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SOILS OF THE HIGHLAND AND MOUNTAINOUS AREAS OF KENYA WITH SPECIAL EMPHASIS ON AGRICULTURAL SOILS

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ABSTRACT Kenya's landscape is of great topographic diversity, rising from sea level to 5,199 m a.s.l. at the summit of Mount Kenya. Climate, geology, and relief have created different agro-climatic zones with highly variable soil developments. These are discussed with reference to the highland areas above 1,500 m.

Of the fourteen major soil types, the dominant ones are Ferralsols, Acrisols, Phaeozems, and Nitosols. Deforestation, agricultural use of slopes, and overgrazing have significantly degraded most soils in the highlands, although they have good structure and relative resistance to soil erosion. A number of conservation measures were introduced in the late 1920s and again after 1972. Since 1980, the government has also heavily encouraged afforestation to control erosion.

RÉSUMÉ *Sols des régions de hautes terres et de montagnes au Kenya, en particulier les sols favorables à l'agriculture.* Le terrain du Kenya présente une grande diversité topographique, s'élevant du niveau de la mer jusqu'à 5.199 m au sommet du mont Kenya. Le climat, la géologie et le relief ont créé différentes zones agro-climatiques avec des développements de sol très variés. Ceux-ci sont passés en revue en faisant référence aux régions de hautes terres au-dessus de 1.500 m.

Parmi les quatorze principaux types de sol présents, les plus importants sont les Ferralsols, Acrisols, Phaeozems et Nitosols. La déforestation, l'utilisation des pentes pour l'agriculture, et le surpâturage ont sensiblement dégradé la plupart des sols dans les hautes terres, bien que ces sols aient une bonne structure et relativement une bonne résistance à l'érosion. Un certain nombre de mesures de conservation des sols ont été prises à la fin des années 20 et de nouveau après 1972. De plus, le gouvernement a depuis 1980 fortement encouragé l'afforestation pour lutter contre l'érosion.

ZUSAMMENFASSUNG *Bodentypen des Hochlandes und der Gebirge Kenyas mit spezieller Beachtung der landwirtschaftlichen Böden.* Kenya's Landschaft weist grosse topographische Variationen auf und erstreckt sich vom Meeresspiegel bis zum Gipfel des Mount Kenya (5199 m ü.M.). Klima, Geologie und Relief haben die Entwicklung verschiedener agro-klimatischer Zonen mit sehr unterschiedlicher Bodenbildung bewirkt. Im vorliegenden Artikel werden die Boden typen für das Hochland oberhalb 1500 m ü.M. diskutiert.

Von 14 Hauptbodentypen sind Ferralsol, Acrisol, Phaeozem und Nitosol die wichtigsten. Entwaldung, landwirtschaftliche Nutzung der Hänge und Ueberweidung haben die meisten Böden im Hochland degradiert, obwohl sie eine gute Struktur aufweisen und resistent gegen Erosion sind. Eine Reihe von Konservierungsmassnahmen wurde in den 1920er Jahren und wiederum nach 1972 eingeführt. Seit 1980 wurde auch die Aufforstung durch die Regierung stark gefördert.

INTRODUCTION

Kenya is located on the eastern part of the African continent. It lies approximately between latitudes 4°21′ North and 4°28′ South, and between longitudes 34° and 42° East. The Equator almost divides the country into two equal parts. The total surface area is approximately 583,000 km².

The landscape of Kenya displays great topographic diversity. It rises from sea level at the coast to 5,199 m at the summit of Mount Kenya. As a result of this complex terrain, different regions of the country experience extremely varied climates in terms of both precipitation and temperature. The country also has a variety of rock types, ranging from Basement System rocks of Precambrian age to Tertiary volcanics and Cenozoic unconsolidated sediments. This variation in geology (parent material), coupled with variation in relief and climate, has resulted in the formation of a wide range of soils. In this paper a brief outline of the soils encountered in the Highlands of Kenya is given. Emphasis is laid on those soils that are important for agriculture.

The "Kenya Highlands" refers to those areas lying above 1,500 m a.s.l. The mountainous areas, which in this paper will be considered as part of the Highlands, refer to those elevated areas that have a relief intensity of 300 m or more.

LOCATION AND PHYSICAL FEATURES

Figure 1 shows the location of the highlands of Kenya and the relative altitude. The physical characteristics of these areas are closely related to their geological foundation (Ondigo, 1971). The Great Rift Valley divides the

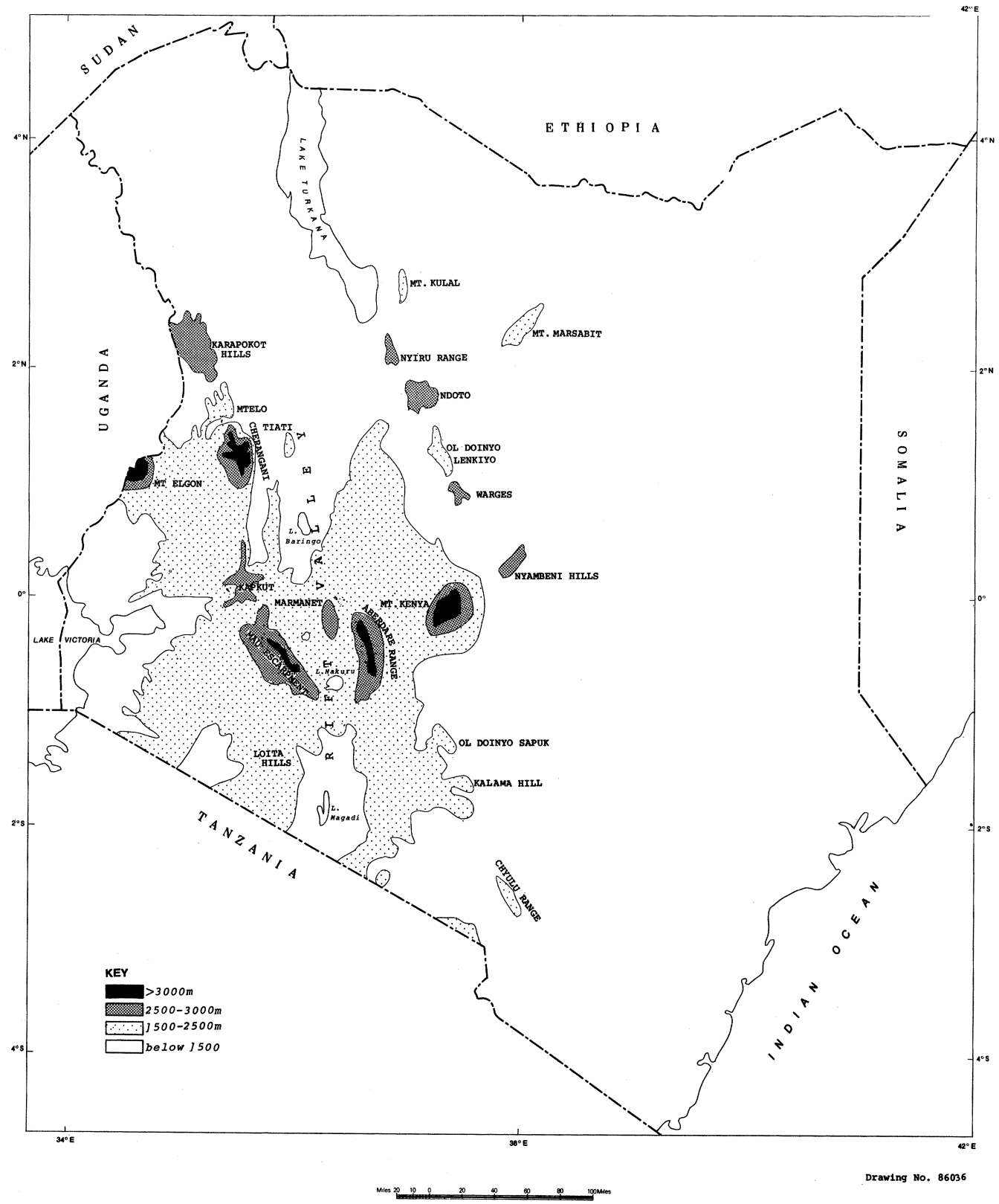

Figure 1. Relief of the Highlands and mountainous areas of Kenya.

Figure 2. Coffee at flowering stage in Central Kenya is mainly grown in the Upper Midland zone between 1,500 and 1,850 m.

Kenya Highlands into three broad units: namely the Highlands to the east of the Rift Valley, those to the west, and those of the Rift Valley itself.

The Highlands to the east of the Rift Valley include Mount Kenya (highest peak 5,199 m), the Aberdare range (highest peak 3,999 m), the Athi Kapiti Plains and Machakos hills (1,500 m), the Nyiru-Ndoto and Mathews ranges (2,752 m, 2,637 m, and 2,375 m, respectively). Occurring also east of the Rift Valley are the Nyambeni hills (2,514 m), Mount Marsabit (1,702 m), and the Chyulu Range (2,081 m). The bulk of these highlands are dominated by the mid-Tertiary to Recent volcanic lavas and most of the area is a rolling landscape.

The Highlands west of the Rift Valley include the Cherangani Hills (3,444 m—the highest non-volcanic point in Kenya), the Mau Escarpment (3,098 m), Mount Elgon (the highest peak—4,321 m), the Kara Pokot Hills (2,791 m), the Uasin Gishu Plateau (varying from 2,100 to 2,750 m), the Trans-Nzoia uplands (average altitude 1,900 m but rising to 2,500 m), the Sotik-Kericho uplands (averaging about 1,800 m), and the Kisii highlands (varying from 1,500 to 2,150 m). The Kisii highlands consist of a maturely dissected landscape which preserves some remnants of the Gondwana Summit Plain (Ojany, 1968).

Within the Highlands area of the Rift Valley is the volcanic cone of Longonot (2,776 m) and the Menengai cauldera. Lakes Naivasha, Elmenteita, and Nakuru are also found in this area at altitudes between 1,800 and 2,000 m.

CLIMATE AND LAND USE

The effects of altitude dominate the climate of the Highlands of Kenya. On the basis of altitude and climatic characteristics, the Highlands can be divided into four main agro-climatic zones, namely, the Afro-alpine zone, the Upper Highland zone, the Lower Highland zone, and the Upper Midlands zone (Jaetzold and Schmidt, 1982).

The Afro-alpine zone lies above 3,050 m and has temperature conditions that are ill-suited for trees or crops; hence the bulk of the Highlands in this zone is not used for agriculture. The Upper Highland zone lies between 2,450 and 3,050 m and has temperature conditions suitable for frost-resistant crops. This area is also suitable for sheep. The Lower Highland zone occurs between 1,850 and 2,450 m and has temperature conditions highly suitable for tea and pyrethrum; this area is also favourable for dairy pastures, potatoes, vegetables, wheat, barley, and long-maturing maize. The Upper Midland areas lie between 1,500 and 1,850 m and have temperature conditions which are very suitable for coffee and maize (Figures 2 and 3); tea is also grown in the upper levels of this zone.

Table 1 gives a summary of the agro-climatic zones of the Highlands of Kenya and of the major crops grown.

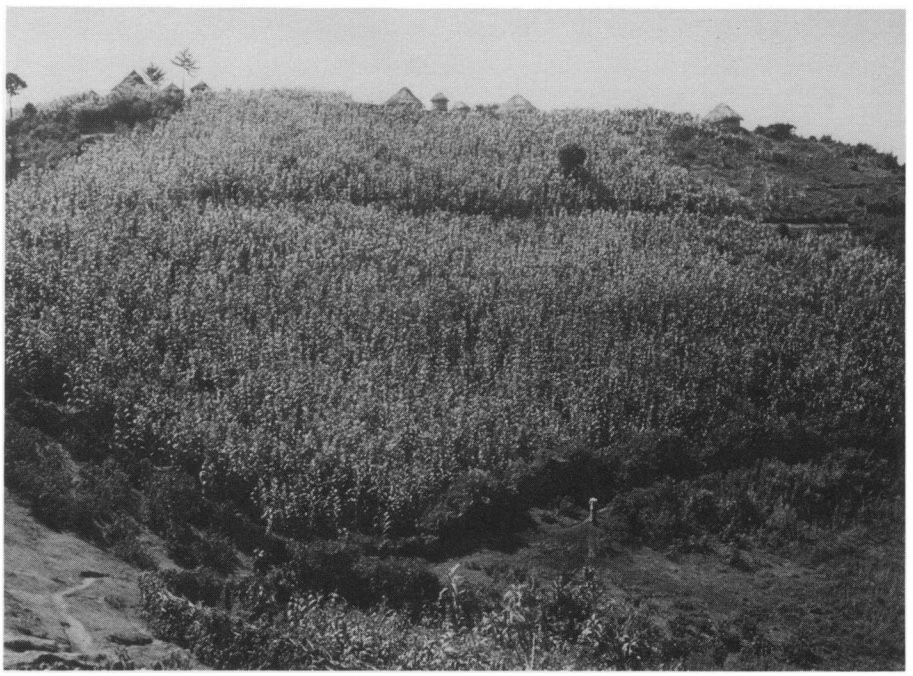

Figure 3. Small-scale maize farming on hillslopes greater than 30 percent in the Kapswar area.

Table 1
Agro-climatic belts, temperature, and land use of the Highlands of Kenya

Agro-climatic belt	Altitude (m)	Mean annual temperature (°C)	Land use-major crops
Afro-alpine	Over 3,050	Less than 10	Not suitable for trees or crops.
Upper Highland	2,450–3,050	10–14	Pyrethrum, wheat, barley, sheep, dairy cattle.
Lower Highland	1,850–2,450	14–18	Tea, pyrethrum, potatoes, vegetables, maize, dairy cattle, wheat.
Upper Midland	1,500–1,850	18–20	Coffee, maize, tea, sunflowers.

Sources: Jaetzold and Schmidt (1982) and Sombroek *et al.* (1982).

SOIL TYPES

Figure 4 shows the distribution of the major soil types found in the Highlands and mountainous areas of Kenya. They are classified according to the concepts of the FAO/UNESCO Soil Map of the World (FAO, 1974). Fourteen major soil types are found in these areas; only a brief description will be given here, with special emphasis on those soils that are important for agriculture.

Ferralsols are found in the Trans-Nzoia Plateau and parts of the Kisii highlands. These soils are strongly weathered and leached, and therefore are chemically poor. Their natural fertility is restricted to the A-horizon and is related to the organic matter content. The B-horizon has low cation exchange capacity (CEC) (less than 16 milliequivalents per 100 g clay) and is dominated by sesquioxides and silicate clays having a 1:1 lattice. Addition of fertilizer or manure is necessary for optimum crop production. These soils have an excellent capacity to hold moisture since they are deep and porous and generally have a high clay content. Although these soils may not be highly erodible, soil conservation measures are necessary.

Acrisols are strongly weathered with a base saturation determined by NH_4O Ac at pH 7.0 of less than 50 percent. The B-horizon is characterized by illuviation of silicate clay minerals which leads to strong variations of texture over relatively short distances. The subsoil is often impervious and therefore restricts rooting, and is relatively low in water storage capacity.

Regosols are stony and rocky soils of widely variable chemical fertility, depending on parent material. They have a low moisture storage capacity. These soils are generally encountered in the steeper areas of the Highlands and mountains.

Luvisols resemble the Acrisols but have a base saturation determined by NH_4O Ac at pH 7.0 of more than 50 percent. They have a low to moderate natural fertility. Those Luvisols found in the drier parts of the Highlands have a tendency to form a strong seal on the surface which leads to low infiltration rates (Figure 5). This causes high runoff which leads to erosion of the more fertile topsoil.

Phaeozems are soils with dark coloured topsoil which

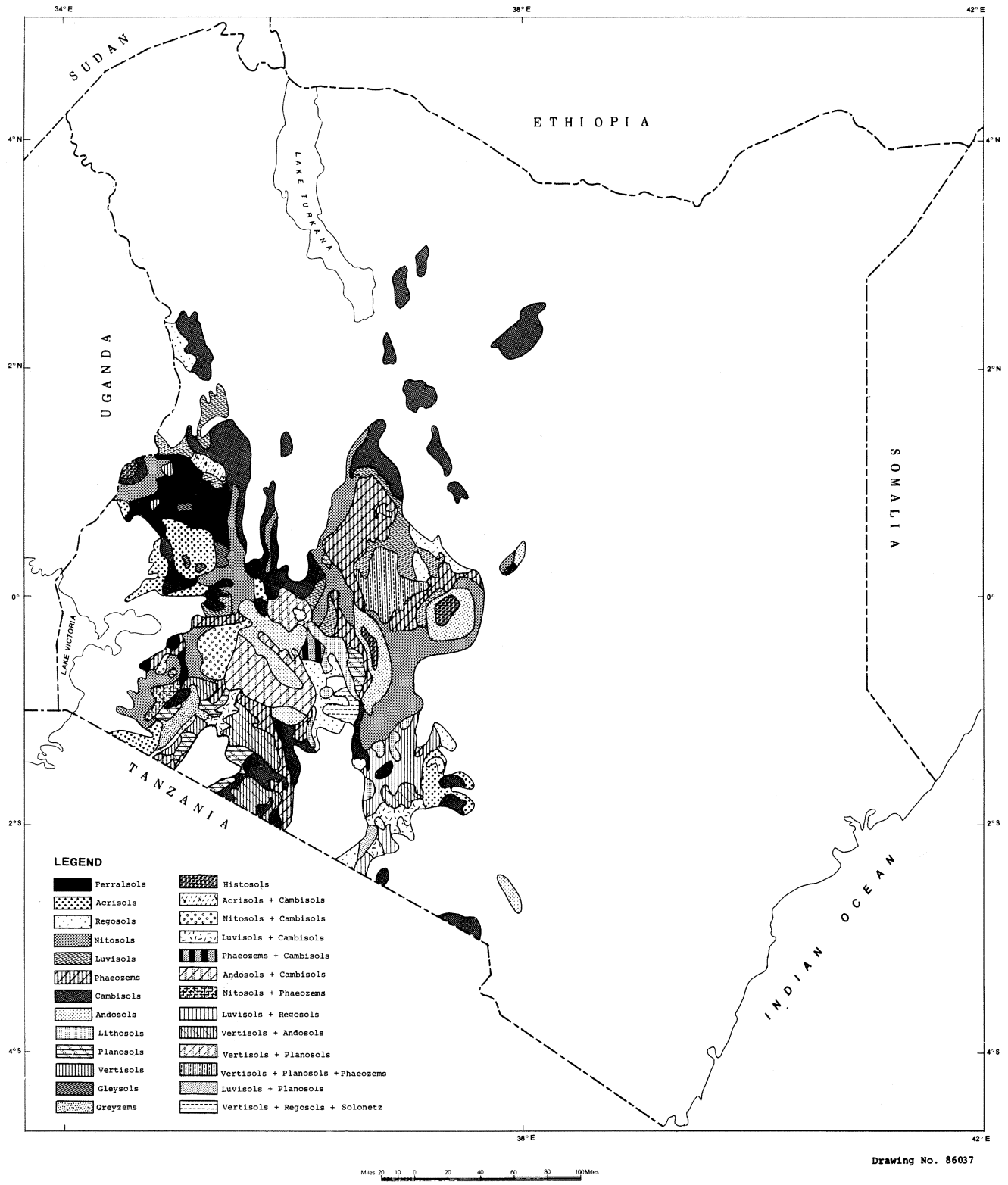

Figure 4. Distribution of soils of the Highlands and mountainous areas of Kenya.

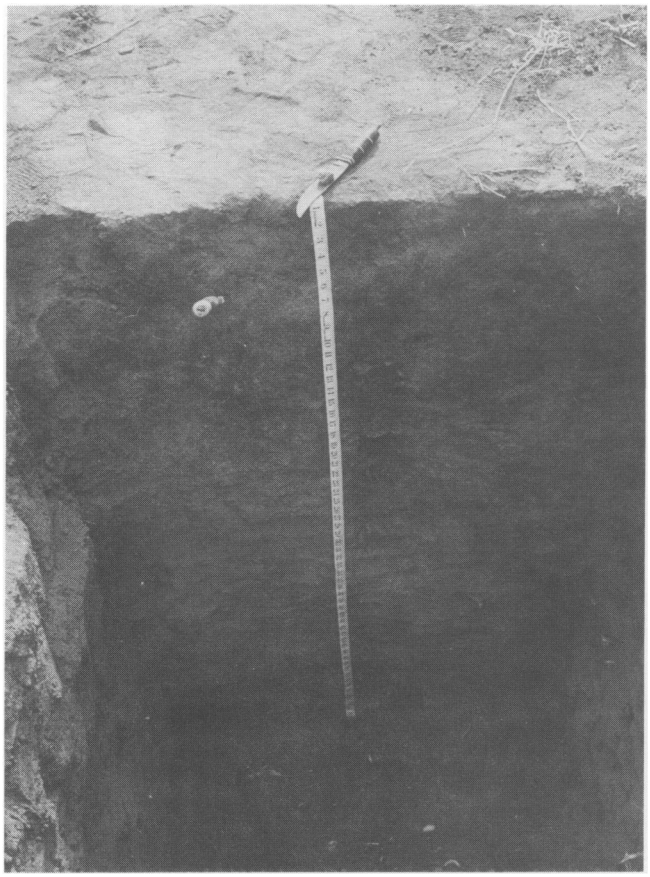

Figure 5. Chromic Luvisol in the drier area of the eastern Kenya Highlands; note the surface sealing.

Figure 6. A humic Cambisol in the Kapswar area; note the root distribution. Profiles in these high altitudes are characterized by high content of organic matter.

Table 2
Some chemical and physical properties of selected soils of the Highlands of Kenya

Soil type and (site)	Horizon	pH-H_2O 1:2.5	Organic carbon (%)	N (%)	CEC me/100 g soil	Base saturation (%)	Particle size distribution in % weight		
							Sand	Silt	Clay
Humic Nitosol	Ap	5.8	4.07	0.51	27.0	83	28	26	46
(Elgeyo Marakwet)	Bt	4.8	1.22		16.0	45	22	20	58
Dystric Nitosol	Al	5.5	2.1	0.25	6.0	19	20	14	66
(Mt. Kenya)	Bt	5.6	0.76		17.0	14	16	10	74
Humic Acrisol	A	5.6	5.11	0.31	43.3	47	32	28	40
(Mt. Kenya)	Bt	5.4	1.14		21.6	33	13	20	67
Luvic Phaeozem	A	6.9	0.79	0.23	36.4	82	28	24	48
(Laikipia)	Bt	7.5	0.64	0.11	43.2	100	24	14	62
Humic Cambisol	Au	5.3	5.77	1.10	48.0	67	56	22	22
(Cherangani Hills)	Ac	4.8	4.16		28.0	7	42	16	42
Humic Andosol	A	3.9	5.48	0.66	38.0	3	5	42	53
(Aberdare slopes)	Bu	4.3	2.20		32.0	3	5	35	60
Dystric Planosol	Ap	5.3	3.16	0.28	21.6	19	6	56	38
(Kinangop)	Bt	5.8	2.54		29.8	50	16	28	56

Sources: Muchena and Kibe, 1984; Speck, 1982; and Staff of the Kenya Soil Survey, 1977.

is high in organic matter and is non-acid. These soils are usually very fertile because they contain large quantities of organic matter, abundant mineral nutrients, and have an excellent physical structure. They are found in the Kisii highlands, the Laikipia plateau, and the Narok area.

Cambisols are young, little weathered soils with moderate to high natural fertility. They are common in mountainous areas and steeplands. The bulk of them, particularly those encountered at high altitudes, have high organic matter content (Table 2 and Figure 6).

Nitosols (commonly referred to in Kenya as Nitisols) are soils 150 cm deep or deeper, showing evidence of movement of clay within the profile; they have diffuse soil horizon boundaries (Figure 7). In Kenya these soils were popularly referred to as Kikuyu Red Loam and were also formerly called reddish brown lateritic soils and ferrisols. They have a favourable moisture storage capacity and aeration. They show a marked structural stability which allows cultivation even on moderately steep gradients. They are usually red, dark red, dusky red, or dark reddish brown in colour. Their chemical properties vary widely. The organic matter content, cation exchange capacity, and percentage base saturation range from low to high. These soils are known to have a high degree of phosphorus-sorption. For optimal crop production they require fertilizer or manure and are some of the best agricultural soils found

Figure 7. Nitosol: very deep (often greater than 200 cm) and with a marked structural stability; commonly found in the Upper Midland zones.

Figure 8. Planosols of the Kinangop plateau; note the very flat topography in the foreground.

in the country; they are found extensively in Central Kenya on both slopes of Mount Kenya and the Aberdare range, the Kisii highlands, the Sotik and Kericho highlands, and around Mount Elgon.

Andosols are soils that are formed from recent volcanic material and they have been referred to as volcanic ash soils. They may be coarse or fine textured but usually have a high silt content; they are porous, have a low bulk density (less than 0.85 g/cm^3), high organic matter, and a high water storage capacity. In general, they are fertile and have good physical characteristics. Erosion may be a serious problem as they consist of rather loose material and often occur on steep slopes of the volcanic areas. Another limiting factor of these soils is phosphate fixation, especially if the pH is low. Problems with micro-nutrients are also common. Andosols are found in the Chyulu Range, the Highlands in the Rift Valley, for example Longonot, the slopes of Mount Kenya, and in the Aberdare Range. These soils are extensively used for agriculture, including tea, wheat, and maize.

Lithosols are shallow, stony, and rocky soils. Their fertility depends on the parent material. These soils are found in mountainous areas on steep slopes, and are not suitable for agriculture.

Planosols (Vlei soils) are imperfectly drained. They are often waterlogged and have very slow vertical and horizontal drainage. Their soil fertility status ranges from low to moderate. Artificial drainage is the main management requirement of these soils. Planosols occur on flat, old land surfaces such as the Laikipia plateau, the Kinangop plateau, and the Sotik plateau (Figure 8).

Vertisols are dark, cracking soils, popularly known as black cotton soils and, formerly, as grumusols. They are usually poorly drained and are fine in texture—more than 35 percent clay. A striking feature is their capacity to expand and contract with changes in moisture content. During the dry season they shrink and large cracks develop. Chemical fertility of vertisols is usually high, except for nitrogen and phosphorus. They have high cation exchange capacity. Because they are very sticky when wet and extremely hard when dry, their workability is poor. Within the highlands the vertisols are found in the Narok area, on the Athi Kapiti plains, and on the Laikipia plateau.

Gleysols are poorly drained mineral soils which are periodically waterlogged. They are found in swampy and marshy areas within the Highlands. Their fertility is widely variable; some are very acid whereas others have topsoils with high organic matter. Artificial drainage is the most important management requirement.

Greyzems are soils rich in humus and have a grey colour. They are found in the Southwestern highlands and their natural fertility is moderate.

Histosols are poorly drained soils with a thick topsoil that contains a high percentage of organic matter. They are encountered in minor valleys and bottomlands of Mount Kenya, Mount Elgon, and the Aberdares.

Prior to cultivation most of the soils found in the Highlands of Kenya have high organic matter. However, on clearing and subsequent cultivation there is a rapid deterioration of soil organic matter. Continuous cropping without fertilization leads to rapid loss of organic matter and nitrogen.

SOIL EROSION AND CONSERVATION

Although the bulk of the soils found in the Highlands of Kenya have good structure and are relatively resistant to erosion compared to those found in the drier parts of the country, they can experience serious erosion problems,

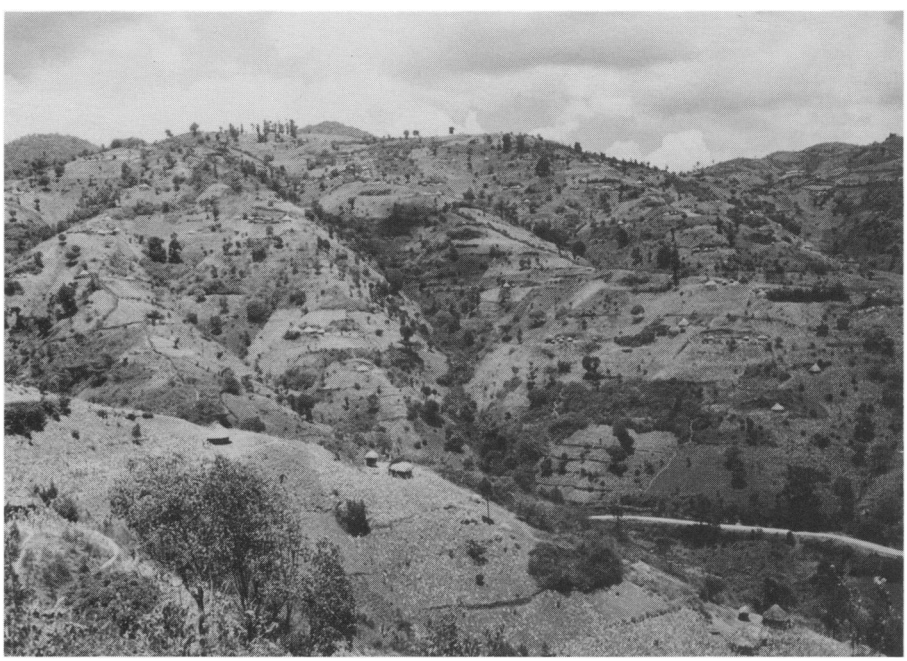

Figure 9. The Kapswar area; cultivation on very steep slopes (greater than 35 percent) is often carried out without effective soil conservation measures.

particularly if cultivated on steep slopes without effective conservation measures (Figure 9). The severity of soil erosion problems in the cultivated parts of the Highlands of Kenya was realised as early as the late 1920s, and by the period 1930–1940 enforced soil conservation measures were introduced (Maher, 1937, 1938). Unfortunately, during the early 1960s there was considerable laxity in soil conservation efforts; the soil conservation measures which were being carried out were not maintained, and terraces started to disappear at a faster rate than they were being constructed. However, from 1972 onward a countrywide soil conservation programme has been undertaken to increase the awareness of the importance of protecting the soil resources from erosion and degradation. Simple and cheap soil conservation measures have been carried out in most parts of the country, particularly in the steep cultivated areas. Soil conservation measures which are commonly practised are cultural: for example, strip cropping, contour farming, companion crops, and rotation; and physical, such as cut-off drains, artificial water ways, and terraces.

At the national level, afforestation is now encouraged as a measure to control erosion. In 1980, the Permanent Presidential Commission on Soil Conservation and Afforestation was established to co-ordinate soil conservation and afforestation activities. In addition, the Soil and Water Conservation Branch of the Ministry of Agriculture and Livestock Development, in co-operation with a large number of government departments, non-governmental organizations, and community development groups, has been directly or indirectly involved in promoting activities related to soil conservation.

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