodibility factor, K, is expressed as the average annual soil loss in tons/acre for continuous clean-tilled fallow on a 9% slope, 72.6 feet (22m) long.

The cropping management factor, C, is difficult to evaluate because of the number of possible cropping sequences which vary from place to place. It is expressed as the ratio of soil loss under a given crop and its management to that from an identical area of bare soil. A base value for C is 1 for a straight row of fallow and for up and downhill cultivation. All other values are therefore less than 1. The support practice factor, P, varies with the particular conservation technique employed. Values range from 0.25 to 1.0, depending on slope steepness. Greater detail on the composition and evaluation of factors of L, S, C and P in USLE estimates is given in a paper by Wischmeier (1976).

2.2.3 Deterministic Models

For soil erosion research, these models employ numeric values to quantify the factors of erosion, transport, and deposition. They can also be derived empirically or by calibration using simulation techniques. Several of these are available for example Williams, 1975 and Degani *et al.*, 1979.

Williams (1975) developed sets of equations based on the Wischmeier-Smith soil loss equation to predict sediment yield and concentration from drainage basins up to 2600km^2 subdivided into basins of 26 km^2 or smaller. He computed sediment yield from a storm event using the equation:

$$Y = 11.8 (Q \times qp)^{0.56} KCPLS$$

Where:

Y = sediment yield (metric tons)

Q = storm runoff volume (replacing the rainfall factor R)

qp = peak runoff rate (metric tons)

The factors of K (erodibility); C (crop management); P (erosion control practices) and LS (slope length and steepness) are weighted to determine a single value for each drainage basin. The Q and qp variables are estimated using the U.S. Soil Conservation Service runoff curve numbering techniques. Mean annual sediment yield is computed by integrating a fequency curve of storm sediment yields and dividing by the largest return period. Williams indicated that the modified equation can be applied to large watersheds if sediment sources are uniformly distributed over the drainage basin. The methodology is useful in areas where little or no data are available.

Degani _et al_. (1979) developed a soil erosion model, SOILCART, based on the Wischmeier-Smith soil loss equation. SOILCART is a simulation technique that provides a quantitative spatial assessment of potential erosion. With basic data derived from air photographs and topographical sheets, the potential soil loss with various changes in farm land use may be assessed. In the calibration, a basin is subdivided into cells, and the cells are assigned the soil loss equation parameters. In addition to calculating potential soil erosion for each cell, a flowline defines the path over which eroded material passes to arrive at a defined drainage channel. Flowlines are based on the respective slope length and steepness for each cell. This method was tested by Lewis (1981) on three small basins in Tanzania where reservoir sedimentation due to human activities had occurred. SOILCART produced good estimates, as compared to measured sediment rates determined by a two-year field investigation (Rapp et al. 1972) in the same area. It was evident from Lewis's study that as basin area increases predicted values decrease.

These deterministic models described above provide an estimate of the areal distribution of sediment sources within a watershed in addition to enabling estimates of total erosion. These are desirable features especially in developing countries, where demands for immediate answers to many soil erosion and sedimentation problems are made.

2.2.4 Factorial Studies

Knowledge of the distribution of soil erosion potential throughout a country or a region is an important aid to broad-scale resource and land use planning. Additional advantages accrue if the method by which the erosion potential is developed also identifies the major factors and describes how they influence the distribution of soil erosion. Given this information, the planner can explain in precise terms the reason for a particular level of erosion in a region and can predict how a change in any factor is likely to increase or decrease the soil erosion potential. This is particularly relevant to problems associated with resettlement of people.

Factorial analysis enables the potential for soil erosion to be assessed on a national, regional or even local basis under a wide range of conditions. Without explaining the processes of erosion, but assuming that each of the causal factors relates individually to soil erosion, the spatial distribution of each factor is measured and plotted. One of these methods was devised by Stocking and Elwell (1973) and applied in Zimbabwe (Rhodesia). It consisted of a scoring system for rating erosion risk. Employing arbitrary scores (1-5) for each of the causal factors, specifically, rainfall erosivity, ground cover, slope, soil erodibility and human occupation, a map was constructed to plot erosion hazard. The approach has limitations and, as discussed by Morgan (1979), each factor is treated independently, irrespective of the fact that there is interaction among the factors. For example, it cannot bring out the interaction between erosivity and erodibility. It is known that rainsplash causes surface sealing of the soil which consequently reduces the latter's infiltration rate thus increasing both the amount of runoff and soil erodibility. Clay soils, specifically montmorillonite, are known to become impervious due to particle swelling when wetted by rainwater (Brady, 1974). These two important interactions between soils and rainfall are totally ignored by this factorial model. Moreover, the use of different slope steepness categories might yield different assessments of the degree of erosion risk. Assigning the same weight to each factor also limits the value of the technique, in that one or two factors may be dominant in the determination of actual erosion risk. Human occupation, based on settlement type and density, is very difficult to assess, and changes in land use, for example, may alter the applicability of this particular factor. Nonetheless, this factorial technique is highly advantageous in developing countries, where expensive field experiments are usually not possible. Spatial variation in soil erosion risk is easily examined on the erosion hazard map. Soil conservation planning could thus be directed to those areas that show the greatest erosion potential.

The preceding review of soil erosion approaches reveals that a variety of scientific techniques is being developed that may have some relevance to a given physical and cultural environment. Future work should be directed to the critical process variables that control erosion and sedimentation.

Chapter III

THE STUDY AREA

Sondu Basin (Figure 5) lies in western Kenya and covers an area of about 3,525 km^2 or about 0.6% of Kenya's total area. The Basin drains portions of six administrative dictricts, namely Nakuru, Narok, Kisii, Kisumu, South Nyanza and Kericho, of which the latter occupies about 75% of the entire watershed (Figure 6). The Basin is divided into Administative Locations (Figure 7).

The Basin is in one of the most densely populated rural areas of Kenya, and the inhabitants are engaged in both subsistence and cash crop farming. The farms are generally small, averaging about one acre (0.4 ha.) each, and cultivation goes on side by side with pastoral activity. Among the food crops grown are millet, sorghum, sweet-potatoes, cassavas, vegetables, and maize. The latter is cultivated both for home consumption and for cash, and has become a monocrop in some parts of the Basin. Pyrethrum and tea are the main cash crops, and Kericho district is the principal producer of the latter in Kenya.

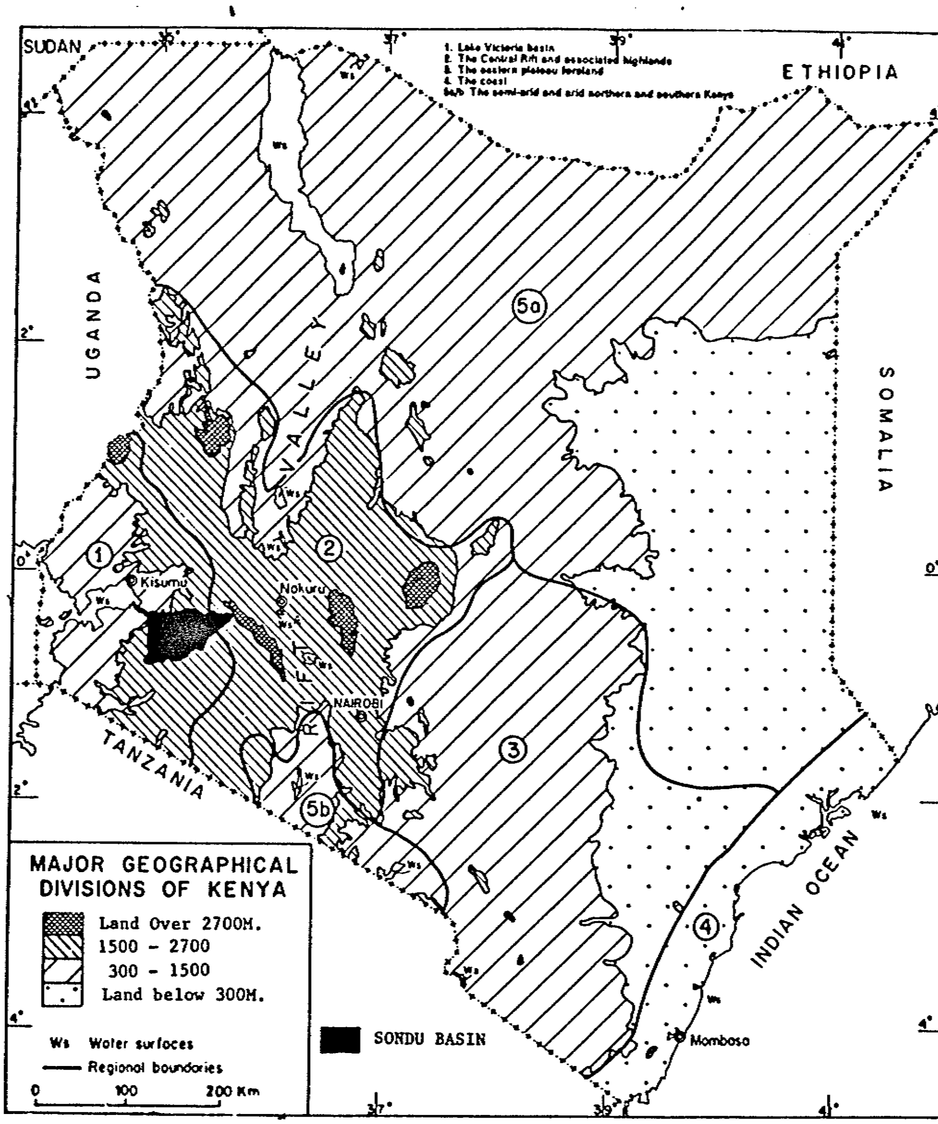


Figure 5: The Physical Regions Of Kenya (after Ominde, 1968)

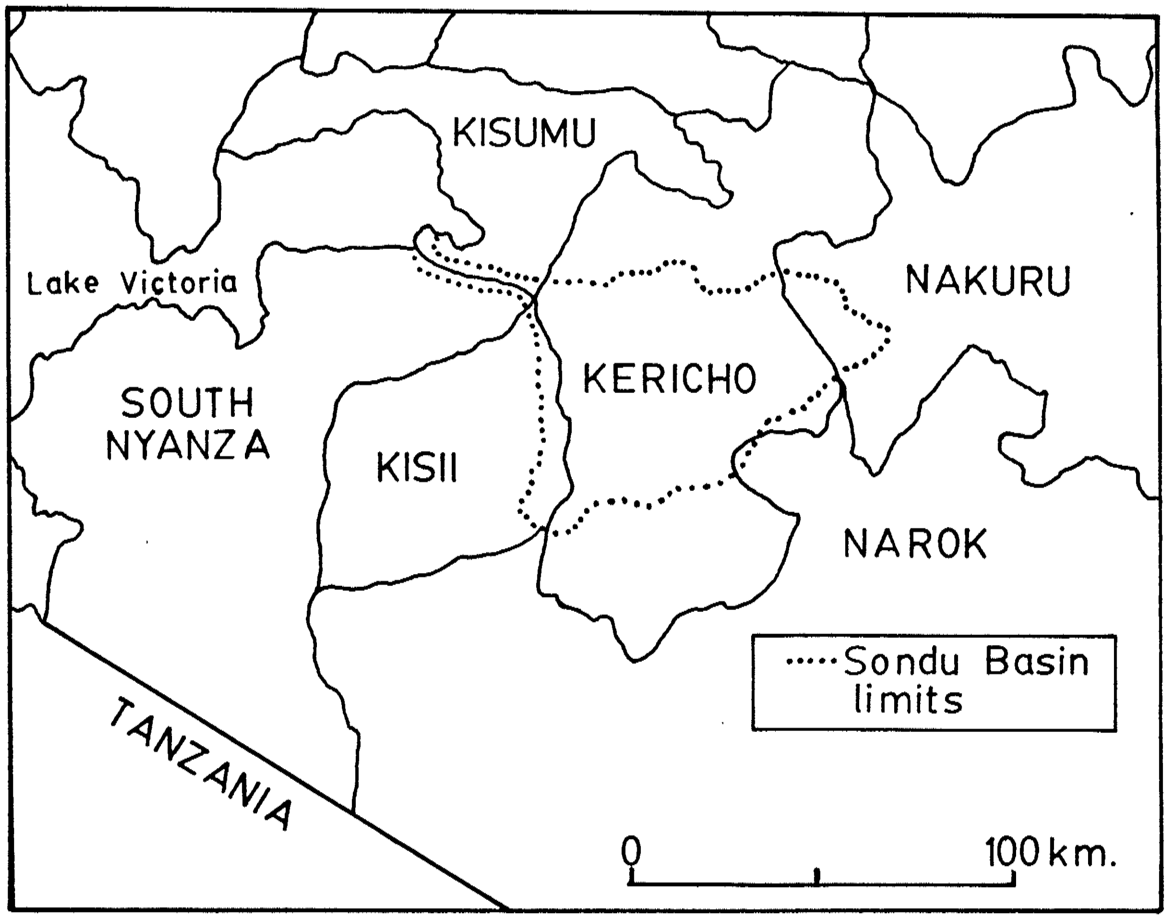


Figure 6: The Administrative Districts in Sondu Basin

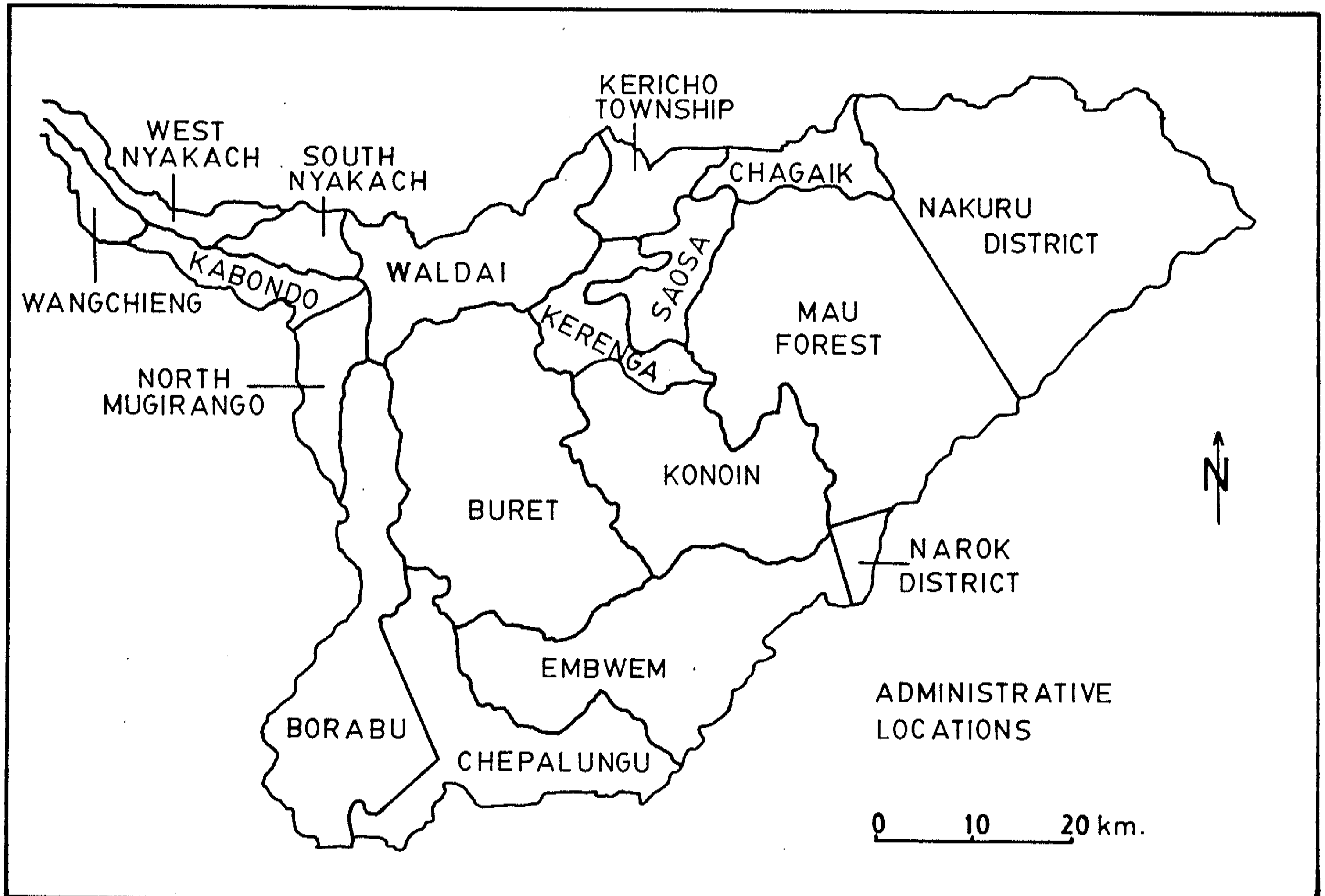


Figure 7: Administrative Locations in Sondu Basin

3.1 GEOMORPHOLOGY

Sondu Basin rises from an altitude of 1,128m above sea level on Lake Victoria to 3,048m on the Mau Ranges. It is on these ranges that most of the tributaries of the Sondu River originate.

There are four major relief regions in the Sondu Basin namely: Mau Ranges, Kericho Plateau, Kisii Highlands, and Lake Victoria basin. The Mau Ranges consist of mountains and hills which rise to between 2,600 and 3,048m above sea level, and are drained by many parallel streams which flow from the top of the ranges to Kericho Plateau below (Figure 8). These streams flow along faults which are associated with the downwarping of the Lake Victoria basin. Ojany and Ogendo (1973) have noted that all Kenyan rivers which flow from the Mau Ranges into Lake Victoria are essentially parallel as they flow on the edge of the downwarp to this lake.

Kericho Plateau slopes from the Mau Ranges gently towards the west. This plateau is between 1,600 and 2,600m above sea level, and consists generally of broad, convex interfluves alternating with incised valleys, that posses convexo-concave slopes and flat bottoms.

The eastern section of the Plateau lies between 2,100 and 2,600m above sea level, and has gently undulating topography. The western section is between altitudes of

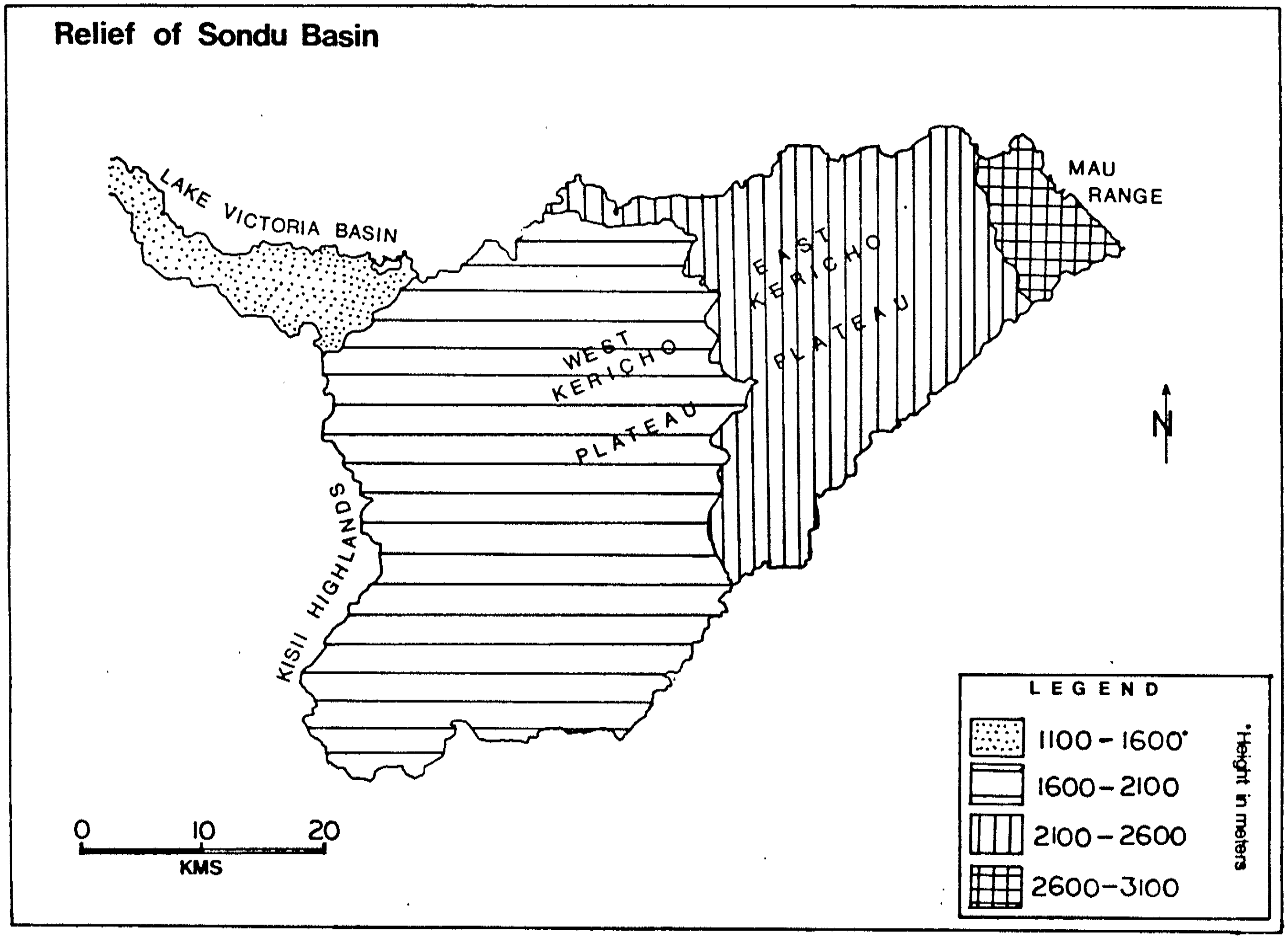


Figure 8: The Relief of Sondu Basin

1,600 and 2100m, has some rolling terrain and parts that are undulating. This section has somewhat deranged drainage pattern, with streams interrupted by marshes. The pattern exists on part of the plateau where interfluves crests are almost uniform at an altitude of 1800m. Gibb (1956) has suggested that most of the middle sections of the stream courses in the Basin are fault-guided. Field observations for this thesis show that the Sondu and its tributaries flow in deep and wide valleys in the western part of Kericho Plateau; these streams appear to be underfit, but they are most likely occupying small rift valleys.

The Kisii Highlands consist of steeply sloping residual hills and mountains, rising to altitudes of about 2300m, on the eastern side of the High Kisii Plateau. These highlands form the western drainage divide of the Sondu Basin. They are drained by numerous parallel streams which flow into the Kipsonoi River, a major tributary of the Sondu River which flows from the south-east. These streams have heavily dissected the Kisii Highlands resulting in the spur and valley topography found in most parts of these highlands.

The Lake Victoria basin has the lowest altitudes in Sondu Basin. It rises gently from Lake Victoria, at 1,160m above sea level, to an altitude of 1,500m at the edge of Nyabondo Plateau. The gradient is low especially near the Lake Victoria. The Sondu River meanders in this section and flows into Lake Victoria via marshes. There are few short tributaries of the Sondu in this section which seem to join it at right angles.

3.2 GEOLOGY

Much of the eastern three-quarters of the study area is covered by volcanic material which was emitted during fissure eruptions in the Tertiary and Quaternary Periods (Ojany,1966). The eruptions took place along tectonic lines of weakness on the western side of the Great Rift Valley. The rest of the Sondu Basin has exposed Precambrian rocks of the Nyanzian System and of Kisii Series. The Nyanzian System consists mainly of a great thickness of basic, intermediate, and acidic lavas, up to 2800 million years old (Ojany, 1966). The Kisii Series is a part of the Bukoban System, which is very extensive in Tanzania. The rocks of this Series are at least 670 million years old, and are composed of mainly lavas and some quartzites. There are also Precambrian granites in the western part of the study area. The details of the distribution of these rocks are shown on the geological map of the Basin (Figure 9).

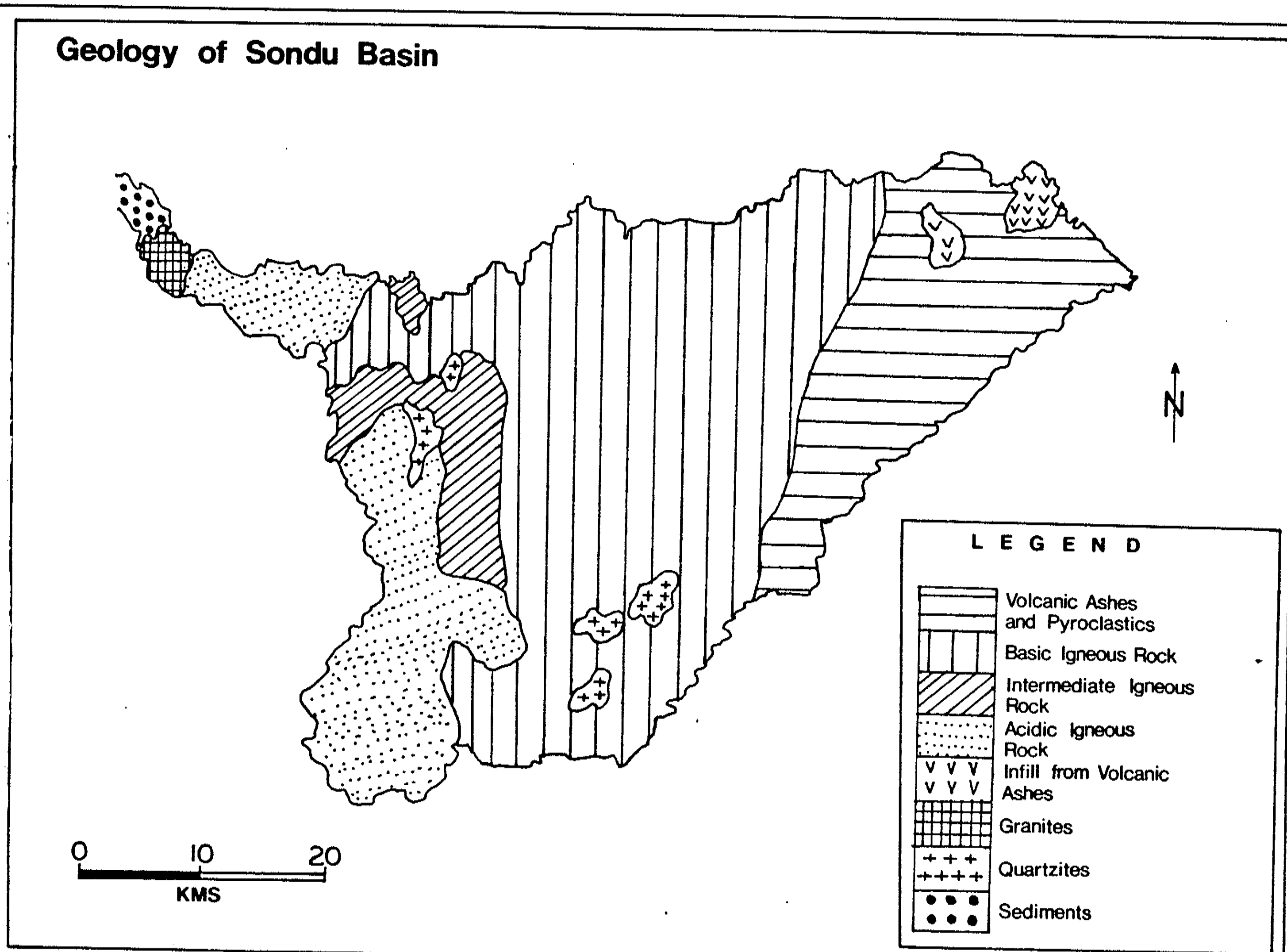


Figure 9: Geology of Sondu Basin

3.3 SOILS

Soils of the study area are derived largely from igneous material. They have recently been reclassified and described in detail by the Kenya Soil Survey (Sombroek et al., 1982). The distribution of these soils is illustrated in figure 10. This recent classification takes into account the relationship between landforms, geology, and soils (Table 1). The Kenyan classification is based on one by FAO-UNESCO that was designed to provide a basis for international correlation of soils. In this system, the soils are identified on the basis of their physical and chemical properties, as well as on morphological characteristics (Sombroek et al. 1982, p.11). The sections which follow describe the main soils of Sondu Basin as identified by this new classification.

3.3.1 Nitisols

Owing to their high fertility, Nitisols are agriculturally very important, not only in Sondu Basin but in the whole country. They were formerly called Reddish Brown Lateritic Soils, and elsewhere in Africa are referred to as Nitosols.

In colour, Nitisols are dark red or dark reddish brown, and have friable fine clay. These soils show eluviation of clay particles within the profile, and do not possess conspicuous horizon boundaries (Muchena et al, 1982). They have a high rate of water transmission and low runoff. Nitisols have been developed from either basic igneous rocks, such as basalt, or intermediate ones, such as andesite. They are described in detail by Sombroek et al, (1982, p.13). In Sondu Basin, Nitisols are found mainly on the ridge crests of the Kericho Plateau, in soil mapping units R9, R10, Uh1, Um3, and Um5, (Figure 10).

3.3.2 Andosols

These soils have a high fertility, but they are often deficient in micronutrients. Andosols possess a high silt content and are dark greyish brown. They display a thick humic top soil. Since Andosols have developed on Holocene volcanic ashes, they typically possess high porosity, high permeability and, therefore, low surface runoff. These soils occur on ridge crests on the western side of the Mau Ranges and on the eastern part of Kericho Plateau (units Lu1 and R13).

3.3.3 Cambisols

Cambisols have a high fertility, and are agriculturally very important. They possess distinct soil horizons, with the B horizon altered by chemical weathering. Cambisols are often found on valley sides in those localities where Nitisols and Andosols occupy interfluve crests. Cambisols are loamy, have a high permeability, and therefore exhibit little surface runoff. Some Cambisols have been developed on Tertiary basic igneous rocks (units R10, Uh1, Um3). Other Cambisols are found overlying either intermediate igneous rocks (Um5) or acid ones (Ul10). Additionally, there are Cambisols developed on Holocene pyroclastics in association with Andosols (Lu1 and R13). Finally, Cambisols may be found on Precambrian rocks (H15).

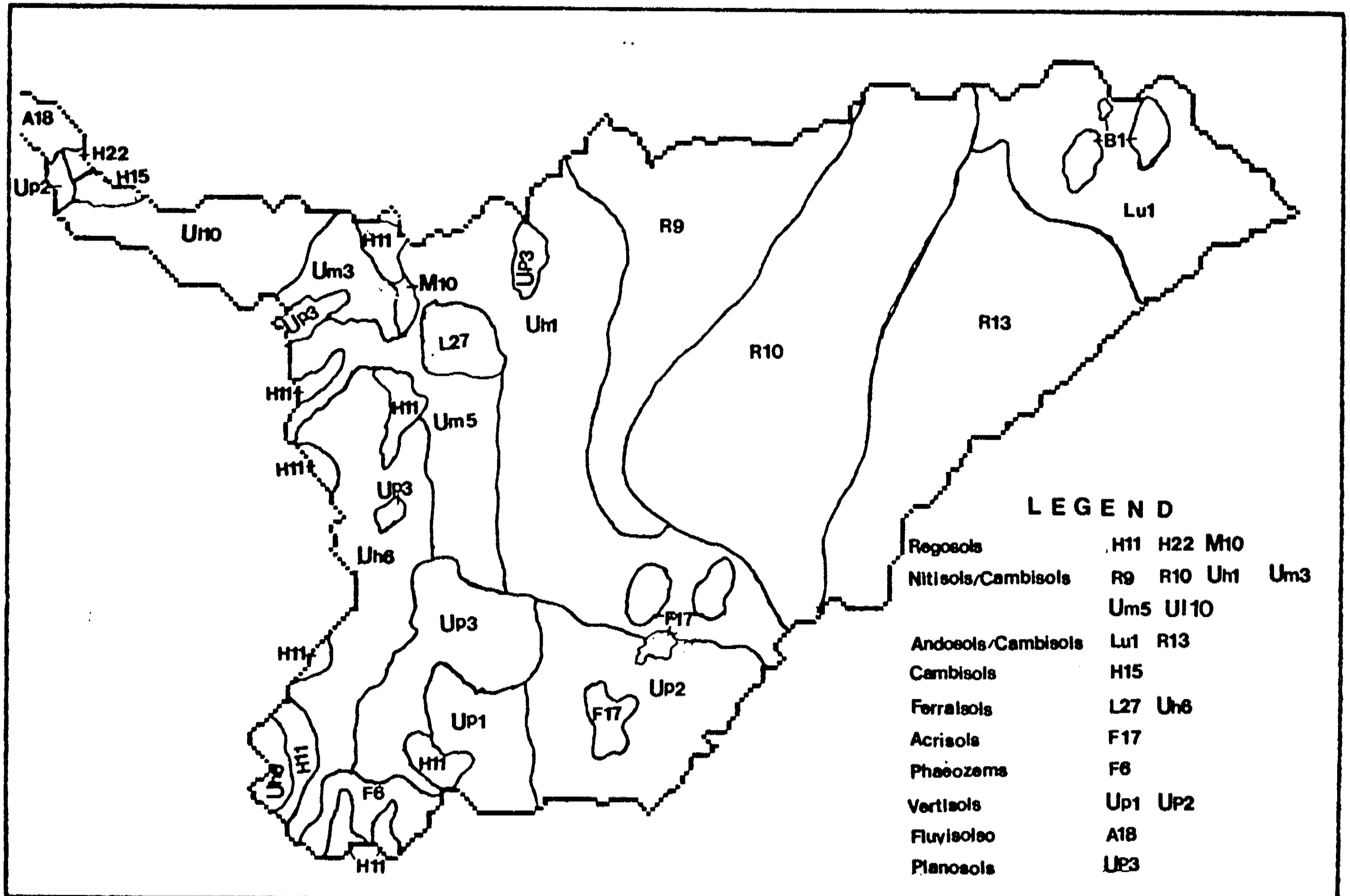


Figure 10: Soils of Sondu Basin

3.3.4 Ferralsols

Ferralsols have been formed from acid igneous rocks, where rhyolites occur admixed with volcanic ash (Uh6). They are also derived from quartzitic parent rock (L27). Ferralsols are soils in which chemical weathering has decomposed feldspars, micas, and ferromagnesian minerals from the acid igneous rocks. Clay-sized secondary minerals, consisting chiefly of iron and aluminum sesquioxides, and the clay mineral kaolinite, have been left behind after leaching of silica. Ferralsol fertility is restricted to the A horizon, where organic matter is present. These soils are very friable, highly porous and very permeable.

3.3.5 Planosols

Planosols are soils developed mainly on flat land, although they are also found on some convex slopes. The soils are dark greyish brown, and have a firm clay underlying a thin loamy topsoil. The clay pan is responsible for very low infiltration and frequent waterlogging. Planosols have developed mainly from acid igneous rocks with a mixture of volcanic ash. The soils are found in unit Up3.

3.3.6 Vertisols

These soils are popularly known in Kenya as 'black cotton soils.' They are fine textured and composed largely of clay minerals, especially montmorillonites. The latter impart plasticity and stickiness to the soils during the wet season and a pronounced hardness during the dry season. Vertisols are impermeable, so possess a very low rate of water transmission, and consequently produce a very high runoff. These black soils have developed from dark parent material comprised of basic lavas and ash, on gently undulating upland plains, and are found in units Up1 and Up2.

3.3.7 Fluvisols

Fluvisols have developed on recent alluvial deposits. They are young soils which have no horizons; they show some stratification due to deposition of sediments. The fertility of fluvisols depends on the nature of the watershed rocks which determine alluvial composition. They have low permeability and high runoff, probably because of high clay content. In Sondu Basin they occur in soil unit A18, which is situated on the Sondu floodplain near Lake Victoria (Figure 10).

3.3.8 Acrisols

Derived from quartzitic regolith, Acrisols have a low organic matter content and high acidity. They are deep, reddish brown weathered soils, in which the B horizon is characterised by illuviation of silicate clay minerals. Acrisols have a high infiltration rate and, therefore, generate low runoff. They are found on gently inclined footslopes (unit F17) in the southwest part of Kericho Plateau.

3.3.9 Phaeozems

Phaeozems are dark reddish soils, rich in organic matter, and possessing a non-acidic topsoil. The porosity of these soils is high, but their permeability is moderate, and therefore they are subjected to moderate runoff. Phaeozems have been developed on colluvium from acid lava and pyroclastics of Quaternary volcanoes. The soils occur on gently inclined footslopes in southwestern Kericho Plateau (unit F6).

3.3.10 Regosols

Regosols have low organic matter and low fertility. Owing to their sandy and stony nature, they possess great porosity and extremely high permeability, resulting in low runoff and often droughty conditions. They have been developed from undifferentiated Precambrian rocks, as well as some igneous rocks of Holocene origin. Regosols are found on moderate and steep slopes of hillsides and escarpments in the Kisii Highlands (units H11 and M10) and on the steep slopes of the western escarpment of Nyabondo Plateau (H22).

TABLE 1

Soil Classification According to Landforms and Geology

(after Sombroek et al, 1982)

R VOLCANIC FOOTRIDGES - dissected lower slopes of older volcanoes and mountains - undulating to hilly topography

Soils developed on Tertiary basic igneous rocks.

R9 - Nitisols and Cambisols

Soils developed on Tertiary basic igneous rocks with volcanic ash admixture

R10 - Nitosols and Cambisols

Soils developed on pyroclastic rocks of Recent Volcanoes

R13 - Andosols and Cambisols

Uh UPPER MIDDLE-LEVEL UPLANDS - undulating to rolling topography with altitudes of 1500-2500m

Soils developed on Basic Igneous rocks.

Uh1 - Nitisols and Cambisols

Soils developed on acid igneous rocks

Uh6 - Ferralsols

Um LOWER MIDDLE-LEVEL UPLANDS - undulating topography with altitudes of 1000 - 2000m

Soils developed on basic igneous rocks

Um3 - Nitisols

Soils developed on intermediate igneous rocks

Um5 - Nitisols

Ul LOWER LEVEL UPLANDS - gently undulating topography with altitudes of 600-1800m

Soils developed on acid igneous rocks

Ul10 - Cambisols

Up UPLAND/HIGH-LEVEL PLAINS - gently undulating with altitudes of 1500-2000m

Soils developed on Basic igneous rocks

Up1 - Vertisols

Soils developed on basic igneous rocks with volcanic ash mixture

Up2 - Vertisols

Soils developed on acid igneous rocks with a mixture of volcanic ash.

Up3 - Planosols

L PLATEAUS AND UPLAND PLAINS _ flat to gently undulating topography.

Soils developed on Quartzites

L27 - Ferralsols

Lu PLATEAUS AND HIGHLANDS - undulating topography

Soils developed on ashes and other pyroclastic material of Recent Volcanoes

Lu1 - Andosols and Cambisols

H HILLS AND MINOR SCARPS

Soils developed on granites

H11 - Regosols

Soils developed on undifferentiated Precambrian rocks

H15 - Cambisols

Soils developed on Jurassic Sandstones

H22 - Regosols

M MOUNTAINS AND MAJOR SCARPS

Soils developed on precambrian rocks

M10 - Regosols

F FOOTSLOPES - gentle lower slopes of hillsides

Soils developed on colluvium from acid igneous rocks with a mixture of volcanic ash

F6 - Phaeozems

Soils developed on colluvium from quartzites

F17 - Acrisols

B BOTTOMLANDS

Soils developed on infill from volcanic ashes

B1 - Planosols

A FLOODPLAINS

Soils developed on sediments from various sources

A18 - Fluvisols

3.4 HYDROCLIMATE

3.4.1 Rainfall

Western Kenya lies within the equatorial portion of the wet and dry tropics, and possesses two rainfall seasons in the year. The seasonality of precipitation is primarily the result of the north-south movements of the Inter-Tropical Convergence Zone (I.T.C.Z.) between the northern and southern hemispheric sub-tropical anticyclones. As the I.T.C.Z. oscillates slowly across East Africa, the Sondu Basin is alternately affected by south-east trade winds, bringing moist air off the Indian Ocean and often resulting in heavy rains (long rains), and dry north-east trade winds yielding light rains (short rains). These rains are separated by transitional, drier seasons.

In addition to the airmasses associated with the south-east and north-east monsoons, the incidence of rain can also be linked to Lake Victoria, a large lake capable of generating its own maritime climate, and to the Congo airmass which originates from the Atlantic Ocean. The Congo airmass is very unstable and convectional storms easily develop in it (Ojany and Ogendo, 1973).

Between October and February, the ITCZ lies mainly south of Sondu Basin. At the time when the harmattan and the north-east trades affect the Basin, there is atmospheric stability, therefore very little rain falls during this period. Evaporation is great, and plants show wilting tendencies.

About March, the ITCZ has moved northwards over the Sondu Basin, and the latter falls under the influence of south-east trade winds. Conditions become moist, and the dry harmattan is replaced by a humid period with light showers first beginning in the Mau Ranges. In the months of April to June the rains become both frequent and widespread. Most often they are accompanied by convectional thunderstorms. The south-east airmass persists more or less with the same vigour and consistency until about the end of June, when it begins to get weaker. These long rains provide the bulk of moisture during the wet season.

The land is relatively bare (due to ploughing, grazing, and wilting), at the advent of the long rains and precipitation at the start of the season is intense, hence this is a period of potentially high soil erosion. The short rains, occuring between October and December, are intense but do not have the erosional potential of the early long rains, since at this time vegetation growth is established. However, erosional potential is still great because soil moisture levels are high and rainfall intensity often exeeds infiltration rates. Thus a large proportion of the precipitation results in a high overland flow.

The distribution of mean annual precipitation in Sondu Basin is shown in figure 11, and is mainly affected by the atmospheric controls discussed above. It is interesting to note that the central Kericho Plateau receives more rainfall than the much higher Mau Ranges (over 1,500mm and less than 1,300mm respectively). Although altitude is an important determinant of rainfall amounts in East Africa, this is not true of the Sondu Basin where the precipitation distribution reflects the diminishing influence of Lake Victoria and the Congo Airmass eastwards.

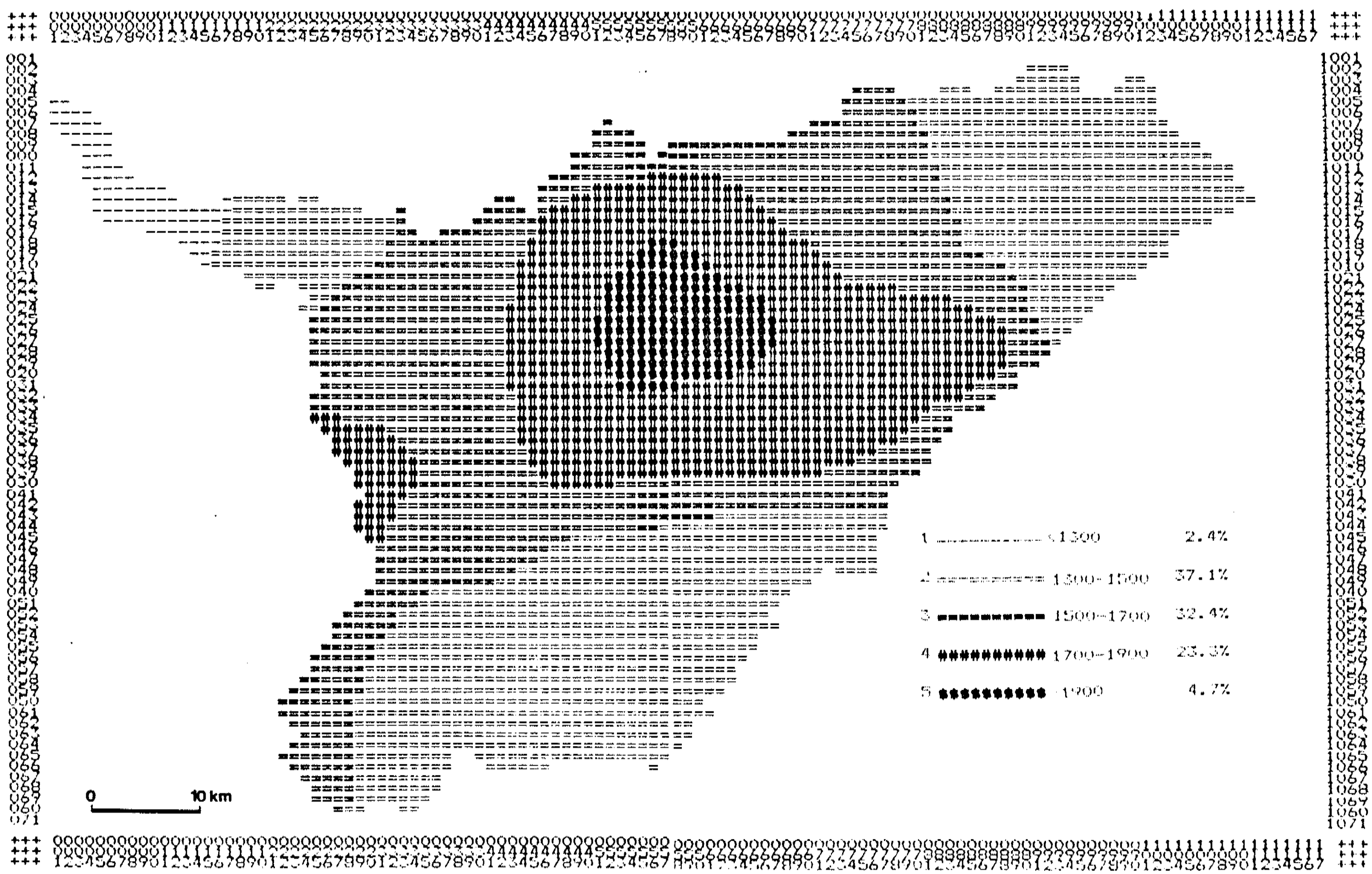


Figure 11: Mean annual rainfall distribution, according to Erosion Categories 1 to 5

3.4.2 Temperature and Potential Evaporation

Temperatures in Sondu Basin, as in other areas of Kenya, are controlled largely by altitude. Thus the highest temperatures are around Lake Victoria, whereas the lowest ones are on Mau Ranges. Mean annual daily minimum temperatures range between 6°C on Mau Ranges and 18°C near Lake Victoria, while the mean annual daily maxima are between 18°C and 34°C respectively for the same locations.

Potential evaporation (P.E.) is a measure of evaporation that would occur at a given temperature if enough water was available throughout the year. The mean annual P.E. for Sondu Basin (figure 12) is closely related to altitude and temperature. Thus, Mau Ranges which are at an altitude of about 3000m have a mean annual P.E. of just under 1400mm of water, whilst Lake Victoria basin at approximately 1100m has a mean annual P.E. of 2000mm. Potential Evaporation is important in soil erosion studies, since it indirectly indicates the moisture that would be available for plant growth and transpiration and unavailable for runoff. Whereas plants tend to protect the soil against erosion, runoff promotes the latter.

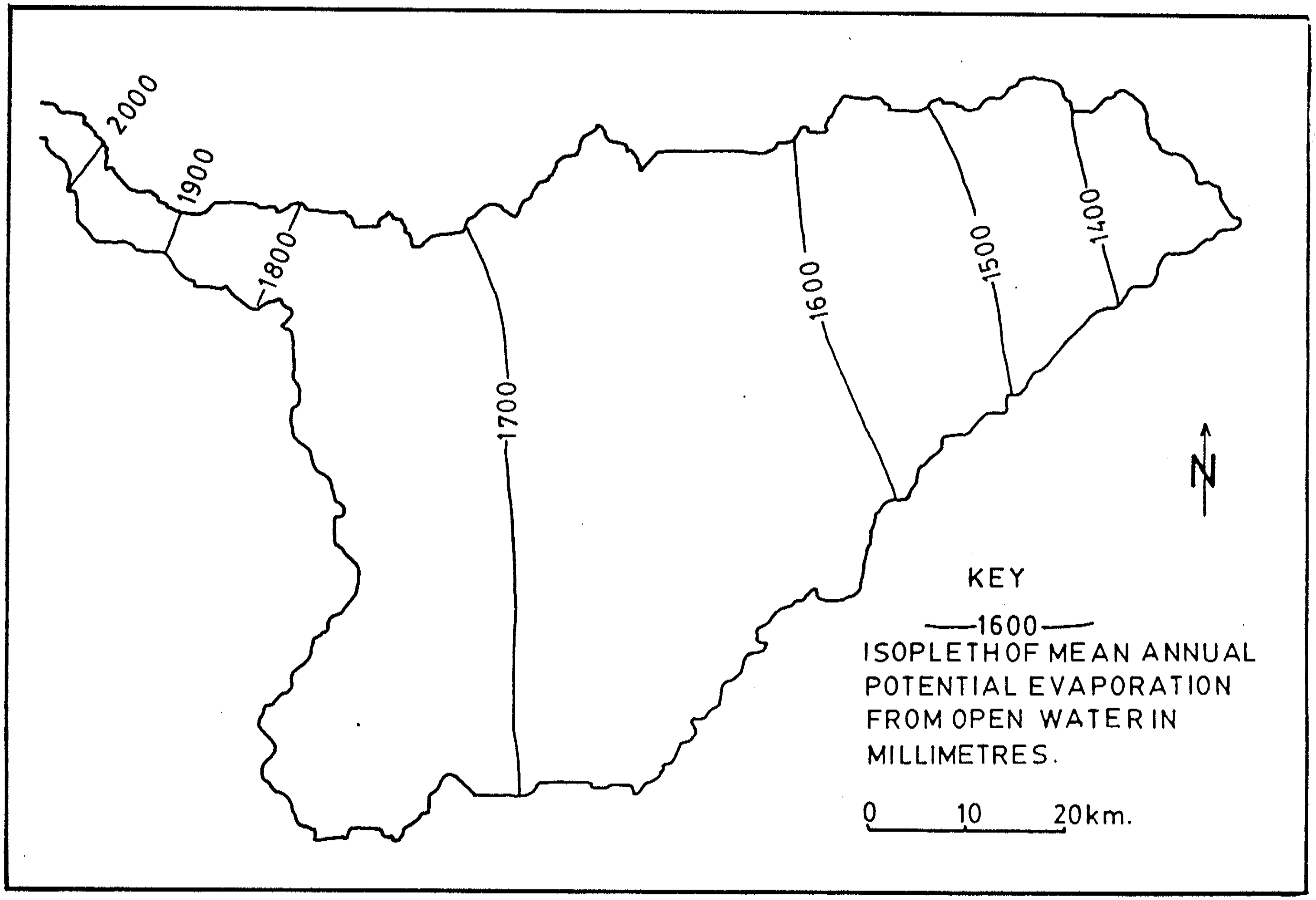


Figure 12: Potential Evaporation of Sondu Basin (after Ongweny, 1980)

3.4.3 **Mean Annual Runoff**

Runoff is defined here as precipitated water that is not infiltrated and therefore flows downslope at the ground surface. It indicates the amount of water available for detaching and transporting soil particles. The mean annual runoff of Sondu Basin (Figure 13) is highest on central Kericho Plateau (over 600mm) and lowest (less than 300mm) in the Lake Victoria basin.

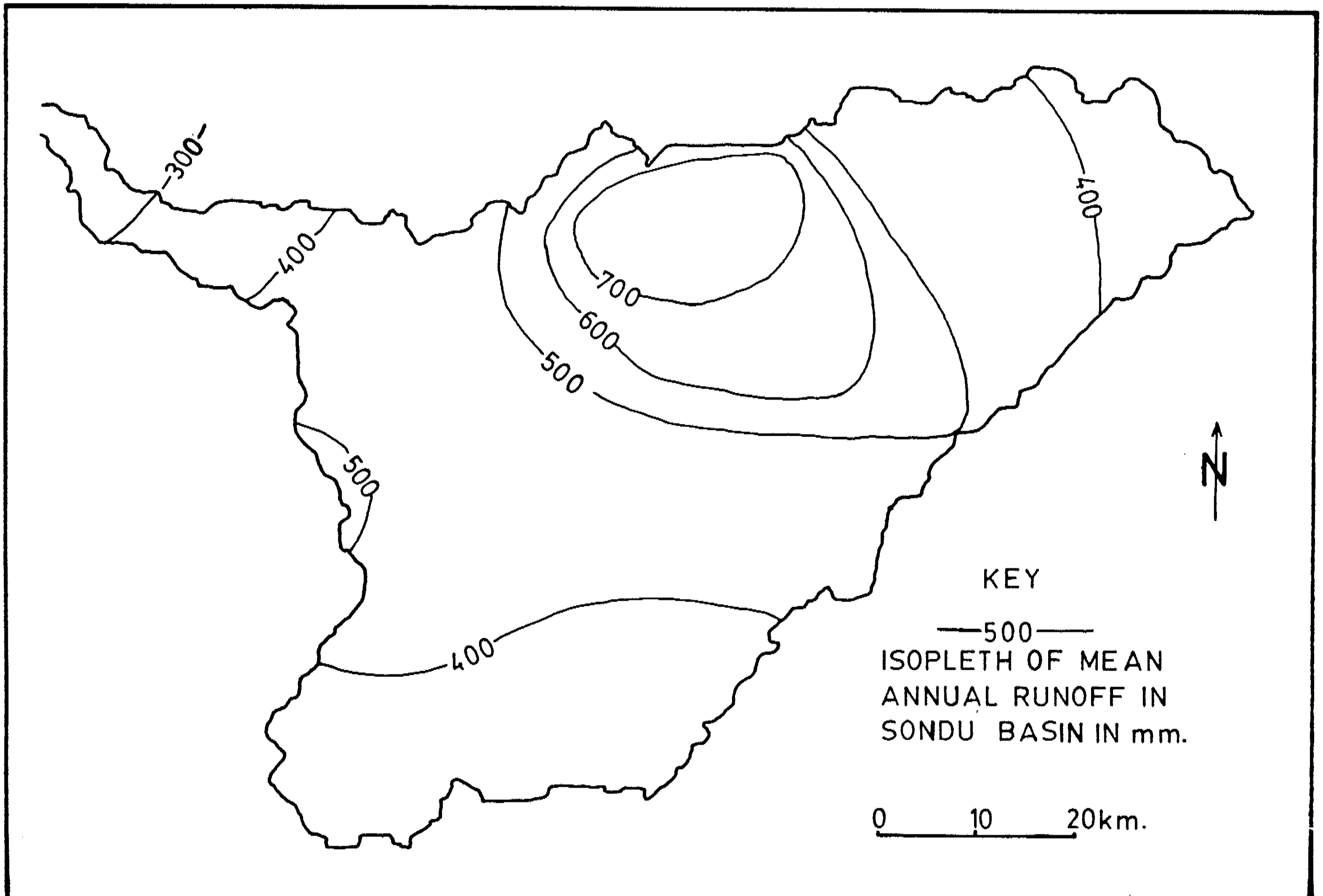


Figure 13: Runoff Distribution in Sondu Basin (after Ongweny, 1980)

3.4.4 Soil Moisture

Soil moisture is fundamentally dependent on amount of rainfall and evapotranspiration. Precipitated water that does not infiltrate the soil, or evaporate directly from its surface, becomes runoff. Consequently, at any location the difference in value between rainfall amount (input) and runoff is an approximate expression of soil infiltration. Infiltrated water determines the soil moisture available for plant growth, which has implications in terms of soil erosion potential. In Sondu Basin, the computed values of soil moisture, derived from the subtraction of runoff from rainfall amounts are high (over 1000mm) in Mau Ranges, central and southwestern Kericho Plateau, and Lake Victoria Basin but lower in Kisii Highlands, and western and eastern Kericho Plateau (Figure 14).

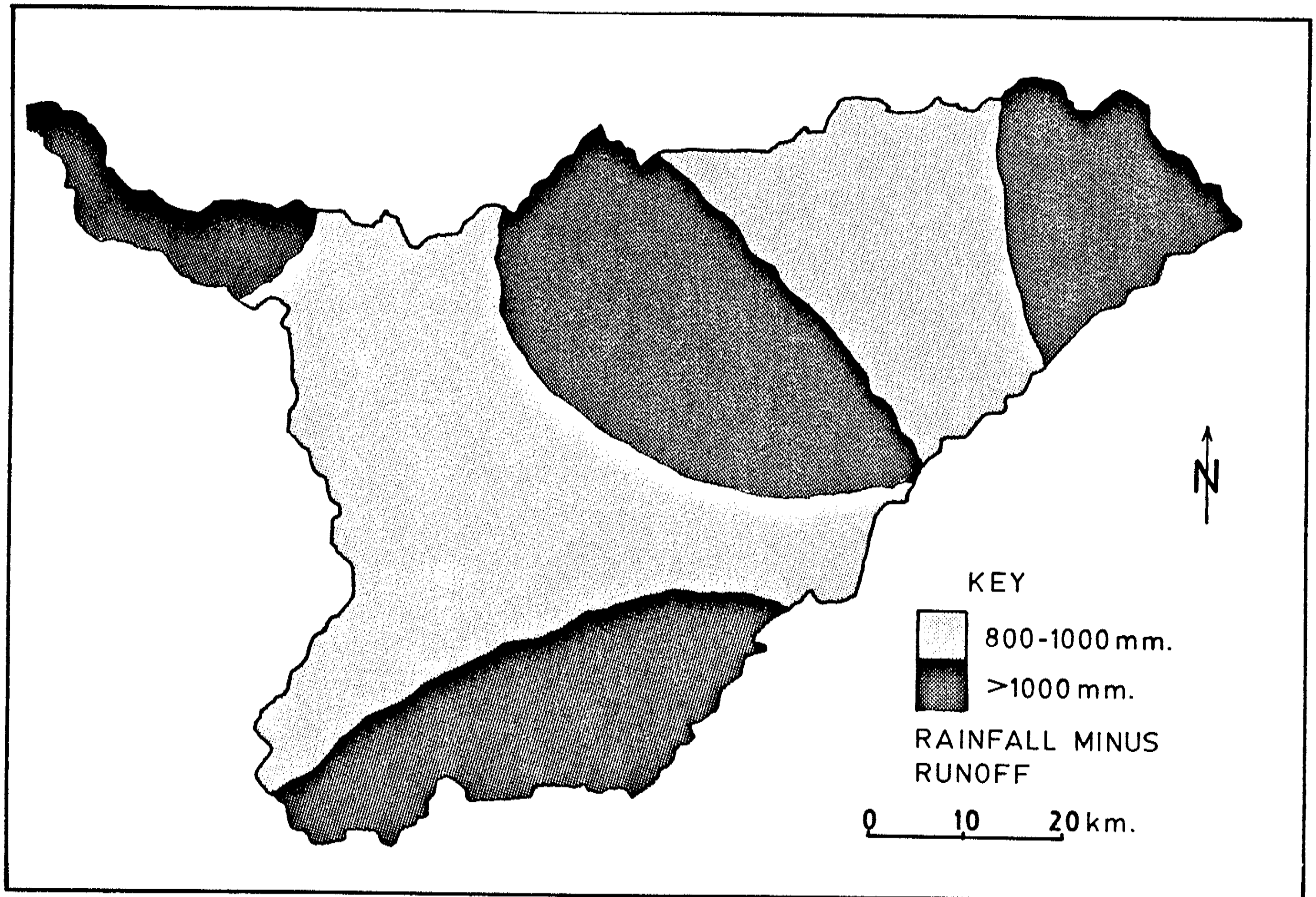


Figure 14: Rainfall Minus Runoff in Sondu Basin (after, Ongweny, 1980)

3.5 VEGETATION

Sondu Basin has two large areas of forest namely Mau forest, Mau Forest, and Mau Nature Reserve. In recent years, so much of these forests have been cleared to give room for agricultural expansion.

The vegetation that was destroyed or severely modified by human activities is being replaced by bush and secondary forests of varying age and species composition. The typical surviving species are described by Edwards(1940), and include a belt of bamboo (Arundinaria alpina) which is found between 2,434 and 3,048m above sea level. White cedar (Juniperus procera), white olive (Olea chrysophylla), and brown olive (Olea hochstetteri) and podo (Podocarpus milanjianus) are found between 1,829 and 2,438m above sea level.

The fallow fields rapidly develop into profuse lush bushes, tangled weeds, brambles, and thorns. Three to four year fallow fields are very leafy, dense and almost impenetrable during the wet season. The early fallows are composed of tall grasses interpersed with shrubs. The dominant grass where forests have been cleared is Pennisetum clandistenum (Kikuyu grass). Other dominant grass species are Pennisetum shimperi, Eleusine jaegeri and Themeda Triandra, all reaching over one and a half metres high if undisturbed. The old fallows and secondary forests, which are randomly cleared of vegetation, are often penetrable in both wet and dry seasons. In areas under cultivation, no natural vegetation remains except along river valleys. Swamps and marshes, which are colonised by papyrus, reeds and other aquatic plants, occur on Fluvisols on the Sondu floodplain and on Vertisols and Planosols on flat interfluve crests on the Kericho Plateau.

Chapter IV

METHODOLOGY AND DATA SOURCES

4.1 BASIS OF METHODOLOGY

The current thesis research adopts Stocking and Elwell's factorial approach in assessing soil erosion potential (Stocking and Elwell, 1973). The method was used in their nationwide survey of soil erosion risk in Zimbabwe. Using available data, the factors of rainfall erosivity, relief, vegetative cover, soil erodibility, and human influence were assessed for each $184km^2$ unit in a grid network over the whole country. Stocking and Elwell described a simple method of factor analysis to obtain a composite model of erosion potential, and they created a map of Zimbabwe that depicted the spatial variations in the combined erosion potential and the dominant factors responsible for it.

Conceptually and methodologically, this thesis follows the factor analytical investigation of erosion hazard in Zimbabwe (Stocking and Elwell, 1973), but the procedure used in the current study of Sondu Basin is more sophisticated because a computer program called Map Analysis Package (MAP), developed by Tomlin (1986), was used instead of the manual calculations and choropleth mapping employed by Stocking and Elwell.

4.2 FACTORS OF EROSION

Five factors of erosion were considered in the Sondu Basin study. These are rainfall erosivity, vegetation cover, soil erodibility, amplitude of relief, and human influence. For two of the factors, specifically amplitude of relief and soil erodibility, sufficient data were collected to provide very adequate descriptors of their individual effects on soil erosion. Less precise data were available for the three other factors, represented by generally related parameters. These factors, which were also fundamentally those used by Stocking and Elwell (1973), were selected because they were considered the most important ones in causing soil erosion.

As mentioned in chapter 2 (pp 42 to 44), the factorial method of analysis has various limitations. These limitations are summarised below:

1. Each of the factors of erosion is assumed to affect soil erosion in an independent way, although factors of erosion are actually interdependent and interact with each other.
2. Class sizes of each factor are arbitrarily established using this technique. By employing smaller class sizes, the importance of the factor in determining soil erosion potential is increased, and may be over-emphasised. This is exemplified by the

impact of doubling class sizes in the case of gradient; with a very small gradient interval, the top class (factor score 5) would include moderate as well as steep slopes, thus exaggerating the importance of slope as a factor.

3. There are difficulties in obtaining reliable parameters for describing the factors of erosion. For example, neither settlement(number of dwellings) nor population density may be the best parameters for describing human influence on soil erosion potential. Likewise permeability may not be the optimal parameter for describing soil erodibility.
4. The method assigns equal weight to each of the five factors, but in reality, one or two factors may be of overriding importance in determining soil erosion potential in Sondu Basin. For example, human influence may be a more potent determinant of soil erosion potential than amplitude of relief.
5. Linear relationships are suggested by the factor scores, ranked 1 to 5. However, the actual relationships between a factor and the soil erosion potential is likely to be non-linear, in that a small increase in erosivity, for example, would induce a disproportinately larger (i.e. exponential) soil loss. Conversely, a large increase in amplitude of relief may only produce a modest increase in erosion.

4.2.1 Erosivity

Erosivity is the potential power of rain to cause soil erosion. The tremendous kinetic energy in falling raindrops provides a basic input for erosion of the soil. Erosivity is a function of rain intensity and duration, and of the mass, diameter and velocity of the raindrops (Morgan, 1979, p.18).

Differences of opinion exist as to the most suitable parameters for measuring rainfall erosivity, probably because of the variety of rainfall types, land use conditions, soil and slope characteristics at various geographical locations. The method commonly used to compute the rainfall erosivity factor entails use of the kinetic energy of the entire rainstorm and its maximum 30 minute intensity (Wischmeier and Smith, 1978). The energy-intensity parameter, the EI_{30} index, is the product of the kinetic energy of the storm, expressed in foot-tons per acre-inch or Joules-mm/m^2/hr, and the maximum half-hour intensity of the storm in inches per hour (mm/hr).

Although the EI_{30} index has proved to be a highly reliable predictor of soil losses from bare soils, especially in the USA where it was developed, Stocking and Elwell (1976, p.232) assert "that there is strong evidence to show that EI_{30} is the nearest 'universal' parameter that can be expected to arise in explaining soil loss from a reliable base, namely bare or continuous fallow." Recently, a Kenyan study of soil loss in relation to rainfall erosivity demonstrated that the EI_{30} index was satisfactory (Ulsaker and Onstad, 1984). The index has not been utilised in the thesis research, however, because the data required for computing this energy-intensity parameter are lacking at the rainfall recording stations in the Sondu Basin.

An alternative erosivity parameter was sought which could be used to predict soil losses from rainfall. The new variable, mean annual rainfall, is not as statistically significant as EI_{30}, but is introduced as a substitute for rainfall erosivity indices. Previous researchers have found a linear relationship between mean annual rainfall and mean annual erosivity. Stocking and Elwell (1973) demonstrated graphically and statistically that there is a direct linear relationship between these variables in Zimbabwe (Figure 15). Nonetheless, they recognised that local topographic conditions may create anomalous erosivity values in relations to mean annual rainfall amounts. As Kenya resembles Zimbabwe in terms of its tropical setting on the African Plateau, where rains are frequently intense, it is assumed that the basically linear relationship between mean annual rainfall and erosivity also exists within the Sondu Basin.

Moore (1979) collected data for 35 stations in East Africa, and found linear relationships between the kinetic

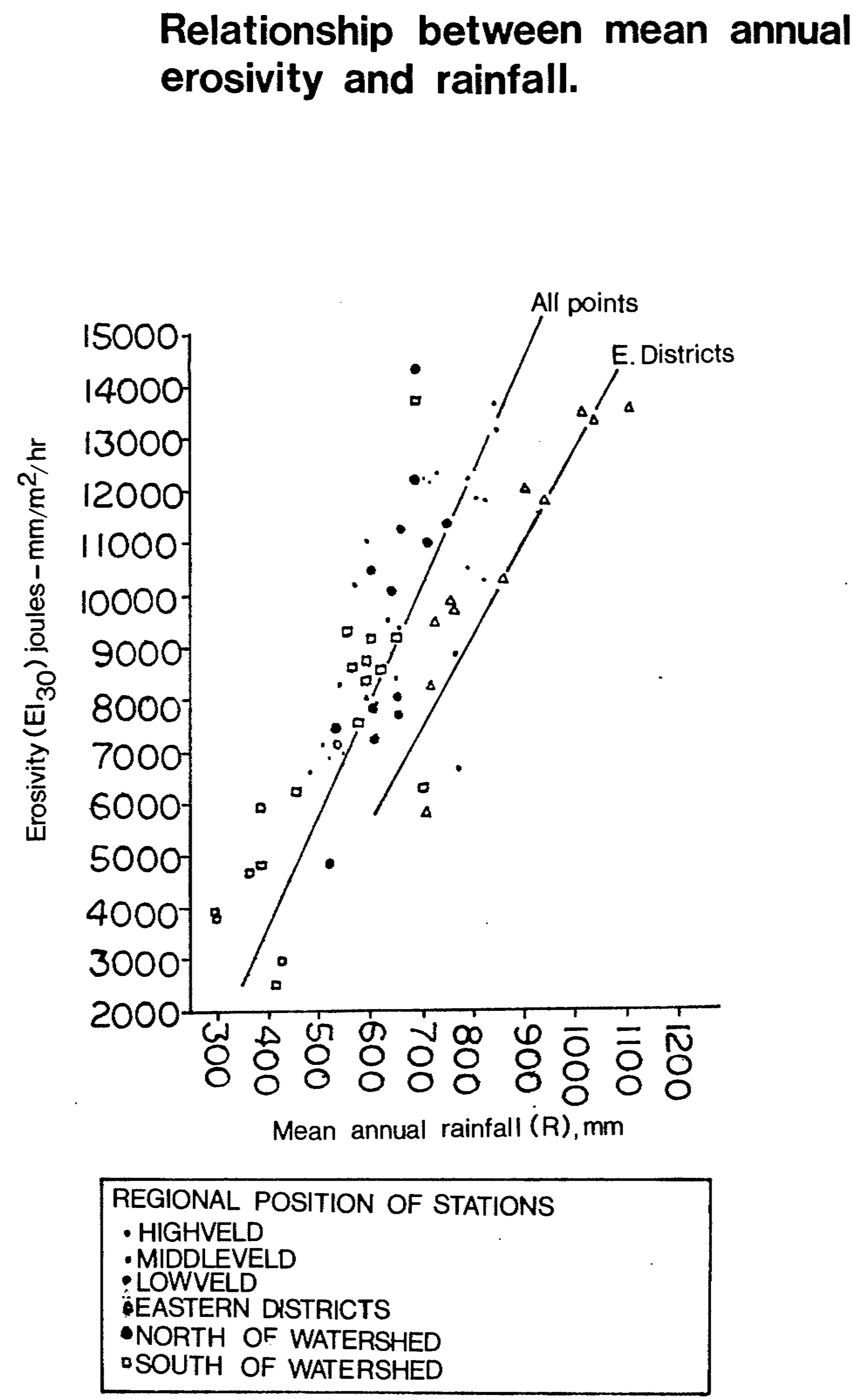


Figure 15: Relationship between Mean Annual Rainfall and Mean Annual Erosivity (after Stocking and Elwell, 1973)

energy of rainfall, expressed by $KE_{15}>25$ (kinetic energy for the 15 minute greatest intensity rainfall with intensity exceeding 25mm/hr) and $KE_{30}>25$ erosivity indices, and mean annual rainfall for four regions, specifically, the Uganda Plateau, Coastal Region, and two inland regions, above and below 1250m respectively (Figure 16). The Sondu Basin falls within the inland region above 1250m, where a linear relationship between mean annual rainfall and $KE_{15}>25$.

The Stocking and Elwell (1973) and Moore (1979) studies demonstrated a linear relationship between mean annual rainfall and erosivity. Consequently, it is assumed that a similar relationship exists between these two variables in Sondu Basin. A map of mean annual rainfall of Sondu Basin (Figure 11) was used to derive rainfall values for rating erosivity interms of factor scores for different localities.

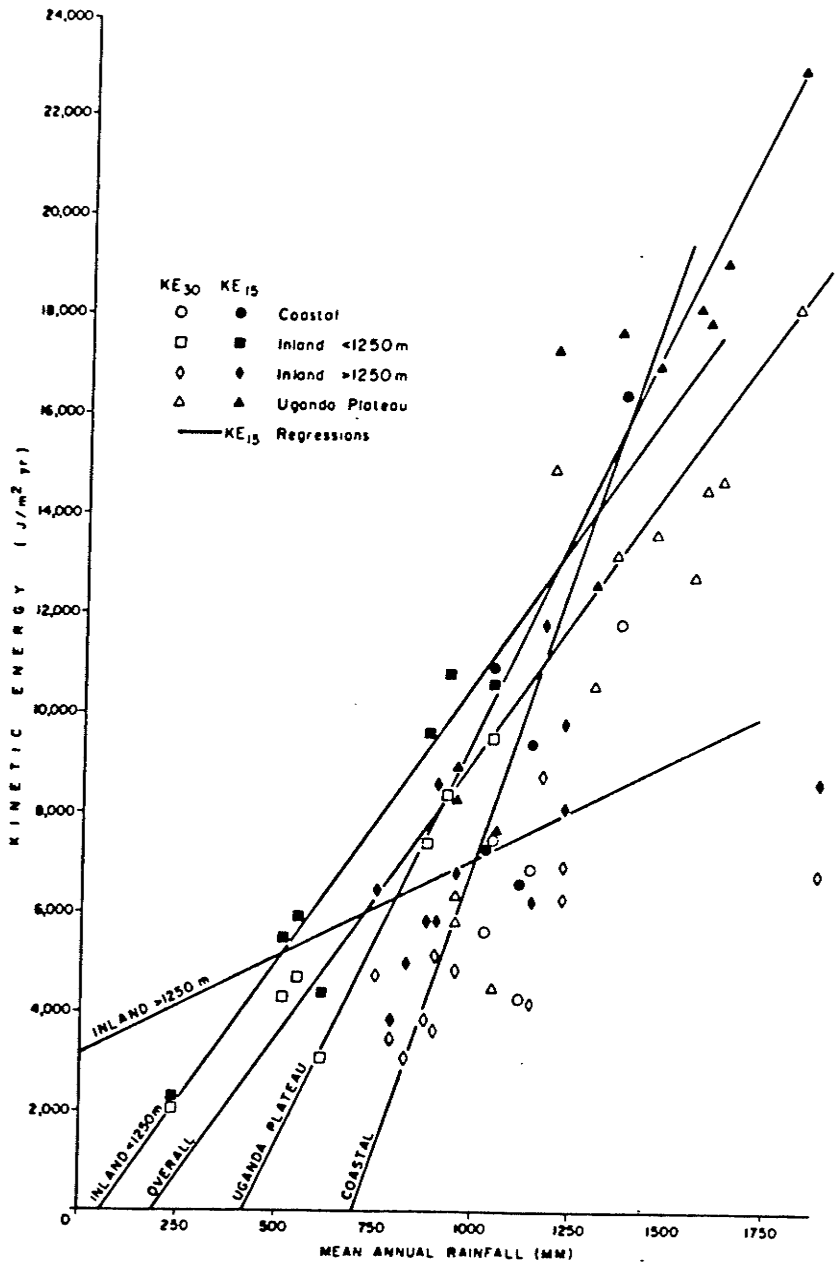


Figure 16: The Relationship Between Kinetic Energy (KE_{15} >25 and KE_{30} >25) And Mean Annual Rainfall (after Moore, 1979)

4.2.2 Amplitude of Relief

Since the current study has utilised topographical maps, the conventional but laborious Wentworth method of calculating average slope gradients from contour information (Wentworth, 1930) could have been used. As the Sondu Basin (area 3,525km^2) was divided into grid squares of one square kilometre each, a much faster method of estimating gradient per square kilometer was sought. Amplitude of relief, which is the difference in altitude between the highest and lowest points within a kilometre grid square, has been used in this thesis.

The amplitude of relief parameter was used as early as 1935 by Smith (1935) in order to analyse the relief of the surface of the state of Ohio. He took a contour map of Ohio on a scale of 1:600,000 and divided it into rectangles of 5 minutes each of longitude and latitude, representing approximately 4.40 by 5.75 miles on the ground. He then calculated the difference in height between the highest and the lowest points in each rectangle, obtaining about 2,000 values which were plotted in the centre of each square on the base map. Isopleths, indicating areas having the same amplitude of relief, were interpolated for each 100 feet difference. The map was then shaded in 8 units to indicate areas having the same amplitude.

The significance of amplitude of relief in soil erosion studies has been emphasised by Holy and Vitkoya (1970) in Czechoslovakia and Keech (1968) in Zimbabwe. Since previous research has employed amplitude of relief as a good descriptive parameter of slope, it has been used in this thesis in preference to Wentworth's method. However, a 10% grid sample of Sondu Basin was analysed using Wentworth's method and compared with the respective amplitude of relief data. A correlation was run between corresponding average gradient and amplitude of relief values. This correlation yielded an R^2 of 0.891 at the 0.001 level of confidence. Based on this result, together with the previous use of the amplitude of relief parameter, the latter was employed as a surrogate for average slope gradient.

4.2.3 Vegetation Cover

A plant cover is one of the most important controlling influences in the soil erosion process, yet vegetation is highly susceptible to human-induced change. Vegetation plays a vital role in protecting the soil against erosion. Plants intercept raindrops so that their kinetic energy is dissipated rather than transferred to the soil. Furthermore, plants impede the surface flow of rainwater downslope, thereby reducing its erosiveness. The plant root network tends to increase soil permeability and also anchor the soil. Morgan (1979) states that the effectiveness of a vegetation mantle in reducing soil erosion depends upon the density of the plant cover and its root density, as well as the continuity and height of the plant canopy.

Hudson (1971) described a remarkable difference in soil loss from bare soil and from a plot protected by a mosquito gauze (simulating a dense vegetal cover) in Zimbabwe: the average annual soil loss over a six-year period was $141.3m^3/ha$ for the bare soil plot but only $1.2m^3/ha$ for the gauze protected plot. Moore et al. (1979) measured runoff and soil loss from three sites with similar soils, but different grass cover percentages, in Machakos, Kenya, and found that runoff and soil losses were very high from a bare soil but low from a grassed site. Elwell (1972) related soil losses from field plots to vegetal cover percentages. The data has been plotted by Stocking and Elwell (1973) as shown on figure 17. The inverse relationship is distinctly curvilinear, with accelerating increase of soil loss with decreasing vegetation from poor (sparse) cover to bare soil. However, the curve is approximately linear over a large range of cover values, i.e. from good to poor.

Since little detailed local information exists about the percentage of vegetal cover in the Sondu Basin, it is necessary to seek an indirect way of estimating the spatial variation of this parameter of soil erosion potential. A detailed vegetation map of Kenya, prepared by the British Special African Commonwealth Assistance and published by the

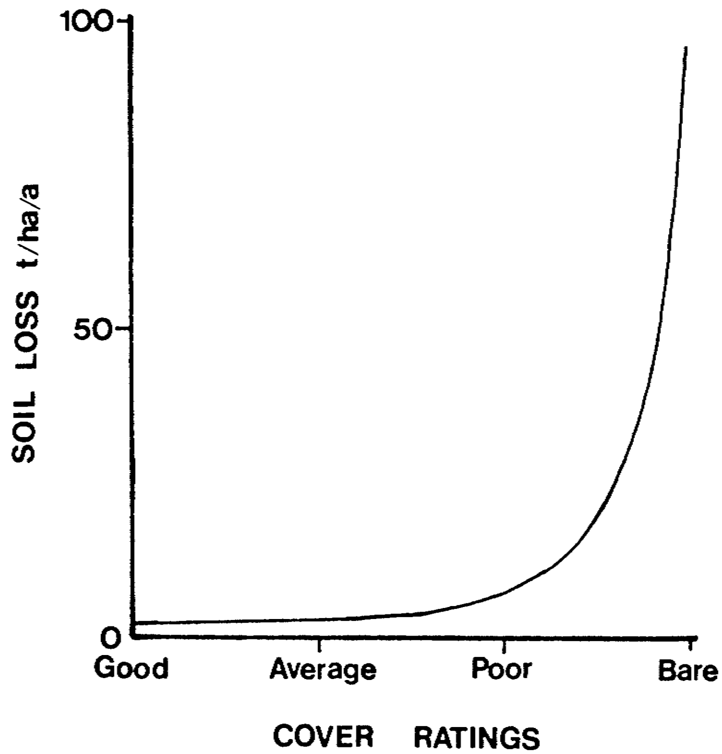


Figure 17: Variation in soil loss against cover from a 4.5% slope (Stocking and Elwell, 1976)

Government of Kenya (Appendix G), was used to define different types of plant covers in Sondu Basin, and five categories emerged. These five categories have been summarised on Table 2. The details of these five categories are given below:

1 Forest

(a) mountain bamboo thicket.

(b) bamboo forest mixtures.

(c) undifferentiated montane sclerophyll forest.

(d) undifferentiated moist montane forest.

2 Vegetation where Impeded Drainage

(a) papyrus, bullrush, swampgrass, and reed swamp.

(b) undifferentiated grasslands.

(c) euphorbia with acacia and thicket remnants.

(d) Acacia geradii with impeded drainage.

3 Open Grassland

(a) montane open grasslands.

(b) open grasslands from evergreen and semi-deciduous bushland.

4 Scattered Trees Intermingled With Long or Short Grass and Cultivation cummunities

(a) burnt-out savanna-grassland areas.

(b) cultivated from Vernonia and Bridelia types.

(c) cultivated from montane sclerophyll forest.

(d) cultivated from moist intermediate forest.

TABLE 2

Erosion Categories

Category	Soil Erodibility	Vegetative Cover	Rainfall Erosivity (mm)	Amplitude (m)	Human Influence (Buildings)
1 Very Low	Soils with a very high rate of water transmission and very low runoff potential. Regosols	Forest	< 1300	0-43	0-20
2 Below Average	Soils with a high rate of water transmission and low runoff potential. Andosols, Nitosols, Cambisols, Acrisols, Ferralsols	Marsh, bog, papyrus reeds - vegetation with impeded drainage	1300-1500	44-87	21-41
3 Average	Soils with a moderate rate of water transmission and moderate runoff potential. Phaeozems	Open Grassland	1500-1700	88-131	42-62
4 Above Average	Soils with a slow rate of water transmission and high runoff potential. Vertisols	Scattered trees intermingled with long or short grass and cultivation communities	1700-1900	132-175	63-83
5 High	Soils with a very slow rate of water transmission and very high runoff potential. Planosols and fluvisols	Forest clearings, cultivation communities, and bare ground	> 1900	176-221	84-104

5 Forest Clearings and Cultivation Communities

(a) cultivated Kikuyu grass area.

(b) cultivated from Triumfetta-Vernonia types.

(c) burnt-out clump-grassland.

(d) cultivated from montane sclerophyll forest.

(e) undifferentited clump-grassland.

(f) bare ground.

The vegetation cover decreases progressively from forest (assumed to give maximum cover percentage) to forest clearings, cultivation communities, and finally bare ground (assumed to give minimum cover percentage). A linear relationship is assumed to exist between these vegetative cover categories and the magnitudes of their respective soil erosion potentials.

4.2.4 Soil Erodibility

The ability of soil to resist erosion depends upon its physical and chemical properties determining particle detachability and transportability. Soil erodibility is a function of stratification, porosity, permeability, clay content, volume change, dispersion properties, moisture content, and frost susceptibility (Johnson,1961). These erodibility factors are in turn determined by actual grain size, as well as grain size distribution, sorting, shape, specific gravity, orientation (Morisawa, 1985).

In Kenya, climate plays an important role in determining the runoff characteristics of soils. Barber et al. (1979) used a portable rainfall simulator to illustrate this point by comparing the infiltation rates of two soils which had almost identical soil-particle size fractions. A Kabete soil (high rainfall regime) had 15 to 17% runoff while a Machakos soil (low rainfall regime) had 67 to 71% runoff. The erodibility of these soils were 0.03 and 0.49, respectively, on the Universal Soil Loss Equation erodibility scale. Soils in the very high rainfall areas of the Kenya Highlands and Lake Region are particularly known for their deep, permeable profiles and high infiltration rates. On the other hand, those of low rainfall areas tend to be compact and shallow, and have low infiltration rates. One would therefore expect the soils of the study area to be generally resistant to erosion since the basin lies within the high rainfall regions of the Kenya Highlands and Lake Basin.

Over the last half-century, many different soil erodibility indices have been devised, and several have used permeability as the main criterion. Unfortunately, few erodibility studies have been done in Kenya, and no such records were available for reference. However, the Kenya Soil Survey (Sombroek, et al 1982) classification of Kenya's soils employs some erodibility properties and conforms to the reqirements of an erodibility classification.

In this thesis, soil groups have been chosen as convenient units for assessing relative erodibility. The regosols (deep sands and gravels) possess exceptionally high infiltration rates because of their pronounced permeability. They are given a rating of 1, indicating very low erodibility. Andosols, Nitisols, Cambisols, Acrisols, and Ferralsols are rated equally as 2. These soils have high rates of water transmission and rather low runoff potential. Phaeozems are rated 3, owing to their moderate permeability and infiltration and, consequently, moderate runoff potential. A rating of 4 is granted to Vertisols which are highly susceptible to soil erosion on account of their low infiltration rates. Fluvisols and Planosols are essentially impermeable, and when drained are particularly prone to soil erosion; they are, therefore, awarded the highest rating (5) in terms of relative erodibility.

4.2.5 Human Influences

The interaction between man and his environment in Kenya has been dealt with in many publications, but the human influence on soil erosion, with a few notable exceptions (Dunne, 1979; Moore, 1979; Moore, 1983; and Lewis, 1985), has tended to be neglected. Investigations of Moore (1979) in Machakos District, Kenya revealed that erosion rates of up to 5 to 10mm/yr. were common in both cultivated and grazing land. Dunne (1979) found that rural roads contribute a large fraction of sediments leaving agricultural lands of Kenya. Moore (1983) has emphasised the role of overstocking in causing soil compaction in the semi-arid areas of Kenya. Lewis (1985), working in Kiambu and Muranga districts of Kenya, found that fields in annual crops especially cotton and maize, resulted in highest soil losses and that perennial cash crops resulted in lowest soil losses.

Accelerated soil erosion is a response to land use changes, such as deforestation, cultivation and livestock grazing, which may possess complex spatial associations. Stocking and Elwell (1973, p.101) assert that "It is by reference only that some measure can be introduced which adequately explains the variability of soil erosion from human influences independent of other factors." Population density reflects the number of people living in an area and in agrarian rural areas of Kenya, it directly measures the number of people who attempt to gain a livelihood from the land. Indirectly, agricultural population density serves as an indicator of intensity of land utilization.

In the research for this thesis, detailed demographic data were unavailable for the determination of population densities for every square kilometre of the Sondu Basin. Consequently, settlement was used as a parameter.

A method was developed whereby buildings were counted, using 1:50,000 topographical maps, for every square kilometre of Sondu Basin (Appendix G). The Basin is essentially an area of farm settlement, where the number of buildings is an indication of the density of the agricultural population. All buildings are residential, except for tea factories and public buildings such as schools. However, such buildings were not counted. Urban areas like Kericho and Sotik, whose cells had many more buildings than those in the rural areas, were given the highest value of the rural cells to avoid discrepancies which would be brought about by a wide range of building frequencies.

The use of building counts, per unit area, from vertical aerial photographs, as an estimation of population density has been utilised by Watkins and Morrow-Jones (1985) in Boulder, Colorado, for two census dates i.e. 1970 and 1980. They developed an equation which converts the number of houses, vacancy rates, and the number of persons per household for each structure type to the total population of the area covered by the photograph. Their estimation from building counts on the aerial photographs showed a population of 10,589 people, against 10,803 of the actual census for 1970, a relative error percentage of only -1.98. The 1980 estimate, based on building counts, showed a total of 15,322 people, against 14,117 for the actual census, a relative error percentage of +8.54. These results were within acceptable levels of accuracy, and confirmed to the author that counting buildings on topographical maps was an appropriate measure of population density, since these maps were prepared from aerial photographs. The assumption in this thesis is that soil erosion potential increases with increasing population pressure on the land, manifest as increased settlement. The range of building count data were divided into five equal parts (Table 2).

4.3 MAP ANALYSIS PACKAGE

In the next phase of the investigation, the five parameters representing factors of erosion were scored, and their respective distributions were mapped. A computer program developed by Tomlin (1986) was used in this process. The program, called Map Analysis Package (MAP), treats the distribution of each factor within the Basin as a separate overlay. The spatial content of an overlay is represented in digital form as an ordered set of numbers. Grid cells, each one kilometre square, were used for inputting data. A grid cell is a row-column position within a uniformly placed pattern of perpendicular rows and columns covering a bounded plane (Appendix A). By superimposing the grid pattern over the Sondu drainage basin, a map or overlay category was associated with each cell to characterise that geographic location. Every grid cell of an overlay was characterised by a single factor value, or score. There were therefore five overlays for the quintet of factors, as shown in Appendices B to F

MAP requires that all overlays must encompass a complete rectangular area (appendix A). It also necessitates that all overlays within the same data base (i.e. Sondu Basin) have the same row-column dimensions.

For MAP to function, all data must be at the same level of measurement, that is, the ordinal scale. This necessitates the use of qualitative expressions for ranking according to relative importance in determining erosional potential. Hence the range of parameter values for each individual factor was divided into five categories, as mentioned in the preceding pages of this chapter, ranging from LOW(1) to HIGH(5) soil erosion potential. The categories of erosion, and procedures used for allocating these categories, are shown on table 2.

4.4 PROCEDURE OF ANALYSIS

4.4.1 Determination of High Potential Areas of Erosion

In the spatial analysis of Sondu Basin soil erosion potential the following method was adopted. For each grid cell, its five factor scorings (Appendices B to F) were summed. For example, the grid cell containing Kericho town (176-F2 on base map, figure 18) has an above average erosivity (4); a sparse vegetative cover (4); a below average amplitude (2); a soil of below average erodibility (2); and a high settlement density (5), and possesses an aggregate compound score of 17. The scorings within the Sondu Basin varied from 7 in the Mau Forest to 20 (south-east of Mikomoni, 100-D5 on the base map). Following the technique devised by Stocking and Elwell (1973), these aggregate (compound) scorings were placed into seven overall categories by linking pairs of values, i.e. 7-8, 9-10,...19-20 (Table 4). Each of the seven categories of compound scores was given a descriptive soil erosion potential adjective varying from Very Low to Very High and numbered from 1 to 7 respectively. The overall erosion potential map (Figure 19) was shaded by computer according to the seven categories (Table 4).

Over most of the Sondu Basin, regionalisation of soil erosion potential is clearly discernible. In some cases, notably along forest margins, adjacent grid cells have markedly different scores owing to the coincidental occurrence of a localised high settlement density and low vegetation cover compared to the adjacent forest where settlement was nil and vegetation cover was maximum. The spatial pattern is locally intricate and it is not feasible to draw smoothed boundaries around each category of erosion. However, this does not detract from the overall visual effect in showing the erosion potentials of specific areas.

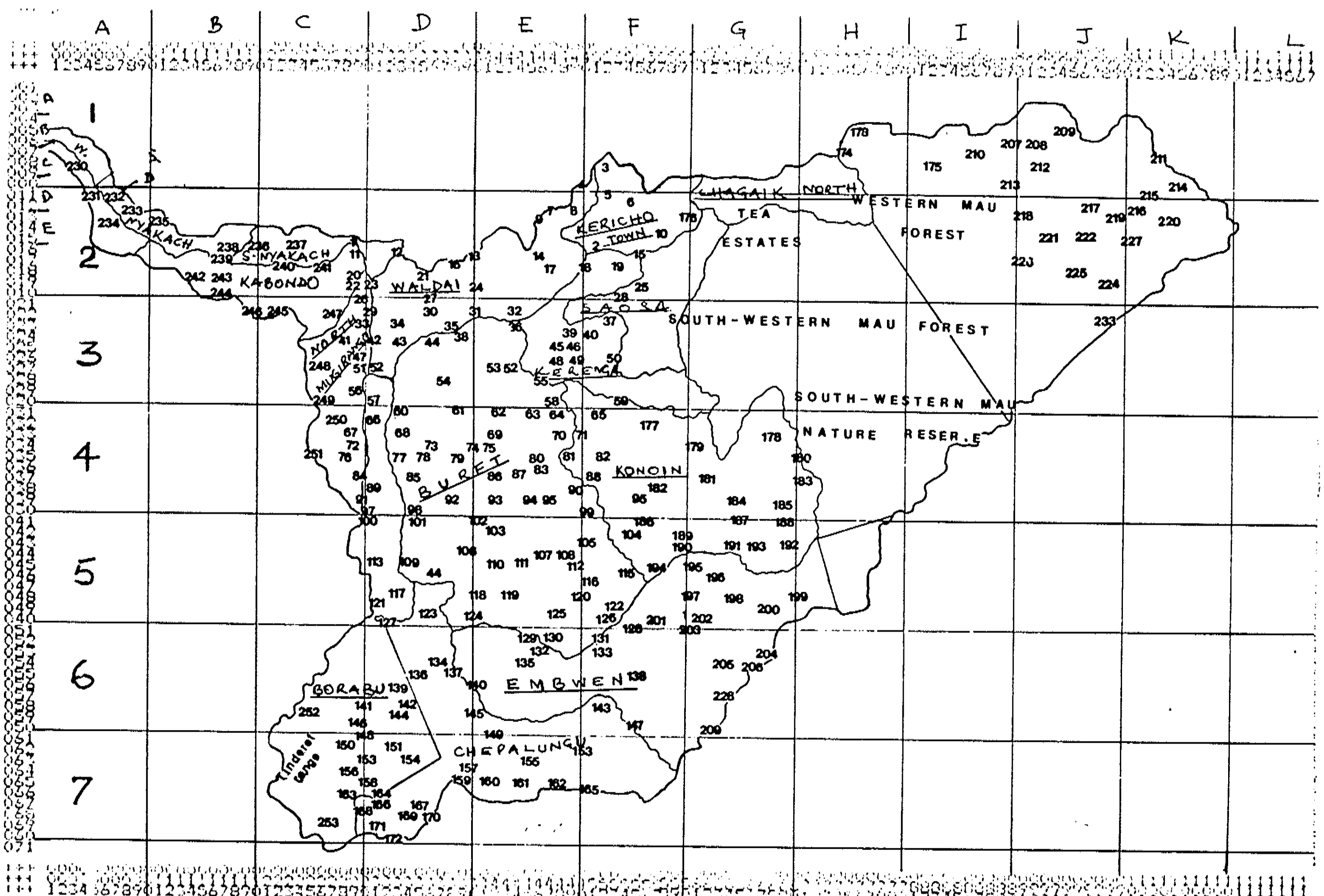


Figure 18: Base Map of Sondu Basin

TABLE 3

Key to the base map

1. Sondu T.c.
2. Cheptoroiet
3. Kapsoit
4. Kiptoboit
5. Boriborwet
6. Kaptebeswet
7. Sosiot
8. Cheptenye
9. Teldet
10. Kerenga
11. Agai
12. Tonungoi
13. Kiptere
14. Gaparok
15. Kapindege
16. Kakibei
17. Kiptule
18. Tegat
19. Kapsuser
20. Atela
21. Marumbasi
22. Namba
23. Matongo
24. Chemamul
25. Masabet
26. Nyaututu
27. Kebenet Sch.
28. Chebaoni Tea Est.
29. Matongo (near Musaria)
30. Kebenet shops
31. Chebirbei
32. Kapmaso
33. Musaria
34. Nyabwaruru
35. Kebenet junction
36. Kabianga
37. Tagabi
38. Koiwalelach
39. Chepkosilen
40. Ainabkoi
41. Gekonge
42. Magwagwa
43. Ikamu
44. Mindililwet
45. Kitio Tea Est.
46. Jamji
47. Igare
48. Chemosot
49. Jamji Tea Est.
50. Changoni Tea Fact.
51. Lyoniego
52. Nyakenyomasye
53. Roret
54. Mabasi
55. Kabartegan Sch.
56. Kenguso
57. Misogwa
58. Kabartegan Mkt.
59. Kimulot
60. Ngoina Schl.
61. Kapkisara
62. Cheboror
63. Getarwet
64. Kaminjewet
65. Chemalal
66. Ikonge
67. Tombe
68. Ngoina
69. Cheboin
70. Cheptulyeb
71. Cheimen
72. Changombe
73. Kipsamoi
74. Kapsegut
75. Kiptome
76. Itibo
77. Teritor Tea Est.
78. Kimoro Tea Est.
79. Tebesonik
80. Kiptewit
81. Kusumek
82. Chemelet
83. Lelagin
84. Kenyuru
85. Kaldet Est.
86. Kurongo
87. Cheborge
88. Kabianget
89. Kenyuru Mkt.
90. Litein
91. Bunyunyu
92. Kapsimbiri
93. Kapsegut
94. Chepkoyet
95. Boito
96. Ngesumin
97. Nyamiramga
98. Kiroga
99. Chemoiben Hill Sch.
100. Mikomoni
101. Kibugat
102. Kibwastuiyo
103. Mombwo
104. Chebilat
105. Kapkatet
106. Kapsinendet
107. Sosit
108. Chebitet
109. Kipkebe
110. Masubet
111. Cheplanget
112. Daraja Sita
113. Mugura Est.
114. Monier Est.
115. Chebirkelek
116. Chesityot
117. Kapkimolwa
118. Chebonge
119. Kaplong
120. Balek
121. Mwangoris Hill
122. Kamungei
123. Jebilat
124. Sotik
125. Kimolwet
126. Kipsonoi
127. Mateget
128. Kamakoso
129. Yaganek
130. Keroncho
131. Chebole
132. Metoit
133. Chebango
134. Chemosot
135. Kitajit
136. Kokwa
137. Jujuliet
138. Kiplelji
139. Simbout
140. Keringet
141. Menyenya
142. Kipsarokwek
143. Kanusin
144. Kamangoit
145. Kaitet Ranch
146. Singoiwek
147. Mutarakwa Hill
148. Nyansiongo
149. Kapkelei
150. Narangai

151. Isoge
152. Ndamichoni
153. Manga
154. Kineni Ranch
155. Sigorian
156. Ngumbaut
157. Mosonik Hill
158. Naumoni
159. Ndanai Hill
160. Kamugeno
161. Oldebesi
162. Kapsesosio
163. Riang'ombe
164. Tapnabei
165. Makumenyi
166. Kongere Hill
167. Kiptenden Hill
168. Rietago
169. Kipsimboi Hill
170. Cheplelwa
171. Lietego
172. Gelegele Hill
173. Chepsir
174. Kapkatungor Tea Est.
175. Githima
176. Kericho Town
177. Kimulot
178. Embomos
179. Chebangang
180. Kipkiyen
181. Kaptekengwet
182. Itare
183. Sotik Sch.
184. Koiwa Harambee
185. Taboinoi
186. Chebilat
187. Koiwa
188. Cheptalal
189. Mogogosiek
190. Saseta
191. Kiptenden Sch.
192. Satiet
193. Terek Hill
194. Mogonjiet
195. Ruseya
196. Kapkoros
197. Kimargis
198. Kiplokji
199. Ndaraweta
200. Marinyin
201. Kamoguso
202. Boito
203. Chesoen
204. Aisaik
205. Kabungut
206. Silibwet
207. Kerisa
208. Mustuni Farm
209. Mawingo
210. Kio
211. Sasumua Farm
212. Chepitet Farm
213. Saino Farm
214. Chesingele
215. ADC Farm
216. Grassland Research Station
217. Poulton
218. Taloa
219. Westerland
220. Ryan
221. Tinet Farm
222. Matunda
223. Mwangati
224. Kewamoi Farm
225. Boron
226. Kittery Farm
227. Elleshope
228. Kapsimotwa
229. Kapkwen
230. Osodo
231. Nyakwere
232. Samgoro Hill
233. Fotobiro Hill
234. Apuku
235. Andingo Opanga
236. Nyakach Mission
237. Kabete
238. Gari
239. Mamboleo
240. Miriu
241. Dirubi
242. Ramula
243. Nyandolo Hill
244. Wangapala
245. Otworo
246. Oriang
247. Pala
248. Nyamusi
249. Obwari
250. Kebabe
251. Nyaramba
252. Kijaur
253. Bongota

TABLE 4

Erosion Potential Of Sondu Basin

	Compound Scores	Area In Sq.Km.	%Of Total Area	Erosion Potential
1.	7-8	182	5.2	Very Low
2.	9-10	1111	31.5	Low
3.	11-12	778	22.1	Below Average
4.	13-14	821	23.3	Average
5.	15-16	537	15.2	Above Average
6.	17-18	89	2.5	High
7.	19-20	7	0.2	Very High

By overlaying the base map (Figure 18) on the overall erosion potential map (Figure 19), and with the aid of the key to numbers provided by Table 4, the erosion potential of any place in the Sondu Basin can be determined. Additionally, the base map includes all recent boundaries of the Administrative Locations within Sondu Basin; changes in the boundaries of Locations have occurred from time to time. The positions of enumerated place names on the base map (Figure 18) are approximately correct, having been transferred directly from their precise locations on 1:50,000 topograhical maps of the Basin (Appendix G).

The aim of this thesis is to locate areas of high soil erosion potential within the Basin. Such areas are defined as those grid squares with compound scores of 15 or more. Consequently, with reference to Table 4, categories 1 to 4 (designated 'Very Low' to 'Average' respectively) have been excluded from the analysis of results. However, the overall erosion potential map and surface (Figure 19 and Appendix O

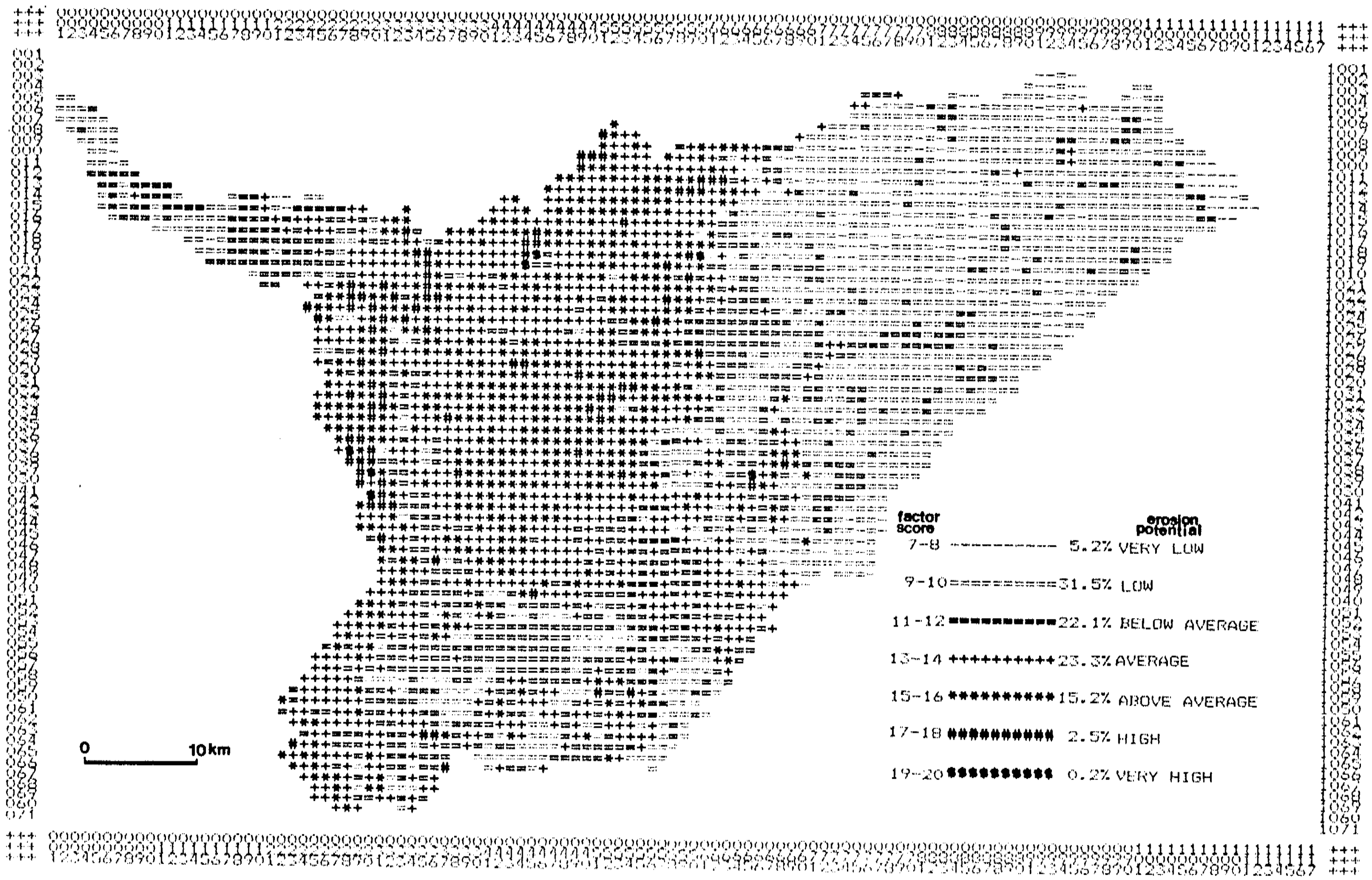


Figure 19: Overall Erosion Potential Categories, based on Compound Factor Scores, in Sondu Basin

respectively) shows the location of areas possessing compound scores falling within the lower categories of erosion, and is useful, therefore, in identifying their respective locations.

4.4.2 Identification of Dominant Factors

The second objective of the thesis is to determine the causative factors of erosion within the high potential erosion areas. A causative, or dominant, factor of erosion is defined as a factor whose score exceeds the statistical average factor score. For example, in the 'Above Average' erosion category, a grid cell area possessing a compound score of 15 has, therefore, an average factor score of 3, and consequently any factor having a score above 3 in this specific cell is considered dominant. Dominant factors are assumed to be largely responsible for high soil erosion potential in any of the areas placed in categories 5, 6, or 7 in Figure 20.

Each of the five dominant factors has been individually mapped (Figures 22, 23, 25, 27 and 29) to show its distribution in the entire Sondu Basin. For each factor, the respective map portrays areas where that factor is a dominant one. The subsequent analysis has focussed on the identification of dominant factors within the areas that possess a high soil erosion potential, i.e. compound scores of 15 or above (Table 4).

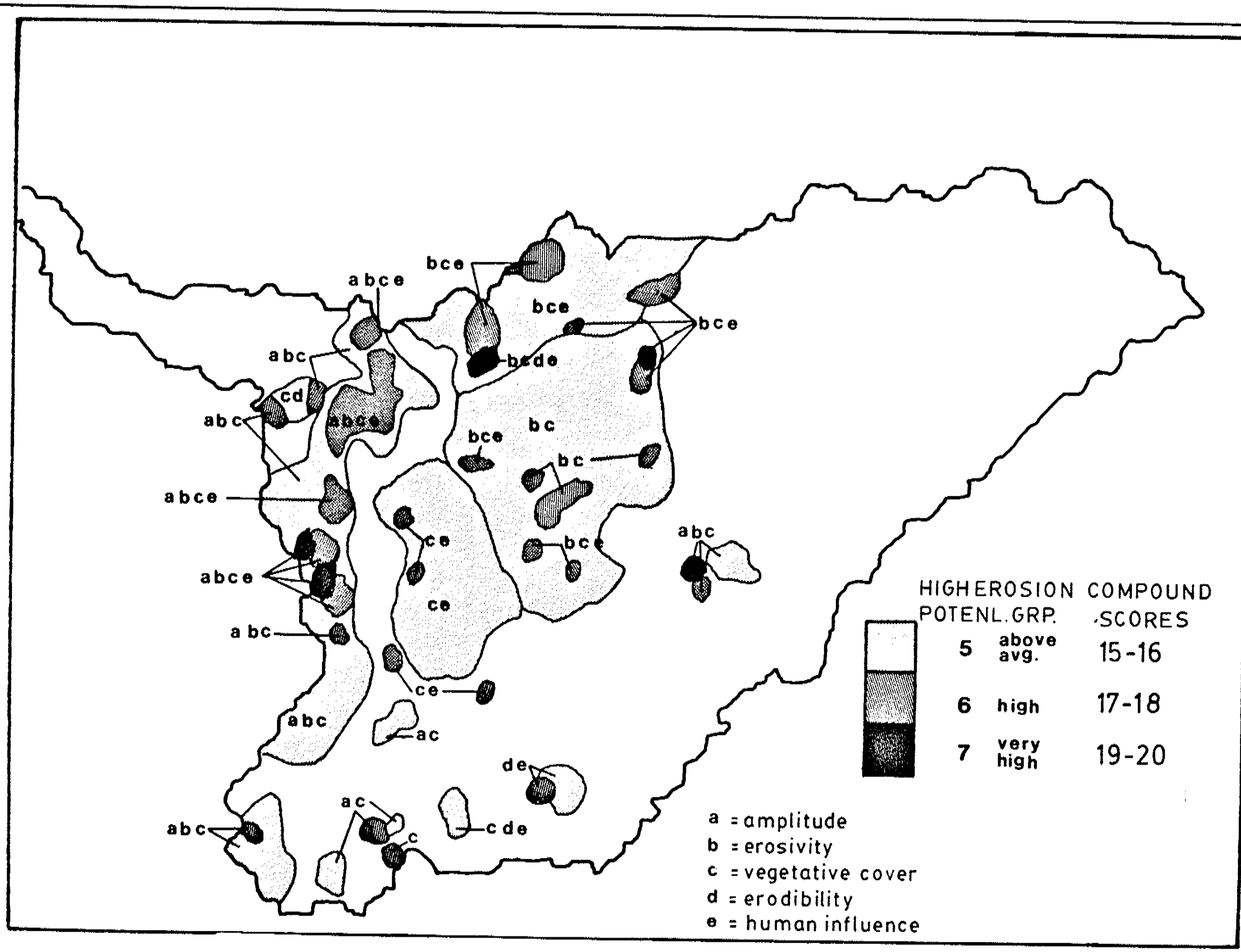


Figure 20: Areas of High Erosion Potential, showing Association of Dominant Factors'

Dominant factors within the areas of high erosion potential are determined by overlaying the high erosion potential map (Figure 20) on each of the dominant factor maps one by one. On the high erosion potential map, dominant factors have been letter-coded (a: amplitude, b: erosivity, c: vegetation cover, d: erodibility, e: human influence). Each geographical area belonging to a high erosion potential group (categories 5, 6, 7 in Figure 20) on the map has been letter-annotated to summarise its respective association of dominant factors. In some localities as many as four dominant factors occur within associations.

Chapter V

RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

The previously stated aim of the thesis is two-fold. Firstly, the areas of high potential erosion within Sondu Basin are determined and their distribution mapped. Secondly, the causative or dominant factors of soil erosion in the areas of high erosion potential are identified and illustrated (Figure 20).

The objective of the current chapter is to explain how the causative factors, individually or in association with one another, determined the soil erosion risk in the high erosion potential areas identified (Figure 20). Explanations are given in light of the land use systems of the Sondu Basin. Land use data of the Basin are derived from the publications of the Ministry of Finance and Planning of Kenya. For each of the five major factors in the study, its influence on soil erosion is discussed, its spatial distribution and dominance within Sondu Basin are described, and the interaction with other factors analysed. Finally, the findings of other workers regarding the respective role of each factor are compared with the results from this analysis.

5.2 THE INFLUENCE OF ERODIBILITY ON SOIL EROSION IN SONDU BASIN

Erodibility is the most important soil factor which affects soil erosion. Erodibility comprises both soil detachability and transportability, and is a function of many soil properties including permeability, porosity, stratification, clay content, volume change and dispersion properties (Johnson, 1961). In current work, relative permeability has been employed as the parameter representing soil erodibility.

The map of soil erodibility distribution in Sondu Basin (Figure 21) shows that approximately 87% of the Basin has below average soil erodibility i.e. categories 1 and 2 (Appendix E). Consequently, for most of the Sondu Basin soil erodibility is not a major problem in the inducement of soil erosion.

The major areas of high erodibility are in Chepalungu, Embwem, and Borabu Locations. The soils of high erodibility in these areas are Planosols and Vertisols (Figure 10). Minor areas of high erodibility are in the Locations of North Mugirango (Planosols), West Nyakach (Fluvisols), Wangchien'g (Fluvisols), Waldai (Planosols) and on footslopes of Mau Ranges (Planosols).

Erodibility is a dominant factor of erosion on the eastern and extreme southern parts of Kericho Plateau and on

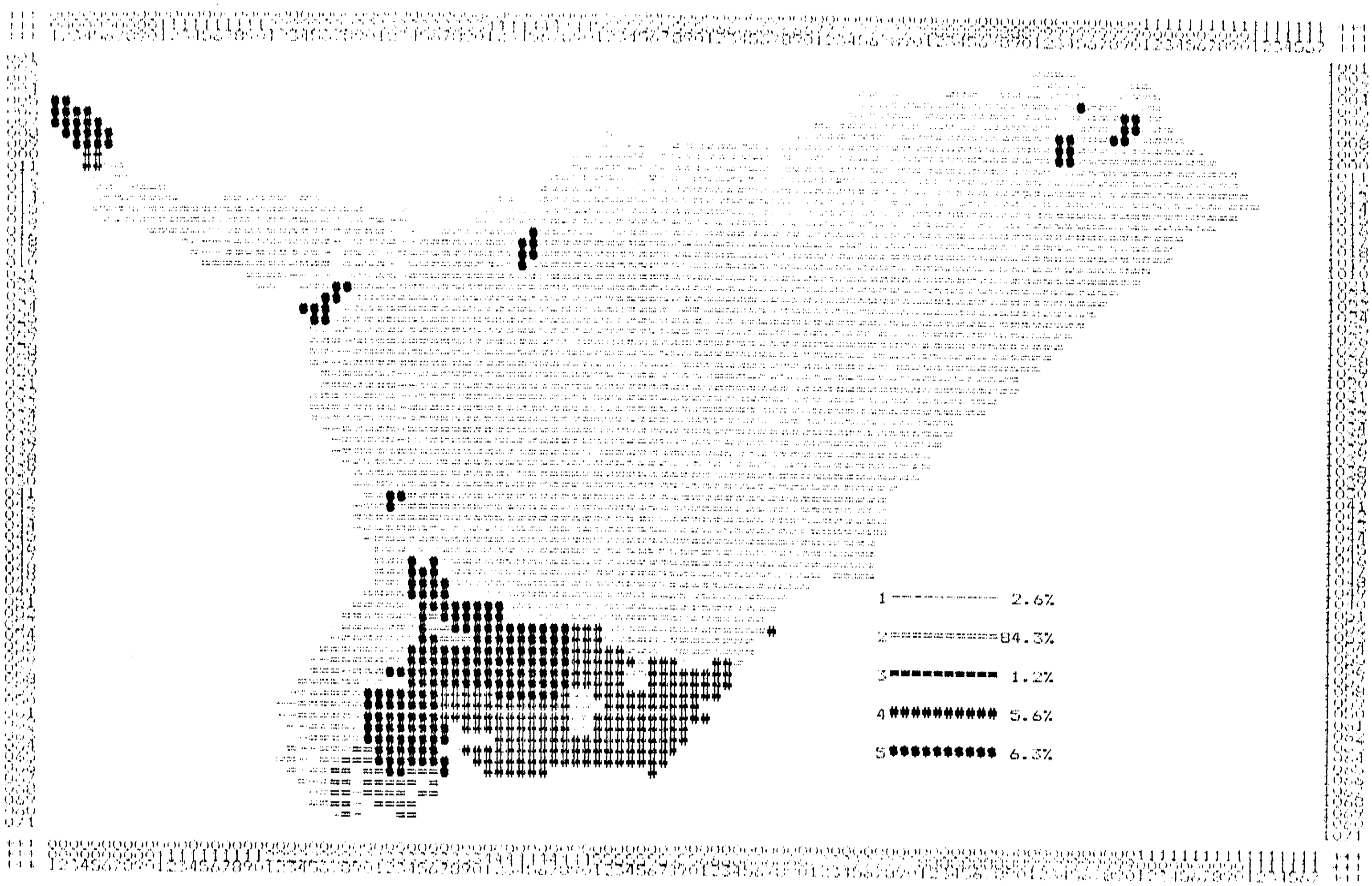


Figure 21: Distribution of Soil Erodibility, according to Erosion Categories 1 to 5

Mau Ranges, and in a small section in the west of the Basin, near Lake Victoria (Figure 22). These areas comprise 32.2% of Sondu Basin.

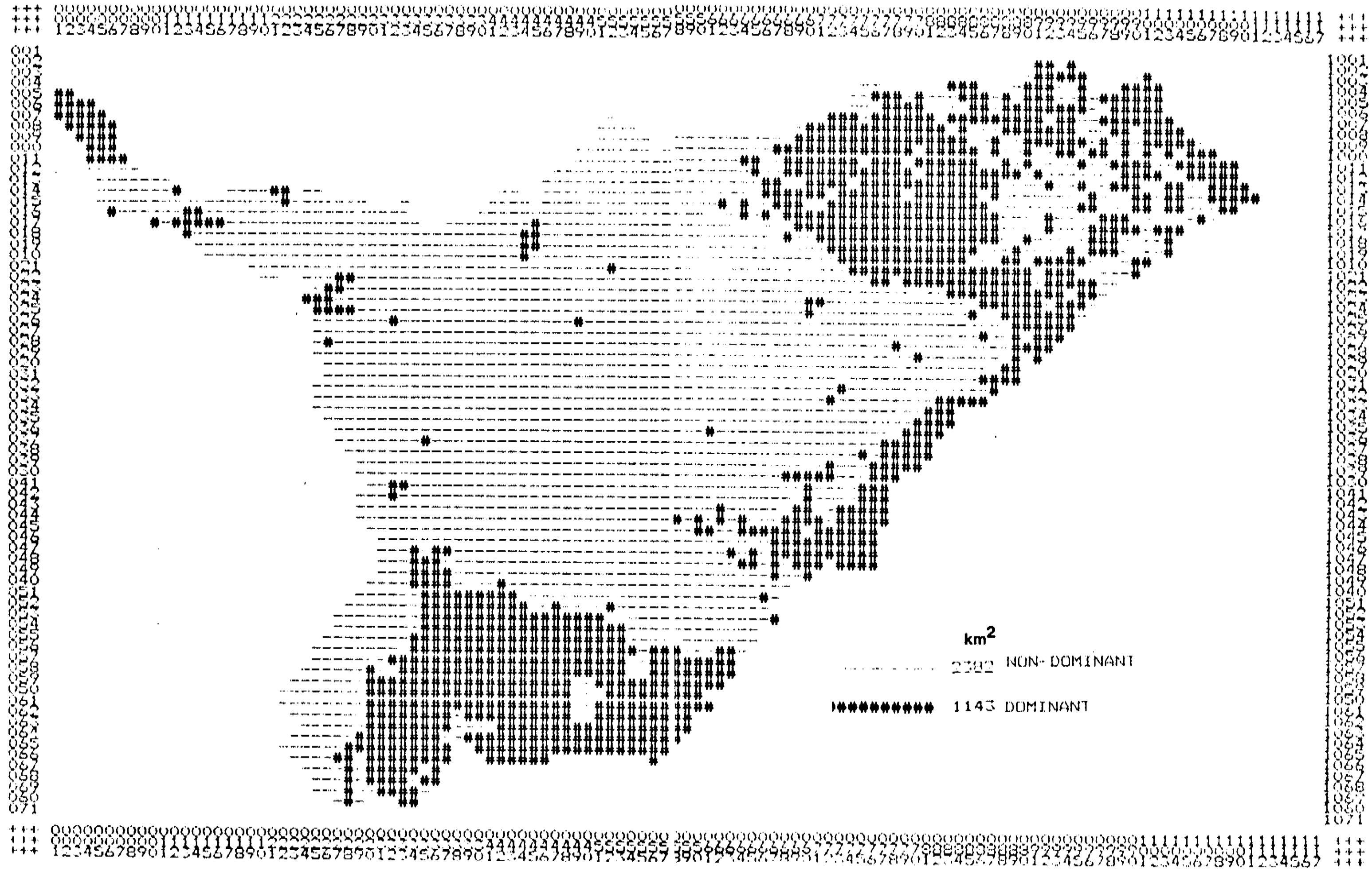


Figure 22: Areas where Soil Erodibility Is A Dominant Factor

5.2.1 Interaction Of Erodibility With Other Factors

Erodibility is not a critical determinant of soil erosion in most areas of Sondu Basin, owing to the high permeability of most of the soils. It is, however, a significant problem in the south-western section of western Kericho Plateau where impermeable Planosols and Vertisols are common. Additionally, Fluvisols, which occupy some parts of Lake Victoria Basin, have a high erodibility.

5.2.1.1 Erodibility - Human Influence (de)

Human influences of cultivation and livestock grazing on highly erodible soils in the south of the Sondu Basin, specifically Chepalungu and Embwem Locations, have elevated the soil erosion potentials of these areas. In these areas grazing occupies up to 64% of the land, while maize covers between 20 and 24% and bareground between 7 and 10% of the land area (Appendices H, I, and J). Human influence is an important factor of soil erosion potential in these areas of highly erodible Planosols and Vertisols. The former are poorly drained, having a very firm cracking clay immediately underlying a shallow topsoil of friable loam. When used by livestock, the permeability of these Planosols is further reduced because of overgrazing and compaction due to trampling, and therefore runoff increases. Vertisols, like Planosols, have low permeability and a high rate of runoff, and human use of these fine-textured soils increases their potential for soil erosion.

5.2.1.2 Comparative Findings

Working in Muranga and Kiambu Districts of Kenya, Lewis (1985) found that the volcanic soils of these areas have very low erodibility. Sondu Basin soils have parent rocks that are usually igneous, and often volcanic in origin; they posses high permeabilities and low erodibility values, with a few exceptions. Lal (1975) has indicated that in general, soils of high permeability experience little erosion. To a large extent, this relationship is true of the Sondu Basin. The whole of Mau Forest which possesses Andosols, Nitisols and Cambisols of high permeability also has low erosion potentials. On the other hand, Lal's assertion contradicts the findings in this study which have shown high soil erosion potential even in areas where permeability is high, as in eastern Kericho Plateau. It would seem that other factors may have more influence on soil erosion than permeability in these areas.

5.3 RAINFALL EROSIVITY AND SOIL EROSION IN SONDU BASIN

Rainfall erosivity is the ability of rain to cause erosion. The dissipation of raindrop energy and mass on the ground surface by rainsplash, depending on its kinetic energy, causes breakage and detachment of soil particles.

Where there is a marked seasonality of rainfall, with accompanying rainstorms of high intensity, as in Sondu

Basin, an increase of soil erosion potential occurs if agriculture is practiced, since often a period exists early in the growing season when the ground is devoid of vegetation. The concentration of rainstorms in short seasons is widespread in Sondu Basin. A wet period of high intensity rainfall alternates with a dry period. Erosion becomes severe in Sondu basin because soil moisture levels in the wet season are high, and the rainfall intensity rates often exceed infiltration rates. The situation is even more severe as the intense rains usually come in the early part of the growing season before sufficient plant cover is established.

The long rains in Sondu Basin begin around April after a five-month dry season. Bush clearing, burning, tilling, and seeding leave the land bare of vegetation, and when the rains arrive, they literally beat on the soil with their characteristic large drop sizes and cause soil particles to detach and be washed away. The short rains begin around October and, though their intensity is lower than that of the long rains, soil erosion potential is still high because of great antecedent soil moisture.

In general, rainfall decreases outwards from the centre of the Basin (Figure 11). This central part of the Basin is located in Saosa and Kerenga locations and the western part of South-Western Mau Forest (E3 and F3)); it receives annual rainfall amounts in excess of 1900mm per year. An exception to this systematic decrease of rainfall with distance from the centre of the Basin is the central part of Kisii Highlands which receives 1700mm rain per year. The lowest rainfall is received around the mouth of River Sondu near Lake Victoria (1100mm per year).

Erosivity is a dominant factor in all places where mean annual rainfall is 1500mm or more (Figure 23). According to the factor scoring technique used in this thesis, erosivity is the only dominant factor on the upper slopes of Mau Ranges, despite their receiving only 1300mm of rainfall per year.

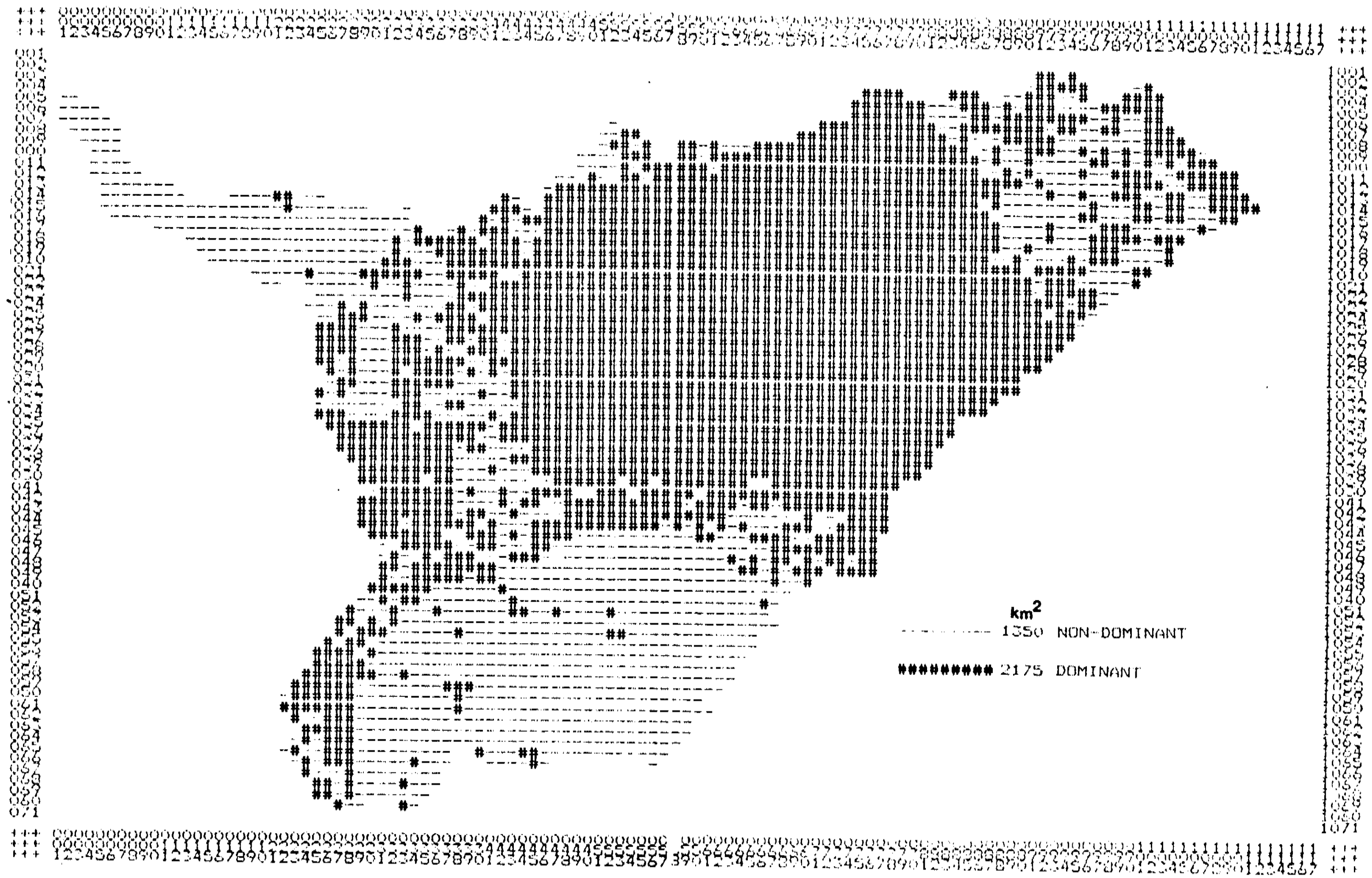


Figure 23: Areas where Erosivity Is A Dominant Factor

5.4 INTERACTION OF EROSIVITY WITH OTHER DOMINANT FACTORS

5.4.1 Erosivity - Vegetative Cover Association (bc)

The association of high rainfall erosivity and poor vegetative cover (bc) is found mainly in the tea estates of Saosa, Kerenga and eastern Buret. Table 5 shows the areal extent of tea grown in this zone by peasant and by commercial companies combined.

TABLE 5

Land Under Tea In The Erosivity-Vegetation Zone(bc)

	Hectares
Kerenga	1614
Saosa	3713
Konoin	4189
Buret	2232

Source: Ministry of Finance and Planning, Kenya.

Although most of the tea bushes grown in commercial estates provide a complete canopy, and therefore give excellent ground cover conditions for the soil, the role of tea in intercepting raindrops and thereby minimising soil erosion, is not apparent in the recognition of the vegetation cover as a dominant factor in this zone. The vegetation cover parameter used in this study for the determination of the factor scores is based largely on the relative protection provided by natural vegetation, but since most of the latter in the Locations described above has been cleared for the cultivation of tea and other crops, the land in this zone (bc) has been classified as land having little or no vegetation cover. Thus the common factor scores awarded the cells in this zone were 4 or 5. The soil erosion potential of this zone with its tea plantations might, therefore, be lower than the potential derived by the method employed in this thesis.

Besides the estate-grown tea, there is also tea produced by peasant farmers within this portion of the Kericho Plateau. On smallholdings, because of poor management practices in tea cultivation, sizable spaces exist between individual tea bushes, thereby allowing raindrops to reach the ground directly. Observations by the author have identified gullies of various sizes between tea bushes. The potential for soil erosion in these smallholdings on which tea is produced is more likely to correlate with the actual soil erosion.

5.4.1.1 Comparative Findings

The current study reveals that in Sondu Basin high soil erosion potentials occur in areas receiving at least 1500mm rainfall per annum. Moore (1979) reported that, for Kenya, the Kenya Highlands and Lake Victoria regions have a high rainfall erosivity and high soil erosion potential. However, within Sondu Basin alone, high soil erosion potential occurs only in the Highlands. Elwell and Stocking

(1976) have observed that the timing of erosive rains may be crucial to soil erosion in regions of pronounced seasonality of precipitation, specifically because of fluctuations in the proportion of ground covered by natural vegetation. The interaction of highly erosive rains and cultivated plants in determining soil erosion potential was also demonstrably important.

5.5 AMPLITUDE AND SOIL EROSION IN SONDU BASIN

One of the most important variables affecting soil erosion is slope; this is because the velocity and quantity of runoff passing over a piece of ground is strongly controlled by this slope property. In this thesis, amplitude of relief has been employed as the parameter representing slope. All other things being equal, as amplitude increases, runoff increases, and a greater amount of soil is washed downslope. The importance of amplitude-soil loss relationship is greater in tropical areas like Sondu Basin than in temperate areas because of the high energy impact of rain and, therefore, high rate of soil erosion.

The amplitude-soil loss relationship is significant in Sondu Basin because of the existence of steep slopes in many areas, especially on the Kisii Highlands and on Kericho and Nyabondo Plateaus (Figure 24). The western part of the Basin, along the drainage divide, stands out as a zone of

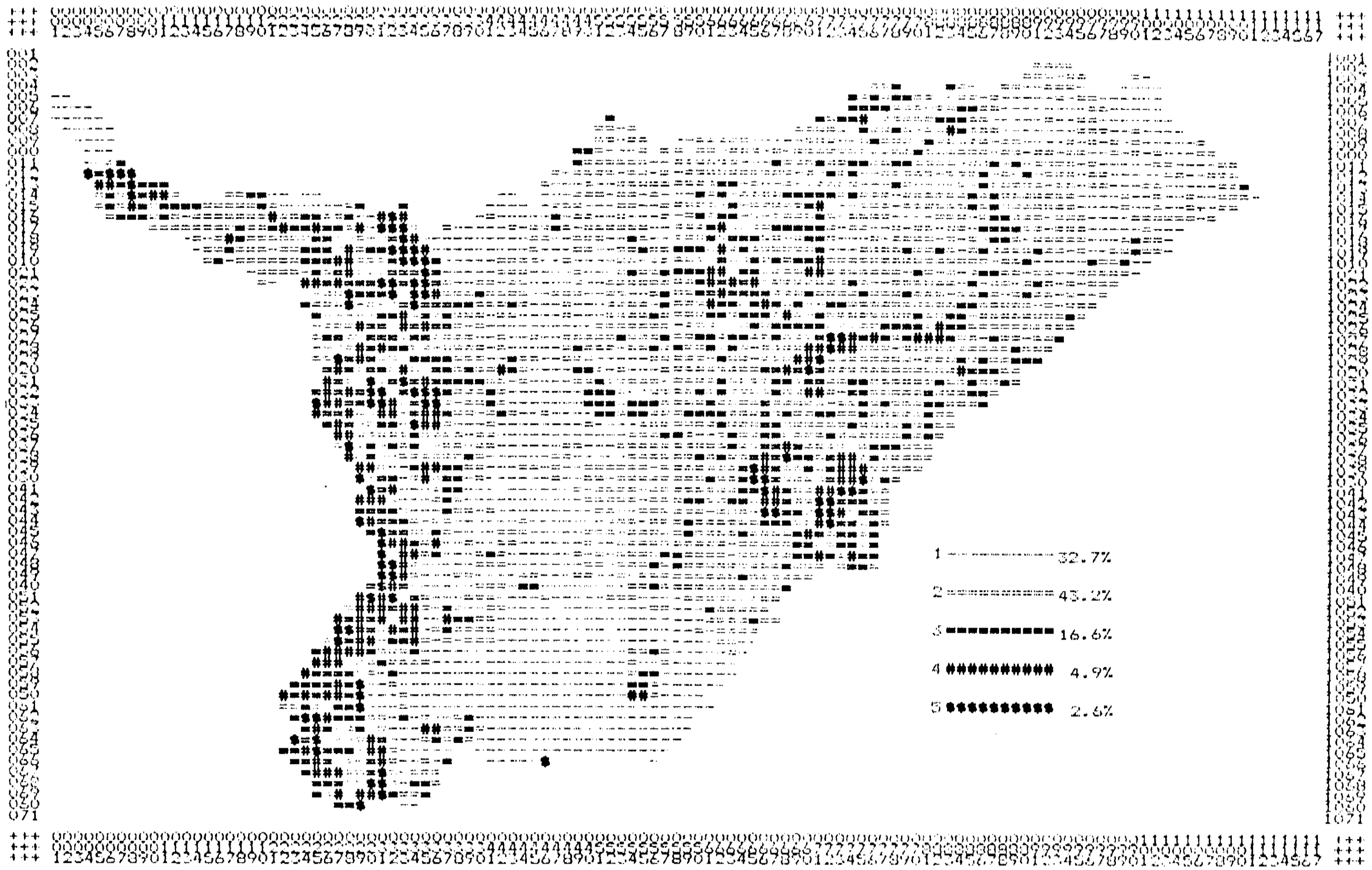


Figure 24: Distribution of Amplitude of Relief, according to Erosion Categories 1 to 5

high amplitude of relief. The zone runs from Tinderet Range in the south-west to Sondu market (1-C2) in the north (Figure 18), and is made up of a line of steep sided hills and scarps which are a part of the more extensive Kisii Highlands.

The eastern zone of the Sondu Basin contains pockets of high amplitude related to steep slopes of Koiwa Ridge. This zone lies between Koiwa (187-G4) and Cheptalal (188-G5).

Amplitude is a dominant factor mainly within Kisii Highlands and Eastern Kericho Plateau (Figure 25). Within those areas where amplitude is dominant, there are two main zones of high soil erosion potential. The first zone, in Kisii Highlands, extends all the way from Tinderet Range northwards to Marumbasi (21-D2). By contrast, in eastern Kericho Plateau, only the limited area of steeply sloping land on Koiwa Ridge possesses a high erosion hazard.

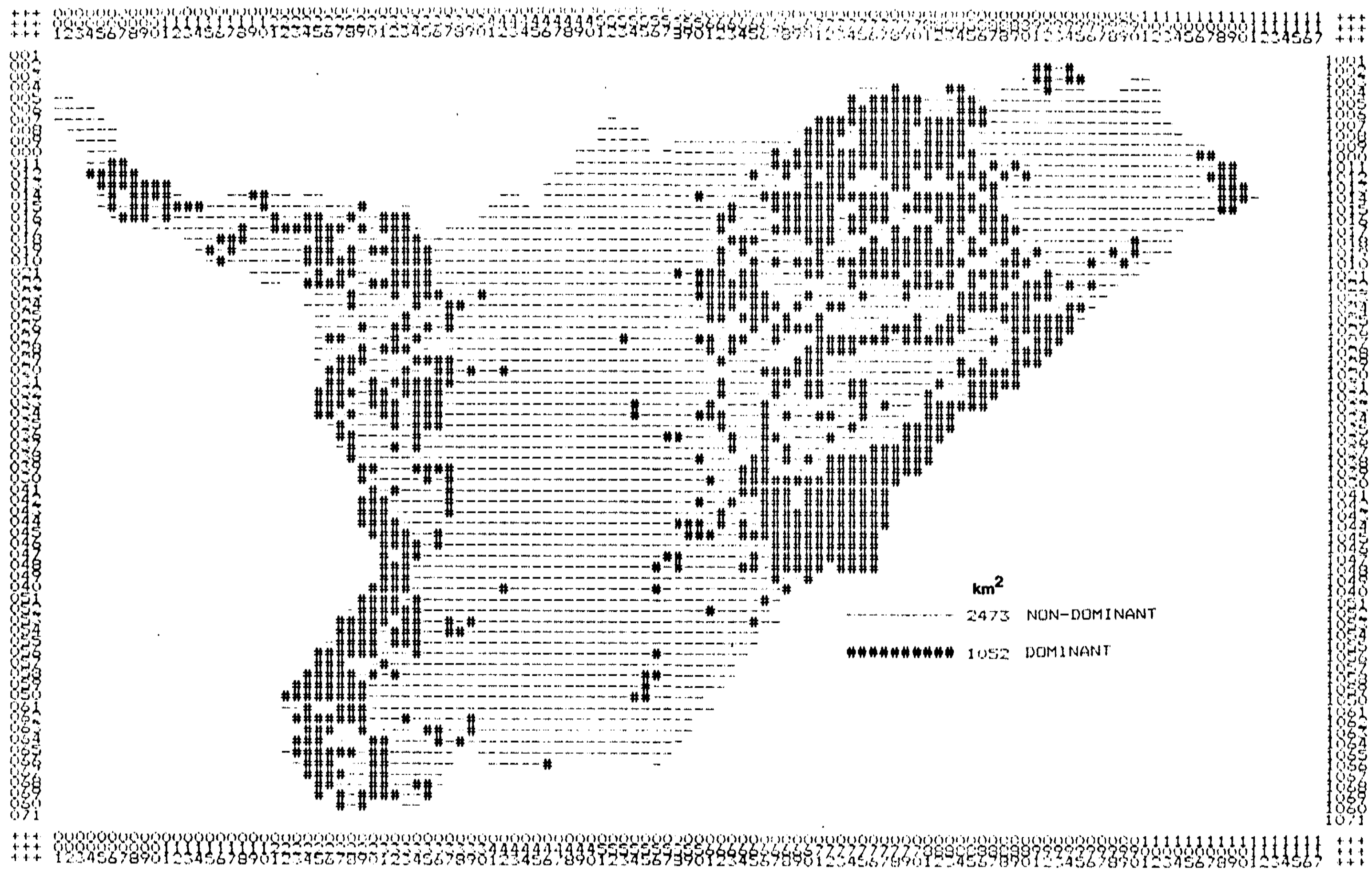


Figure 25: Areas where Amplitude Is A Dominant Factor

5.5.1 INTERACTION OF AMPLITUDE WITH OTHER DOMINANT FACTORS

5.5.1.1 Amplitude - Vegetative Cover (ac)

In Western Kericho Plateau (Figure 20, D7 and E7), there are several small areas where amplitude and vegetative cover are the only dominant factors. In these localities a poor vegetative cover of short grass communities interspersed with cultivated plots has increased the soil erosion potential of the steeply-sloping land.

5.5.1.2 Amplitude - Erosivity - Vegetative Cover (abc)

The removal of the natural vegetation cover has exposed the steep slopes of Kisii Highlands and Koiwa Ridge to the direct impact of raindrops, and consequently, to significant soil loss. Landuse maps of Kisii and Kericho Districts, Appendices I and M, (within which the Kisii Highlands region occurs), show that 53% of Borabu, 35% of North Mugirango, and 64% of Waldai and Buret Locations are under grazing. Domesticated livestock, especially cattle grazing is clearly the most widespread land use in this part of the Basin and, therefore, a major cause of natural vegetation reduction, which has augmented the role of amplitude in increasing soil erosion potential. The presence of completely bare ground on steep slopes greatly increases the impact of gradient on soil erosion. Therefore, it is disturbing to note that there are sizable areas of steepland in Borabu, North Mugirango and Buret Locations, where 12%, 23% and 10% respectively are bare ground (Appendices N and J).

In Koiwa area (G4), the high rainfall erosivity and poor vegetative cover have supplemented the influence of slope in determining soil erosion potential. Landuse maps of the area (Appendices H to J), indicate that Koiwa region has 20% of its land area under maize, 50% under grazing and 10% bare ground. The cultivation of maize, a row crop, on the steep slopes of Koiwa Ridge increases the impact of gradient on soil erosion. Roads, tracks and footpaths constituting 4% of the Koiwa area also accelerate the soil erosion process, especially on steep slopes.

5.5.1.3 Amplitude - Erosivity - Vegetative Cover - Human Influence (abce)

The association of the four dominant factors of amplitude, erosivity, vegetative cover, and human influences in Sondu Basin occurs in several areas within Kisii Highlands, extending from Mikomoni (100-D5) to the northern margins of the Basin. Human exacerbation of the soil erosion hazard on steep slopes in Kisii Highlands is manifest in such activities as cattle grazing and cultivation, both of which are important here. The Mikomoni area, possessing this association of four dominant factors, has the highest erosion potential in Sondu Basin, with a compound score of 20.

5.5.1.4 Comparative Findings

The findings in this thesis on the significance of amplitude as a determinant of erosion potential in Sondu Basin largely agree with those of previous workers. Geomorphic studies by Kirkby (1969) indicate that sediment transport increases with slope steepness. Studies by Hudson and Jackson (1959) in Zimbabwe found that, although slope gradient is an important determinant of erosion, its significance is increased where there are high intensity rains. Thomas et al. (1981) found that the greatest soil erosion in the Machakos District of Kenya occurs on steep slopes. Similarly, Dunne (1977), working in the Athi-Amboseli area of Kenya, demonstrated that soil erosion increases with slope angle. On the other hand, Lewis (1981) could not establish any relationship between soil loss and slope gradient in western Nigeria.

5.6 VEGETATION COVER AND HUMAN INFLUENCES ON SOIL EROSION

The removal,reduction or deterioration of a vegetation cover is primarily controlled by human activities. This is true of Sondu Basin, where forests have been cleared for cultivation of crops and rearing of livestock. Two categories of human-induced effects exist on farmlands in Sondu Basin. First, accelerated erosion often occurs on land that is cropped annually. Many of the farming activities, such as clearing, burning, ploughing, planting, and weeding, that are associated with sedentary agriculture in Sondu Basin augment the soil erosion risk. A second critical effect is a reduction in the natural vegetation cover. A vegetation mantle impedes and intercepts falling raindrops, thereby reducing their ability to cause erosion at the soil surface. The interception of raindrops is achieved mainly by living plants, but also by litter on the ground. Vegetation is apparently the most important factor in minimising soil erosion, because plants protect the ground surface from rainsplash, reduce the velocity of overland flow, and through improving soil structure and permeability, increase the infiltration capacity. Ground surface roughness, owing to dead leaves and twigs, retards and divides water flow into small fractions, and correspondingly inhibits the development of erosive sheetflow. Furthermore, plant roots tend to keep the soil *in situ*, by increasing its apparent cohesion and its resistance to water erosion, hence reducing the amount of surface wash.

In the Sondu Basin, a sizable agricultural population (evident through building counts in settlements, Figure 28), coupled with the system of local cash cropping and grazing, often leads to deterioration and reduction in the natural vegetation cover. Owing to this plant cover reduction, the fertility of the soil has been diminished significantly, and large areas that once yielded a source of food supply have become unproductive. With the progressive degradation of the vegetation mantle, the soils of Sondu Basin have been increasingly exposed to ground surface compaction and water erosion, as rills and gullies, ensues. Additionally, the reduction in the vegetation cover due to farming practices has altered the flow regime of Sondu River and its tributaries. With increased stream flow, there is often enhanced lateral erosion of channels. Related to the problem of soil erosion by running water is the physical exhaustion of the soil organic matter and nutrients. Sondu Basin farming practices, and the widespread cutting of firewood and burning of charcoal, deplete the soil and convert farmlands into marginally productive areas. All these processes outlined can be seen over a period of years in a cycle, in which a reduction in the vegetation cover depletes the organic content of the A horizon of the soil, leading to a lower infiltration capacity and increased overland flow. Generally, two classes of soil degradation problems may be distinguished in Sondu Basin. There are short-term problems, which occur during and immediately after specific human activities on the farmlands, and long-term problems, which tend to persist for at least a decade. The degree of seriousness of these anthropogenic soil erosion problems is dependent upon the nature of human activities on farmlands. The major agricultural activities in Sondu Basin which have a bearing on soil erosion are: (i) Clearing of the land, which includes slashing and felling

(ii) Ploughing, sowing, planting and weeding (iii) Grazing of cattle, sheep and goats.

5.6.1 Cultural Farming Practices in Sondu Basin

The human activities in Sondu Basin are essentially an expression of the agricultural system. The latter represents an interaction between physical and socio-economic factors with the farmer being the link. An appreciation of the role of cultural farming practices in relation to vegetation cover is necessary in order to understand the anthropogenic impact on soil erosion in Sondu Basin.

Landuse within the Sondu Basin, as in other rural areas of Kenya, is primarily oriented towards small-scale subsistence farming, based on the rotation of bush fallows (chapter one, p.2), scattered plots of maize, sorghum, millet, beans, peas, sweet potatoes, cassava and vegetables. In addition to subsistence crops, there are cash crops and livestock. The principal cash crop is tea, which, as mentioned previously, is grown either in large estates or by smallholders. Maize is cultivated both as a cash crop and food crop. Livestock are permitted to graze anywhere on uncultivated land.

Traditionally, the land was allowed to rest for at least eight years after harvesting crops for two or three consecutive years. This was to enable the recovery of nutrient reserves that had been exploited. With the expansion of population and the accompanying increasing demand for food, the traditional bush fallowing cycle has been significantly reduced in time. The net result is increased soil erosion in the Sondu Basin. Cropping practices and conservation measures such as growing of cover crops and mulching (specifically, the covering of the soil with crop residues such as maize stalks or straw), add humus to the soil, reduce evaporation and surface runoff, thus improving moisture relationships. These agronomic measures are hardly practiced in Sondu Basin, even though many farms are small which makes such measures feasible and practicable.

The combined influence on soil erosion of farm practices that currently exist in Sondu Basin is described and explained below:

5.6.1.1 Fallowing

Jacks (1956), Gourou (1953, 1956), Ruthenberg (1970), and Greenland (1976) all stress that the traditional agricultural system of shifting cultivation in tropical areas achieved an ecological balance. This balance was maintained between agricultural practices and the physical environment under low population pressure. Today, with increasing population densities, there is growing pressure on the land, resulting in an ecological imbalance. In Sondu Basin, agricultural changes resulting from augmented population pressure include the shortening of the fallow period, the extension of the area under cultivation, and the planting of row crops in consecutive years. One serious effect of the shortening of the fallow period, during which various indigenous plants provide some ground cover affording protection to the topsoil, is increased soil erosion by rainsplash and surface runoff.

5.6.1.2 Bush Clearing and Deforestation

In some areas of Sondu Basin, especially in the tea growing zone, the mechanisation of agriculture, including the mechanical clearing of bush or forest and the use of machinery in soil preparation, has greatly increased the susceptibility of the land to erosion. Observations by the author in Mau Forest indicated the frequent use of crawler tractors with tree pusher and root-rake attachement for deforestation. The tree pusher is mounted above a root-rake, which travels through the soil removing tree roots, stumps and debris. Considerable soil disturbance takes place during this operation. Kunkle and Dye (1981) reported a study in Peru which compared the effects of slush-and-burn clearings with those observed from bulldozer clearings. Crop yields were higher and soil properties were more favourable in slash-and-burn clearings than on land cleared by tractors. Bulldozer clearings resulted in increased bulk densities and reduced infiltration rates in soils. However, the clearing of most small areas of bush in Sondu Basin is undertaken manually by smallholders. It is accomplished with simple implements, such as machetes and axes. The operation is primarily carried out in the dry season and, by itself, does not cause much erosion. Large scale deforestation is highly mechanised, however, and increases soil erosion mainly as a consequence of soil compaction by the machines.

5.6.1.3 Burning

Slash-and-burn techniques have been a component of traditional shifting cultivation in tropical Africa. In Sondu Basin, the burning of cleared timber and undergrowth is often an accompaniment of bush removal. Burning is also used annually to eliminate crop residues from the ground, and to encourage fresh growth of fodder for livestock, and even to flush out small game. Roose and Asseline (1978) observed that burning the crop residue increased soil erosion several fold compared with unburnt control. Burning is part and parcel of the farming practice in Sondu Basin and therefore a cause of accelerated erosion. As a consequence of fire, mineral nutrients, such as potassium and phosphorus, are added to the soil, and nitrogen content is increased by raising the soil pH (Lal, 1975). Timber burning in forests increases the pH by at least three units, thereby promoting alkalinity (Goudie, 1981). However, fire exposes the soil to erosion by destroying the leaf litter, soil organic matter and soil structure. Despite the initially porous soil surface mixed with ash after vegetation burning, the bare ground is quickly compacted by raindrop impact of heavy rains, and soil infiltration rates become very low, thereby facilitating water erosion (Lal, 1985).

5.6.1.4 Tilling

Tilling the soil in the Sondu Basin is still achieved by smallholders use of hoes or ox-ploughs. Hoeing is the most traditional method of soil preparation and the least likely to encourage soil erosion. Increased adoption of mechanised ploughing, with the greater availability of tractors, has amplified soil disturbance and increased its potential for erosion.

5.6.1.5 Planting

After the land is cleared and tilled, the traditional system of intercropping of arable crops is implemented. In Sondu Basin, the use of hoes for digging the surface is an activity associated with planting. Root crops, such as sweet potatoes and cassava, are planted in heaps and mounds. Vegetables, and grains such as sorghum and millet, are planted by digging or scratching the ground. Maize is normally monocultural, being sown as a single row crop. The heaps, mounds, and scratched surfaces, intermingled with seeds, seedlings and sprouts, are directly exposed to heavy rains during the period immediately following planting, and this is a particular soil erosion hazard on sloping land.

5.6.1.6 Weeding

To a great extent weeds, like cultivated plants or shrubs, fairly effectively protect the soil from raindrop impact, but these are plants that grow where they are not wanted. Weeding on Sondu Basin arable farms is usually conducted three times each year. The maize crop itself is weeded at least twice in a single growing season. Weeding, performed manually with a hoe, exposes the soil to raindrop impact and also creates innumerable small shallow hollows in the soil surface that collect rainwater and seem to accelerate the development of minor rills (Okigbo, 1975).

5.6.1.7 Livestock Keeping

Although many farmers in Sondu Basin restrict the movement of their livestock by tethering, most farmers leave their animals to wander unrestrained, consequently they invariably cause damage to crops and to natural vagetation. Goats are notorious in this regard, and their browsing, grazing and trampling possibly constitute a serious erosion hazard in the Basin, especially when their numbers and movements are uncontrolled. Trampling by livestock, converts upslope animal footpaths to runoff channels, inducing gully erosion.

The intensity of all the above mentioned human activities is manifest in an overall reduction in the vegetation mantle within Sondu Basin, and in increased soil erosion in its high erosion potential areas.

5.6.2 Main Areas of Vegetation and Human Influence

The human activities discussed above are greatest where settlement densities are high. The main areas of high settlement density are on Kericho Plateau. It is these regions that possess the least amount of natural vegetation. The lowest settlement densities are found in Mau Forest, and in the western and south-western parts of Sondu Basin. Figures 26 and 27 show respectively the distribution of the ranking of vegetation cover and areas where the vegetation cover (because of its nature and paucity) is a dominant causative factor of erosion. Likewise, Figures 28 and 29 show respectively the distribution of the ranking of settlement and areas where settlement is a dominant causative factor of erosion.

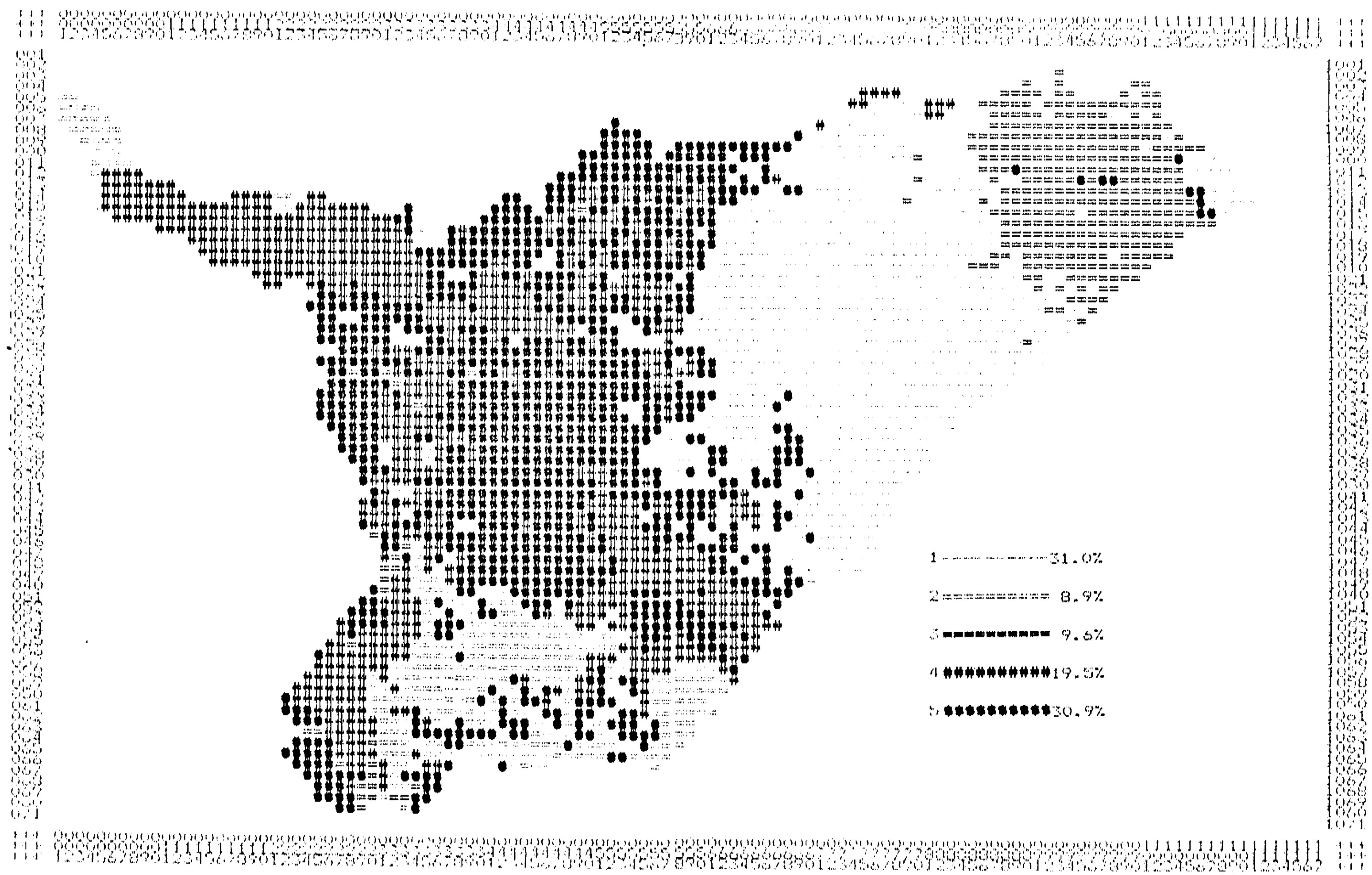


Figure 26: Distribution of Vegetation Cover, according to Erosion Categories 1 to 5

5.6.2.1 Settlement - Vegetative Cover

The main region of the Basin where only high settlement density and low vegetative cover combine to increase the potential for soil erosion is in central Buret Location (D4, D5, E4, and E5). Table 6 shows the current land use in Buret Location and demonstrates the magnitude of human interference in this part of Sondu Basin. With the exception of forest, hedges and woodlots which collectively constitute only 6.9% of Buret, the rest of land uses have

TABLE 6

Landuse In Buret Location, 1983

	Percentage Area Occupied
Grazing	63
Maize	15
Tea	5.0
Bare Ground	5.5
Roads, Tracks, and Footpaths	4.6
Hedges and Woodlots	6.0
Forest	0.9

Source: Mnistry of Finance and Planning, Kenya.

high erosion potential.

The following is a discussion of the land use in Buret which is associated with high potential erosion. The effects of these types of land use on soil erosion applies both to Buret and other areas where such land uses are found in Sondu Basin.

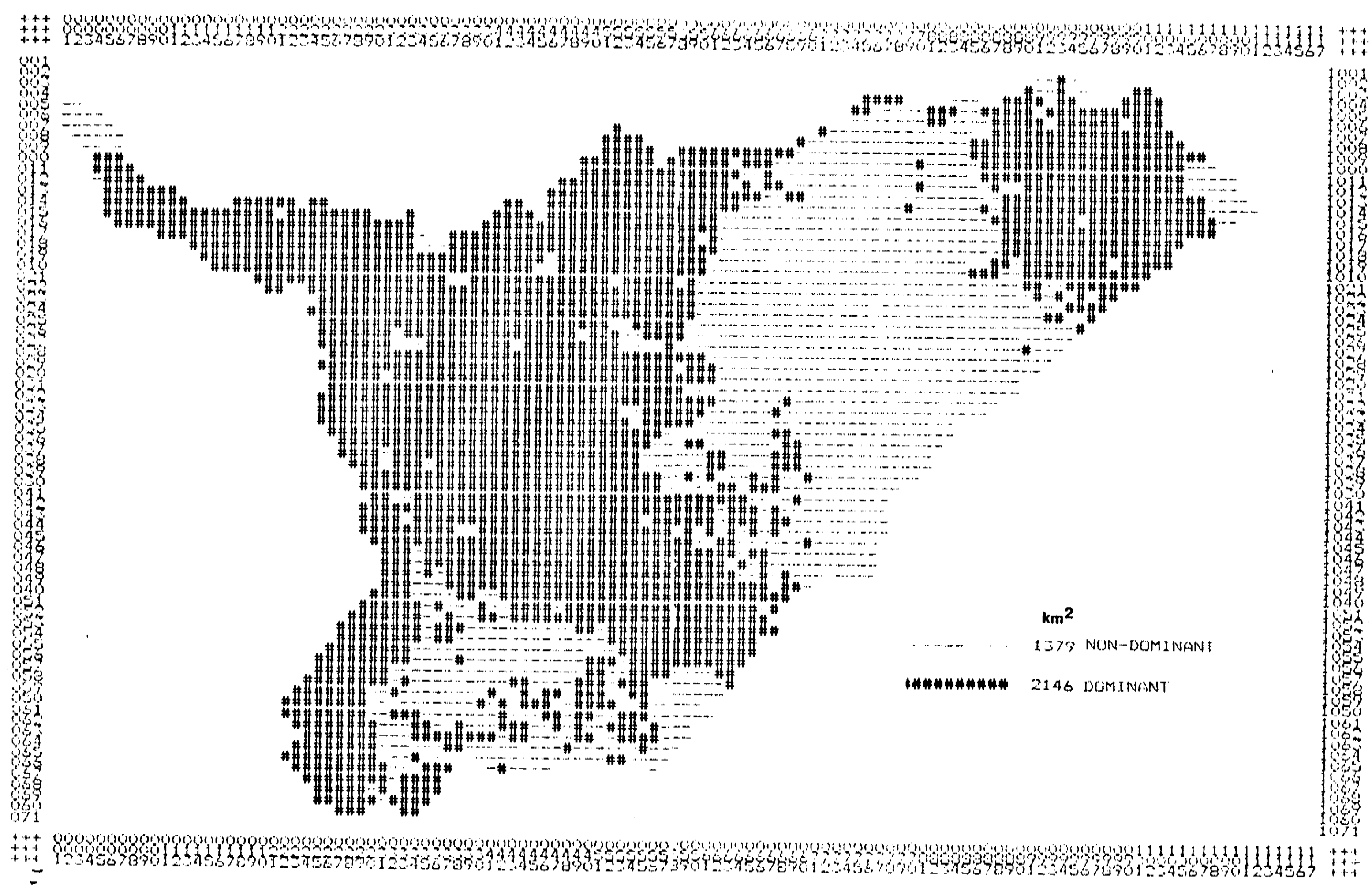


Figure 27: Areas where Inadequacy of Vegetative Cover Is A Dominant Factor

5.6.2.2 Grazing

Grazing occupies the largest area in Buret, with 63% of the land under it. Grazing and browsing by animals reduce vegetation cover consequently exposing the soil to raindrop impact, which results in splash erosion. Trampling of the soil surface by livestock compacts the soil and reduces its infiltration rate thereby increasing surface runoff. The latter washes the soil downslope and also detaches soil particles as it flows.

Traditionally, the Kipsigis people who live in Buret Location were mainly pastoralists. They kept large numbers of cattle, because the wealth of a man was judged by the quantity rather than the quality of his cattle. In the process of modernisation of the rural economy, the Kipsigis people now grow various food and cash crops, like tea and pyrethrum, but they have not abandoned their traditional custom of keeping large numbers of cattle. Thus, cultivation goes on side by side with the rearing of large numbers of mainly unproductive cattle. This overstocking has led to overgrazing, especially in Buret Location where up to 64% of the land is used directly for livestock rearing. Most of the grazing land is gullied, and severely so where cattle trails lead to watering points.

5.6.2.3 Maize

Maize constitutes 15% of Buret land use and has become almost a monocrop in Kericho District (Ojany and Ogendo, 1973). Being a row crop, maize accelerates soil erosion (Okigbo, 1975; Morgan, 1979; Batie, 1983). Maize grown in Buret is mainly for sale to other parts of Kenya where high population densities have increased the demand for food. As population pressure mounts, more and more land is being used for growing maize, either by clearing forests or by converting some of the grazing land. Furthermore, the high prices paid by the Kenya Government for this crop are encouraging more farmers in Buret to put larger areas of their land into maize cultivation. Unfortunately, the maize is frequently grown on hillsides, and more often than not farmers cultivate up and down the slope, thereby accelerating soil erosion. Moreover, the clean weeding which is done on maize fields (for higher yields) and the incomplete canopy which this crop provides the ground further exacerbate soil erosion.

5.6.2.4 Tea

Tea occupies about 5% of the land area of Buret. This crop has been demonstrated to contribute low soil loss in Kericho (Othieno and Laycock, 1977). Whereas the findings of Othieno and Laycock are true for well managed tea estates (in Saosa, Kerenga, and Kericho Township Locations), observations by the author of tea grown by smallholders in Buret and similar areas showed lack of continuous canopy coverage (unlike company-owned estates), and erosion is common between individual tea bushes.

5.6.2.5 Bare Ground, Roads, Tracks, and Footpaths

These areas are devoid of any form of vegetation cover. Most inclined tracks and footpaths leading to markets, streams or connecting homes eventually turn into gullies due to surface water erosion. New footpaths are then started beside gullied ones, but when these too are eroded, large gullies are created. Rural tracks also become gullied in the same way as footpaths, but the resultant gullies are much bigger.

5.6.2.6 Erosivity - Vegetative Cover - Erodibility - Settlement (bce & bcde)

Other areas in Sondu Basin where human influences and vegetation cover in association with other dominant factors (bce and bcde) have caused erosion potential to be high are in Waldai, Kericho Township, and Chagaik Locations (Figure 20). Table 7 shows the current land uses in these high potential areas of erosion. The processes by which accelerated soil erosion is induced under these various land uses have been discussed in relation to Buret Location.

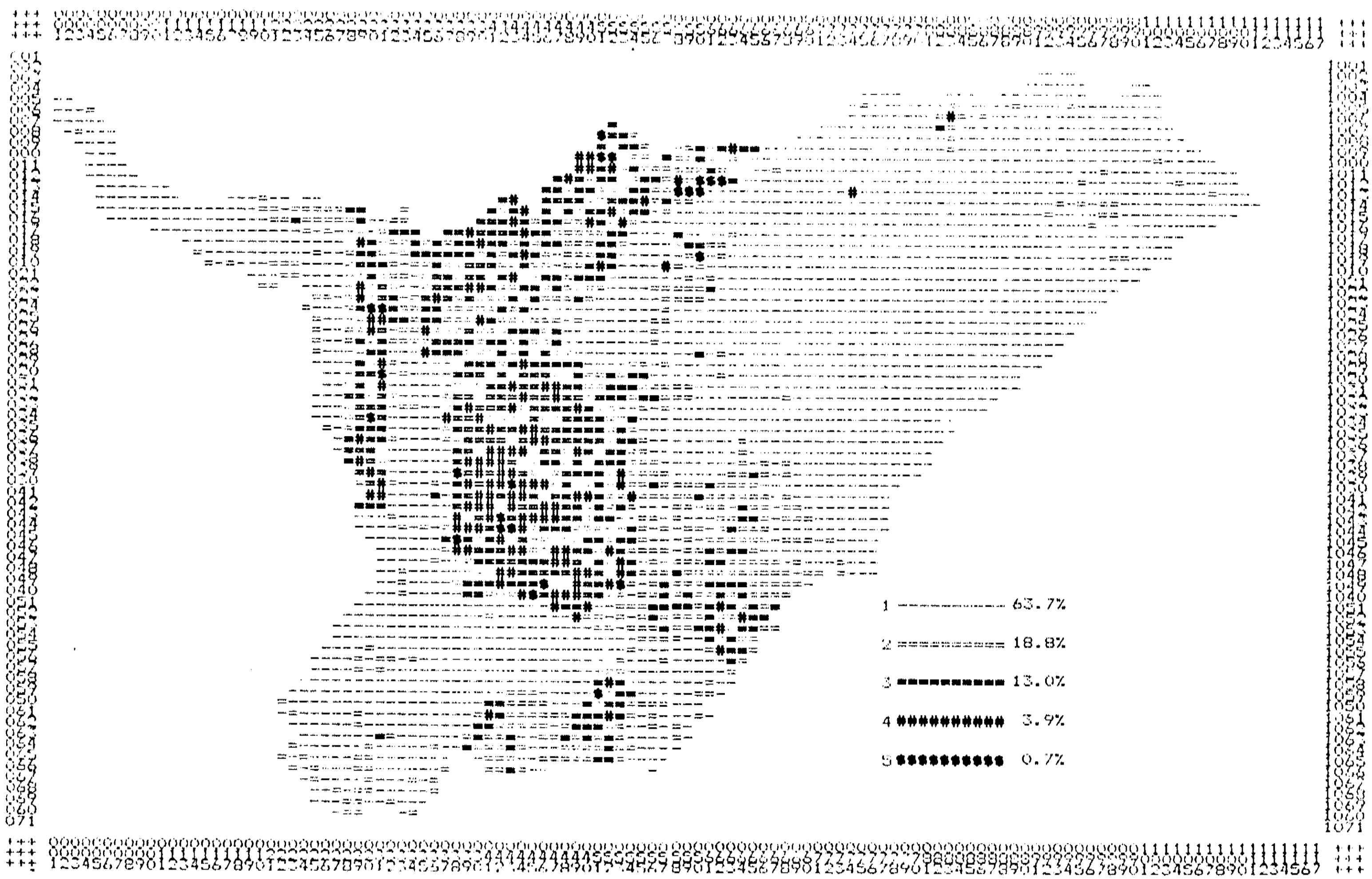


Figure 28: Distribution of Settlement, according to Erosion Categories 1 to 5

TABLE 7

Landuse In Waldai, Kericho And Chagaik Locations, 1983 By Percentage Of Land Area

	WALDAI	KERICHO TOWNSHIP	CHAGAIK
Grazing	42.0	22.0	17.0
Maize	23.2	10.7	-
Tea	-	34	4.5
Bare Ground	7.0	7.0	7.0
Roads/Tracks/Footpaths	2.0	4.0	2.0
Hedges and Woodlots	13.0	-	-
Forest	-	7.3	63
Others	12.8	15.0	6.5

Source: Ministry of Finance and Planning, Kenya.

5.6.2.7 Comparative Findings

Findings from this study have demonstrated that areas of high soil erosion potential are very closely associated with the regions of sparse vegetation and high settlement density. These results agree with the findings of other workers elsewhere. Research by Christiansson (1981) in Dodoma, Tanzania demonstrated that erosion by water was slight on densely-vegetated inselbergs but greater on bare pediments. Moore _et al_. (1979), working in the Machakos District of Kenya, discovered that runoff and soil losses were very high from a bare, eroding, subsoil but low on a recently ploughed grassed site. Also in the Machakos District,Thomas _et al_. (1981) found soil erosion to be higher on cultivated land within densely populated localities than in other areas. Working in various parts of south-west Kenya, Dunne (1979) reported that sediment yield

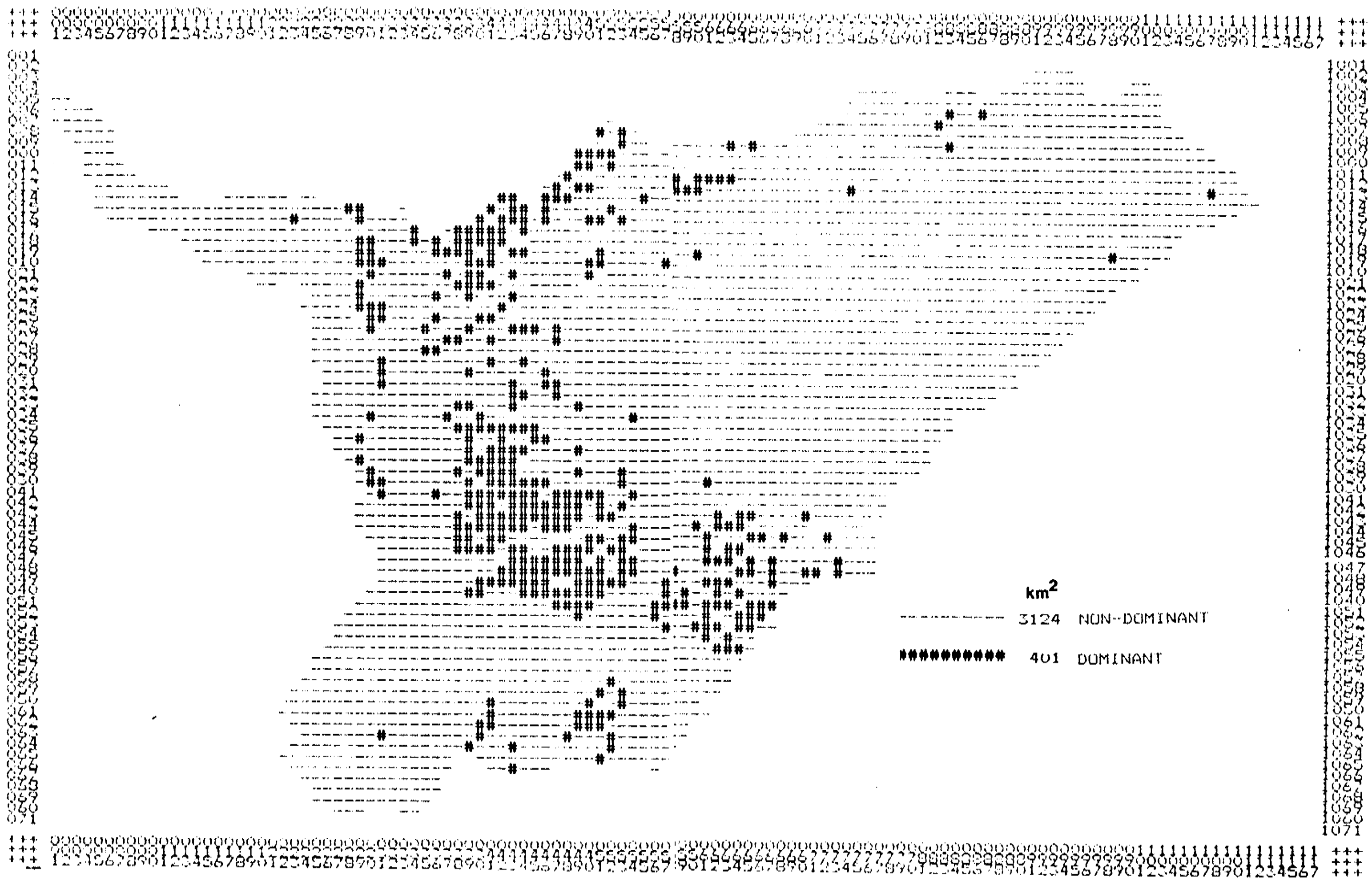


Figure 29: Areas where Settlement Is A Dominant Factor

from agricultural catchments was far higher than that from partially or completely forested ones. Elwell and Stocking (1976) stated that, in Zimbabwe, soil erosion is closely related to the percentage of vegetal cover of the ground.

The current investigation in Sondu Basin has demonstrated that high potential for erosion exists in areas where maize occupies at least 10% of the land. These areas are in Buret (51%), Waldai (23.2%), Kericho Township (10.7%) and Koiwa Ridge area (20%). This finding is in agreement with those of other earlier workers. Okigbo (1975), Morgan (1979) and Batie (1983) have all found that fields under maize tend to possess very high soil loss.

Since most of the areas of high erosion potential in Sondu Basin are where human settlement is dense and natural vegetation cover has been cleared, the findings of this thesis largely agree with others in eastern Africa. However, this study has shown high erosion potentials even in areas of large tea estates within Kericho Township, Kerenga, and Saosa. The tea bushes in most of these company-owned tea estates in Sondu Basin possess a complete canopy (unlike smallholder tea farms in other parts of the Basin) and have been indicated as yielding a low soil loss (Othieno and Laycock 1977). Lewis (1985) also found low soil losses from tea bush mantles in Muranga and Kiambu Districts of Kenya. The difference in the findings regarding soil erosion in tea estates in Sondu Basin and elsewhere in Kenya may be due to the fact that the model used in this thesis regarded all cultivated land as having minimal vegetation cover.

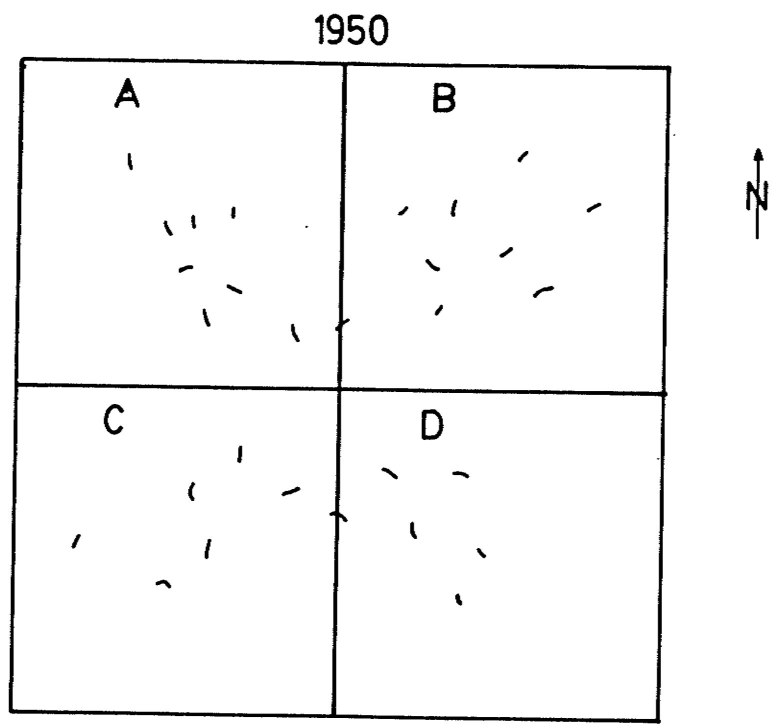
In Sondu Basin soil erosion potentials are high in areas with large percentages of grazing, e.g. Buret (Table 6), Kericho Township, and Chagaik Locations (Table 7). In Kenya, Pereira et al. (1967) observed that trampling of 20 yearling cattle on one acre for two days induced severe runoff and soil erosion even from a field with continuous grass cover. Christiansson (1981) observed that when a protected catchment was opened for cattle grazing, sediment yield rose by 50%. Moore et al. (1979) used a portable rainfall simulator to show that higher rates of soil erosion occurred on bare, overgrazed land than on arable fields under similar precipitation intensity conditions. Lastly, working in south-western Kenya, Dunne (1979) observed maximum sediment yields from those drainage basins experiencing heavy grazing pressure. In this thesis high soil erosion potentials have likewise been found in areas where grazing is the major land use.

5.7 TESTING THE MODEL

After locating areas of high potential erosion and their causative factors, it was deemed necessary to test the model used in this thesis by producing evidence of actual soil erosion occurrence in Sondu Basin localitites highlighted as possessing a severe erosion risk.

5.7.1 Measurement of Gullies From Aerial Photographs

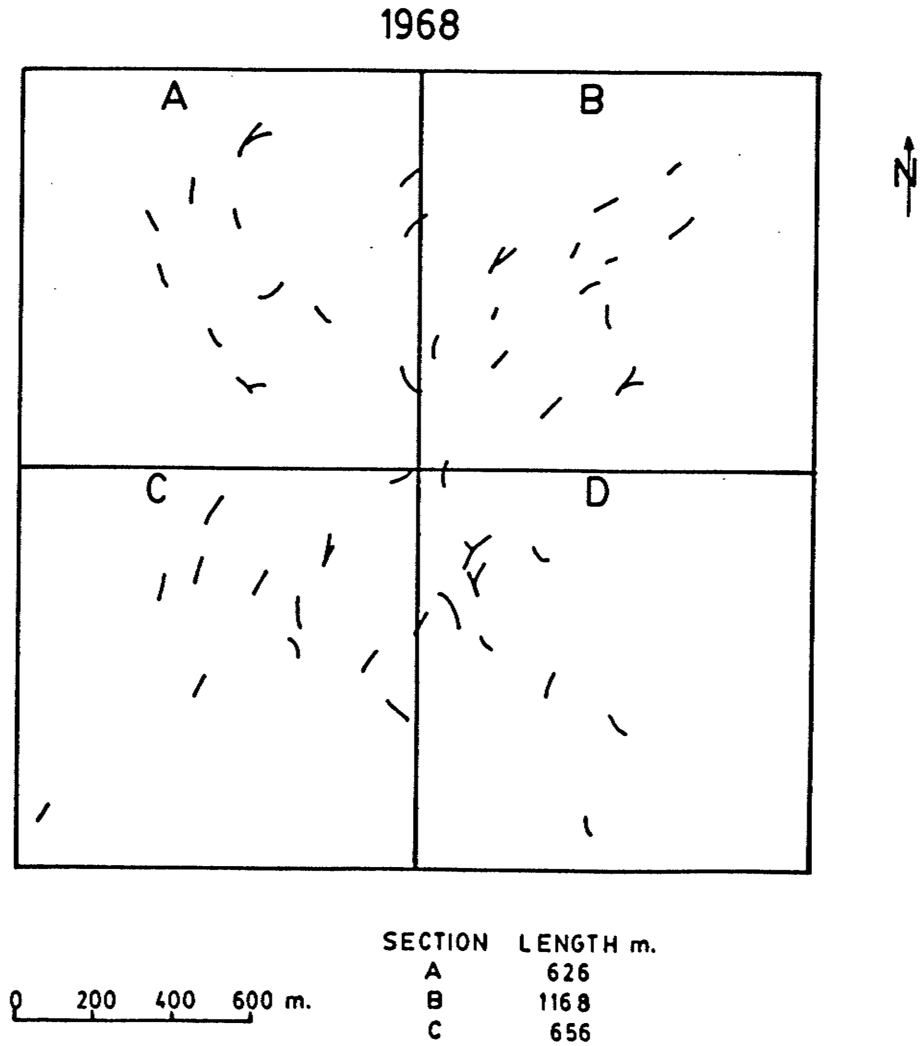
The existence of gullies is evidence of soil erosion by concentrated water flow. Furthermore, the increase of gully lengths over a period of time demonstrates that headward gully erosion continued during that timespan. The technique of erosion assessement using gully length measurements from vertical aerial photographs has been successfully undertaken by Stocking (1972) in Zimbabwe. A comparison of gully lengths from vertical aerial photographs taken at different times was undertaken for a locality within Sondu Basin. The latter has very little photographic coverage, and the author was fortunate to find stereopairs of the same locality of high potential erosion for 1950 and 1968. It was not possible to identify the same gullies in the two stereopairs. This may be due to the fact that some gullies had since been comouflaged by vegetation and apparently disappeared on the air photographs, whilst new ones had developed on different sites. It was feasible to measure the lengths of all visible gullies within a common four square kilometres in the two stereopairs. This was accomplished using a Chinagraph pencil while studying the photographs under a mirror stereoscope. Figures 30 and 31 show precise plots of gullies on four adjacent one kilometre grid squares for 1950 and 1968 based on the aerial photographic interpretation.



0 200 400 600 m.

SECTION	LENGTH m.
A	286
B	356
C	324
D	260
TOTAL	1226

Figure 30: Gully Lengths From 1950 Aerial Photograph



SECTION	LENGTH m.
A	626
B	1168
C	656
D	770
TOTAL	3220

Figure 31: Gully Lengths From 1968 Aerial Photograph

The total lengths of gullies had increased in each of the four grid squares within the 18 year period. Aggregate gully length for the locality increased from 1226m in 1950 to 3220m in 1968, an increase of about 163%. The four square kilometre locality studied covers an area between Kabianga (36-E3) and Kitio (45-E3), and according to the factor scoring in this thesis, belongs to Group 5 (Above Average) erosion potential. Worse gullying may be expected, therefore, in Groups 6 and 7.

5.7.2 Suspended Sediment Yield Increases

As described in Chapter 2, sediment yield is sometimes employed as a measure of soil loss within drainage basins. Variations in suspended sediment yield within Sondu Basin can be obtained from data at the sediment and streamflow monitoring station 1JG1 at Sondu Trading Centre (1-C2, Figure 18). 93% of the Sondu Basin area is situated upstream from this monitoring station. The latter monitors all the sediment yield from the areas of high erosion potential in the Basin. Therefore, it can be asserted that the general overall increase in suspended sediment yield at Sondu Trading Centre between 1949 and 1984 (Figure 32) is a consequence of inducement of soil erosion, particularly in those areas of high erosion potential.

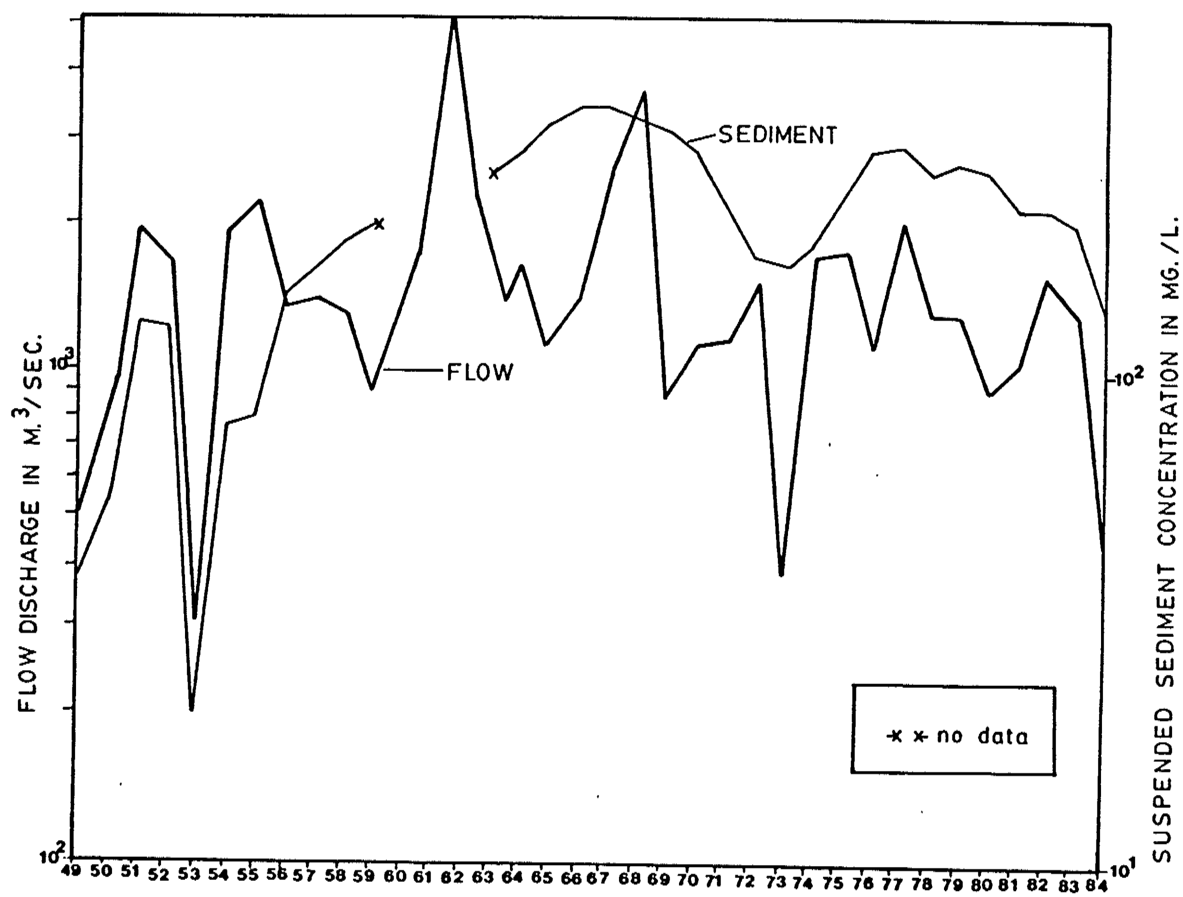


Figure 32: Sediment And Flow Discharge, Sondu River at Sondu Trading Centre 1949-1984

Chapter VI

SUMMARY AND CONCLUSIONS

6.1 INTRODUCTION:

The general objective of this thesis is to investigate soil erosion potential in Sondu Basin, western Kenya. The specific aims of the thesis are:-

1. To locate areas of high erosion potential within the Sondu Basin.
2. To determine the particular dominant or causative factors of erosion in those areas identified as possessing high erosion potential.

In Chapter I the physical, demographic and historical background to soil erosion in Kenya is furnished. The role of traditional shifting cultivation and bushfallow in soil erosion control is examined. Additionally, the impact of population expansion is discussed in terms of its effects on soil erosion. Chapter II presents a literature review of concepts and methodology pertinent to soil erosion research. It discusses the factors determining soil erosion, and provides a detailed survey of different approaches to studying the problem. A physical geographical account of the study area, Sondu Basin, is given in Chapter III, with special reference to its soils, geomorphology and hydroclimate. Chapter IV discusses the methodology and data sources of the study. The latter has adapted Stocking and Elwell's (1973) factorial analytical approach at the national scale to the study of soil erosion potential in a medium-sized catchment. The utility and procedures of Map Analysis Package, a new computer mapping system, are explained. The rationale for selection of a parameter for each of the five causative factors analysed in the research is provided. Finally, the distribution of areas of different erosion potential and the patterns of their dominant factors are ascertained through computer mapping. Chapter V offers a description and explanatory discussion of the spatial distribution of high soil erosion potentials in Sondu Basin. It gives an account of each erosion factor, its distribution, and the interaction between dominant factors in determining the severity of erosion risk in the high potential areas. Finally, a brief presentation of the evidence of actual soil erosion in Sondu Basin is made by measurements, in one locality, of gully lengths from aerial photographs, as well as by suspended sediment yield data, over a period of three and a half decades, obtained from one monitoring station.

6.2 RESEARCH DESIGN

Identification of areas of high erosion potential is seen as an essential step towards soil conservation in Sondu Basin. The conceptual framework for this thesis establishes erosion potential as being dependent upon the interaction between physical and human factors, with the latter playing a major role. As population pressure on the land increases, human-induced actual soil erosion is expected to accelerate.

The technique used in this thesis is fundamentally that employed by Stocking and Elwell (1973) in their study of soil erosion risk in Zimbabwe. A simple method of factor analysis to obtain a composite model of soil erosion potential was described; spatial variations in erosion potential were then mapped. The method is predicated on the identification of major determinants of soil erosion. These causal factors are rainfall erosivity, soil erodibility, vegetation cover, slope gradient, and human influence on the land. Parameters were selected, for measurement purposes, for each of these five factors. Mean annual rainfall was employed as a parameter of rainfall erosivity. Amplitude of relief was employed as a parameter of slope gradient. Relative permeability of soil groups has been used as a parameter for soil erodibility. In the case of vegetation cover, the vegetation map of western Kenya enabled the identification of five different categories of plant cover, varying from 'forest' to 'forest clearings and cultivation communities' (the latter generally possessing little natural vegetation but much cultivated land and intermittently bare land). In the absence of detailed local demographic data, settlement was used as a parameter for the factor of human influences, which are predominantly agricultural pursuits in this rural, agrarian Basin. The parameter of settlement was quantified in terms of building counts.

Employing a new Geographic Information System computer package, Map Analysis Package, for each one kilometre square area in a fixed grid pattern of Sondu Basin, the five parameters were individually scored on an ordinal scale 1 (low) to 5 (high) in terms of soil erosion potential. Following this, the aggregate (compound) scores were then derived. The choice of seven categories of compound scores, and their mapping, enabled a detailed impression of variations in soil erosion risk throughout Sondu Basin to be obtained.

In line with the stated objectives of the thesis research, only those areas of high erosion potential were identified and subsequently examined in terms of principal factors determining their erosion risk. The dominant factors of soil erosion potential were mapped separately, and their role in determining high risk areas was ascertained by an overlaying technique. A letter-annotated map (Figure 20), revealing the association of dominant factors in various areas of high erosion potential in Sondu

Basin, was produced. This map was the basis for subsequent explanatory accounts of the research findings (Chapter V).

6.3 FINDINGS

The analysis of the results of the soil erosion potential mapping investigation in Sondu Basin progressed in three stages:

1. A survey of the distribution of erosion potential within the Basin was briefly undertaken.
2. The spatial distribution of areas of high potential erosion was examined.
3. The distribution of dominant factors of erosion and their spatial associations within the high potential areas was explained in terms of specific local and more general determinants of erosion risk.

6.3.1 Overall Distribution of Erosion Potential

In terms of overall erosion potential in Sondu Basin, a number of observations can be made about its spatial distribution. There is a general tendency for soil erosion to be high in the central and western parts of the Basin and much lower towards the Basin outlet (Lake Region) and headwaters (Mau Ranges). The major areas of high potential erosion are on western Kericho Plateau and in Kisii Highlands. Areas of low potential erosion are mainly in Mau

Forest, Mau Nature Reserve, and south-west Mau Forest, as well as the Lake Victoria Basin.

6.3.2 High Potential Areas Of Erosion

Three groups (5 to 7) of high potential erosion were identified and mapped (Figure 20). These groups are described as Above Average (5), High (6), and Very High (7), and are based on compound scores of 15-16, 17-18 and 19-20 respectively (Table 3). For each specific area identified on the map, the particular association of dominant factors, from among amplitude of relief (a), rainfall erosivity (b), vegetation cover (c), soil erodibility (d) and human influence (e), is recorded cartographically and summarised in tabular form (Table 8).

TABLE 8

Summary of High Potential Erosion Regions

Category of High Potential Erosion	Dominant Factors	Location
1 (Above average)	abc	Boraku, N. Mugrango, Western Waldai, Koiwa Ridge (Konoin locations)
	bce	Kericho Township, western Chagaik, and eastern Waldai
	bc	Eastern Buret, western Konoin, Saosa and Kerenga locations
	ce	Central Buret
	ac	North-western Chepalungu location (around Chemosot and Kokwa)
	cd	North Mugirango (Gekonge and Musaria areas)
	acd	Borabu (Kinem land area) and Reitago
	cde	Chepalungu (around Kapkelei and Kamungeno)
	de	Chepalungu (around Kanusin and Manga)
2 (High)	bc	Around Kaminjewet (64-E4) Around Cheimen (74-F4) Around Chemalal (65-F4) Around Chemelet (82-F4) Kerenga - Mau Forest border

Category of High Potential Erosion	Dominant Factors	Location
	bce	Around Gaparok (14-E2) Kericho-Kerenga border, north of Kapsuser (176-F2) Around Kericho town (176-F2) Between Kapsoit (3-F1) and Cheptenye (8-E2)
	ce	Around Kipsamoi (73-D4), Kapsimbiri (92-D4), Yaganek (129-E6), and Mindililwet (44-D5) in Buret.
	abc	Around Musaria (33-C3) Around Mugura Estate (113-D5) Tinderet Range (Borabu location) Koiwa (187-G4)
	abce	Area around Marumbasi (21-D2), Kebenet (30-D3), Nyatwaruru (34-D3), Nyakenyomasye (52-D3) Around Ikonge (66-D4)
	acd	Around Kenini Ranch (154-D7)
	de	Between Manga (153-E7) and Kanusin (143-F6)
	cd	Between Pala (247-C3) and Gekonge (41-C3)
3 (Very High)	bcde	Area around north Kapmaso (32-E3)

Category of High Potential Erosion	Dominant Factors	Location
	abce	Between southern Itibo (76-C4) and Western (89-D4) Around Mikomuri (100-D5)
	abc	Parts of Koiwa area (187-G4)
	bce	Eastern Saosa (F3) near Mau Forest

Key: a = amplitude
b = erosivity
c = cover
d = erodibility
e = human influence

6.3.3 Dominant Factors of High Potential Erosion

The dominant factors of soil erosion in the areas of high potential erosion have been mapped along with the erosion groups in figure 20. Their particular associations, together with areas of occurrence, are itemized in Table 8. The analysis has disclosed that slope, expressed as relief amplitude, is a major cause of soil erosion in Kisii Highlands, and Koiwa Ridge. Rainfall erosivity is an important factor in the central and northern sections of western Kericho Plateau. The factor of vegetation cover is identified as a major determinant of erosion in virtually all the high potential areas; this implies that inadequate ground cover protection of the soil is widespread in areas with partial or almost complete removal of natural vegetation for farming. Erodibility is not a crucial determinant of high soil erosion potential in the Basin except in its southern part where Planosols and Vertisols predominate. According to the parameter used to measure human influence in this research, this variable is a dominant factor of high erosion potential in western Kericho Plateau and Kisii Highlands because of agriculture, which demands the clearing of vegetation for the cultivation of crops and rearing of livestock.

6.4 RECOMMENDATIONS

In this thesis, areas of high potential erosion in Sondu Basin have been located. The dominant factors which cause them have also been identified and mapped. Thus, the potential for erosion can be reduced if the impacts of these factors can be minimised. On the basis of this, the following recommendations are made with a view to reducing the soil erosion potential in the high risk areas identified.

6.4.1 Cultivated Land

For Sondu Basin, agronomic measures, which maintain a protective vegetative cover over the soil, are more successful than mechanical measures, such as terracing, in reducing actual soil erosion and in lowering the potential for the latter. In general, agronomic measures directly protect the ground surface from erosional processes such as rainsplash, sheetwash, rilling, and gullying, yet they are less expensive than mechanical measures, which are costly in terms of labour and money for both installation and maintenance (Morgan, 1979). Nevertheless, on steep cultivated land in the Machakos Hills in Kenya, mechanical measures, especially terracing, are widespread and, according to Moore (1979), insufficient attention has been given to conservation strategies involving crop management and grassland improvement.

6.4.1.1 Cropping System

In the traditional agriculture of Sondu Basin, intercropping of arable crops, some of which are planted and harvested at different times, ensures that the soil is usually protected by a vegetative cover. Currently, crops such as maize are planted in widely-spaced rows, exposing the soil more to erosion than are non-row crops, such as cowpeas, forage grasses, and sweet potatoes, which are planted closer together and provide adequate soil cover. While monocropping with maize, as practiced in Sondu Basin, can lead to severe soil erosion, this is much reduced if the cereal is intercropped with protection-effective leguminous crops such as cowpeas, or even with sweet potatoes. It is therefore recommended that the practice of intercropping be encouraged as an essential component of the farming system of the Sondu Basin.

Cropping systems which cater for minimum tillage, and which permit maximum periods of soil cover, are generally desirable with respect to erosion control. This can be done by practicing strip cultivation, with only the seed line cultivated, or with wider cultivated strips alternated with grassed strips. Since zero tillage, as practiced in North America, is expensive for farmers, in terms of the high cost of herbicides, it is recommended that strip farming be practiced in these high potential areas.

6.4.1.2 Weeding

In the tropics, clean weeding seriously exposes the soil to erosion, unless the crop canopy is thick enough to protect the ground. It is therefore recommended that weed supression by mulching or by close cropping, be practiced.

A mulch, or crop residue cover, simulates the effect a growing vegetation mantle, in that it directly protects the soil from rainsplash and erosive running water. Provided that the mulch is dense and covers at least 70% of the soil surface, weed suppression and erosion control are likely to be achieved.

6.4.2 Grazing

The practice of leaving livestock to wander, which is commonplace in much of Sondu Basin, causes damage to crops and natural vegetation by their unrestrained grazing, browsing and trampling, and therefore exacerbates soil erosion. It is recommended that livestock should be restricted by fencing or tethering and that rotational grazing, entailing sequential movements of stock from one pasture to the next, be practiced. Rotation will be effective, however, only if the dangers of traditional overstocking are recognised.

6.5 SUGGESTION FOR FURTHER RESEARCH

This thesis has identified areas which possess high potentials for soil erosion in the Sondu Basin. It has also ascertained the principal factors causing high erosion risk in those areas. However, it is apparent that there is need for more detailed research in specific areas of Sondu Basin in order to understand how these physical and human determinants of soil erosion interact, particularly through land use and land management.

A significant advance in the comprehension of soil erosion risk in Sondu Basin could be achieved by undertaking detailed field studies in three or four small areas of Kisii Highlands and Kericho Plateau that have been identified as possessing very high erosion potentials. Application of the same methodology used in this thesis, but with the derivation of more refined parameters for erosion factors, especially slope gradient, ground cover, and 'human influence' (utilising measures of specific agricultural activities, such as livestock densities for grazing) could be very valuable. Additionally, field research is needed to measure soil losses from bounded erosion plots directly installed in fields under different ground covers and monitored throughout the growing season. These experimental plots should be established on the highly erodible Planosols and Vertisols. Agronomic research in Sondu Basin should be undertaken on crop combinations that demonstrably reduce soil erosion, as well as on the economic feasibility of the practice of no-tillage cultivation without herbicides, which was used to control erosion in traditional farming.

6.6 SUMMARY

This thesis has produced a broad soil erosion potential survey of Sondu Basin, examining individual erosion factors and their interactions, and acquiring an insight into the present state of this hazard in the Basin. Essentially, this research lays the groundwork for local studies in greater depth selected from a wide range of field conditions. Nevertheless, this thesis does endeavour to furnish information, through its series of maps, on soil erosion potential within Sondu Basin.

Developing countries need inexpensive methods of identifying areas of high erosion risk, so that they can make maximum use of their limited resources to conserve their soils. Soil conservation strategies should therefore be directed to the areas identified as having a high erosion hazard. The main achievements of this thesis research are the identification of those areas in the Sondu Basin where the soil erosion potential is high, and the elucidation of dominant factors responsible for their high risk. Knowledge of these areas should help planners in Kenya direct their efforts to biological, especially agronomic, measures of soil erosion control in specific areas of severe erosion hazard in Sondu Basin.

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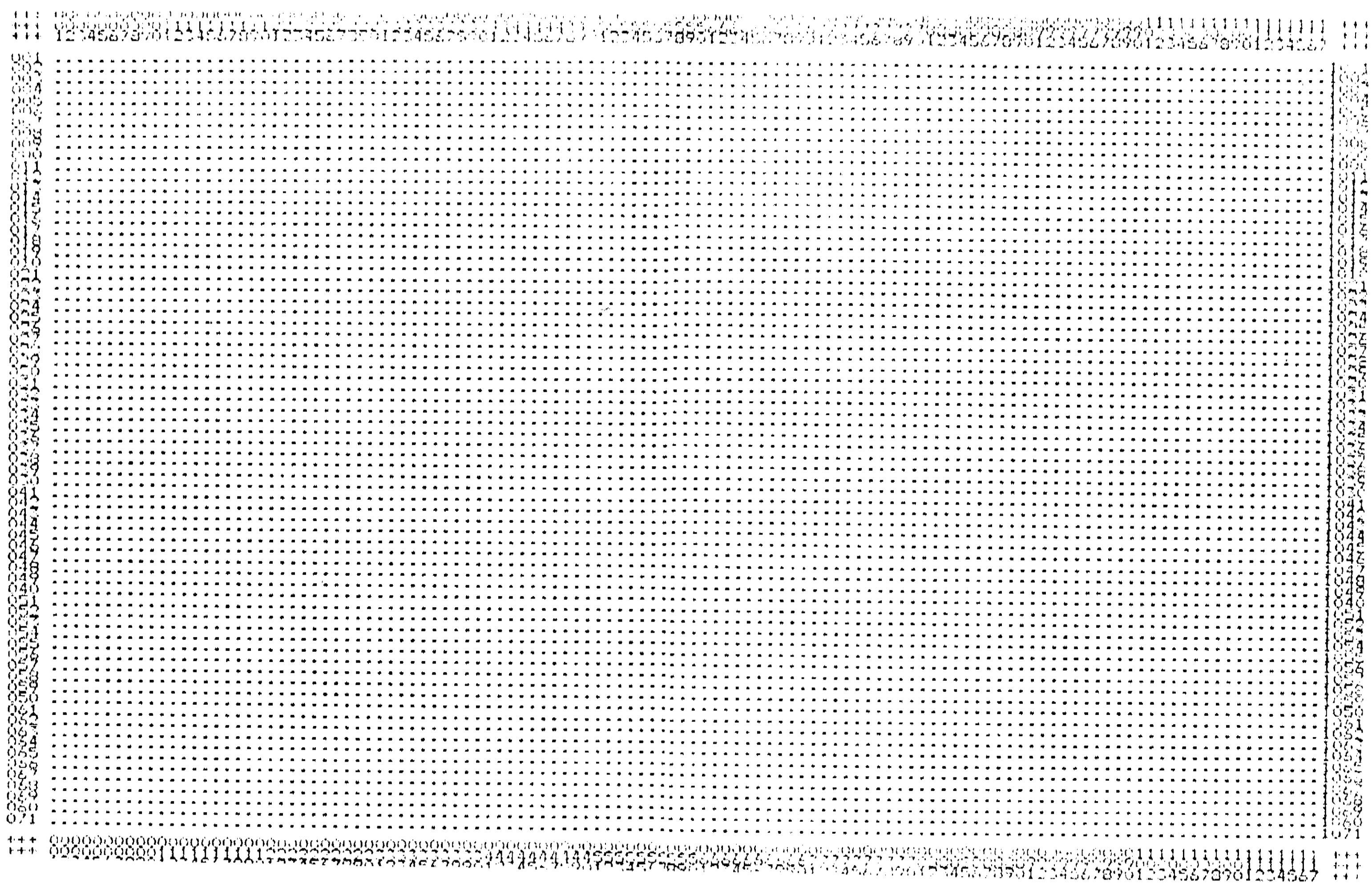
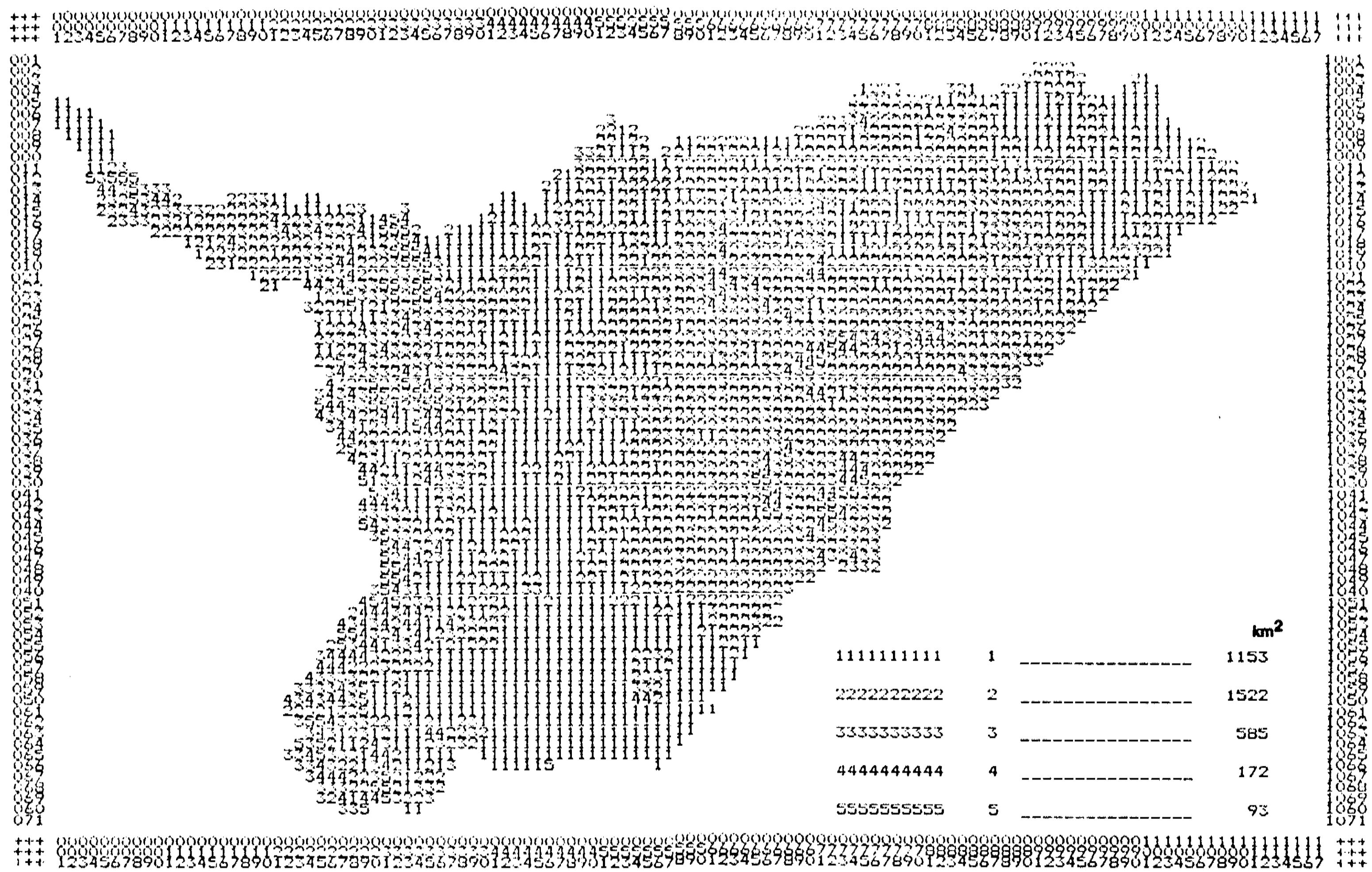
APPENDICES

Appendix A



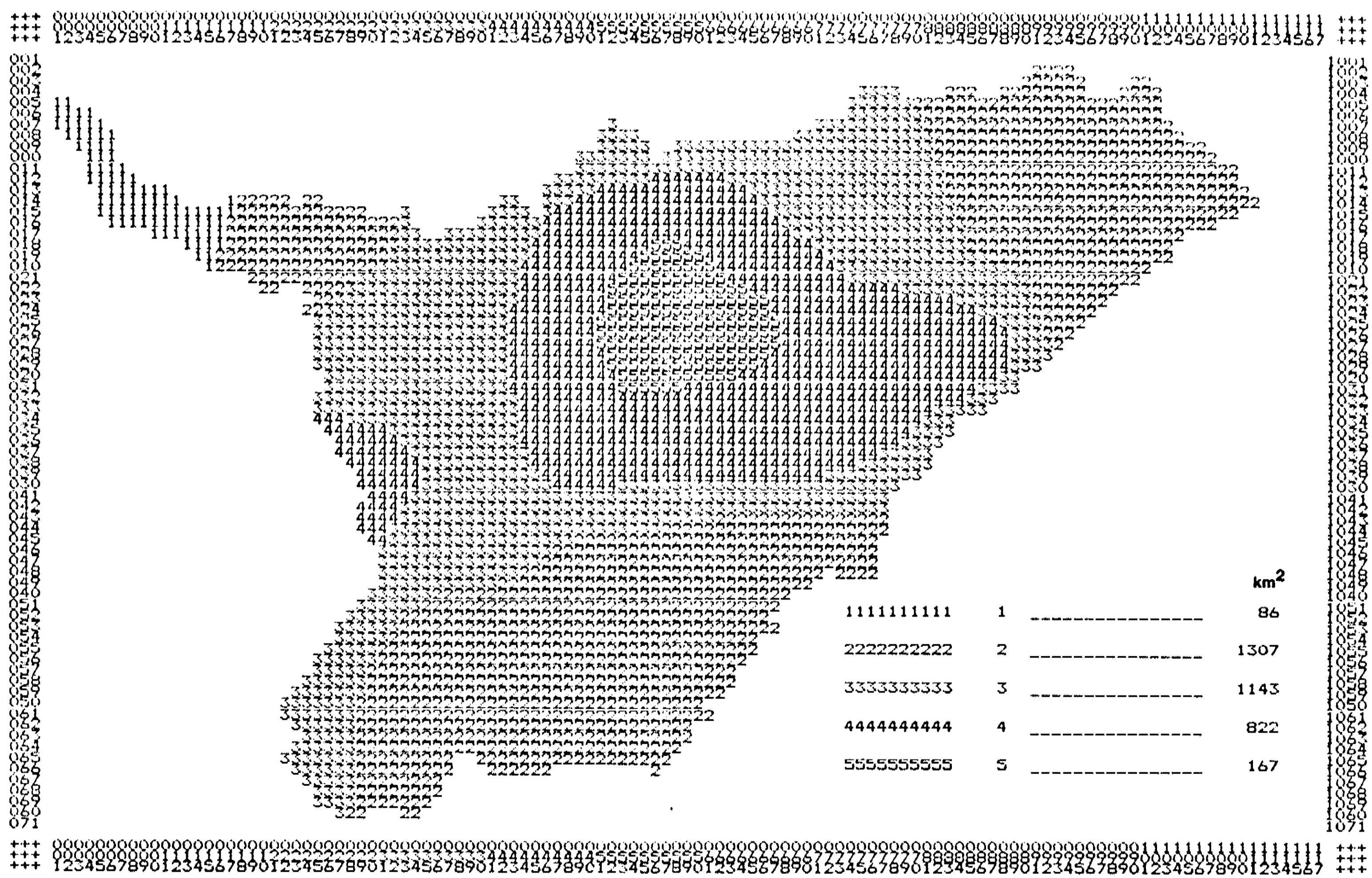
Grid Plan

Appendix B



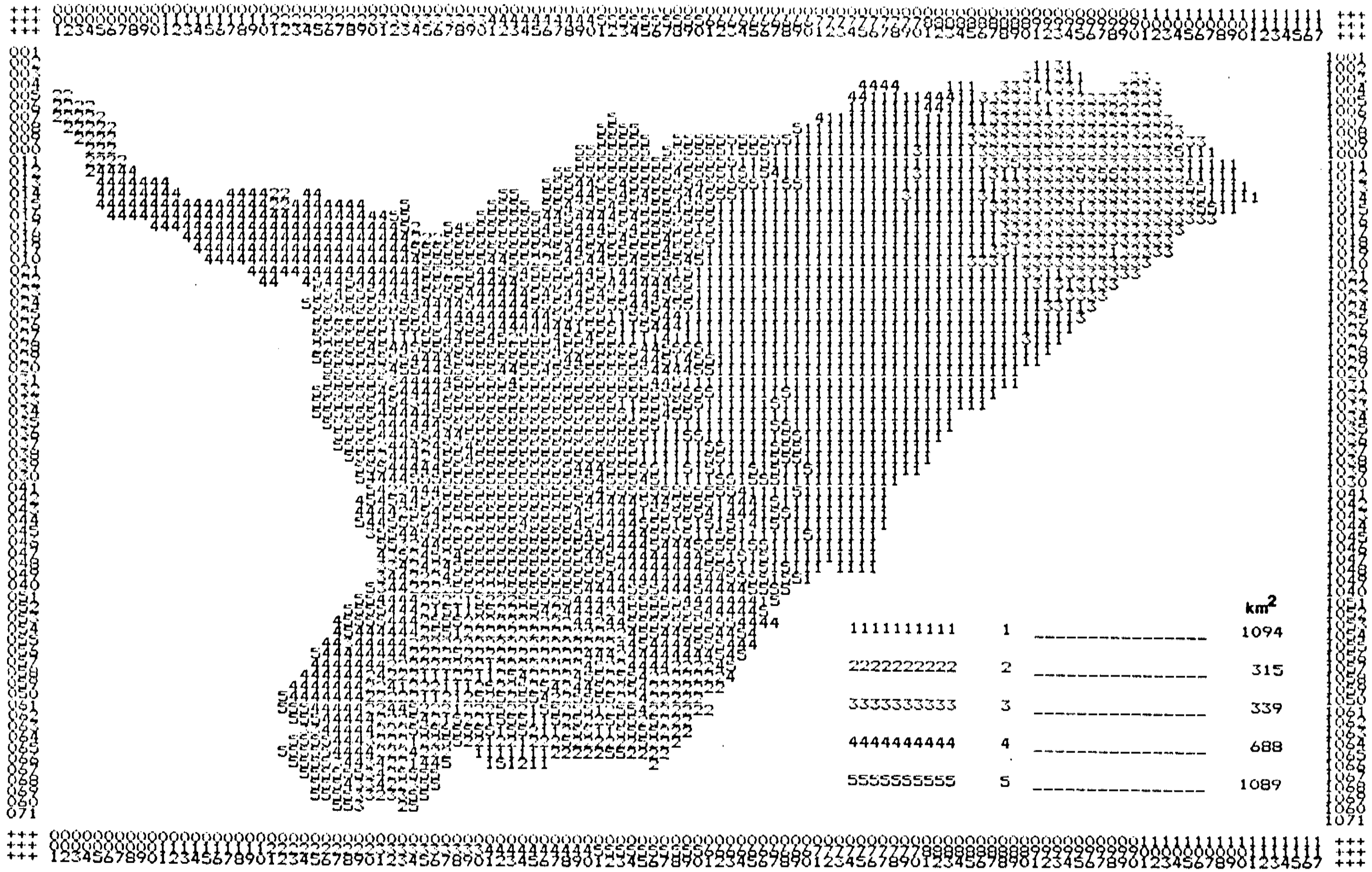
Amplitude Scorings

Appendix C



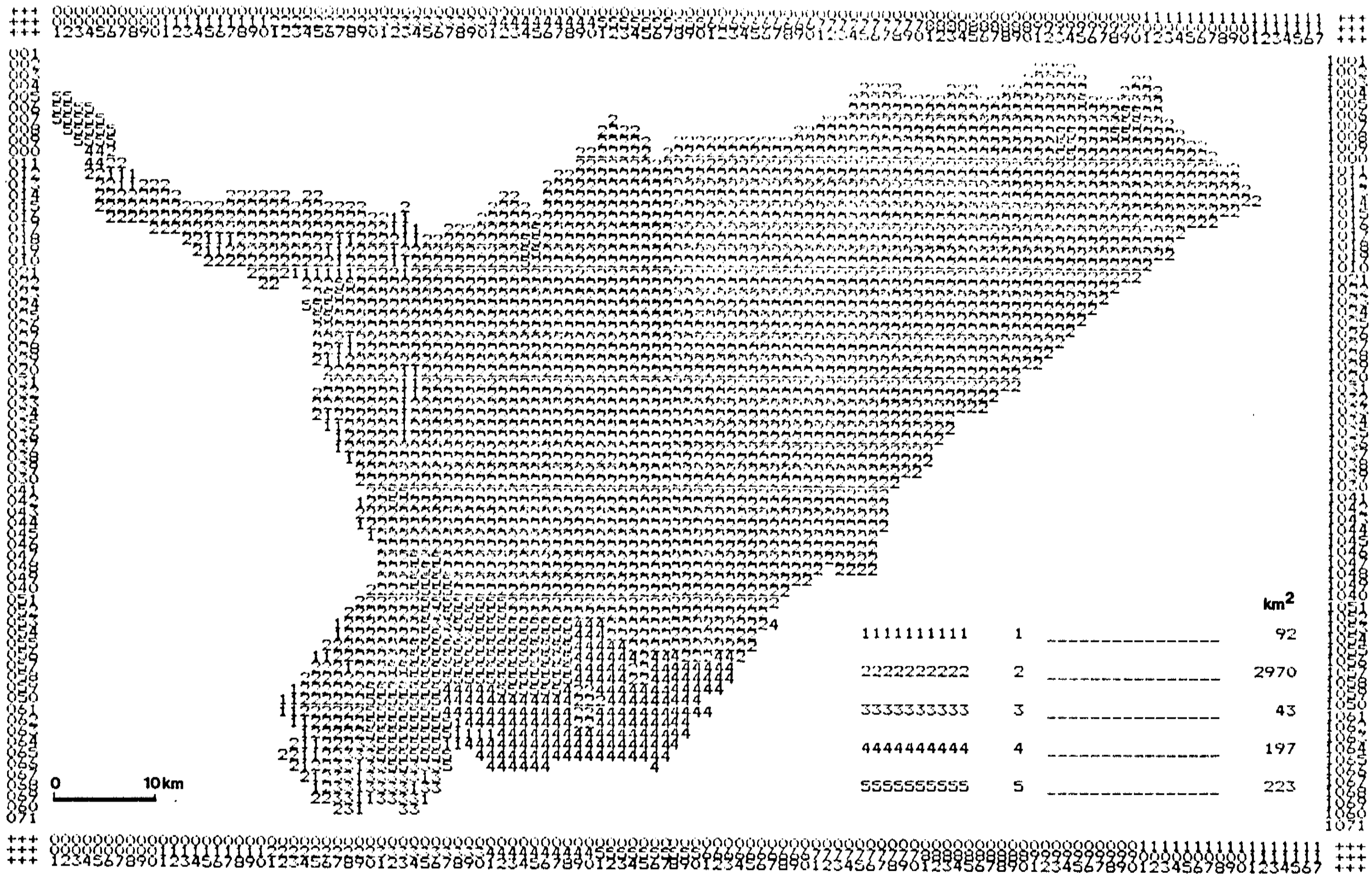
Erosivity Scorings

Appendix D



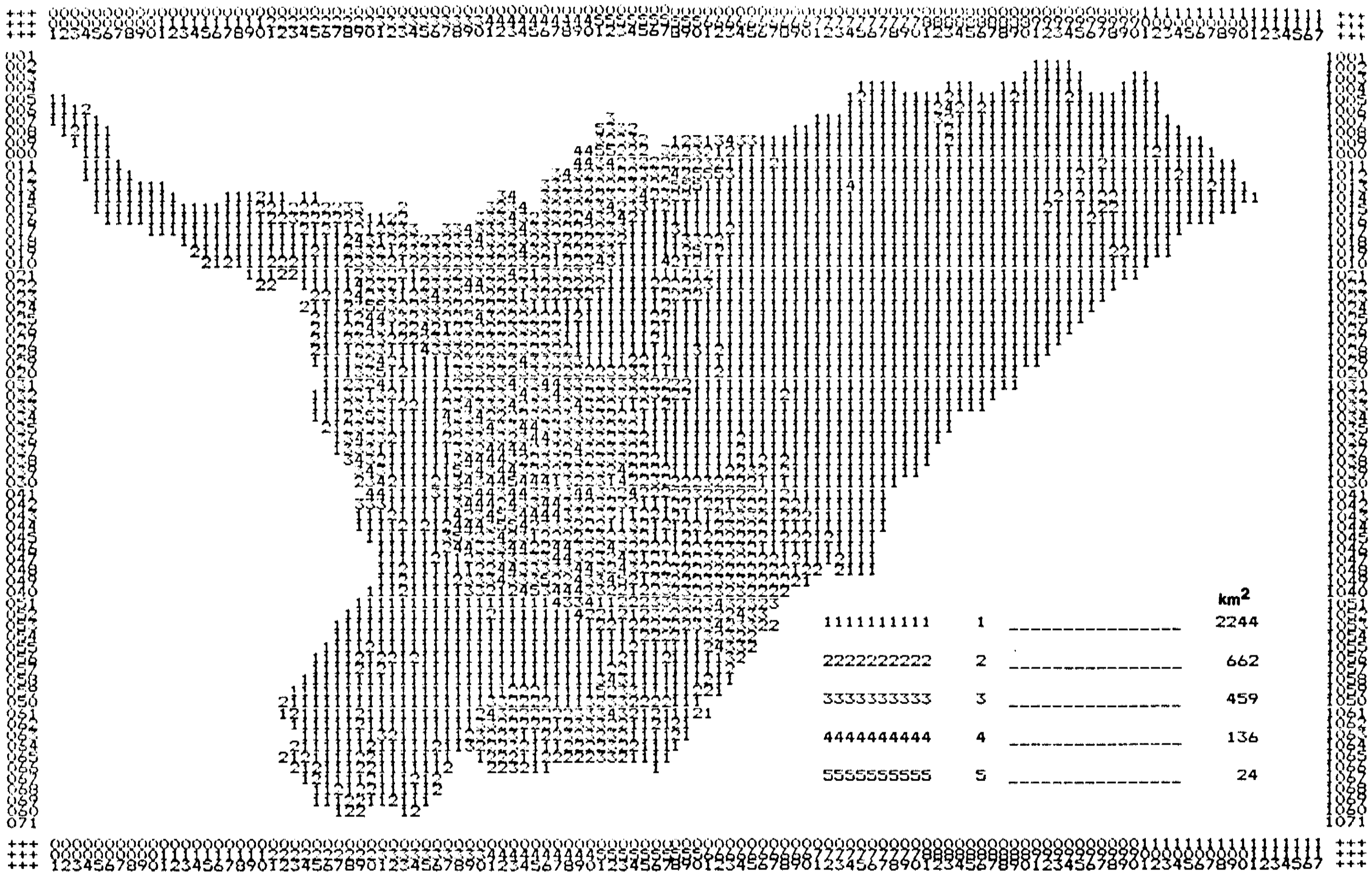
Vegetative Cover Scorings

Appendix E



Erodibility Scorings

Appendix F



Settlement Scorings

Appendix G

LIST OF MAPS USED IN THE STUDY

TOPOGRAPHICAL MAPS

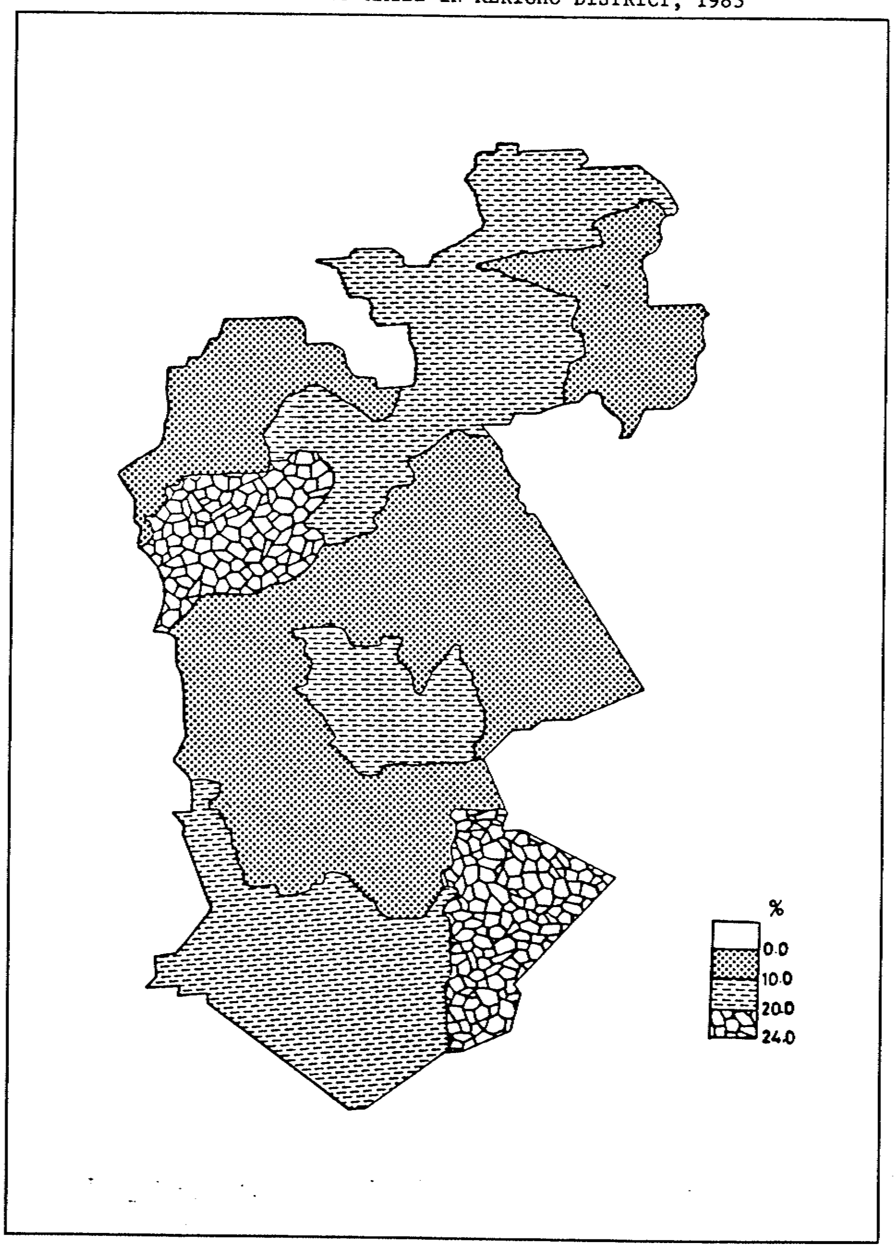
NAME OF MAP	SCALE	SERIES	SHEET	EDITION
KERINGET	1:50,000	Y731(D.O.S.423)	118/3	5-D.O.S. 1972
OLENGURUONE	1:50,000	Y731(D.O.S.423)	132/1	6-D.O.S. 1972
TENWEK	1:50,000	Y731(D.O.S.423)	131/2	5-D.O.S. 1971
NYAKACH	1:50,000	Y731	116/4	4-D.O.S.
KISII	1:50,000	Y731	130/2	4-D.O.S.
BELGUT	1:50,000	Y731(D.O.S.423)	117/3	5-D.O.S. 1971
NYANGWESO	1:50,000	Y731	130/4	4-D.O.S.
BOMET	1:50,000	Y731	131/4	5-D.O.S. 1971
KERICHO	1:50,000	Y731(D.O.S.423)	117/4	5-D.O.S. 1971
CHEPALUNGU	1:50,000	Y731(D.O.S.423)	131/3	5-D.O.S. 1971
CHEMAGEL	1:50,000	Y731(D.O.S.423)	131/1	5-D.O.S. 1971

OTHER MAPS

1. Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980, scale 1:1,000,000. Republic of Kenya, Ministry of Agriculture-National Agricultural Laboratories, Kenya Soil Survey.
2. Mean Annual Rainfall Map of Kenya, WHO/Kenya 3202-MAP No. 8 1973.
3. 1:250,000 Vegetation/Landuse Survey Map of South Western Kenya-Kenya Government (prepared by the British Government's Ministry of Overseas Development (Directorate of Overseas Surveys)under the Special Commonwealth Assistance Plan 1969.
4. Distribution of Hydrologic Soil Groups-sheet 1 of 2-Ministry of Water Development-Republic of Kenya, 1980.

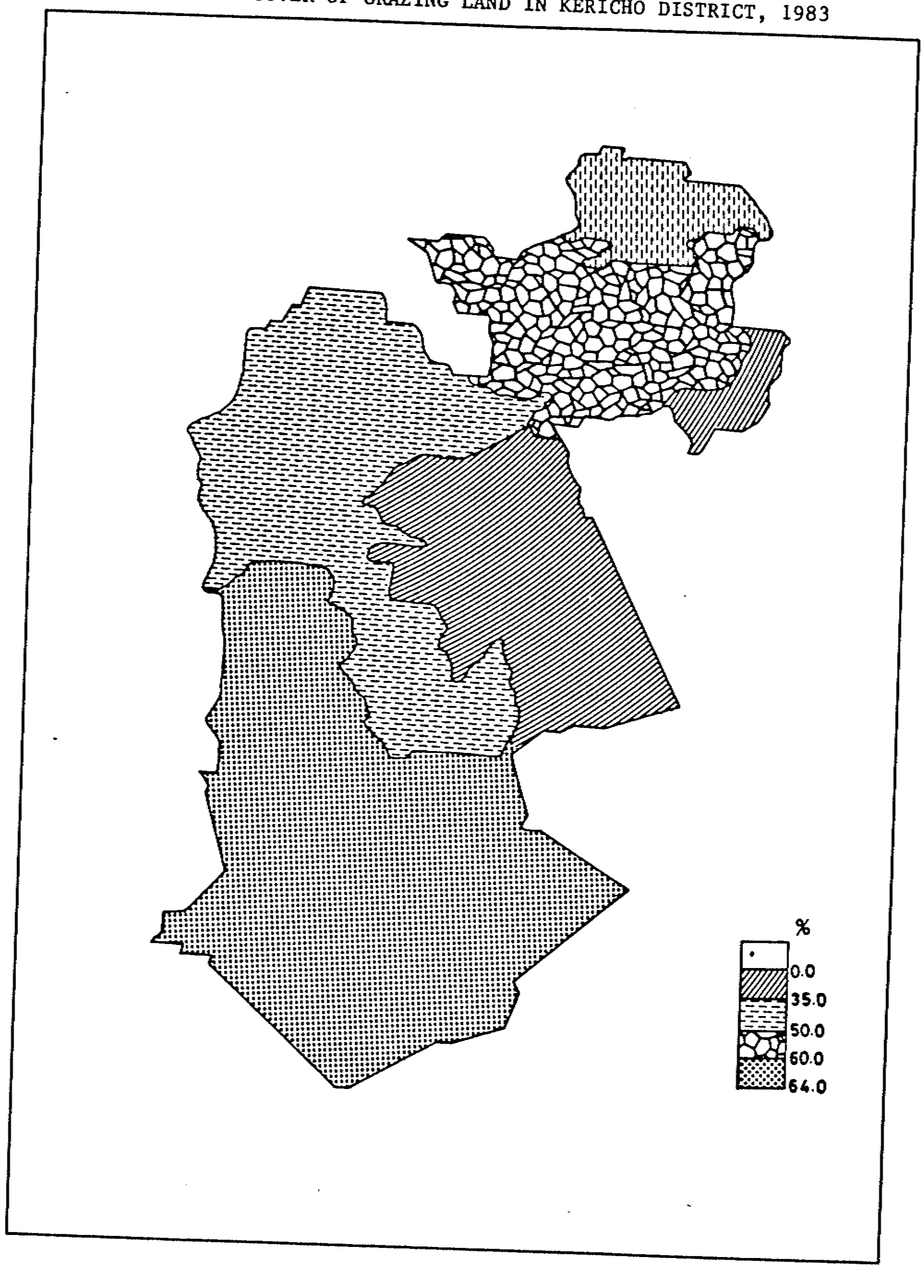
Appendix H

PERCENT COVER OF MAIZE IN KERICHO DISTRICT, 1983



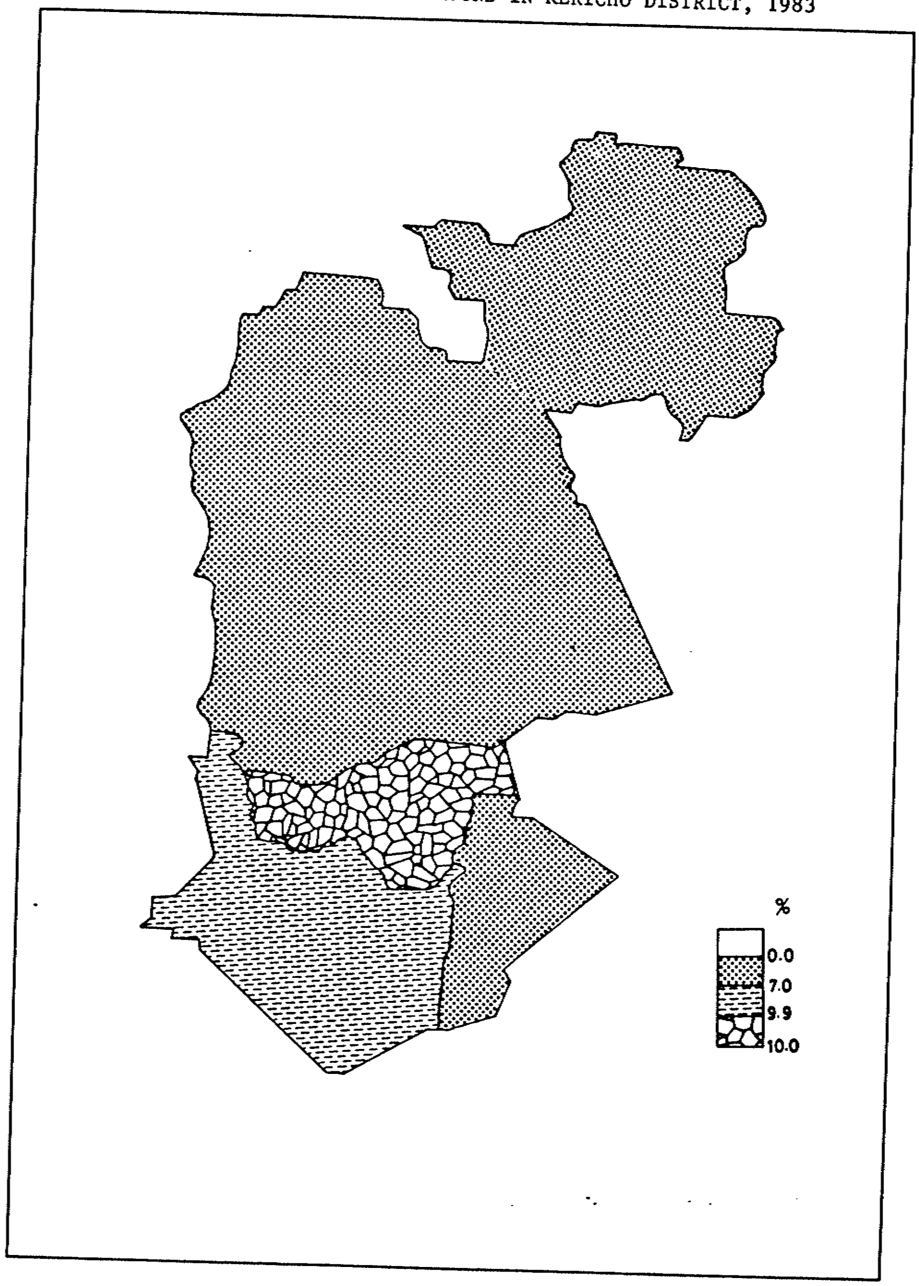
Appendix I

PERCENT COVER OF GRAZING LAND IN KERICHO DISTRICT, 1983



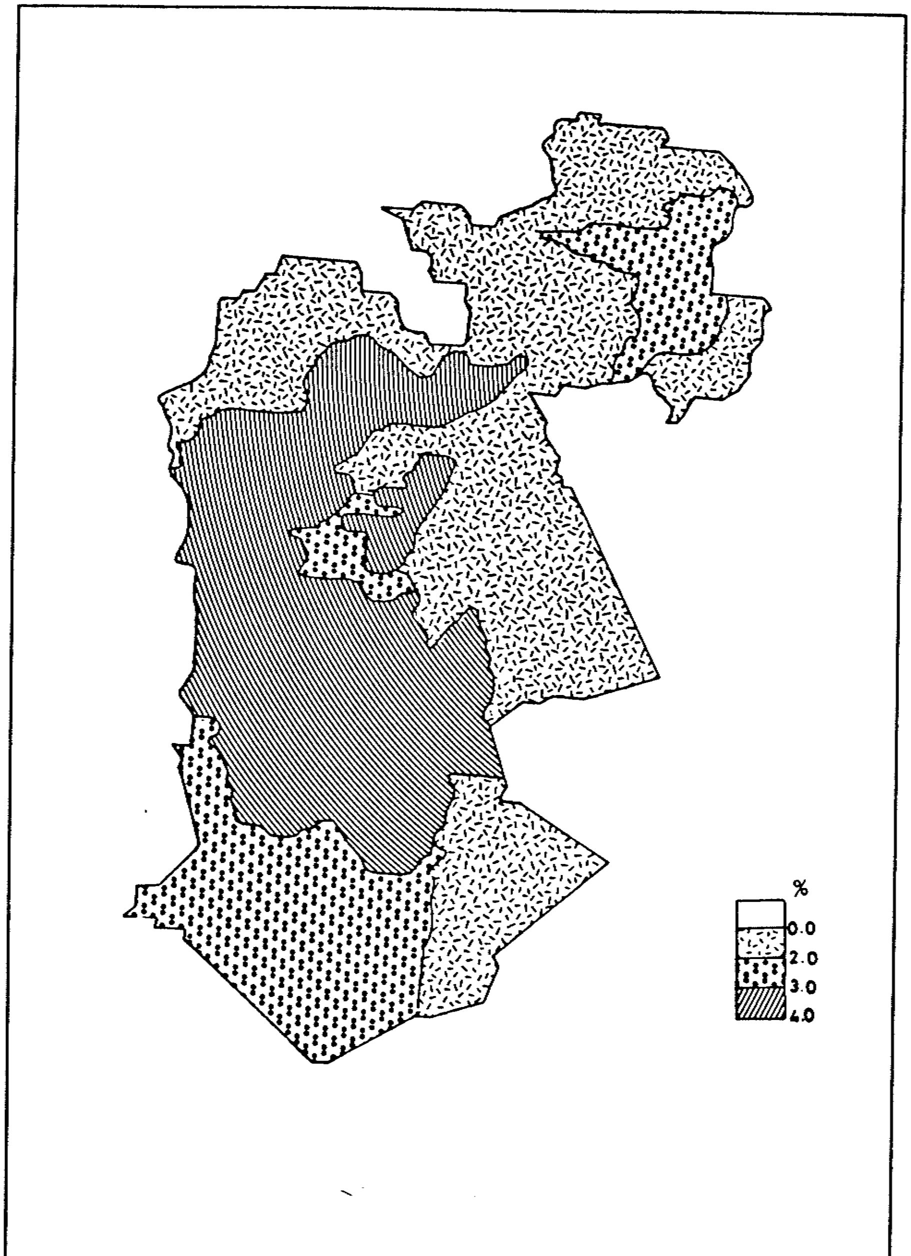
Appendix J

PERCENT COVER OF BARE GROUND IN KERICHO DISTRICT, 1983



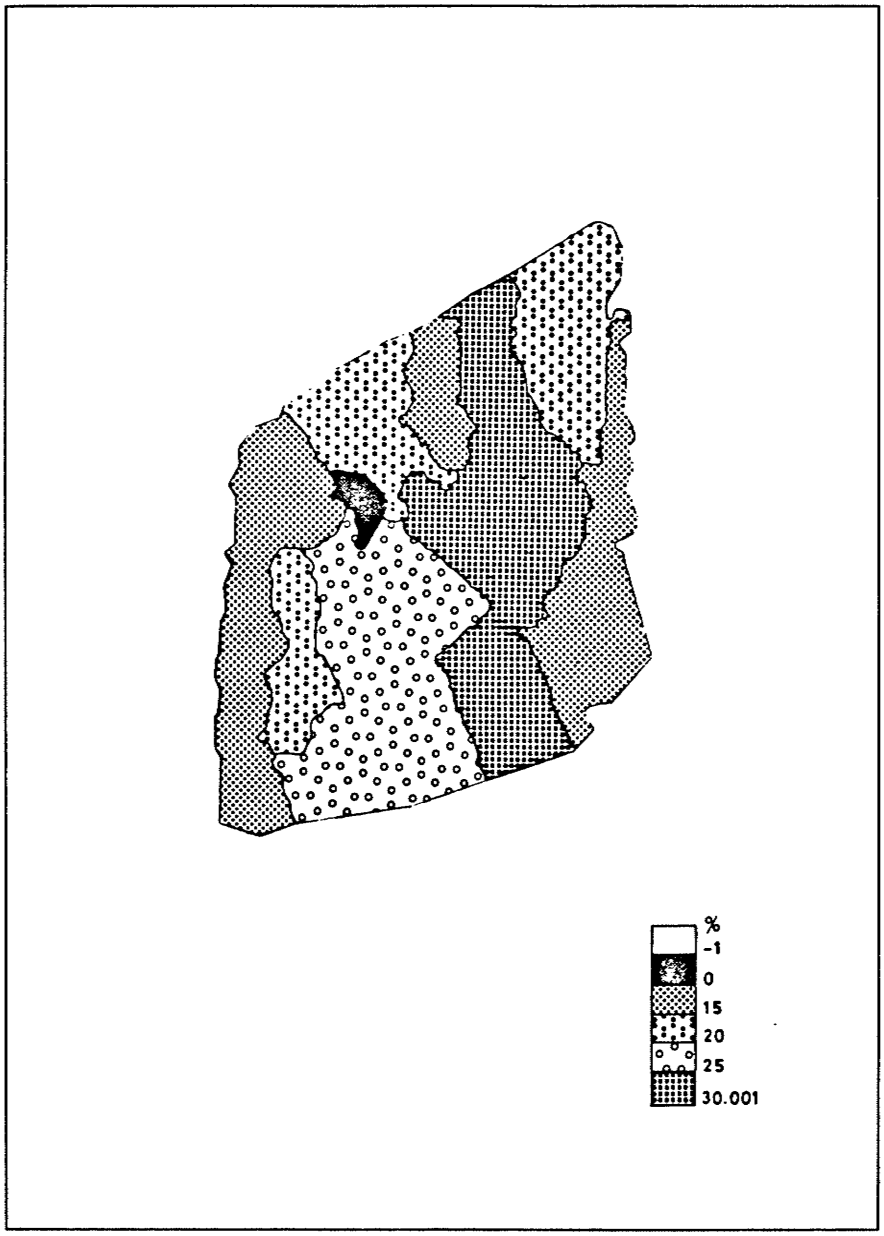
Appendix K

PERCENT COVER OF ROADS/TRACKS/FOOTPATHS IN KERICHO DISTRICT, 1983



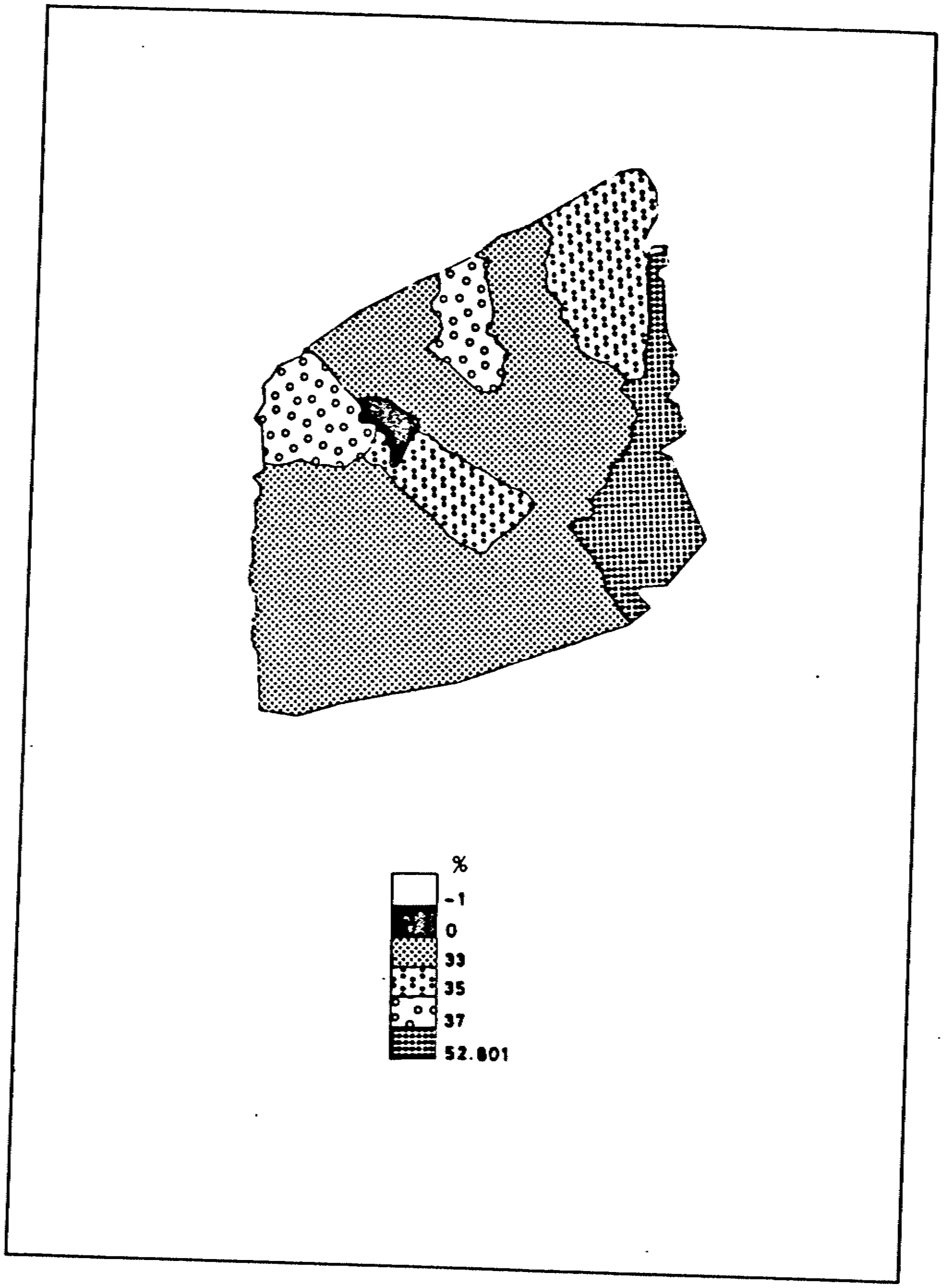
Appendix L

PERCENT COVER OF MAIZE IN KISII DISTRICT, 1983



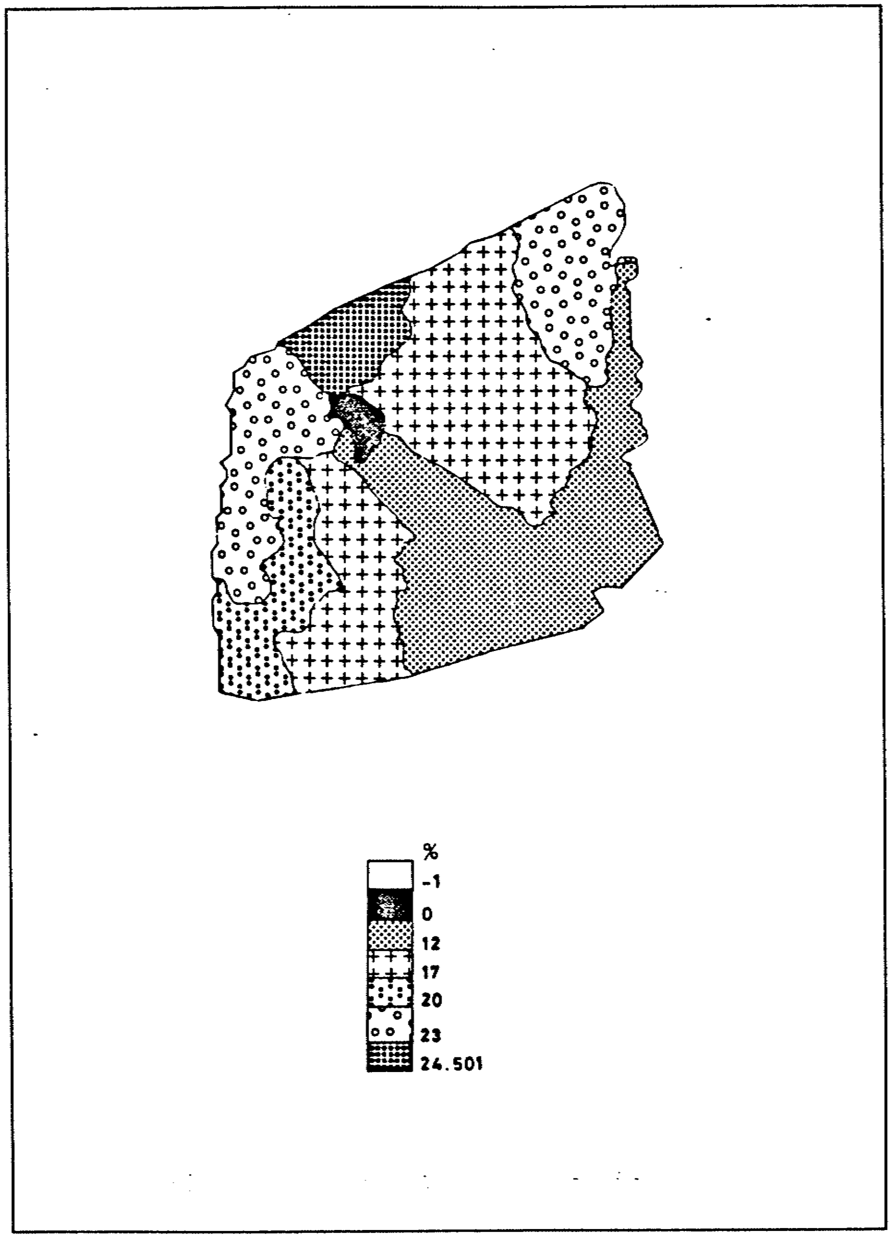
Appendix M

PERCENT COVER OF GRAZING LAND IN KISII DISTRICT, 1983.

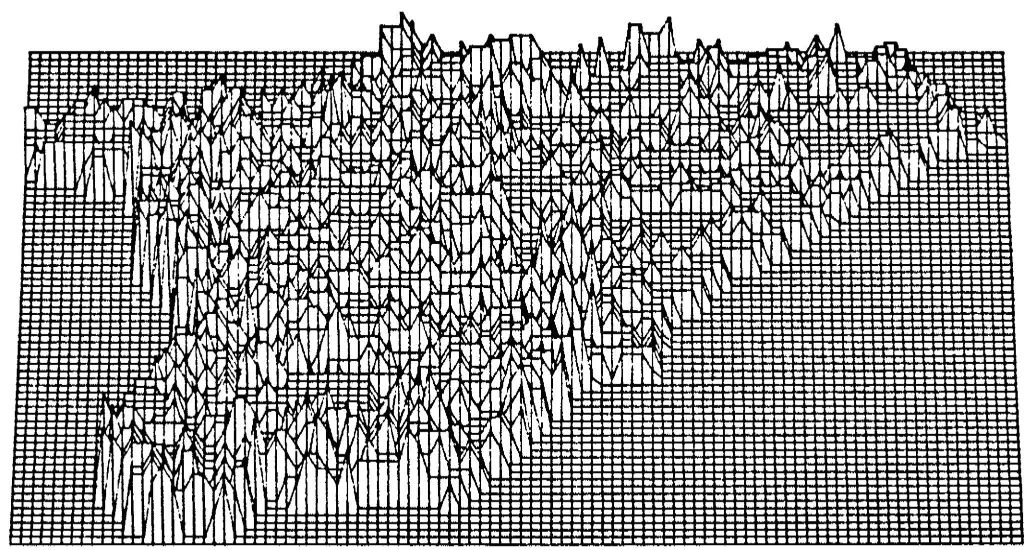


Appendix N

PERCENT COVER OF BARE GROUND IN KISII DISTRICT, 1983



Appendix O



EROSION POTENTIAL SURFACE

DATA

.1 Amplitude

1.	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
4.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
5.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
6.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
7.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
8.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
9.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
10.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
11.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
12.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
13.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
14.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
15.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
16.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0060
17.		0060	0060	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
18.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
19.	3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
20.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
21.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
22.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
23.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
24.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
25.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0080	0060
26.		0060	0040	0060	0060	-1	-1	-1	-1	0060	0020	-1	-1	-1
27.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
28.	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
29.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
30.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
31.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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33.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0040	0060	0060	0120
34.		-1	-1	-1	-1	0100	0060	0040	-1	-1	0060	0060	0020	0040
35.		0060	0060	0060	0040	-1	-1	-1	0020	0020	0020	0020	-1	-1
36.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
37.	5	0000	0000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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39.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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42.		-1	-1	-1	-1	-1	-1	-1	-1	0100	0080	0100	0080	0100
43.		0120	0080	0060	0040	0040	0060	0060	0040	0060	0040	0040	0040	0020
44.		0020	0060	0040	0080	0060	0040	0040	0000	0020	0000	0020	-1	-1
45.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
46.	6	0000	0000	0000	0000	-1	-1	-1	-1	-1	-1	-1	-1	-1
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52.		0060	0060	0040	0060	0080	0120	0120	0060	0060	0040	0040	0040	0040
53.		0020	0040	0040	0040	0060	0060	0020	0040	0020	0020	0020	-1	-1
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57.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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60.		-1	-1	-1	-1	-1	0100	0080	0100	0100	0140	0060	0080	0080
61.		0060	0060	0060	0100	0100	0100	0080	0060	0040	0040	0040	0040	0020
62.		0060	0040	0040	0060	0060	0040	0040	0020	0040	0040	0020	0020	-1
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66.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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70.		0080	0040	0080	0080	0140	0100	0060	0060	0060	0020	0040	0020	0040
71.		0040	0020	0040	0060	0060	0060	0040	0020	0060	0020	0020	0020	0020
72.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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74.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
75.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
76.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0060	0060
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78.		0040	0040	0040	0040	0060	0060	0060	0040	0040	0080	0100	0080	0060
79.		0060	0040	0100	0080	0080	0080	0060	0060	0040	0060	0060	0020	0040
80.		0040	0040	0060	0040	0060	0040	0060	0040	0060	0020	0020	0020	0020
81.		0020	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
82.	10	-1	-1	-1	0000	0000	0000	-1	-1	-1	-1	-1	-1	-1
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85.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0120	0100	0060	0040
86.		0040	0040	0060	-1	0060	0060	0040	0080	0060	0040	0060	0060	0060
87.		0040	0080	0040	0060	0060	0060	0060	0080	0080	0080	0080	0080	0080
88.		0060	0120	0080	0060	0060	0080	0060	0080	0040	0060	0060	0040	0060
89.		0080	0040	0060	0060	0040	0040	0060	0040	0080	0040	0060	0040	0040
90.		0040	0060	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
91.	11	-1	-1	-1	0015	0000	0061	0106	-1	-1	-1	-1	-1	-1
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94.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0120	0080	0080	0060
95.		0060	0060	0060	0020	0040	0080	0060	0080	0080	0080	0060	0040	0040
96.		0040	0100	0080	0060	0060	0100	0060	0080	0100	0120	0080	0060	0100
97.		0120	0080	0060	0060	0060	0040	0080	0060	0100	0040	0100	0040	0080
98.		0060	0060	0060	0040	0080	0040	0040	0040	0040	0040	0060	0060	0040
99.		0040	0040	0040	0060	0060	-1	-1	-1	-1	-1	-1	-1	-1
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103.		-1	-1	-1	-1	-1	-1	-1	0080	0040	0060	0060	0060	0060
104.		0040	0080	0060	0040	0060	0040	0060	0060	0080	0060	0080	0060	0060
105.		0060	0060	0060	0040	0060	0020	0100	0080	0100	0020	0040	0060	0060
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107.		0080	0080	0060	0040	0060	0060	0040	0040	0040	0040	0020	0060	0060
108.		0040	0040	0060	0060	0060	-1	-1	-1	-1	-1	-1	-1	-1
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110.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
111.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
112.		-1	-1	-1	-1	-1	-1	0060	0020	0020	0040	0060	0040	0040
113.		0060	0080	0080	0080	0060	0080	0060	0060	0060	0120	0100	0020	0060
114.		0040	0020	0080	0020	0060	0080	0080	0060	0060	0040	0040	0040	0100
115.		0060	0040	0040	0040	0040	0060	0040	0100	0080	0060	0060	0060	0080
116.		0040	0060	0080	0040	0060	0060	0040	0040	0040	0080	0060	0040	0020
117.		0040	0040	0040	0060	0080	0100	-1	-1	-1	-1	-1	-1	-1
118.	14	-1	-1	-1	-1	0076	0107	0076	0259	0122	0152	0137	0046	-1
119.		-1	-1	-1	0076	0061	0091	0091	0000	0000	-1	0015	0030	-1
120.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
121.		-1	-1	0020	0020	-1	-1	0040	0040	0040	0080	0060	0060	0040
122.		0060	0060	0040	0060	0040	0040	0040	0100	0080	0100	0020	0080	0060
123.		0080	0080	0100	0100	0100	0100	0120	0080	0100	0060	0060	0060	0040
124.		0060	0060	0060	0060	0060	0060	0100	0080	0100	0060	0060	0060	0060
125.		0060	0060	0080	0020	0040	0040	0040	0060	0020	0020	0060	0040	0040
126.		0060	0040	0040	0060	0060	-1	-1	-1	-1	-1	-1	-1	-1
127.	15	-1	-1	-1	-1	0076	0107	0076	0137	0122	0061	0107	0107	0107

128.		0091	0061	0061	0061	0061	0061	0091	0076	0000	0015	0030	0000	0000
129.		0030	0046	0120	-1	-1	-1	0100	-1	-1	-1	-1	-1	-1
130.		-1	0020	0040	0020	0020	-1	0040	0060	0080	0080	0020	0040	0040
131.		0060	0060	0020	0040	0060	0080	0060	0080	0060	0040	0100	0040	0080
132.		0080	0060	0060	0080	0120	0140	0060	0040	0040	0060	0060	0060	0040
133.		0060	0060	0060	0060	0060	0060	0100	0080	0100	0060	0060	0060	0060
134.		0060	0060	0080	0020	0040	0040	0040	0060	0020	0020	0060	0040	0040
135.		0060	0040	0040	0060	0060	-1	-1	-1	-1	-1	-1	-1	-1
136.	5. 16	-1	-1	-1	-1	-1	0046	0091	0107	0107	0061	0107	0061	0030
137.		0046	0061	0061	0046	0046	0046	0061	0152	0061	0061	0091	0091	0046
138.		0076	0107	0040	0040	0160	0180	0140	-1	-1	-1	-1	-1	-1
139.		0020	0060	0020	0000	0000	0040	0020	0100	0040	0060	0060	0040	0040
140.		0060	0020	0040	0040	0060	0020	0080	0100	0080	0100	0100	0040	0060
141.		0040	0060	0080	0060	0080	0100	0060	0020	0060	0060	0060	0060	0040
142.		0020	0040	0040	0080	0060	0060	0040	0060	0120	0120	0080	0060	0060
143.		0040	0080	0080	0060	0040	0040	0020	0040	0060	0060	0060	0060	0060
144.		0060	0020	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
145.	17	-1	-1	-1	-1	-1	-1	-1	-1	-1	0046	0061	0046	0046
146.		0046	0046	0046	0076	0107	0046	0046	0091	0137	0107	0122	0137	0122
147.		0107	0076	0140	0020	0200	0180	0200	0080	-1	-1	0060	0040	0040
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150.		0080	0100	0100	0100	0100	0100	0060	0040	0060	0060	0040	0040	0080
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152.		0040	0060	0060	0060	0040	0040	0000	0020	0020	0060	0040	0040	0020
153.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
154.	18	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0030
155.		0061	0030	0061	0137	0107	0061	0076	0061	0076	0061	0061	0091	0091
156.		0061	0030	0080	0040	0080	0120	0220	0160	0020	0020	0040	0020	0040
157.		0040	0040	0040	0020	0040	0080	0080	0040	0040	0060	0060	0060	0040
158.		0020	0100	0080	0040	0040	0080	0060	0080	0100	0080	0100	0100	0120
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163.	19	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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165.		0076	0152	0060	0100	0120	0180	0220	0180	0140	0040	0020	0040	0040
166.		0020	0040	0040	0040	0040	0060	0040	0020	0040	0060	0060	0040	0040
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174.		0137	0152	0080	0080	0080	0120	0280	0220	0220	0120	0020	0020	0040
175.		0040	0040	0060	0060	0080	0060	0040	0020	0060	0040	0040	0040	0020
176.		0080	0080	0020	0060	0080	0080	0060	0060	0080	0120	0080	0060	0100
177.		0060	0100	0080	0100	0100	0140	0080	0080	0060	0080	0080	0080	0060
178.		0060	0060	0080	0060	0060	0060	0060	0060	0040	0080	0080	0120	0040
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183.		0122	0152	0080	0080	0080	0120	0120	0120	0200	0120	0020	0020	0040
184.		0020	0040	0060	0060	0060	0020	0040	0040	0040	0060	0040	0040	0040
185.		0080	0100	0060	0080	0100	0100	0100	0100	0140	0140	0080	0120	0100
186.		0060	0080	0080	0080	0140	0140	0080	0080	0060	0080	0060	0060	0080
187.		0040	0100	0060	0040	0060	0040	0060	0100	0100	0080	0080	0040	0080
188.		0080	0040	0040	0080	0060	0080	0080	0060	0040	-1	-1	-1	-1
189.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
190.	. 22	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
191.		-1	-1	-1	-1	-1	-1	0046	0030	-1	-1	0152	0152	0122

192.		0152	0107	0100	0100	0180	0220	0100	0200	0200	0120	0060	0040	0040
193.		0060	0080	0040	0060	0060	0040	0020	0040	0040	0080	0040	0020	0080
194.		0080	0060	0060	0080	0080	0060	0060	0100	0140	0100	0160	0100	0140
195.		0080	0080	0060	0060	0080	0080	0060	0060	0100	0080	0040	0040	0060
196.		0060	0060	0060	0060	0060	0040	0100	0000	0060	0060	0040	0080	0120
197.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
198.	.	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
199.	23	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
200.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0015	0061
201.		0076	0198	0100	0100	0120	0180	0080	0200	0220	0160	0080	0080	0080
202.		0100	0080	0060	0060	0060	0040	0040	0060	0060	0060	0040	0040	0060
203.		0080	0020	0040	0060	0100	0060	0080	0120	0100	0140	0120	0120	0100
204.		0100	0080	0060	0080	0100	0060	0080	0080	0080	0100	0060	0060	0080
205.		0100	0060	0060	0080	0040	0080	0060	0100	0060	0040	0060	0100	0080
206.		0080	0040	0060	0040	0040	0080	-1	-1	-1	-1	-1	-1	-1
207.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
208.	24	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
209.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0091	0061	0046
210.		0046	0183	0000	0060	0040	0080	0120	0220	0100	0100	0100	0100	0120
211.		0080	0060	0080	0120	0060	0040	0040	0040	0060	0040	0040	0040	0060
212.		0060	0080	0060	0040	0100	0080	0080	0060	0140	0120	0100	0080	0100
213.		0140	0120	0060	0100	0040	0040	0100	0100	0080	0060	0060	0080	0060
214.		0080	0060	0060	0060	0060	0100	0100	0080	0060	0060	0080	0060	0040
215.		0080	0040	0060	0080	0060	-1	-1	-1	-1	-1	-1	-1	-1
216.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
217.	25	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
218.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0091	0030
219.		0015	0015	0020	0020	0100	0120	0160	0080	0100	0080	0100	0080	0080
220.		0080	0040	0060	0060	0040	0040	0020	0040	0060	0040	0040	0040	0060
221.		0080	0060	0060	0100	0060	0060	0080	0060	0100	0100	0080	0100	0100
222.		0120	0080	0140	0060	0040	0100	0080	0060	0060	0060	0080	0080	0080
223.		0080	0100	0080	0060	0100	0100	0040	0060	0080	0060	0060	0060	0060
224.		0080	0060	0100	0060	-1	-1	-1	-1	-1	-1	-1	-1	-1
225.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
226.	26	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
227.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0030	0076
228.		0061	0061	0140	0100	0100	0080	0160	0100	0140	0100	0100	0060	0040
229.		0060	0040	0040	0000	0020	0020	0040	0040	0040	0040	0040	0060	0060
230.		0060	0060	0060	0080	0060	0040	0060	0080	0060	0080	0060	0060	0100
231.		0060	0100	0120	0100	0120	0100	0080	0060	0060	0080	0080	0100	0100
232.		0100	0100	0060	0140	0120	0120	0060	0060	0060	0060	0060	0080	0060
233.		0060	0080	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
234.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
235.	27	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
236.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0046	0091
237.		0122	0076	0080	0120	0100	0100	0800	0100	0100	0080	0080	0080	0080
238.		0040	0040	0080	0020	0040	0060	0020	0040	0060	0060	0060	0060	0060
239.		0100	0060	0080	0060	0100	0060	0060	0100	0100	0060	0100	0100	0080
240.		0060	0120	0080	0060	0060	0100	0180	0200	0140	0120	0140	0100	0080
241.		0100	0160	0140	0140	0120	0080	0080	0040	0100	0060	0060	0040	0060
242.		0060	0100	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
243.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
244.	28	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
245.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0015	0030
246.		0061	0076	0140	0120	0140	0120	0120	0080	0080	0040	0080	0080	0080
247.		0080	0040	0080	0040	0020	0040	0040	0020	0060	0100	0080	0080	0060
248.		0020	0060	0080	0120	0060	0100	0080	0060	0100	0080	0100	0080	0040
249.		0080	0080	0060	0080	0160	0160	0180	0140	0160	0080	0060	0080	0040
250.		0060	0080	0060	0060	0060	0080	0080	0060	0060	0080	0100	0080	0060
251.		0060	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
252.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
253.	29	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
254.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0061	0061
255.		0183	0091	0140	0120	0080	0060	0060	0100	0120	0100	0100	0060	0080

256.		0080	0040	0040	0100	0060	0060	0040	0040	0060	0080	0080	0020	0020
257.		0040	0040	0040	0060	0080	0080	0080	0060	0040	0100	0060	0060	0040
258.		0060	0080	0080	0140	0160	0180	0080	0060	0060	0080	0060	0060	0060
259.		0060	0040	0060	0060	0060	0100	0080	0100	0060	0060	0100	0120	0100
260.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
261.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
262.	30	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
263.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0122
264.		0152	0091	0060	0120	0100	0080	0140	0060	0040	0100	0100	0060	0120
265.		0080	0080	0140	0100	0080	0020	0040	0040	0020	0100	0100	0060	0040
266.		0060	0020	0040	0040	0080	0080	0060	0080	0060	0080	0080	0060	0080
267.		0120	0100	0140	0120	0180	0100	0060	0080	0080	0080	0060	0060	0060
268.		0080	0080	0080	0060	0080	0140	0120	0100	0100	0080	0080	-1	-1
269.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
270.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
271.	31	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
272.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0152
273.		0107	0061	0080	0240	0080	0100	0180	0120	0160	0100	0120	0100	0120
274.		0100	0060	0080	0040	0080	0040	0020	0040	0020	0080	0080	0100	0060
275.		0060	0080	0060	0060	0040	0060	0060	0060	0080	0100	0080	0080	0080
276.		0080	0120	0100	0080	0100	0120	0080	0080	0120	0120	0080	0060	0080
277.		0060	0060	0080	0100	0060	0080	0120	0080	0080	0100	0080	-1	-1
278.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
279.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
280.	32	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
281.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0107	0137
282.		0098	0167	0100	0220	0220	0060	0100	0200	0200	0240	0100	0080	0060
283.		0060	0100	0080	0000	0040	0040	0040	0020	0040	0040	0100	0100	0100
284.		0060	0040	0060	0060	0060	0060	0080	0100	0080	0100	0060	0060	0060
285.		0080	0100	0060	0080	0140	0140	0080	0040	0120	0100	0080	0080	0060
286.		0060	0060	0100	0060	0060	0080	0120	0120	0080	-1	-1	-1	-1
287.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
288.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
289.	33	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
290.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0183	0167
291.		0167	0107	0120	0180	0200	0160	0060	0120	0200	0180	0080	0040	0060
292.		0080	0120	0080	0020	0020	0040	0020	0040	0040	0040	0100	0100	0100
293.		0080	0100	0120	0100	0080	0060	0080	0060	0100	0080	0080	0080	0060
294.		0120	0080	0080	0080	0080	0060	0040	0060	0060	0120	0060	0100	0080
295.		0060	0060	0100	0100	0080	0060	0060	0100	-1	-1	-1	-1	-1
296.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
297.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
298.	34	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
299.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0152	0107
300.	9	0122	0137	0060	0060	0140	0160	0040	0120	0140	0160	0100	0060	0060
301.		0040	0080	0100	0080	0040	0020	0060	0040	0040	0040	0020	0100	0120
302.		0060	0120	0100	0080	0080	0060	0100	0120	0100	0120	0060	0060	0080
303.		0120	0080	0100	0060	0060	0100	0100	0060	0060	0100	0060	0600	0600
304.		0080	0800	0100	0080	0060	-1	-1	-1	-1	-1	-1	-1	-1
305.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
306.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
307.	35	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
308.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0122
309.		0167	0091	0040	0080	0120	0120	0040	0180	0140	0140	0080	0040	0040
310.		0040	0060	0040	0020	0040	0020	0040	0040	0040	0040	0060	0040	0040
311.		0040	0040	0080	0060	0060	0080	0080	0060	0080	0100	0060	0080	0060
312.		0120	0100	0080	0080	0060	0060	0080	0060	0100	0080	0060	0060	0080
313.		0100	0060	0100	0060	0080	-1	-1	-1	-1	-1	-1	-1	-1
314.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
315.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
316.	36	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
317.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
318.		0152	0137	0060	0060	0080	0080	0060	0120	0080	0080	0080	0080	0020
319.		0060	0080	0040	0020	0040	0020	0040	0040	0040	0020	0040	0040	0040

320.		0040	0060	0060	0060	0100	0100	0080	0040	0020	0060	0100	0080	0060
321.		0100	0100	0080	0060	0060	0080	0100	0060	0080	0060	0080	0060	0080
322.		0100	0080	0100	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1
323.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
324.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
325.	37	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
326.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
327.		0061	0198	0060	0120	0040	0100	0080	0100	0040	0040	0080	0060	0040
328.		0080	0060	0020	0020	0020	0020	0040	0040	0060	0060	0040	0040	0040
329.		0060	0060	0060	0060	0060	0060	0080	0080	0080	0080	0100	0060	0060
330.		0100	0100	0140	0120	0060	0060	0080	0080	0060	0060	0120	0100	0100
331.		0080	0060	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
332.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
333.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
334.	38	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
335.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
336.		-1	0152	0080	0100	0040	0040	0080	0080	0060	0080	0080	0060	0100
337.		0060	0020	0020	0020	0040	0040	0040	0060	0060	0040	0040	0040	0040
338.		0040	0080	0060	0060	0080	0080	0060	0100	0080	0100	0060	0060	0120
339.		0160	0100	0180	0100	0100	0080	0100	0160	0160	0060	0120	0080	0080
340.		0060	0080	0060	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
341.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
342.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
343.	39	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
344.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
345.		-1	-1	0160	0140	0060	0040	0020	0120	0140	0140	0100	0120	0080
346.		0060	0020	0020	0040	0060	0060	0040	0060	0040	0040	0060	0080	0060
347.		0060	0080	0060	0040	0060	0060	0080	0080	0080	0060	0060	0120	0220
348.		0140	0100	0060	0080	0100	0080	0100	0140	0140	0140	0080	0080	0080
349.		0080	0080	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
350.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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352.	40	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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354.		-1	-1	0180	0040	0100	0100	0040	0080	0140	0060	0120	0100	0040
355.		0060	0040	0020	0040	0020	0040	0040	0060	0040	0040	0060	0060	0040
356.		0060	0060	0060	0060	0060	0080	0080	0060	0100	0080	0060	0100	0220
357.		0180	0120	0060	0080	0060	0080	0100	0160	0140	0180	0080	0100	0080
358.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
359.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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361.	41	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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363.		-1	-1	-1	0200	0120	0140	0020	0020	0000	0080	0100	0100	0040
364.		0020	0020	0020	0040	0040	0040	0040	0040	0040	0060	0040	0060	0060
365.		0060	0060	0040	0060	0060	0060	0080	0080	0080	0080	0080	0120	0100
366.		0200	0140	0100	0060	0060	0160	0140	0220	0200	0100	0080	0060	-1
367.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
368.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
369.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
370.	42	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
371.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
372.		-1	-1	0160	0160	0140	0060	0040	0020	0040	0060	0100	0080	0040
373.		0020	0020	0020	0040	0040	0040	0040	0040	0020	0040	0060	0060	0060
374.		0060	0060	0040	0060	0080	0060	0100	0100	0080	0080	0100	0120	0080
375.		0160	0160	0100	0080	0080	0200	0220	0120	0120	0100	0080	0080	-1
376.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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379.	43	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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381.		-1	-1	0100	0100	0120	0120	0080	0020	0020	0020	0100	0060	0060
382.		0040	0060	0040	0040	0020	0040	0040	0040	0020	0040	0040	0060	0060
383.		0040	0040	0080	0060	0060	0080	0080	0080	0040	0080	0060	0080	0040

384.		0200	0180	0100	0100	0080	0180	0220	0140	0080	0100	0100	0080	-1
385.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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390.		-1	-1	0200	0160	0100	0120	0120	0060	0040	0060	0080	0040	0040
391.		0020	0000	0020	0020	0060	0020	0040	0040	0040	0040	0040	0040	0060
392.		0060	0060	0040	0060	0060	0080	0100	0080	0060	0060	0080	0080	0080
393.		0120	0120	0100	0080	0080	0160	0180	0100	0120	0080	0100	0080	-1
394.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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396.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
397.	45	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
398.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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465.		0060	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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472.		0060	0060	0040	0020	0040	0020	0020	0020	0020	0020	0020	0040	0020
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474.		0080	0060	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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552.		0091	0091	0100	0080	0060	0040	0100	0020	0080	0020	0020	0080	0120
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597.		0137	0076	0080	0120	0200	0060	0020	0060	0080	0080	-1	-1	-1
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606.		0122	0076	0080	0200	0200	0080	0020	0100	0100	0080	-1	-1	-1
607.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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613.	69	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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615.		0137	0030	0140	0160	0200	0100	0060	0080	0120	-1	-1	-1	-1
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619.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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621.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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623.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
624.		0091	0107	0180	-1	-1	-1	0040	0040	-1	-1	-1	-1	-1
625.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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631.	71	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
632.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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636.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
637.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
638.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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.1	Rainfall													
1.	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
4.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
5.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
6.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
7.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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9.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
10.	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
11.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
12.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
13.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
14.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
15.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
16.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0130
17.		0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
18.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
19.	3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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21.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
22.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
23.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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25.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0130	0130
26.		0130	0130	0130	0130	-1	-1	-1	-1	0130	0130	-1	-1	-1
27.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
28.	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
29.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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31.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
32.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
33.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150	0150	0150
34.		-1	-1	-1	-1	0130	0130	0130	-1	-1	0130	0130	0130	0130
35.		0130	0130	0130	0130	-1	-1	-1	-1	0130	0130	0130	-1	-1
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37.	5	0110	0110	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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46.	6	0110	0110	0110	0110	-1	-1	-1	-1	-1	-1	-1	-1	-1
47.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
48.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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51.		-1	-1	-1	-1	-1	-1	-1	-1	0150	0150	0150	0150	0150
52.		0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
53.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1
54.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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56.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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58.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150
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61.		0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
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63.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

64.	8	-1	0110	0110	0110	0110	0110	-1	-1	-1	-1	-1	-1	-1
65.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
66.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
67.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
68.		0150	0150	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
69.		-1	-1	-1	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
70.		0150	0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
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72.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
73.	9	-1	-1	0110	0110	0110	0110	-1	-1	-1	-1	-1	-1	-1
74.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
75.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
76.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
77.		0150	0150	0150	-1	-1	0150	0150	0150	0150	0150	0150	0150	0150
78.		150	150	150	150	150	150	150	150	150	150	150	150	150
79.		0150	0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
80.		130	130	130	130	130	130	130	130	130	130	130	130	130
81.		0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
82.	10	-1	-1	-1	0110	0110	0110	-1	-1	-1	-1	-1	-1	-1
83.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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85.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150	0150	0150
86.		0150	0150	0150	-1	0150	0150	0150	0150	0150	0150	0150	0150	0150
87.		150	150	150	150	150	150	150	150	150	150	150	150	150
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89.		130	130	130	130	130	130	130	130	130	130	130	130	130
90.		0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
91.	11	-1	-1	-1	0110	0110	0110	0110	-1	-1	-1	-1	-1	-1
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94.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150	0150	0150
95.		150	150	150	150	150	150	150	150	150	150	150	150	150
96.		150	150	150	150	150	150	150	150	150	150	150	150	150
97.		0150	0150	0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	0130
98.		130	130	130	130	130	130	130	130	130	130	130	130	130
99.		0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1
100.	12	-1	-1	-1	0110	0110	0110	0110	0110	-1	-1	-1	-1	-1
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105.		150	150	150	150	150	150	150	150	150	150	150	150	150
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107.		130	130	130	130	130	130	130	130	130	130	130	130	130
108.		0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1
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112.		-1	-1	-1	-1	-1	-1	0150	0150	0150	0150	0150	0170	0170
113.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0150
114.		150	150	150	150	150	150	150	150	150	150	150	150	150
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116.		130	130	130	130	130	130	130	130	130	130	130	130	130
117.		0130	0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1	-1
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122.		170	170	170	170	170	170	170	170	170	170	170	170	170
123.		150	150	150	150	150	150	150	150	150	150	150	150	150
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125.		130	130	130	130	130	130	130	130	130	130	130	130	130
126.		0130	0130	0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1
127.	15	-1	-1	-1	-1	0110	0110	0110	0110	0110	0110	0110	0110	0110

128.		0110	0110	0110	0110	0130	0130	0130	0130	0130	0130	0130	0130	0130
129.		0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
130.		-1	0150	0150	0150	0150	-1	0150	0170	0170	0170	0170	0170	0170
131.		170	170	170	170	170	170	170	170	170	170	170	170	170
132.		0170	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
133.		0150	0150	0150	0150	0150	0130	0130	0130	0130	0130	0130	0130	0130
134.		130	130	130	130	130	130	130	130	130	130	130	130	130
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136.	16	-1	-1	-1	-1	-1	0110	0110	0110	0110	0110	0110	0110	0110
137.		0110	0110	0110	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
138.		0130	0130	0130	0130	0130	0130	0150	-1	-1	-1	-1	-1	-1
139.		0150	0150	0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170
140.		170	170	170	170	170	170	170	170	170	170	170	170	170
141.		0170	0170	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
142.		0150	0150	0150	0150	0150	0150	0130	0130	0130	0130	0130	0130	0130
143.		130	130	130	130	130	130	130	130	130	130	130	130	130
144.		0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
145.	17	-1	-1	-1	-1	-1	-1	-1	-1	-1	0110	0110	0110	0110
146.		0110	0110	0110	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
147.		0130	0130	0130	0130	0130	0130	0150	0150	0150	0150	0150	0150	0150
148.		0150	0150	0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170
149.	170													
150.		0170	0170	0170	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
151.		0150	0150	0150	0150	0150	0150	0130	0130	0130	0130	0130	0130	0130
152.		130	130	130	130	130	130	130	130	130	130	130	130	130
153.		0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
154.	18	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0110
155.		0110	0110	0110	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
156.		0130	0130	0130	0130	0130	0150	0150	0150	0150	0150	0150	0150	0150
157.		0150	0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170
158.		0170	0170	0170	0190	0190	0190	0170	0170	0170	0170	0170	0170	0170
159.		0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150	0150	0150
160.		0150	0150	0150	0150	0150	0150	0130	0130	0130	0130	0130	0130	0130
161.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1
162.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
163.	19	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
164.		0110	0110	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
165.		0130	0130	0130	0130	0130	0150	0150	0150	0150	0150	0150	0150	0150
166.		0150	0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170
167.		0170	0170	0190	0190	0190	0190	0190	0190	0170	0170	0170	0170	0170
168.		0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150	0150
169.		0150	0150	0150	0150	0150	0150	0150	0150	0130	0130	0130	0130	0130
170.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1
171.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
172.	20	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
173.		-1	0110	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
174.		0130	0130	0130	0130	0150	0150	0150	0150	0150	0150	0150	0150	0150
175.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170
176.		0170	0190	0190	0190	0190	0190	0190	0190	0190	0170	0170	0170	0170
177.		0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150
178.		0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0130	0130	0130
179.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1	-1
180.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
181.	21	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
182.		-1	-1	-1	-1	-1	0130	0130	0130	0130	0130	0130	0130	0130
183.		0130	0130	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
184.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170
185.		0190	0190	0190	0190	0190	0190	0190	0190	0190	0190	0170	0170	0170
186.		0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150
187.		0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0130	0130
188.		0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1	-1	-1
189.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
190.	22	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
191.		-1	-1	-1	-1	-1	-1	0130	0130	-1	-1	0130	0130	0130

192.		0130	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
193.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0190
194.		0190	0190	0190	0190	0190	0190	0190	0190	0190	0190	0190	0190	0170
195.		170	170	170	170	170	170	170	170	170	170	170	170	170
196.		0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0130
197.		0130	0130	0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1
198.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
199.	23	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
200.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0130	0130
201.		150	150	150	150	150	150	150	150	150	150	150	150	150
202.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0190
203.	190													
204.		0190	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
205.		0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150	0150	0130
206.		0130	0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1	-1
207.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
208.	24	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
209.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0130	0130	0150
210.	150													
211.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170	0190
212.		190	190	190	190	190	190	190	190	190	190	190	190	190
213.		0190	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
214.		0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0130
215.		0130	0130	0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1
216.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
217.	25	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
218.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
219.		150	150	150	150	150	150	150	150	150	150	150	150	150
220.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0190	0190
221.		190	190	190	190	190	190	190	190	190	190	190	190	190
222.		0190	0190	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
223.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150
224.		0130	0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1
225.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
226.	26	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
227.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
228.		150	150	150	150	150	150	150	150	150	150	150	150	150
229.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0190	0190
230.		190	190	190	190	190	190	190	190	190	190	190	190	190
231.		0190	0190	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
232.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150
233.		0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
234.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
235.	27	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
236.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
237.		150	150	150	150	150	150	150	150	150	150	150	150	150
238.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0190	0190
239.		190	190	190	190	190	190	190	190	190	190	190	190	190
240.		0190	0190	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
241.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150
242.		0150	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
243.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
244.	28	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
245.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
246.		150	150	150	150	150	150	150	150	150	150	150	150	150
247.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170	0190
248.		190	190	190	190	190	190	190	190	190	190	190	190	190
249.		0190	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
250.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150
251.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
252.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
253.	29	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
254.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
255.		150	150	150	150	150	150	150	150	150	150	150	150	150

256.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170	0190
257.		190	190	190	190	190	190	190	190	190	190	190	190	190
258.		170	170	170	170	170	170	170	170	170	170	170	170	170
259.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150
260.		0150	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
261.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
262.	30	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
263.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150
264.		150	150	150	150	150	150	150	150	150	150	150	150	150
265.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
266.		0190	0190	0190	0190	0190	0190	0190	0190	0190	0190	0190	0170	0170
267.		170	170	170	170	170	170	170	170	170	170	170	170	170
268.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	-1	-1
269.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
270.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
271.	31	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
272.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150
273.		150	150	150	150	150	150	150	150	150	150	150	150	150
274.		0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170
275.		0190	0190	0190	0190	0190	0190	0170	0170	0170	0170	0170	0170	0170
276.		170	170	170	170	170	170	170	170	170	170	170	170	170
277.		0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	-1	-1
278.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
279.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
280.	32	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
281.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
282.		150	150	150	150	150	150	150	150	150	150	150	150	150
283.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170
284.		170	170	170	170	170	170	170	170	170	170	170	170	170
285.		170	170	170	170	170	170	170	170	170	170	170	170	170
286.		0170	0170	0170	0170	0170	0170	0150	0150	0150	-1	-1	-1	-1
287.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
288.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
289.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
290.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0150	0150
291.		150	150	150	150	150	150	150	150	150	150	150	150	150
292.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170
293.		170	170	170	170	170	170	170	170	170	170	170	170	170
294.		170	170	170	170	170	170	170	170	170	170	170	170	170
295.		0170	0170	0170	0150	0150	0150	0150	0150	-1	-1	-1	-1	-1
296.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
297.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
298.	34	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
299.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0170	0170
300.		0170	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150
301.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170
302.		170	170	170	170	170	170	170	170	170	170	170	170	170
303.		170	170	170	170	170	170	170	170	170	170	170	170	170
304.		0170	0170	0150	0150	0150	-1	-1	-1	-1	-1	-1	-1	-1
305.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
306.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
307.	35	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
308.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0170
309.		0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150	0150	0150
310.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170
311.		170	170	170	170	170	170	170	170	170	170	170	170	170
312.		170	170	170	170	170	170	170	170	170	170	170	170	170
313.		0170	0150	0150	0150	0150	-1	-1	-1	-1	-1	-1	-1	-1
314.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
315.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
316.	36	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
317.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
318.		0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150	0150
319.		0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170	0170

320.		170	170	170	170	170	170	170	170	170	170	170	170	170
321.		170	170	170	170	170	170	170	170	170	170	170	170	170
322.		0150	0150	0150	0150	-1	-1	-1	-1	-1	-1	-1	-1	-1
323.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
324.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
325.	37	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
326.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
327.		0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150
328.		0150	0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170
329.		170	170	170	170	170	170	170	170	170	170	170	170	170
330.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150
331.		0150	0150	0150	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
332.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
333.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
334.	38	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
335.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
336.		-1	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150
337.		0150	0150	0150	0150	0150	0170	0170	0170	0170	0170	0170	0170	0170
338.		170	170	170	170	170	170	170	170	170	170	170	170	170
339.		0170	0170	0170	0170	0170	0170	0170	0170	0170	0150	0150	0150	0150
340.		0150	0150	0150	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
341.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
342.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
343.	39	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
344.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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347.		170	170	170	170	170	170	170	170	170	170	170	170	170
348.		0170	0170	0170	0170	0170	0170	0150	0150	0150	0150	0150	0150	0150
349.		0150	0150	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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356.		150	150	150	150	150	150	150	150	150	150	150	150	150
357.		150	150	150	150	150	150	150	150	150	150	150	150	150
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364.		150	150	150	150	150	150	150	150	150	150	150	150	150
365.		150	150	150	150	150	150	150	150	150	150	150	150	150
366.		0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	0150	-1
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373.		150	150	150	150	150	150	150	150	150	150	150	150	150
374.		150	150	150	150	150	150	150	150	150	150	150	150	150
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382.		150	150	150	150	150	150	150	150	150	150	150	150	150
383.		0150	0150	0150	0150	0150	0150	0150	0150	0150	0130	0130	0130	0130

384.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1
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393.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1
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400.		0150	0150	0150	0150	0150	0150	0150	0150	0150	0130	0130	0130	0130
401.		130	130	130	130	130	130	130	130	130	130	130	130	130
402.		0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1
403.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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409.		0150	0150	0150	0150	0150	0150	0150	0130	0130	0130	0130	0130	0130
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412.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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430.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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447.		0130	0130	0130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

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534.		0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130	0130
535.		130	130	130	130	130	130	130	130	130	130	130	130	130
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544.		130	130	130	130	130	130	130	130	130	130	130	130	130
545.		0130	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1	-1	-1
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615.		0150	0150	0130	0130	0130	0130	0130	0130	0130	0130	-1	-1	-1
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617.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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.1 Vegetation

1.	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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4.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
5.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
6.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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34.		-1	-1	-1	-1	0001	0001	-1	-1	-1	0003	0003	0003	0003
35.		0001	0003	0003	0001	-1	-1	-1	-1	0002	0003	0003	-1	-1
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37.	5	0002	0002	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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43.		0001	0001	0004	0004	0004	0001	0001	0003	0003	0003	0003	0003	0001
44.		0003	0003	0003	000	0003	0003	0003	0003	0003	0003	0003	-1	-1
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52.		0001	0001	0004	0004	0001	0001	0001	0001	0003	0003	0003	0003	0003
53.		0001	0003	0003	0003	0003	0003	0002	0002	0003	0002	0003	-1	-1
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60.		-1	-1	-1	-1	-1	0004	0001	0001	0001	0001	0001	0001	0001
61.		0001	0001	0001	0001	0001	0001	0001	0001	0003	0003	0003	0003	0003
62.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	-1
63.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

64.	8	-1	0002	0002	0002	0002	0002	-1	-1	-1	-1	-1	-1	-1
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67.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
68.		0005	0005	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
69.		-1	-1	-1	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
70.		0001	0001	0001	0001	0001	0001	0003	0003	0003	0003	0003	0003	0003
71.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0002	0003
72.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
73.	9	-1	-1	0002	0002	0002	0002	-1	-1	-1	-1	-1	-1	-1
74.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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76.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
77.		0005	0005	0005	-1	-1	0005	0005	0005	0005	0005	0005	0005	0005
78.		0005	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
79.		0001	0001	0001	0001	0001	0001	0003	0003	0003	0003	0003	0003	0003
80.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0002	0003	0003	0003
81.		0003	0003	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
82.	10	-1	-1	-1	0002	0002	0002	-1	-1	-1	-1	-1	-1	-1
83.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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85.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005	0005	0005
86.		0005	0005	0005	-1	0005	0005	0005	0005	0005	0005	0001	0005	0005
87.		0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
88.		0001	0003	0001	0001	0001	0001	0001	0003	0003	0003	0003	0003	0003
89.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0005
90.		0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
91.	11	-1	-1	-1	0002	0002	0002	0002	-1	-1	-1	-1	-1	-1
92.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1.
93.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
94.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005	0005	0005
95.		0005	0005	0005	0005	0005	0005	0005	0005	0005	0005	0005	0001	0001
96.		0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
97.		0001	0001	0001	0001	0001	0001	0001	0003	0003	0003	0005	0003	0003
98.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003
99.		0001	0001	0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1
100.	12	-1	-1	-1	0002	0004	0004	0004	0004	-1	-1	-1	-1	-1
101.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
102.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
103.		-1	-1	-1	-1	-1	-1	-1	0005	0005	0005	0005	0005	0005
104.		0005	0005	0005	0005	0005	0004	0005	0005	0005	0005	0001	0005	0001
105.		0005	0004	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
106.		0001	0003	0001	0001	0001	0001	0001	0001	0003	0001	0001	0003	0003
107.		0003	0003	0003	0005	0003	0005	0005	0003	0003	0003	0003	0003	0003
108.		0001	0001	0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1
109.	13	-1	-1	-1	-1	0004	0004	0004	0004	0004	0004	0004	-1	-1
110.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
111.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
112.		-1	-1	-1	-1	-1	-1	0005	0005	0005	0004	0004	0005	0005
113.		0004	0005	0005	0005	0005	0005	0005	0004	0005	0005	0005	0005	0005
114.		0001	0001	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
115.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0003	0003	0003	0003
116.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003
117.		0005	0005	0001	0001	0001	0001	-1	-1	-1	-1	-1	-1	-1
118.	14	-1	-1	-1	-1	0004	0004	0004	0004	0004	0004	0004	0004	-1
119.		-1	-1	-1	0004	0004	0004	0004	0002	0002	0002	0004	0004	-1
120.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
121.		-1	-1	0005	0005	-1	-1	0005	0005	0005	0004	0004	0005	0005
122.		0004	0005	0004	0005	0005	0005	0004	0004	0005	0005	0005	0001	0001
123.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
124.		0003	0001	0001	0001	0001	0001	0001	0003	0001	0003	0003	0003	0003
125.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003
126.		0003	0005	0001	0001	0001	0001	0001	-1	-1	-1	-1	-1	-1
127.	15	-1	-1	-1	-1	0004	0004	0004	0004	0004	0004	0004	0004	0004

128.		0004	0004	0004	0004	0004	0004	0004	0002	0002	0004	0004	0004	0004
129.		0004	0004	0004	-1	-1	-1	0005	-1	-1	-1	-1	-1	-1
130.		-1	0005	0005	0005	0005	-1	0005	0005	0004	0003	0005	0005	0004
131.		0005	0005	0005	0005	0005	0004	0005	0005	0005	0001	0001	0001	0001
132.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
133.		0001	0001	0001	0001	0001	0001	0001	0001	0003	0003	0003	0003	0003
134.		0003	0003	0003	0001	0003	0003	0003	0003	0003	0003	0003	0003	0003
135.		0003	0005	0005	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1
136.	16	-1	-1	-1	-1	-1	0004	0004	0004	0004	0004	0004	0004	0004
137.		0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004
138.		0004	0004	0004	0004	0004	0005	0005	-1	-1	-1	-1	-1	-1
139.		0005	0005	0005	0005	0005	0005	0004	0004	0005	0004	0004	0004	0004
140.		0005	0004	0005	0005	0005	0005	0005	0005	0005	0001	001	0001	0001
141.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
142.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0003	0003	0003	0003
143.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003
144.		0003	0003	0003	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
145.	17	-1	-1	-1	-1	-1	-1	-1	-1	-1	0004	0004	0004	0004
146.		0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004
147.		0004	0004	0004	0004	0004	0004	0005	0002	0002	0005	0005	0004	0005
148.		0005	0005	0005	0005	0005	0005	0004	0005	0005	0004	0004	0004	0005
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151.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0003	0003	0003	0003
152.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003
153.		0003	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
154.	18	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0004
155.		0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004
156.		0004	0004	0004	0004	0004	0004	0004	0002	0002	0002	0005	0005	0005
157.		0005	0005	0005	0005	0005	0005	0005	0005	0005	0004	0005	0005	0005
158.		0004	0005	0005	0005	0004	0005	0005	0005	0005	-1	-1	-1	-1
159.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
160.		-1	-1	-1	-1	-1	-1	-1	-1	-1	0003	0003	0003	0003
161.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	-1	-1
162.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
163.	19	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
164.		0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004
165.		0004	0004	0004	0004	0004	0004	0004	0005	0005	0005	0005	0005	0005
166.		0005	0005	0005	0005	0005	0005	0002	0005	0004	0004	0005	0004	0005
167.		0005	0005	0005	0005	0004	0005	0005	0005	0001	0001	0001	0001	0001
168.		1	1	1	1	1	1	1	1	1	1	1	1	1
169.		0001	0001	0001	0001	0001	0001	0001	0001	0003	0003	0001	0003	0003
170.		0003	0003	0003	0003	0003	0003	0001	0003	0003	0003	0003	-1	-1
171.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
172.	20	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
173.		-1	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004	0004
174.		0004	0004	0004	0004	0004	0004	0004	0004	0005	0005	0005	0005	0005
175.		0005	0004	0004	0005	0005	0002	0002	0005	0004	0005	0004	0004	0005
176.		0005	0004	0005	0005	0005	0005	0004	0005	0001	0001	0001	0001	0001
177.		1	1	1	1	1	1	1	1	1	1	1	1	1
178.		0001	0001	0001	0001	0001	0001	0003	0003	0003	0001	0001	0003	0003
179.		0003	0003	0003	0003	0003	0003	0003	0003	0003	0003	-1	-1	-1
180.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
181.	21	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
182.		-1	-1	-1	-1	-1	0004	0004	0004	0004	0004	0004	0004	0004
183.		0004	0004	0004	0004	0004	0004	0004	0004	0005	0005	0002	0002	0005
184.		0004	0004	0005	0005	0004	0005	0005	0005	0005	0004	0004	0005	0001
185.		0004	0004	0005	0005	0005	0001	0005	0001	0001	0001	0001	0001	0001
186.		1	1	1	1	1	1	1	1	1	1	1	1	1
187.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0003	0003
188.		0001	0001	0003	0003	0003	0003	0003	0003	0003	-1	-1	-1	-1
189.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
190.	22	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
191.		-1	-1	-1	-1	-1	-1	0004	0004	-1	-1	0004	0005	0004

192.		0004	0005	0004	0004	0004	0004	0004	0004	0005	0005	0005	0005	0005
193.		0004	0004	0004	0004	0005	0005	0005	0005	0005	0004	0005	0005	0004
194.		0004	0004	0004	0004	0004	0005	0005	0001	0001	0001	0001	0001	0001
195.		1	1	1	1	1	1	1	1	1	1	1	1	1
196.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0003
197.		0001	0003	0001	0003	0001	0003	0003	-1	-1	-1	-1	-1	-1
198.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
199.	23	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
200.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
201.		0004	0005	0005	0005	0004	0004	0004	0004	0005	0005	0005	0005	0004
202.		0004	0004	0004	0004	0004	0005	0004	0005	0004	0004	0005	0004	0005
203.		0005	0004	0004	0004	0005	0005	0005	-1	-1	-1	-1	-1	-1
204.		1	1	1	1	1	1	1	1	1	1	1	1	1
205.		1	1	1	1	1	1	1	1	1	1	1	1	1
206.		0001	0001	0003	0003	0003	0003	-1	-1	-1	-1	-1	-1	-1
207.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
208.	24	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
209.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005	0005
210.		0005	0005	0005	0005	0005	0005	0005	0005	0004	0004	0004	0004	0005
211.		0004	0004	0004	0004	0004	0005	0005	0005	0005	0004	0005	0005	0005
212.		0005	0004	0004	0005	0004	0005	0005	0001	0001	0001	0001	0001	0001
213.		1	1	1	1	1	1	1	1	1	1	1	1	1
214.		1	1	1	1	1	1	1	1	1	1	1	1	1
215.		0003	0003	0001	0001	0003	-1	-1	-1	-1	-1	-1	-1	-1
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217.	25	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
218.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
219.		0002	0002	0005	0005	0005	0005	0005	0005	0004	0004	0004	0004	0004
220.		0004	0004	0004	0004	0004	0004	0004	0005	0005	0005	0005	0005	0001
221.		0001	0005	0005	0005	0004	0004	0001	0001	0001	0001	0001	0001	0001
222.		1	1	1	1	1	1	1	1	1	1	1	1	1
223.		1	1	1	1	1	1	1	1	1	1	1	1	1
224.		0001	0001	0001	0003	-1	-1	-1	-1	-1	-1	-1	-1	-1
225.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
226.	26	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
227.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
228.		0005	0005	0005	0005	0005	0001	0005	0005	0005	0005	0004	0005	0005
229.		0005	0004	0004	0004	0004	0004	0004	0004	0004	0001	0005	0005	0005
230.		0001	0001	0005	0004	0004	0004	-1	-1	-1	-1	-1	-1	-1
231.		1	1	1	1	1	1	1	1	1	1	1	1	1
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233.		0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
234.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
235.	27	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
236.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
237.		0005	0005	0005	0005	0005	0001	0001	0001	0005	0005	0004	0004	0005
238.		0005	0004	0005	0002	0005	0005	0005	0004	0005	0005	0004	0005	0005
239.		0001	0001	0001	0001	0004	0001	0001	0001	0001	0001	0001	0001	0001
240.		1	1	1	1	1	1	1	1	1	1	1	1	1
241.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0003	0001
242.		0001	0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
243.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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245.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0002	0002
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247.		0005	0005	0005	0005	0005	0005	0005	0004	0005	0005	0005	0005	0005
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249.		1	1	1	1	1	1	1	1	1	1	1	1	1
250.		1	1	1	1	1	1	1	1	1	1	1	1	1
251.		0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
252.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
253.	29	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
254.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
255.		0005	0005	0005	0005	0005	0005	0005	0004	0004	0004	0004	0005	0005

256.		0005	0005	0005	0005	0005	0005	0005	0005	0004	0004	0005	0005	0005
257.		0005	0005	0004	0004	0005	0001	0004	0005	0005	0001	0001	0001	0001
258.		1	1	1	1	1	1	1	1	1	1	1	1	1
259.		1	1	1	1	1	1	1	1	1	1	1	1	1
260.		0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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262.	30	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
263.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005
264.		0005	0003	0005	0005	0003	0004	0005	0005	0004	0004	0005	0005	0003
265.		0005	0005	0004	0004	0005	0005	0004	0005	0005	0005	0005	0005	0005
266.		0005	0005	0005	0004	0004	0004	0004	0005	0005	0001	0001	0001	0001
267.		1	1	1	1	1	1	1	1	1	1	1	1	1
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271.	31	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
272.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005
273.		0005	0005	0005	0005	0005	0003	0004	0004	0004	0004	0004	0005	0005
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277.		0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	-1	-1
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281.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
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283.		5	5	5	5	5	5	5	5	5	5	5	5	5
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286.		0001	0001	0001	0001	0001	0001	0001	0001	0001	-1	-1	-1	-1
287.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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290.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
291.		0005	0005	0005	0005	0004	0005	0004	0003	0004	0004	0005	0005	0005
292.		5	5	5	5	5	5	5	5	5	5	5	5	5
293.		0001	0001	0005	0005	0004	0005	0005	0005	0001	0001	0001	0001	0001
294.		0001	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
295.		0001	0001	0001	0001	0001	0001	0001	0001	-1	-1	-1	-1	-1
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299.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005	0005
300.		0005	0005	0005	0005	0004	0004	0004	0004	0004	0005	0005	0005	0005
301.		5	5	5	5	5	5	5	5	5	5	5	5	5
302.		0005	0001	0005	0005	0004	0005	0005	0001	0001	0001	0001	0001	0001
303.		1	1	1	1	1	1	1	1	1	1	1	1	1
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306.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
307.	35	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
308.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0005
309.		0005	0005	0005	0005	0004	0004	0004	0004	0004	0004	0005	0005	0005
310.		5	5	5	5	5	5	5	5	5	5	5	5	5
311.		0005	0005	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
312.		0001	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001
313.		0001	0001	0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1
314.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
315.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
316.	36	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
317.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
318.		0005	0005	0005	0005	0004	0004	0004	0005	0005	0004	0004	0004	0005
319.		5	5	5	5	5	5	5	5	5	5	5	5	5

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321.		0001	0001	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
322.		0001	0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1	-1
323.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
324.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
325.	37	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
326.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
327.		0005	0005	0005	0005	0002	0004	0004	0004	0002	0004	0005	0005	0004
328.		5	5	5	5	5	5	5	5	5	5	5	5	5
329.		0005	0005	0001	0001	0001	0001	0001	0001	0005	0005	0001	0001	0001
330.		0001	0005	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
331.		0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
332.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
333.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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335.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
336.		0005	0005	0005	0005	0002	0004	0004	0004	0002	0004	0005	0005	0004
337.		5	5	5	5	5	5	5	5	5	5	5	5	5
338.		0005	0005	0001	0001	0001	0001	0001	0001	0005	0005	0001	0001	0001
339.		0001	0005	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
340.		0001	0001	0001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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345.		-1	-1	0005	0005	0005	0004	0004	0004	0004	0004	0005	0005	0005
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354.		-1	-1	0005	0004	0004	0004	0004	0005	0005	0005	0005	0005	0005
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356.		0005	0005	0004	0005	0001	0001	0001	0001	0001	0005	0005	0001	0005
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364.		0005	0005	0005	0005	0005	0005	0005	0005	0005	0005	0005	0004	0005
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366.		0001	0001	0001	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001
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372.		-1	-1	0004	0005	0004	0005	0004	0004	0005	0005	0005	0005	0005
373.		0005	0005	0005	0005	0005	0005	0005	0005	0005	0005	0004	0004	0004
374.		0004	0004	0005	0004	0004	0005	0005	0005	0005	0001	0004	0004	0004
375.		0001	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	-1
376.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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384.		0001	0005	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	-1
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393.		0001	0005	0001	0001	0001	0001	0001	0001	0001	0001	0001	0001	-1
394.		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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427.		5	5	5	5	5	5	5	5	5	5	5	5	5
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447.		0005	0005	0005	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

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456.		0001	0005	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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463.		0005	0005	0002	0002	0002	0005	0004	0002	0004	0004	0004	0004	0002
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.1 Soils

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82.	10	-1	-1	-1	0004	0004	0002	-1	-1	-1	-1	-1	-1	-1
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77.		0049	0048	0023	-1	-1	0017	0035	0044	0013	0050	0067	0057	0049
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79.		0000	0000	0003	0005	0021	0008	0000	0006	0012	0002	0011	0001	0009
80.		0000	0000	0008	0005	0000	0008	0000	0000	0000	0000	0000	0000	0000
81.		0014	0014	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
82.	10	-1	-1	-1	0006	0010	0017	-1	-1	-1	-1	-1	-1	-1
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89.		0000	0000	0000	0007	0003	0011	0013	0000	0005	0008	0031	0000	0002
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98.		0011	0002	0005	0013	0019	0021	0007	0009	0000	0014	0002	0002	0000
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122.		0048	0059	0066	0032	0056	0021	0023	0000	0001	0004	0008	0018	0002
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124.		0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0010	0002	0004
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129.		0033	0052	0048	-1	-1	-1	0041	-1	-1	-1	-1	-1	-1
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147.		0014	0016	0030	0016	0034	0045	0049	0047	-1	-1	0052	0052	0065
148.		0043	0054	0059	0052	0067	0055	0058	0038	0035	0040	0037	0041	0058
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156.		0005	0028	0078	0043	0013	0032	0030	0059	0036	0042	0035	0062	0042
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158.		0032	0007	0019	0001	0012	0003	0045	0053	0028	0035	0006	0000	0000
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165.		0010	0038	0051	0050	0036	0018	0029	0060	0053	0060	0046	0057	0052
166.		0038	0056	0040	0046	0069	0045	0033	0015	0035	0035	0035	0054	0050
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265.		0055	0032	0048	0036	0055	0056	0048	0030	0041	0048	0035	0032	0046
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273.		0017	0029	0044	0031	0074	0006	0000	0003	0000	0000	0000	0033	0034
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293.		0016	0013	0033	0018	0027	0011	0009	0011	0014	0009	0002	0000	0000
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310.		0050	0067	0049	0059	0065	0066	0051	0053	0044	0054	0047	0061	0034
311.		0054	0040	0014	0002	0000	0000	0001	0005	0015	0009	0010	0011	0000
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328.		0040	0065	0065	0075	0081	0031	0045	0051	0039	0063	0050	0032	0043
329.		0046	0032	0026	0015	0013	0000	0002	0004	0005	0015	0018	0032	0014
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337.		0073	0070	0065	0051	0026	0036	0056	0056	0023	0046	0041	0059	0053
338.		0061	0035	0031	0027	0019	0000	0003	0010	0006	0016	0017	0033	0018
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