THE UTILITY OF THE M.E.X.E. LAND SYSTEM SURVEY IN WESTERN KENYA AS A PROVISIONAL BASIS FOR MULTIPURPOSE LAND EVALUATION FOR RURAL DEVELOPMENT

by
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MSc-COURSE ON SOIL SCIENCE AND WATER MANAGEMENT

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WAGENINGEN - THE NETHERLANDS

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A thesis presented in partial fulfilment of the requirements for the degree of Master of Science

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SUMMARY

The utility of a soil map or a land system map depends on the kinds of predictions that a user would be able to make from it. The kind of predictions that can be made depend on the amount, reliability, and the type of information given in the map legend and in the accompanying bulletin. Soil maps are often made but their utility from the user's point of view is rarely assessed.

The objective of this study is outlined in chapter 1. The utility of the land system survey in Western Kenya is judged on basis of a reconnaissance soil map. The land system map is compiled for the greater part on basis of aerial photo interpretation whereas the soil map is based on more field observations. The comparative case-study in which the procedures, measurements and criterion used to judge the utility of the land system map (on facet level) are discussed, is given in chapter 4.

Finally chapter 5 states the main conclusions on the usefulness of the land system survey.

1. INTRODUCTION AND AIMS

Man has long been under the impression that the earth's natural resources were unlimited. At present, he is becoming aware of the steadily increasing exploitation of these resources, due primarily to the exponential growth of the world population. For this reason, it becomes indispensable to make an appraisal of these resources in terms of location, quantity and potential. In veiw of this, the subject of land evaluation comes into sight as a guide to rural development planning.

Land evaluation is the assessment of man's possible use of land for agriculture, forestry, engineering, recreation etc (Stewart, 1968). It is the process of collating and interpreting basic inventories of natural resources in order to provide ratings of relative suitability of the few socially and economically promising, physically possible land-use alternatives (F.A.O, Background document,1972). Land evaluation and socio-economic analysis can be regarded as overlapping and mutually supporting phases of a process which provides a foundation for land-use planning with respect to rural development. Excluding socio-economic analysis, which is outside the scope of this paper, an inventory of the natural resources of a region or country is an essential prerequisite of land evaluation. It is upon this basis that land evaluation and land-use planning finds a firm footing. In this context land evaluation is treated as pertinent to agricultural development.

The main aspects of natural resources that are of paramount importance for agricultural land evaluation purposes are climatic conditions, soils, topography, geology, vegetation and hydrology. The inventory or systematic collection and indexing of information on these natural resources can be obtained in two ways. Tracts of land can be surveyed on the basis of integrated units, e.g. in land system surveys, or on the basis of a synthesis of separately surveyed land attributes such as soil surveys, vegetation surveys etc. The land system approach has been applied in Nigeria, Australia, Swaziland, Uganda and Western Kenya. A systematic collection and indexing of information on natural resources was made aimed at providing a basis for regional and rural development planning purposes.

The land system Atlas of Western Kenya (Scott et al., 1971) distinguishes the different types of land facets (see 2.1 for the definit of a land facet), indicates how they can be recognized on aerial photographs, and gives a description of these facets. A delineation of these facets plus their descriptions may well serve as a basic tool for land-use planning. In fact this is the purpose for which the Atlas was made. However, from soil surveys of reconnaissance type (scale 1:100,000) made of some parts of Western Kenya as an inventory of natural resources to serve multipurpose land-use planning some doubts as to the usefulness of the land system approach have given rise to the following question: - "How good are the land facets, once delineated, as a provisional basis for land evaluation in the absence of a more accurate soil map which is based on more field work ". From this point of view, the objective of this study is, therefore, to assess the usefulness of the land system mapping in Western Kenya (on land facet level) as a provisional basis for land-use planning with respect to rural development.

The land system map covers a large area. Consequently, it was necessary to choose a smaller area to serve as a testing case. Thus, the Kindaruma area,which is covered both by a reconnaissance soil map and by the land system survey is selected as the testing case. The reconnaissance soil map (scale 1:100,000) of this area was recently completed by Kenya Soil Survey (1974) on basis of air photo interpretation in combination with extensive field work. It may serve as a reference to judge the usefulness and reliability of the land system survey which is based mainly on photo interpretation alone.

2. LAND SYSTEM SURVEYS AND SOIL SURVEYS

This chapter gives a short description of both the land system and soil survey approach with respect to survey methodology, the maps made and the information provided for each of them.

2.1 Land System Surveys

In Australia, in parts of Africa and in some other countries, the land system approach has been used in land inventory. This technique generally identifies areas with reasonably similar and recurring characteristics of climate, vegetation, geology, soils, land use, and topography.

A Land system is defined as an area or a group of areas throughout which can be recognized a recurring pattern of topography, soils and vegetation (Christian and Stewart, 1953). The components of this pattern are the land facets and a land system is defined on its constituent facets and their interrelationships. The individual land units (facets) are defined by Christian (1957) as "parts of the land surface having a similar genesis and (which) can be described similarly in terms of the major inherent features of consequence to land use, namely topography, soils, vegetation and climate". The land systems are convenient groupings of land facets for mapping land at scales of 1:250,000 to 1:1,000,000. The smaller scale of the land system surveys and the complex land units developed for them have been designed to economize on time and expenditure and to produce a readily understandable document for planning purposes (Thomas, 1969).

The MEXE* land system survey of Western Kenya (Scott et al., 1971) is analogous to the Terrain Classification and Data Storage land systems of Uganda by Ollier et al. (1969) and to the land system survey of Swaziland (Murdoch et al., 1971). The mapping of the land facets and subsequently the land systems is based mainly on air photointerpretation taking into account the existing knowledge provided by geo-

* MEXE- Military Engineering Experimental Establishments: Developed by Beckett and Webster (1965) of the Department of Agriculture, Oxford.

logical, ecological and soil maps. The results of the investigations are presented in the form of an Atlas.

The Atlas in sturdy loose-leaf folders contains descriptions of the landscapes (Land systems), with land system maps. Each land system is illustrated by block diagrams showing all the land facets and their relationship within the system, by aerial photographs (stereo pairs) and by a general description of the system as a whole, with data on climate, geology, geomorphology, soils, vegetation, land use, relief and altitude (see Appendix 2).

The land facets, the basic units of the classification, are described in more detail. For each one the predominant land form, constituent soils, the parent material, hydrological conditions, the vegetation and land use are given. The reader will be able to recognize the land facet in the terrain or on aerial photographs (Scott et al., 1971).

Where the land facet is not sufficiently homogeneous to allow one system of land management, it may be divided into land elements. The land element is equivalent to Bourne's "Site" (Bourne, 1931). It is an area which throughout its extent has similar local environmental conditions. Hence, it is the smallest unit of land likely to be of interest.

In the Atlas too, are presented variants of land systems. The reason for their establishment is the presence or absence of an important land facet or a consistent difference in climate, parent material, soil or vegetation that leaves other attributes apparently unaffected or nearly so.

According to Scott et al. (1971) the information compiled for the land systems should enable planners to decide in broad terms the most appropriate form of land use, what form development should take and what priorities different areas should have. A store of information on the resources of the land organized in the framework of local land facets may then be used when carrying out the actual development.

2.2 Soil Surveys

There has been considerable divergence of opinion on the purpose of soil survey. Consequently, the purpose of soil survey has been defined in different ways. To quote a few, Beckett et al. (1967) say, "soil survey is commonly a laborious and a costly exercise in subjective judgement. The effort and cost are justified only if the end product, the soil map, allows us to make more precise statements about the parts of the landscape covered by each soil unit mapped than could have been made about the landscape at large". According to Klingebiel (1958) the modern soil survey map is designed to show the different kinds of soils that are of agricultural significance. Bie (1972) says that the purpose of soil surveys is the resolution of the soil landscape into subunits about which more accurate and precise statements about properties of expected practical value can be made than is possible about the landscape as a whole. According to Goosen (1967) the purpose of a soil survey is to make an inventory of the soils occurring in a certain area, and a very important part of the survey is the soil map.

In view of the above and many other divergent opinions, it is apparent that there is a need to establish a purpose of a soil survey prior to its execution. The reconnaissance soil surveys (scale 1:100,000) as carried out by the Kenya Soil Survey, are meant to serve multipurpose land use planning. The survey methodology employed in these surveys is based on a physiographic approach. Use is made of aerial photographs to facilitate mapping, but the boundaries between soil units or mapping units are drawn on basis of substantial fieldwork. A soil map and an accompanying bulletin are produced.

The information on the soils existing in Kindaruma area are presented in the map legend (see Appendix 3). The highest categories on the soil map are physiographic land forms based on geomorphology e.g. hills, uplands etc. These physiographic units are subdivided according to the kind of parent material on which the soils are developed, e.g. soils developed on Basement System rocks, and this is further subdivided according to the lithology of the rock e.g. soils developed on quartz rich Basement System rocks, predominantly granitoid gneisses The physiographic units and the different kinds of parent material are chosen in such a way that 1) they are mappable and 2) they lead to seemingly relevant mapping units.

At the lowest level, the soil mapping units are subdivided according to important profile characteristics such as drainage, depth, colour, consistency, texture, stoniness etc.

Each mapping unit is identified on the map by a mapping symbol, for which a code system is used. The symbols appearing in the code system are explained below:

I PHYSIOGRAPHIC UNITS

X Mountains

x hills

AR Subrecent river terraces

II PARENT MATERIAL

B Basement System

U Undifferentiated Basement System rocks

F Basement System rocks rich in ferromagnesian minerals

V Volcanic rocks

O Olivine basalt

K Kenytes

III IMPORTANT PROFILE CHARACTERISTICS

Colour of the B ;-

r = red

b = brown

d = black

Consistency :-

c = compact

profile development:-

a = argillic horizon

depth over rock:-

p depth less than 80 cm but greater than 50 cm

P depth less than 50 cm

depth over petroplinthite/murram;-

m depth between 50 and 80 cm

IV C = complexes

The topography (slope class %) of each mapping unit is indicated in the mapping symbol below a fraction line.

On basis of the information given in the map legend and the accompanying bulletin, land evaluations are made for the envisaged development alternatives. The results of these land evaluations are presented in the form of land suitability maps.

3. GENERAL DESCRIPTION OF THE STUDY AREA

3.1 Location and main geographical features

The Kindaruma area, which is selected as a testing case in this study, is situated in the Eastern Province of Kenya. It covers parts of the Embu, Kitui and Machakos Districts. The area is situated in the southeastern quadrant of degree sheet 44 (Survey of Kenya) and is bounded by latitude 0° 30′and 1° 00′ S and by longitudes 37° 30′and 38° 00′E.

The elevation of the area varies from 4000 ft (1333 m) in the northwest to around 3000 ft (1000 m) in the rest of the area, with an exception of the Kiangombe and Mumoni mountains, which rise to an altitude of 5000-5300 ft (± 1600 m) above sea level.

The two main rivers of the area-the Tana and the Thiba- are perennial, while two others, the Ena and Itabua have a limited flow all year round in the upper part of the catchment area.

The area is traversed by the Embu-Kitui road with branches leading to Siakago, Kiambere and Masinga. In this area, two hydrological power stations, Kamburu and Kindaruma, are situated along the Tana river.

Fig. 1 gives the location of the study area in relation to the area covered by the land system survey.

3.2 Geology and geomorphology

3.2.1 Geology

The study area was geologically surveyed in 1950-51. A map plus report was published in 1952 (Bear, 1952). Most of the area consists of Precambrian rocks of the Basement System (a series of igneous and metamorphic rocks generally with complex structure). The major rocks of the Basement System include granitoid gneisses, undifferentiated banded gneisses and hornblende gneisses. The granitoid gneisses stretch N-S through the area and have suffered granitization. They are, therefore, more resistant to erosion than the banded gneisses.

Other rock types found in the area are crystalline limestones in the southeastern corner of the area where they form numerous parallel lenses. They are more resistant to weathering than the associated country rock and form low-lying ridges and isolated hills with

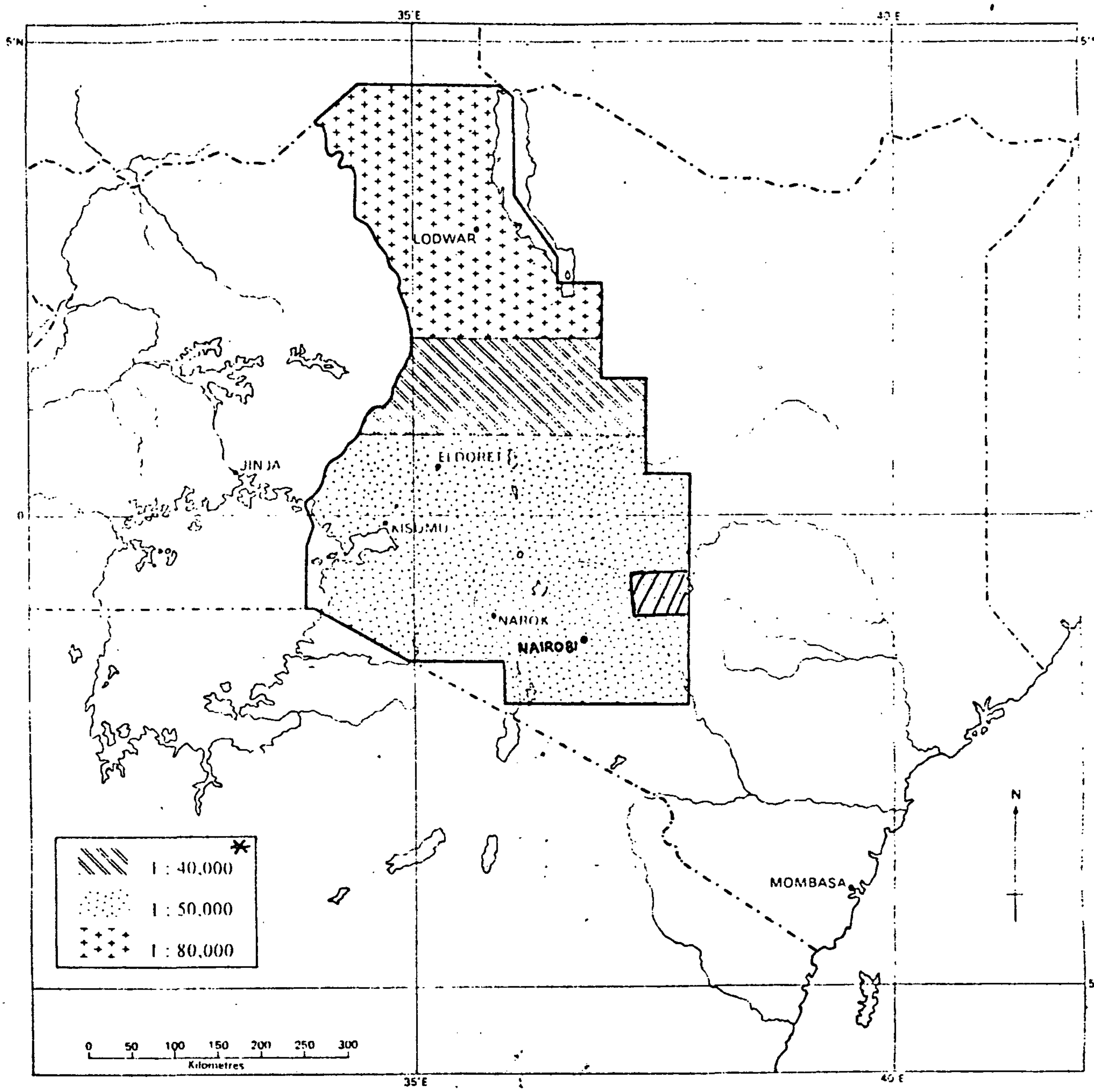


FIG. 1 Location of the study area in relation to the area covered by the land system survey.

* Scale of aerial photographs used in preparation of the land system map.

Study area.

characteristic vegetation.

The Basement System in the northwestern corner of the area is overlain by a thin capping of Mt. Kenya volcanic material, represented by kenytes. The kenyte is a basic phonolitic trachyte of late Tertiary or Pleistocene age (Fairburn, 1966). Olivine basalts are found in Mwea area along the Thiba river.

3.2.2 Geomorphology

The area can be divided broadly into two physiographic units:

- Mountains and hills
- Uplands and plateaus

Mountains and hills are prominent features of the area. Most of these mountains and hills such as Kiangombe and Mumoni consist of granitoid gneisses which are resistant to erosion. The bulk of the area is a planation surface. A part of this planation surface can be considered according to Pulfrey (1960) to belong to the subMiocene bevel which stretches over great parts of Kenya. This planation surface has been rejuvenated by uplift and a drainage pattern has been incised. This is clearly discernible in the northeastern part of the area. At some places, the comparatively flat floor of this surface is broken by inselbergs. In the northwestern part of the area the planation surface is buried under Tertiary Mt Kenya volcanic deposits forming a gently undulating plateau, slightly sloping to the southeast. The boundary of the lava does not form an escarpment. The surface of the lava merges gradually into the planation surface.

3.3 Climate

Apart from the inventory of natural resources, the agricultural potential of an area depends largely on the prevailing climatic conditions. From the climatic variables the balance between rainfall and evaporation, on an annual and particularly on a seasonal basis, are of greatest importance. In this paper, only a summary of the climatic variables is given. For a more comprehensive report the reader is referred to the chapter on climate in the soil survey report of Kindaruma area.

Within the Kindaruma area the average annual rainfall increases in northwestern direction. Most of the area has a rainfall between

600 and 800 mm. Potential evaporation increases in southeastern direction with most of the area having a potential evaporation between 2000 and 2200 mm.

Rainfall is not equally distributed throughout the year. Like in most parts of Kenya there are pronounced wet and dry seasons in the area:- the dry season January-February is followed by a rainy season mid of March-April-end May (long rains), followed by a dry season June-July-August-September-Mid October which is followed by a wet season November- end December (short rains). Braun (K.S.S. 1975) has shown that in 80% of the Kindaruma area, the probability of a moisture deficit during one of the rainy seasons is 60% or more.

4. THE CASE STUDY-COMPARISON OF THE SOIL MAP AND THE LAND SYSTEM MAP (ON FACET LEVEL)

4.1 Working Methods and Procedures

In this study the soil map of the Kindaruma area (see Appendix 3) is used as a reference level to judge the usefulness and reliability of the land system survey (see Fig. 2).

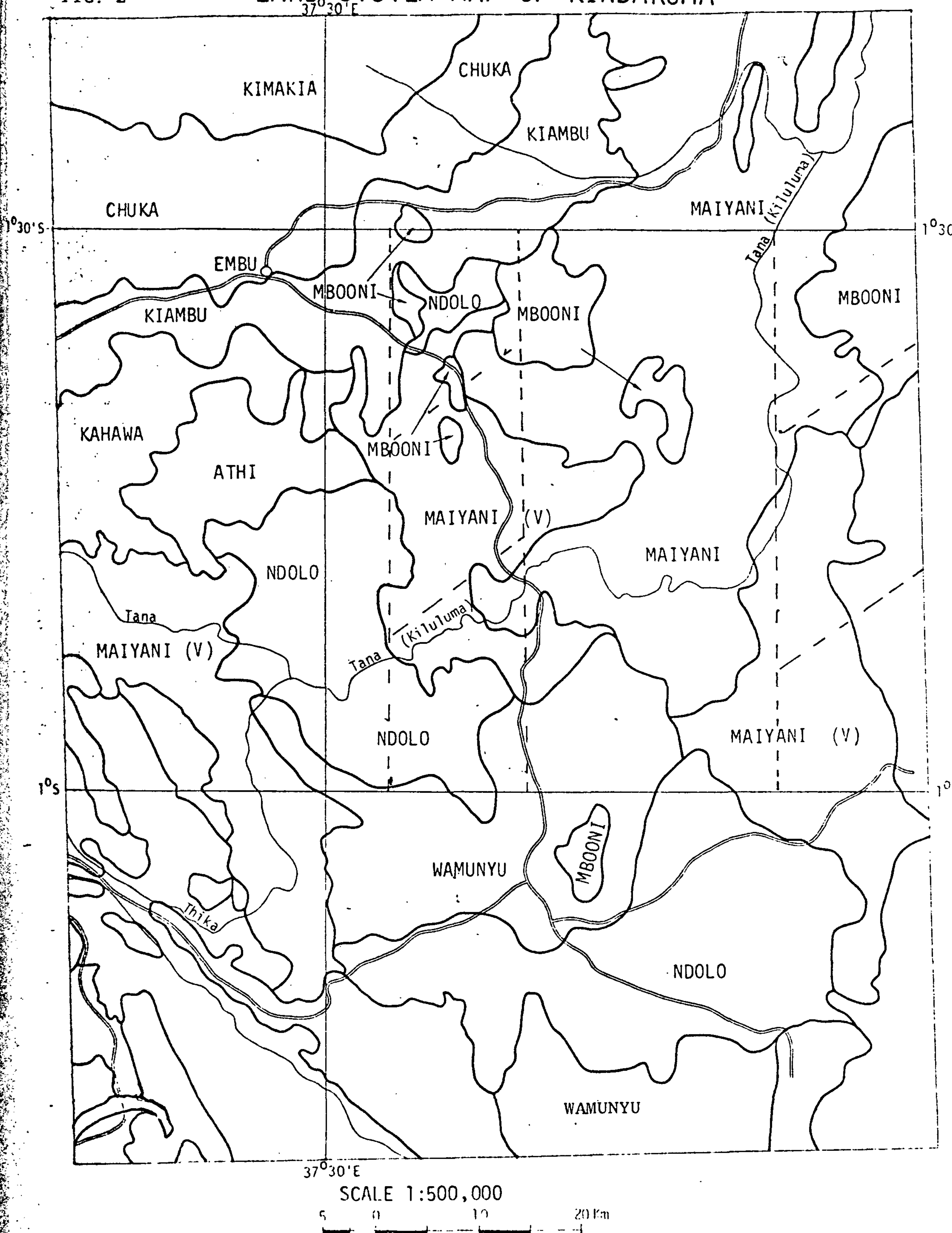
To enable a comparative study to be made it was necessary as a first step to map the land facets as described in the Land System Atlas (Scott et al., 1971). Two north-south sample strips of the study area were selected in such a way that they covered the most important land systems (Mbooni, Kiambu, Ndolo, Wamunyu, Maiyani and Maiyani Variant) as well as the most important mapping units (see Fig. 2 and Appendices 3 and 4).

On the aerial photographs (scale 1:50,000) of the sample strips the land facets were delineated exactly according to the instructions and examples as given in the Land System Atlas of Western Kenya. The delineation of the various land facets on the aerial photographs was done stereoscopically. A Land facet map (scale 1:50,000) was then compiled by transferring the land facet boundaries from the aerial photographs to 1:50,000 topographical sheets. The transfer of this information to the topographical sheets was done mainly by hand with the aid of an optical pantograph. This was done for both sample strips. The land facet maps were then drawn on a transparent paper at scale 1:50,000. Since the soil map (reference level) is at scale 1:100,000 it was necessary to reduce the land facet map of each strip to this scale. The reduction was done photographically. To enable easy comparison by superimposing the land facet map on the soil map the two strips of the land facet maps were separated from each other so that when placed on the soil map they would exactly fit (see Appendix 4).

The two strips of the land facet map include five land systems in which a total of 21 land facets has been identified. The equivalent area on the soil map contains 36 mapping units.

The next step was to check the agreement or non agreement between the soil map and the land facet map. This was done by comparing (a) the boundaries of the land facet map with those of the soil map and (b) the descriptions of the land facets and the soil mapping units

FIG. 2 LAND SYSTEM MAP OF KINDARUMA



KEY

Road
Land System Boundary
River

approximate location of the area covered
land facet map

Derived from Land System
Atlas of Western Kenya

Prepared by E.N. Muchena SS

Drawing No 74033

with respect to soils, topography etc.

Further (c) the amount of information given on the various land facets (in land facet descriptions) and on the soil mapping units (in the map legend and accompanying bulletin) was tested in as far as it would enable a user to make predictions on some major land qualities and characteristics that are used to determine land suitability classes in a land evaluation procedure. This was done by use of a rating system (see 4.3.2). For the ratings of the mapping unit information, the soil map and the land system map (on land facet level) were treated separately, assuming that the information given for each of them, in the land facet descriptions and in the soil map legend and accompanying bulletin respectively, was correct. From these ratings an "informative index" was established for the soil mapping units and the land facets (see 4.3.2 for the definition of the informative index). Then, by comparing the statistical analysis of these "informative indices" the relative efficacy of the land system mapping was judged.

4.2 Land facets and soil mapping units compared

In this chapter the reliability of the land facet map is judged by considering (a) the agreement between the land facet and the soil mapping unit boundaries and (b) the agreement between the land facet and the soil mapping unit descriptions.

4.2.1 Land facet boundaries versus soil mapping unit boundaries

The reliability of the land facet map may be judged from the degree of agreement between the boundaries of the land facets and the soil mapping units. In determining which boundaries agree and which do not agree, the smallest area that can be conveniently shown on the map must be taken into account. Buringh et al, (1962), distinguished this area as 5 x 5 mm in a square form or 2.5 x 10 mm in elongated form. Taking this as a criterion of agreement, the length of the land facet boundaries that agreed with the soil boundaries was measured with the use of a curvimeter. If the distance between the boundaries did not exceed 2.5 mm, they were considered to be in agreement.

The results of the measurements are shown below:

Total length of soil mapping unit boundaries on the map= 1162 cm
Total length of the land facet boundaries on the map = 1317 cm
Total length of the land facet boundaries in agreement with those of the soil mapping units = 497 cm

Expressing the length of the boundaries in agreement as a percentage of the total length of soil mapping unit boundaries, the degree of agreement is 43%. Only 38% of the total length of the land facet boundaries is in agreement with the soil mapping unit boundaries.

It should be noted that the length of the land facets M_4 and M_5, which represent minor and major drainage lines respectively, were not taken into account in the above measurements. They were excluded because they correspond to the minor and major drainage lines on the soil map, whose length too was not measured.

The agreement between the land facet boundaries and the soil mapping unit boundaries is quite good in areas of relatively high relief intensity (e.g. mountains and hills). The reason for this is that these areas can be delineated in the aerial photographs without any difficulty. However, in the gently undulating to rolling landscapes with complex geological formations, photo interpretation does not seem to work very well. Hence, a relatively poor agreement between the land facet boundaries and the soil boundaries.

4.2.2 Agreement between land facet and soil mapping unit descriptions

Taking the soil map as a reference the reliability of the land facet map may be judged by the degree of agreement between the land facet and the soil mapping unit descriptions with respect to soils. A good agreement would imply a high reliability whereas a poor agreement would imply a low reliability.

Only 43% of the land facet boundaries was in agreement with the soil mapping unit boundaries (see 4.2.1). Therefore, to enable judgement to be made, it was necessary to measure the acreage of each land facet that corresponded with the various soil mapping units or vice versa. This was done by superimposing the land facet map on the soil map and the corresponding acreages (in hectares) were measured with the aid of a millimetre paper. According to the map scales (1:100,000 for both) each mm^2 was equal to one hectare.

The results of the measurements are presented in Appendix 1A. The area covered by the various land facets and soil mapping units, expressed as a percentage of the total area measured, are shown in Tables 1 and 2 respectively.

On basis of the results presented in Appendix 1A, the agreement between the land facet and the soil mapping unit descriptions was assessed. A complete agreement was considered if the description of the soils were similar with respect to texture, colour, depth and consistency. If only the description of the texture and consistency was the same, a partial agreement was established. For a no agreement the descriptions were completely different.

The relative degrees of agreement of the land facet descriptions with those of the soil mapping units, expressed in percentabes are presented in Table 3.

TABLE 1. The Land Systems, their constituent facets and the area covered (in %) by each, respectively.

LAND SYSTEM	CONSTITUENT LAND FACETS	AREA IN %	TOTAL AREA COVERED BY EACH LAND SYSTEM IN %
	Mb1	0.07	
MBOONI	Mb4	11.0	12.97
	Mb5	1.7	
	Mb6	0.2	
MAIYANI	M1	6.1	
AND	M2	59.0	
MAIYANI	M3	2.6	67.75
VARIANT	M6	0.05	
	N1	2.5	
NDOLO	N2	5.0	9.7
	N3	2.2	
	W1	4.6	
WAMUNYU	W2	0.5	5.9
	W3	0.7	
	W5	0.1	
	K1	2.55	
KIAMBU	K2	0.75	3.68
	K3	0.08	
	K4	0.3	
	TOTAL	100.0%	100.0%

TABLE 2. The area covered (in %) by the various soil mapping units

SOIL MAPPING UNIT	AREA IN %	SOIL MAPPING UNIT	AREA IN %
XB	10.1	BUra	8.5
xB	2.5	BUrap	3.6
VKr	3.0	BUP	4.2
VKbm	0.2	BFrc	0.7
VOr	0.3	BFrcP	0.4
VOd	0.1	BFd	3.9
BQ1	3.9	BFdP	0.7
BQ1P	4.4	BUr-BUb	3.9
BL1P	0.9	BUrc2-BQ1	1.3
BUr	6.2	BUrap-BUP	2.7
BUrp	0.6	BUP-BQ1P	4.2
BUb	1.3	BFrcp-BFrcP	5.5
BUrc1	1.4	BFrcP-BFdP	1.3
BUrc2	10.3	CV1	1.1
BUrc2p	0.5	CV2	0.3
BUrc3	4.7	CS1	1.3
BUrc3p	1.0	AR1	0.2
BUbc1	2.5		
BUbc2m	2.3	TOTAL	100.0%

The calculations were made as follows:

$$\text{Degree of agreement } (\%) = \frac{a}{A} \times 100\% \text{ or } \frac{b \times 100\%}{A} \text{ or } \frac{c}{A} \times 100\ \%$$

where a = area of the land facet which is in complete agreement with the description of the corresponding soil mapping unit.

b = area of the land facet which is in partial agreement with the description of the corresponding soil mapping unit.

c = area of the land facet which is not in agreement with the description of the corresponding soil mapping unit.

A = total area covered by the respective land facets.

In order to express the relative degrees of agreement as a totality of all the land facets, a weighted agreement was calculated by taking into account the percentage of the area occupied by each land facet. The results of these calculations are presented in Table 4. On basis of these results, and taking the soil map as a reference it may be concluded that about 44% of the land facet map is wrong with respect to the soil information given.

TABLE 3. The relative degrees of agreement between the land facet and the soil mapping unit descriptions, with respect to soils.

LAND FACET	COMPLETE AGREEMENT (in%)	PARTIAL AGREEMENT (in%)	NO AGREEMENT(in%)
Mb1	100	-	-
Mb4	94	-	6
Mb5	52	-	48
Mb6	56	38	6
M1	22	44	34
M2	34	7	59
M3	57	29	14
M6	65	-	35
N1	31	-	69
N2	71	10	19
N3	43	-	57
W1	66	6	28
W2	71	-	29
W3	90	2	8
W5	21	-	79
K1	93	3	4
K2	57	32	11
K3	100	-	-
K4	87	13	-

TABLE 4. Weighted relative degrees of agreement between the land facet and the soil mapping unit descriptions

LAND FACET	COMPLETE AGREEMENT (in%)	PARTIAL AGREEMENT (in%)	NO AGREEMENT (in%)
Mb1	0.07	-	-
Mb4	10.34	-	0.66
Mb5	0.88	-	0.82
Mb6	0.11	0.08	0.01
M1	1.34	2.68	2.08
M2	20.06	4.13	34.81
M3	1.48	0.75	0.37
M6	0.03	-	0.02
N1	0.78	-	1.72
N2	3.55	0.50	0.95
N3	0.95	-	1.25
W1	3.04	0.27	1.29
W2	0.36	-	0.14
W3	0.63	0.01	0.06
W5	0.02	-	0.08
K1	2.37	0.08	0.10
K2	0.43	0.24	0.08
K3	0.08	-	-
K4	0.26	0.04	
TOTAL	46.78	8.78	44.44

From the observations made in the field, the following remarks can be made with regard to the land systems in general:

(i) The Ndolo land system as indicated in the area around Siakago (see Fig. 2, Appendices 3 and 4) is completely wrong. Most of this area should fall into the Maiyani land system.

(ii) There is a no clear cut difference between Maiyani land system and Maiyani Variant land system with respect to the soil descriptions. The soils are described as being red friable clays. This is not quite true since a substantial proportion of this land system was found to have sandy soils. This may account for the relatively high degree of no agreement between the descriptions of the land facets of this land system with the descriptions of the soil mapping units (see Table 4).

(iii) The Maiyani variant land system is supposed to have broad crests carrying black clays (facet 7). However, in the study area no such crests were found with black clay soils. Hence, the occurrence of this land facet is rather doubtful.

4.3 Mapping unit information

4.3.1 General

In this paper the term "mapping unit information" is used to refer to the amount and kind of information that is given for each mapping unit in the map legend and in the accompanying bulletin i.e. a soil survey report or a land system Atlas (Suhardjo, 1973). In addition to the well known soil mapping unit, the land facet is considered here also as a mapping unit.

The kinds of predictions that can be made from the soil map and from the land system map (on land facet level) depends on the mapping unit information, which in turn depends on the type of field and laboratory data collected during the survey. On the other hand the amount of data collected is greatly influenced by the purpose for which the survey is executed. Thus, if the purpose of a soil map or a land system map is to enable the user (a land classification officer, a planner etc) to make more precise statements about soils and other land attributes than he could have done without them, then the utility of a given survey may be judged by assessing the kinds of predictions that can be made from its mapping unit information.

4.3.2 Measurement of mapping unit information

While measuring the mapping unit information the criterion used must be based on the purpose for which the maps are made. Supposing that the principal direction of development envisaged during the execution of the survey is in Agriculture, the map user would expect to get, for each mapping unit, information pertaining to the major land qualities which influence crop productivity and management requirements, as well as the land characteristics which determine these land qualities. The major land qualities considered for agricultural land evaluation purposes in Kenya are; climate, availability of soil moisture, chemical soil fertility, possibilities for the use of agricultural implements, resistance to erosion, hindrance by vegetation, receptivity of a soil as a seed bed (tilth), and presence/absence of waterlogging hazard (K.S.S., 1974).

The information given with respect to the above factors may vary considerably from map to map. The variability of this information can be measured by a qualitative rating system. If all the information required is given, a rating of 4 is used; whereas if no information at all is given, it is denoted by 1.

In this study, the qualitative rating system used to estimate the ability of the soil map and the land system map to enable a user to make predictions of the land qualities pertinent to agricultural land evaluation purposes is shown below:

(a) Availability of soil moisture: Judgement based on the following land characteristics: texture, soil depth, annual precipitation and distribution, potential evaporation, (pF measurements), groundwater level.

Rating	Available information
1.	No information at all.
2.	Information only on soil depth and texture.
3.	Information on soil depth, texture and annual precipitation.
4.	Information on all the land characteristics given.

(b) Possibilities for the use of agricultural implements: Judgement based on the following land characteristics: slope, slope length, rockiness, stoniness of surface soil or shallowness of the bedrock, texture of topsoil, external and internal drainage, surface sealing plus compaction.

Rating	Available information
1.	No information at all.
2.	Information limited only to one factor.
3.	Information of more than two factors but less than five factors given.

4. Detailed information of all factors given.

(c) <u>Chemical soil fertility</u>: Judgement based on; texture, organic matter content, parent material chemical laboratory analysis, field experiments.

Rating	Available information
1.	No information at all.
2.	Only information on texture and parent material is given.
3.	Information on texture, parent material, organic matter content and laboratory data given.
4.	There is information on chemical soil fertility based on field trials.

(d) <u>Resistance to erosion</u>: Judgement based on; slope class (%), susceptibility to sealing (texture plus structure), slope length and climate.

Rating	Available information
1.	No information at all.
2.	Limited information only.
3.	Detailed information of two factors.
4.	Detailed information of all factors.

(e) <u>Presence/Absence of Waterlogging hazard</u>: Judgement based on; drainage and groundwater table.

Rating	Available information
1.	No information at all.
2.	Only slight indications of the drainage conditions.
3.	Drainage conditions are expressed in detail.
4.	Maps or graphs showing groundwater fluctuations are given.

(f) <u>Climate</u>: Judgement based on; annual precipitation and distribution, potential evaporation, and vegetation as an indicator of ecological zones.

Rating	Available information
1.	No information at all.
2.	Only information on vegetation.
3.	Information on annual precipitation given.
4.	Detailed information of all factors given.

The results of the ratings of the mapping unit information for the land facet map and the soil map are presented in Appendices 1B and 1C respectively. For each mapping unit, an "informative index"* is calculated by a multiplication method and by an additive method as follows:

Informative index by multiplication: $X_m = \frac{I - I_{min}}{I_{max} - I_{min}} \times 100\%$

Informative index by addition: $X_a = \frac{Y - Y_{min}}{Y_{max} - Y_{min}} \times 100\ \%$

in which

$I = M \times W \times F \times E \times D \times C$ (calculated value)

$I_{max} = 4 \times 4 \times 4 \times 4 \times 4 \times 4 = 4^6$

$I_{min} = 1 \times 1 \times 1 \times 1 \times 1 \times 1 = 1$

$Y = M + W + F + E + D + C$ (calculated value)

$Y_{max} = 4 + 4 + 4 + 4 + 4 + 4 = 24$

$Y_{min} = 1 + 1 + 1 + 1 + 1 + 1 = 6$

where

M = rating for information on availability of soil moisture.

W = rating for information on possibilities of use of agricultural implements.

F = rating for information on chemical soil fertility.

E = rating for information on resistance to erosion.

D = rating for information on presence/absence of waterlogging hazard.

C = rating for information on climate.

The informative index (for both multiplication and additive methods) is expressed as a percentage of an ideal situation where the maximum

* The concept of informative index is proposed here as a means of testing the amount of information given in a soil map and the accompanying bulletin. Suhardjo(1973) referred to it as an "index of information".

possible information would be given. The index ranges from 0 for no information at all to 100 for the maximum possible information.

To estimate the quality of mapping unit information for the entire map, the mean value ($\bar{X}$) and the coefficient of variation (CV) of the informative indices of all the mapping units are calculated (see Appendices 1B and 1C for the calculation procedure). The results of the calculations are shown in Table 5. The multiplication method was found to be more sensitive to variability of the quality of information given with respect to the factors considered than the additive method.

TABLE 5. The Mean ($\bar{X}$), standard deviation (S_D) and coefficient of variation (CV) of the informative indices of the two maps.

Map	Land facet map		Soil map	
Method	Multiplication	Addition	Multiplication	Addition
Mean informative index, $\bar{X}$	2.84	43.86	53.11	87.66
Standard deviation, S_D	1.60	5.83	7.60	3.00
Coefficient of Variation, CV	56.34	13.29	14.31	3.42

According to Snedecor and Cochran (1967), the coefficient of variation is a measure often used to describe the amount of variation in a population. Its knowledge enables one to evaluate or judge the success of an experiment. In analogy to this, the coefficient of variation of the informative indices may be used as a measure of the variability of the amount and kind of information given for various mapping units. The mean value of the informative index portrays the amount and kind of information given. The ideal map should have a high mean value with a low coefficient of variation. That means much detailed information is equally available about all relevant properties (Suhardjo, 1973). Thus, the higher the mean value of the informative index and the lower the coefficient of variation, the better the quality of the information given in that map.

From the results presented in Table 5, it can be observed that the soil map has the highest mean values ($\bar{X}$=53.11% by multiplication and $\bar{X}$ = 87.66% by addition) and the smallest coefficients of variation (CV = 14.31% by multiplication and CV = 3.42% by addition), whereas the land facet map has the lowest values of $\bar{X}$ (2.84% by multiplication and 43.86% by addition) and the highest CV's (56.34% by multiplication and 13.29% by addition).

5. CONCLUSIONS ON THE USEFULNESS OF THE LAND SYSTEM APPROACH

5.1 In the study area

I. From the comparative study of the soil map and the land system map (on facet level) the following conclusions were made:

(a) Only 43% of the soil boundaries as shown on the soil map were also indicated on the land facet map. Sixty two percent of the land facet boundaries were considered not in agreement with those of the soil map (see 4.2.1).

(b) From the degree of agreement between the land facet and the soil mapping unit descriptions, it was shown that approximately 44% of the land facet map may be considered wrong with respect to the soil information given (taking the soil map as a reference).

(c) Mapping unit information: The soil map had higher mean values of the informative indices ($\bar{X}$ = 53.11% by multiplication and $\bar{X}$ = 87.66 % by addition) and lower coefficients of variation of the informative indices (CV = 14.31 % by multiplication and CV =3.42 % by addition). The land facet map had lower mean values of the informative indices ($\bar{X}$ = 2.84 % by multiplication and $\bar{X}$ = 43.86 % by addition) and the highest coefficients of variation of the informative indices (CV = 56.34 % by multiplication and CV = 13.29 % by addition). From these data it can be clearly seen that the soil map gives better quality of information than the land facet map. The high coefficient of variation obtained for the land facet map implies that the variability of the information given in the land facet descriptions is relatively high as compared to the variability of the information given in the soil map.

It should be noted that this last conclusion is made in relation to the information pertinent to agricultural land evaluation purposes. For engineering purposes, different factors may be used as a criterion for rating the mapping unit information. Therefore, it is likely that different values of $\bar{X}$ and CV of the informative indices may be obtained for both maps with regard to information on land qualities and characteristics pertinent to engineering land evaluation purposes.

Nevertheless, since some of the factors considered for engineerring purposes, such as soil features affecting highway location, building foundations, agricultural drainage etc. depend to a greater extent on the soil information given, and in view of the fact that approximately 44% of the land facet map is wrong with respect to this, it may be equally likely that the land facet map will give less information than the soil map.

II. On basis of the observations made in the field, the following points were noted:

(1) In areas where there was a pronounced relief intensity, such as hills and mountains, a good agreement existed between the land facet and the soil mapping unit boundaries.

(2) A similar observation as in (1) was made in areas where the major geological formation consisted of Tertiary volcanic deposits. However, in the areas of low relief intensity and where the parent materials consisted of the complex geological formations belonging to the Basement System, there was very little or no agreement at all between the land facet boundaries and those of the soil mapping units. This shows that air photo interpretation alone cannot be relied upon in such areas without substantial field observations. Thus, an explanation for the 44% of the land facet map which is wrong with respect to soil descriptions may be sought in photo interpretation mistakes which are probably not checked in the field. To test the seriousness of these mistakes, an investigation on the reliability of aerial photo interpretation in the areas of low relief intensity underlain by the Basement System rocks would be required. This was not carried out in this study.

III. According to Scott et al. (1971) the user of the land system map is supposed to identify the land facets both in the aerial photographs and in the terrain before he can make use of their descriptions. This presupposes that the user, who in most cases is a planner, is well versed in the field of photo interpretation. On the other hand, assuming that the user is a good photo interpreter, a substantial amount of additional field work would be necessary to adapt the land facet maps to a minimum level of reliability with respect to detailed information on land qualities and characteristics required for a preliminary land evaluation for multipurpose land use planning.

5.2 Elsewhere in Western Kenya

The reliability of the land system map has been found to vary considerably in different parts of Western Kenya. Muchena (1975) carrying out a reconnaissance soil survey of part of the Makueni area found out that in the mountainous and hilly areas the land system description (Mbooni Land System) fitted very well with the field observations. However, in the gently undulating to rolling areas, where photo interpretation was less useful due to the complex nature of the parent material,the land system descriptions were less reliable. In Kapenguria, particularly in areas with a marked relief intensity, the land system mapping seems to be quite reliable (Gelens, personal communication). In Kisii area doubts have been expressed on the reliability of the land system survey (Benneme, personal communication).

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APPENDIX IA: Area covered by the land facets (in hectares) in relation to that covered by the corresponding soil mapping units.

SOIL MAPPING UNITS

LAND FACET	Xb	xB	VKr	VKbm	VOr	VOd	BQ1	BQ1P	BL1P	BUr	BUrp	BUb	BUrc1	BUrc2	BUrc2p	BUrc3	BUrc3p	BUbc1	BUbc2m	BUra	BUrap	BUP	BFrc	BFrcP	BFd	BFdP	BUr-BUb	BUrc2-BQ1	BUrap-BUP	BUP-BQ1P	BFrcP-BUrcP	BFraP-BFdP	CV1	CV2	CS1	AR1	TOTAL
Mb1	81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81
Mb4	11342	838	-	-	-	-	245	-	-	548	-	-	-	-	-	-	-	-	-	-	24	27	-	-	-	-	-	-	145	60	-	-	-	-	147	-	13376
Mb5	168	-	26	-	-	-	749	-	-	120	-	71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52	-	-	-	-	-	-	-	832	-	2018
Mb6	122	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82	-	-	-	-	-	-	12	-	-	-	-	-	-	-	216
M1	-	-	-	171	-	-	1319	219	-	1240	-	-	-	2533	47	756	111	255	-	102	384	100	-	-	-	-	-	98	-	-	33	-	22	-	-	4	7394
M2	402	566	198	85	408	112	1555	4786	137	4915	774	519	-	8923	578	4776	1075	566	-	10174	3949	4255	526	340	218	330	4643	834	3053	4962	6289	695	446	37	426	118	71670
M3	176	1418	-	-	-	-	6	83	910	10	-	-	-	50	27	164	18	6	-	53	9	111	-	-	-	-	48	-	30	65	-	-	-	-	8	-	3152
M6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	55
N1	-	8	138	-	-	-	-	-	-	425	-	829	206	68	-	-	-	-	943	-	-	43	-	-	66	38	-	-	-	-	211	-	-	-	24	-	2999
N2	-	12	-	-	-	31	-	-	-	-	-	-	-	6	-	-	-	-	597	-	-	161	264	30	4330	259	-	-	-	-	51	318	-	33	-	-	6092
N3	-	-	31	-	-	-	38	-	-	150	-	121	678	122	-	-	-	34	62	-	-	274	20	52	96	196	23	-	-	-	136	589	-	-	5	27	2654
W1	-	15	-	-	-	-	674	338	-	-	-	-	689	675	-	-	-	2099	903	-	-	19	-	-	56	20	-	102	-	-	-	-	-	-	-	-	5590
W2	-	-	-	-	-	-	55	-	-	-	-	-	89	64	-	-	-	107	248	-	-	18	-	-	-	-	-	9	-	-	-	-	-	-	-	-	590
W3	-	-	-	-	-	-	-	30	-	-	-	-	12	31	-	-	-	17	-	-	-	-	-	-	-	-	-	522	-	-	-	-	-	290	-	-	902
W5	-	29	-	-	-	-	106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135
K1	-	-	2880	-	-	-	3	-	-	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	85	-	72	3	3100
K2	-	84	291	-	-	-	3	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	521	-	-	-	913
K3	-	-	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	94
K4	-	-	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	247	-	21	68	364
TOTAL AREA	12291	2970	3686	256	408	143	4753	5396	1047	7461	774	1554	1674	12472	652	5696	1204	3084	2753	10329	4385	5090	810	422	4766	843	4766	1565	3240	5111	6720	1602	1321	360	1535	256	121,395

APPENDIX IB : Measurements of the mapping unit information for the land facet map.

	CATEGORIES FOR RATING						INFORMATIVE INDEX(X)in%)	
LAND FACET	Availability of Soil Moisture (M)	Possibilities of the use of agricultural implements(W)	Chemical soil fertility (F)	Resistance to erosion (E)	Presence/absence of Waterlogging hazard(D)	Climate(C)	MULTIPLICATION METHOD	ADDITIVE METHOD
Mb1	2	4	2	3	1	3	3.49	50.00
Mb4	2	4	2	3	1	3	3.49	50.00
Mb6	2	3	2	2	1	3	1.73	50.00
M1	2	3	2	2	1	3	1.73	38.89
M2	2	3	2	2	1	3	1.73	38.89
M3	2	4	2	3	1	3	3.49	50.00
M6	2	3	2	2	1	3	1.73	38.89
N1	2	3	2	2	1	3	1.73	38.89
N2	2	3	2	2	1	3	1.73	38.89
N3	2	3	2	2	1	3	2.61	44.44
W1	2	3	2	2	1	3	1.73	38.89
W2	2	3	2	2	3	3	5.25	50.00
W3	2	3	2	2	1	3	1.73	38.89
W5	2	4	2	3	1	3	3.49	50.00
K1	2	3	2	2	1	3	1.73	38.89
K2	2	3	2	2	1	3	1.73	38.89
K3	3	3	2	2	3	3	7.89	55.56
K4	2	3	2	2	2	3	3.49	44.44

For the whole map,	Mean informative index, $\bar{X}$	2.84	43.86
	Standard deviation, S_D	1.60	5.83
	Coefficient of variation, CV	56.34	13.29

APPENDIX 1C: Measurements of the mapping unit information for the soil map

SOIL MAPPING UNIT	Availability of Soil Moisture (M)	Possibilities of use of agricultural implements (W)	Chemical soil fertility (F)	Resistance to erosion (E)	Presence/absence of waterlogging hazard (D)	Climate (C)	INFORMATIVE INDEX (X) in % MULTIPLICATION METHOD	ADDITIVE METHOD
	CATEGORIES OF RATING							
XB	3	4	2	4	3	4	28.11	77.78
xB	3	4	2	4	3	4	28.11	77.78
VKr	4	4	3	4	3	4	56.24	88.89
VKbm	4	4	3	4	3	4	56.24	88.89
VOr	4	4	3	4	3	4	56.24	88.89
VOd	4	4	3	4	3	4	56.24	88.89
BQ1	4	4	3	4	3	4	56.24	88.89
BQ1P	4	4	3	4	3	4	56.24	88.89
BL1P	4	4	3	4	3	4	56.24	88.89
BUr	4	4	3	4	3	4	56.24	88.89
BUrp	4	4	3	4	3	4	56.24	88.89
BUb	4	4	3	4	3	4	56.24	88.89
BUrc1	4	4	3	4	3	4	56.24	88.89
BUrc2	4	4	3	4	3	4	56.24	88.89
BUrc2p	4	4	3	4	3	4	56.24	88.89
BUrc3	4	4	3	4	3	4	56.24	88.89
BUrc3p	4	4	3	4	3	4	56.24	88.89
BUbc1	4	4	3	4	3	4	56.24	88.89
BUbc2m	4	4	3	4	3	4	56.24	88.89
BUra	4	4	3	4	3	4	56.24	88.89
BUP	4	4	3	4	3	4	56.24	88.89
BFrc	4	4	3	4	3	4	56.24	88.89
BFrcP	4	4	3	4	3	4	56.24	88.89
BFd	4	4	3	4	3	4	56.24	88.89
BFdP	4	4	3	4	3	4	56.24	88.89
BUr-BUb	4	4	3	4	3	4	56.24	88.89
BUrc2-BQ1	4	4	3	4	3	4	56.24	88.89
BUrap-BUP	4	4	3	4	3	4	56.24	88.89
BUP-BQ1P	4	4	3	4	3	4	56.24	88.89
BFrcp-BFrcP	4	4	3	4	3	4	56.24	88.89
BFrcP-BFdP	4	4	3	4	3	4	56.24	88.89
CV1	3	4	3	4	3	4	42.17	83.33
CV2	3	4	3	4	3	4	42.17	83.33
CS1	3	4	3	4	3	4	42.17	83.33
AR1	3	4	3	4	3	4	42.17	83.33

		Multiplication method	Additive method
For the whole map,	Mean informative index, $\bar{X}$	53.11	87.66
	Standard deviation, S_D	7.60	3.00
	Coefficient of variation, CV	14.31	3.42

Annex to Appendices IB and IC

Procedure for the calculations

Multiplication method

Informative index, $X_m = \dfrac{I - I_{min}}{I_{max} - I_{min}} \times 100\%$

where

$I = M \times W \times F \times E \times D \times C$

$I_{max} = 4 \times 4 \times 4 \times 4 \times 4 \times 4 = 4^6$

$I_{min} = 1 + 1 + 1 + 1 + 1 + 1 = 1$

Example

For Mb1, $X_m = \dfrac{(2 \times 4 \times 2 \times 3 \times 1 \times 3) - 1}{4^6 - 1} \times 100\% = 3.49\%$

Additive Method

Informative index, $X_a = \dfrac{Y - Y_{min}}{Y_{max} - Y_{min}} \times 100\%$

where

$Y = M + W + F + E + D + C$

$Y_{max} = 4 + 4 + 4 + 4 + 4 + 4 = 24$

$Y_{min} = 1 + 1 + 1 + 1 + 1 + 1 = 6$

Example

For Mb1, $X_a = \dfrac{(2 + 4 + 3 + 3 + 1 + 3) - 6}{24 - 6} \times 100\% = 50.00\%$

For both the multiplication and additive methods:

The mean informative index, $\bar{X} = \dfrac{\sum X_i}{n}$

where $\sum X_i$ is the sum of informative indices for all mapping units.

Standard deviation, $S_D = \sqrt{\dfrac{\sum (X - \bar{X})^2}{n - 1}}$

$$\text{Coefficient of variation, CV} = \frac{S_D}{\bar{X}} \times 100\% = \frac{\text{Standard deviation}}{\text{Mean informative index}} \times 100\%$$

The same calculation procedure is applied for the soil map and the land facet map.

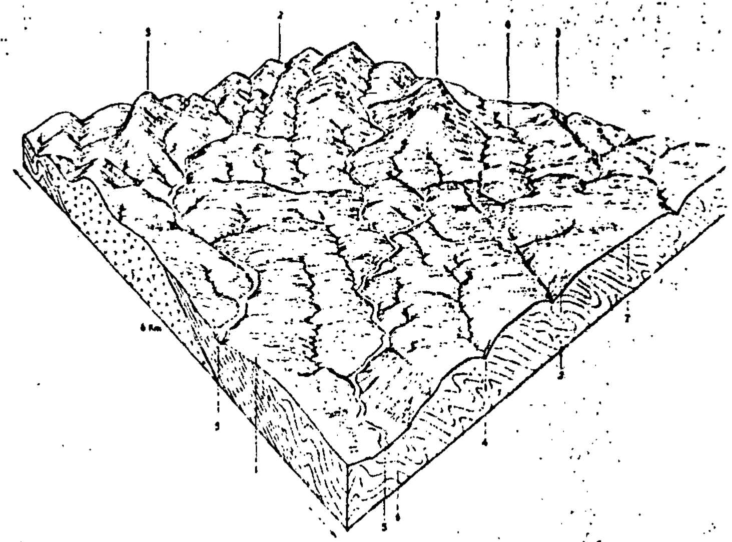
APPENDIX 2

Land System and Land facet descriptions

(from, A Land System Atlas of Western Kenya)

MAIYANI and MAIYANI VARIANT Land System

FACET No.	FORM	SOILS, MATERIALS AND HYDROLOGY	LAND COVER
1	**Ridge crest.** Level to gently sloping, even convex, 100-600 m across.	Brown sandy loam to sandy clay loam 15-20 cms thick over yellow red to red friable sandy clay loam to clay. Generally weathered gneiss occurs at about 120 cms.	*Acacia* savanna, or occasionally cultivated.
2	**Slopes.** Steep or moderately steep but with convex upper portion. 50-100 m high.	Dark reddish brown friable sandy clay loam to clay up to 15 cms over red friable sandy clay. A quartz stone line occurs above weathered gneiss at depths varying from 50-90 cms.	As 1.
3	**Hills.** Steep or very steep, straight sided, either conical or elongated ridges; may be strongly gullied or very irregular due to rock outcrop. Very variable in height from 10-200 m.	Shallow, stony, brown to reddish brown loams over weathered gneiss at depths generally less than 30 cms.	Scrub or thicket.
4	**Minor drainage lines.** Very narrow valley bottoms (5-40 m across) including stream channel.	Mainly exposed rock, shallow pockets of loose brown sands and gravel beds. Subject to seasonal flow.	Thicket.
5	**Main river channel.** 30-100 m across, with nearly vertical banks 1.5-3 m high.	Loose brown sands of variable depth with occasional rock bars. Subject to seasonal flow.	Tree-lined banks.
6	**Valley flats.** Level to very gently sloping with abrupt margins at river bank and outer margins concave; discontinuous, sporadic in occurrence, up to 200 m on either side of river.	Brown sandy loams up to 50 cms over reddish brown sandy loams to sandy clay loams generally over 100 cms deep. Quartz stone lines may be present at about 90 cms.	As 1.
7	**Clay flats.** Level to gentle slopes, occurring as ridge crests and occasionally as benches below facet 1. Up to 500 m wide and sporadic in occurrence. **N.B.** Occurs in Maiyani variant only.	Dark grey plastic sandy loam with angular quartz gravel over 100 cms deep. (This is a remnant of a former much more extensive black clay plain).	Wet grassland with scattered *Acacia drepanolobium*.



MAIYANI and MAIYANI VARIANT

Climate: Rainfall 500-750 mm. November-December, March-April.

Geology: A variety of gneisses of the Basement Complex, together with smaller amounts of basic intrusions and Post-Archaean pelitic rocks (Embur series

Landscape: Extensive areas of ridges and valleys with a dendritic pattern. The ridges may have either sharp crests or broader rounded crests. Occasion. high conical or elongated hills.

Maiyani variant has broad crests carrying black clay soils (facet 7). These represent remnants of a formerly more extensive black clay landscape overlying volcanic rocks, mainly phonolites, of the kind characteristic of several neighbouring land systems (cf. Athi, Ndola, Rumuruti).

Soil: Red friable clays (Ferruginous Tropical Soils and Ferrisols).

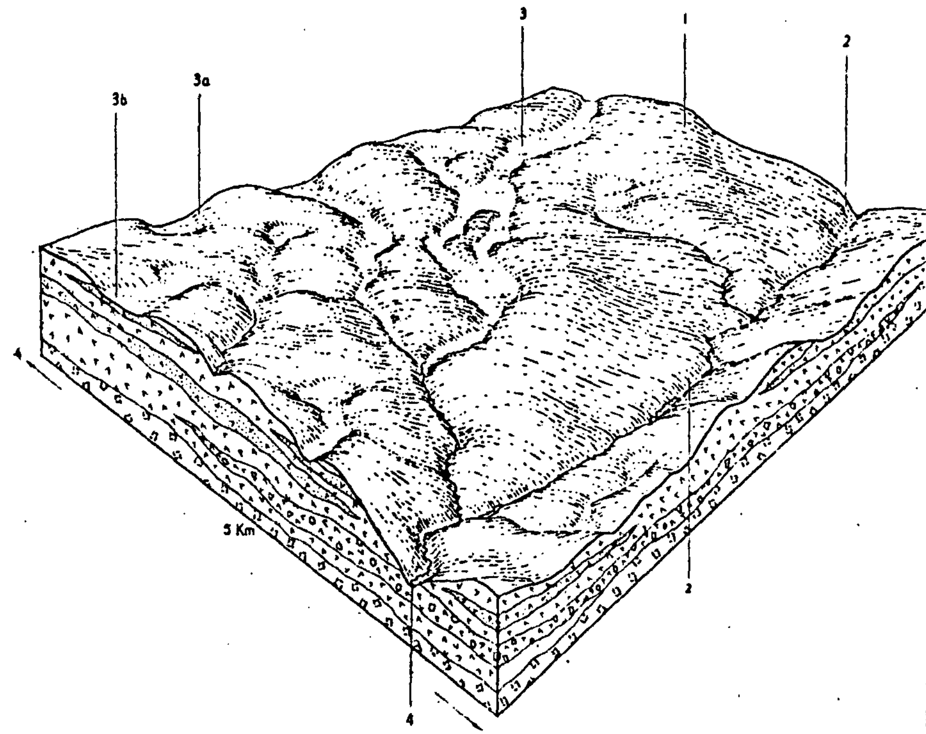
Vegetation: *Acacia* savanna, cultivated or scrub.

Relief: ca. 100 m, where hills present 200 m.

Altitude: 610-1,820 m in South.
1,200-1,950 m in North.

KIAMBU Land System

FACET No.	FORM	SOILS, MATERIALS AND HYDROLOGY	LAND COVER
1	**Ridge crest.** Level to gently sloping, convex, of variable width (200–2,000 m) even. Frequently with broad undulations.	Dark reddish brown friable clay 10–25 cms thick, over dark red to friable clays over 180 cms deep, over weathered rock.	Forest or woodland.
2	**Valley sides.** Steep to moderate convex slopes, 10–30 m high, elongated along the contour.	As 1, but shallower with occasional lava rock outcrop.	Mainly scrub and grassland.
3	**Depressions.** Flat bottomed depressions, rounded or highly elongated in plan. Commonly 240–300 m across.		
	(a) Concave fringes about 50 m wide.	(a) Dark brown to brown friable clay with iron and MnO_2 concretions 10–20 cms thick over strong brown to reddish brown friable clay with iron and MnO_2 concretions. Subject to seasonal seepage.	(a) Mainly scrub and grassland.
	(b) Level floors.	(b) Dark brown to dark greyish brown mottled, plastic clay 10–15 cms thick over dark grey to dark greyish mottled plastic clay. Weathered tuff occurs from 100 cms.	(b) Wet grasslands.
4	**Valley bottoms with streams.** Narrow (20–200 m across), flat or concave in transverse section. Very narrow stream (2–10 m wide).	As 3(b).	As 3(b)



KIAMBU

Climate: Rainfall 750–1,000 m. March–May, November–December.

Geology: A variety of volcanic rocks including trachytic tuffs and agglomerate, basaltic agglomerate, basalts and kenyite (Mount Kenya phonolite) of Tertiary to Pleistocene age.

Landscape: Long broad ridges, approximately parallel, separated by winding valle[ys] of varying width, with streams locally.

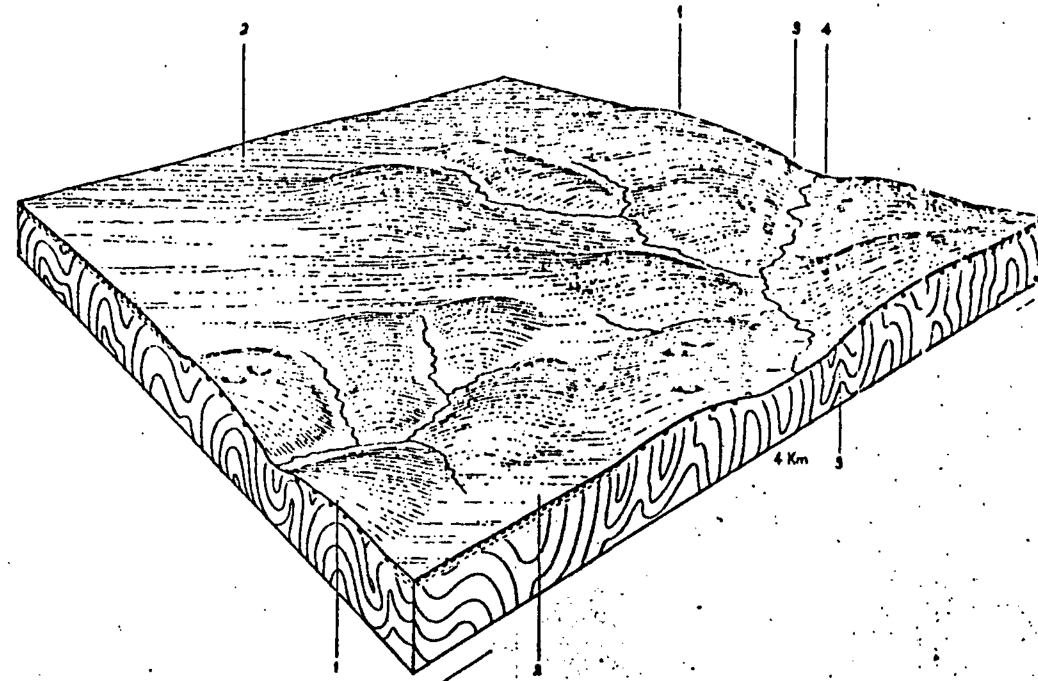
Soil: Red friable clays (Ferrisols).

Vegetation: Woodland, scrub or grassland.

Relief: 30–60 m.

Altitude: 1,430–2,300 m.

FACET No.	FORM	SOILS, MATERIALS AND HYDROLOGY	LAND COVER
	Low ridges. Level to gently sloping, convex, up to 750 m across, 5–10 m high, frequent low conical termitaria, occasional small round depressions 50–100 m across.	Dark brown to dark reddish brown sandy loam to loamy sand 15–30 cms thick over yellow red friable sandy clay with MnO_2 and iron concretions. Massive laterite occurs at about 100 cms. Depressions as facet 2.	There is a characteristic striation pattern evident on air photos. *Acacia* savanna and thicket. Depressions as facet 2.
	Clay plains. Extensive, level to very gently sloping, traversed by occasional shallow narrow drainage lines.	Dark grey to black cracking plastic clays 100–175 cms deep over weathered gneiss. Subject to seasonal waterlogging.	Wet grassland with scattered *Acacia drepanolobium*.
3	**Valley slopes.** Narrow, gentle to moderate slopes, occurring alongside main drainage lines. Often uneven and gullied (caused by dissection below laterite by streams of facet 4).	Reddish brown friable sandy loam up to 15 cms over red friable sandy clay loam. Weathered gneiss occurs at variable depth due to erosion of these slopes but is rarely deeper than 90 cms.	Vegetation as facet 1.
4	**Valley floors.** Narrow (30–100 m wide) level to gently sloping with concave margins including very narrow sinuous stream. Occurs mainly at margins of land system.	As 3. Occasionally subject to seasonal flooding. Stream beds mainly exposed unweathered gneiss, uneven, with pockets of loose brown sands of variable depth.	As 1. Nil.



NDOLO

Climate: Rainfall 500–650 mm. November – December, March – April.

Geology: Basement Complex gneiss.

Landscape: Mosaic of low ridges and clay plains, dissected at margins by seasonal rivers. This forms part of an extensive erosion surface developed during Pleistocene and Recent times.

Soil: Black to very dark grey clays (vertisols).

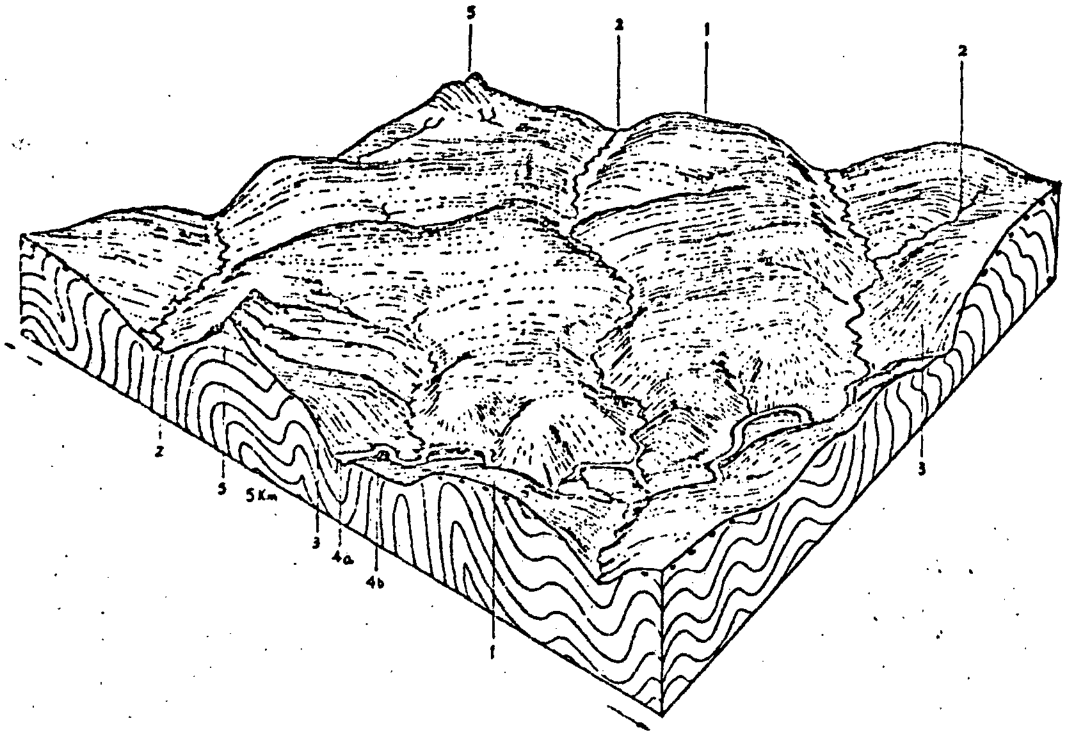
Brown to yellow red sandy clay loams with laterite horizon (Ferruginous tropical soils).

Vegetation: Partly cleared for grazing.

Relief: 10 m.

Altitude: 820–1,370 m.

WAMUNYU Land System



WAMUNYU

Climate: Rainfall 500-750 mm. March-April, November-December.

Geology: A variety of Basement Complex gneisses, with some schists and intrusives.

Landscape: Long ridges separated by narrow flat bottomed minor valley floors, and occasional rivers. In a few places small remnants of the sub-Miocene surface can be distinguished.

Soil: Brown to yellow red clay loams with laterite horizon. (Sols ferrugineux tropicaux).

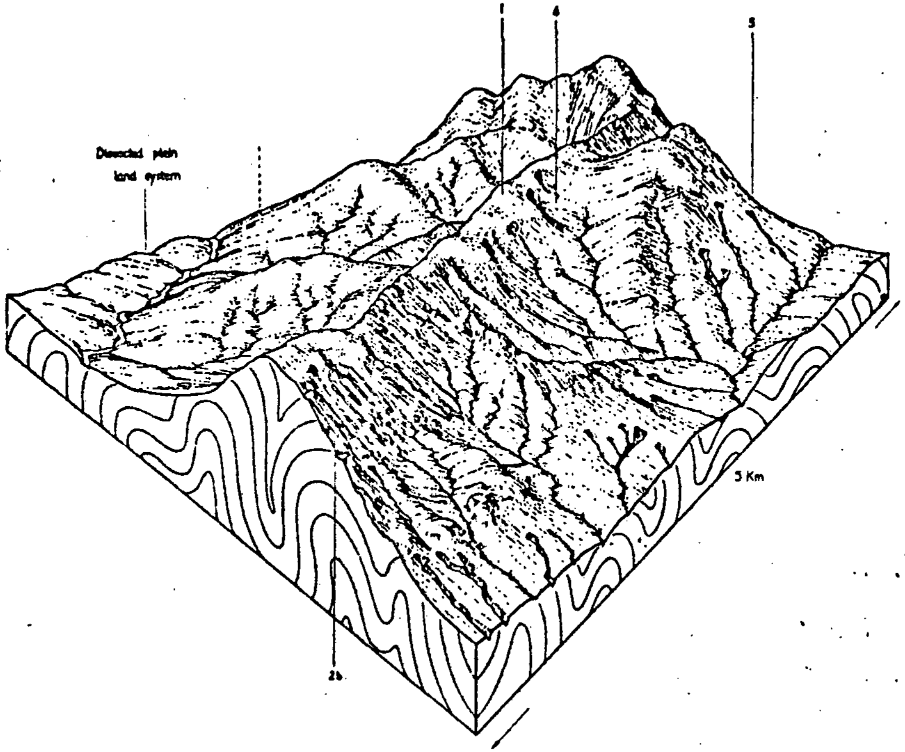
Vegetation:

Relief: 30 m.

Altitude: 750-1,750 m.

FACET No.	FORM	SOILS, MATERIALS AND HYDROLOGY	LAND COV
1	**Rounded ridges.** Long ridges about 1 km across, convex with slopes from level to moderate. Frequently indented by minor drainage lines.	Greyish-brown to dark brown sands to sandy loam up to 15 cms over brown to yellowish brown friable sandy clay loam, massive laterite occurs at depths between 90-120 cms.	*Acacia* savanna mainly cleared cultivation.
2	**Minor valley floors.** Level to gently sloping, usually concave in transverse section, 100-300 m wide, usually including very narrow incised stream channels.	Dark greyish-brown compact sandy loam 30-75 cms thick over dark brown loose coarse sand or plastic clay up to 190 cms deep. Subject to seasonal flooding or water logging.	Grassland.
3	**Main valley slopes.** Straight or slightly convex, uneven, up to 30 m high, moderate or steep slopes.	Reddish brown friable sandy clay loams up to 15 cms over red-reddish yellow friable sandy clays. A quartz stone line overlying weathered gneiss occurs at depths from 90-120 cms.	*Acacia* savanna.
4	**Main valley floor.**	Loose brown sands of varying depth with occasional rock bars.	Nil.
	(a) **River channel.** Winding 20-50 m wide with precipitous banks up to 2 m high and bars.	Seasonal or perennial flow.	
	(b) **Footslopes and flats.** Level to gently sloping, usually slightly uneven, up to 200 m wide on either side of river channel, discontinuous and sporadic in occurrence.	As 3 but generally deeper.	As 1 or cleared cultivation.
5	**Small hills.** Commonly ca.50 m high and 0.5-1 km across; steep, straight sides usually meeting in sharp crests; may be elongated and rugged. Lower flanks frequently deeply gullied.	Shallow stony soils, occasionally bare rock (Gneiss or schist).	Not known.

MBOONI Land System



MBOONI

Climate: Rainfall 500–1,300 m. Highest on hill tops, lowest on footslopes. November–December. March, April.

Geology: Gneisses of Basement Complex, mainly granitic and micaceous but including basic intrusives.

Landscape: This land system includes a number of isolated high hill masses with steep, often deeply dissected margins. The larger occurrences rise to a summit plane closely dissected into a series of closely spaced rounded ridges and spurs separated by narrow valleys. The summit level at 1,700 m to 2,100 m represents a pre-Micocene erosion surface, probably of end-Cretaceous age.

Soil: Red friable clays and reddish yellow sandy clay loams (Ferrisols) and shallow stony soils with rock outcrop.

Vegetation: Cultivated or scrub.

Relief: Maximum (from crest to hill foot) 300–450 m.

On summit plane ca 100 m.

Altitude: 1,200–2,125 m.

FACET No.	FORM	SOILS, MATERIALS AND HYDROLOGY	LAND COVE
	SUMMIT PLAIN		
1	**Ridge crest.** Narrow (a few metres up to 100 m wide, less commonly up to 500 m wide); gently convex with moderate slopes at margins.	(i) Dark grey brown sandy clay loam with quartz gravel 30–40 cm thick over reddish yellow sandy clay over weathered gneiss. (ii) Dark reddish brown sandy clay loam to 30 cm over dark red friable clay or sandy clay to 2 m over weathered rock.	Cultivated or occasionally pl to wattle (*Acac* or *Eucalyptus*.
2	**Valley side.** Steep, straight, or locally concave; ca 100 m high; commonly arcuate in plan.	Dark greyish-reddish brown clay loam or sandy clay loam 20–80 cm deep over weathered rock.	As facet 1.
3	**Valley bottom.** Narrow (10–100 m wide); concave in transverse section with margins gently to moderately sloping. Includes very narrow stream channel.	Dark brown or reddish brown clay loam or sandy clay loam up to 100 cm thick over red, dark red or reddish brown clay loam or clay which may be mottled. Quartz stones locally at 100–150 cm usually with weathered gneiss beneath. Seasonally high water table.	As facet 1.
	STEEP MARGINS		
4	**Steep slope.** Long, straight or slightly irregular, usually ca 300 m high; frequently indented by long straight gullies; locally very irregular, rough or precipitous.	Reddish brown sandy loam with more or less rock and stones over red friable sandy clay loam to clay frequently with quartz stone line at 30 cm or more with rock beneath. Rough and precipitous slope having very shallow stony soil with frequent rock outcrop.	Scrub.
5	**Major footslope.** Gently to moderately sloping; usually concave; up to 600 m long, very steep to precipitous sided gullies locally.	As facet 2.	Mainly cultivate
6	**River channel.** Narrow (20–50 m wide) with very small occurrences of terrace.	Rock and boulders. Flow seasonal or perennial.	Banks tree lined.