National Soil Service
Tanzania

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SOIL SURVEY REPORT OF DODOMA CAPITAL CITY DISTRICT

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Report prepared for the
Government of the United Republic of Tanzania
by
The Food and Agriculture Organization of the
United Nations acting as executing agency for the
United Nations Development Programme

based on the work of :
E. De Pauw Soil Survey Officer
J. P. Magoggo Agricultural Research Officer
J. Niemeyer Associate Expert, Soil Survey

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TABLE OF CONTENTS

		PAGE
ABSTRACT		
Chapter 1.	INTRODUCTION	1
1.1.	Background and implementation	1
1.2.	Summary of conclusions and recommendations	2
Chapter 2.	ENVIRONMENT	6
2.1.	Location, population and communications	6
2.2.	Climate	6
	2.2.1. General	6
	2.2.2. Rainfall	7
2.3.	Geology and tectonics	9
2.4.	Physiography	10
2.5.	Drainage and water resources	13
2.6.	Vegetation, land use and soil erosion	13
	2.6.1. General observations	13
	2.6.2. Distribution of vegetation, land use and soil erosion in relation to physiography	15
Chapter 3.	SOILS	19
3.1.	The Soils Map Legend	19
3.2.	General properties and distribution of the soils	20
3.3.	Description of the soils	26
	3.3.1. Red upland soils	26
	3.3.2. Brown upland soils	30
	3.3.3. Transitional soils	32
	3.3.4. Lowland soils	33
3.4.	Description of the mapping units	35
	3.4.1. Mountains	35
	3.4.2. Hills and inselbergs	35
	3.4.3. Footslopes	36
	3.4.4. Escarpments	40
	3.4.5. Upland plains	41
	3.4.6. Intermediate plains	46
	3.4.7. Lowland plains	47
	3.4.8. Swamps	48
	3.4.9. River valleys	49
Chapter 4.	LAND SUITABILITY EVALUATION	51
4.1.	General considerations	51
4.2.	Relevant land use alternatives	52
	4.2.1. Smallholder rainfed crop production, low inputs (C1)	52
	4.2.2. Commercial rainfed crop production, medium inputs (C2)	54
	4.2.3. Small-scale irrigated crop production (C3)	55
	4.2.4. Unimproved natural grazing (R1)	55
	4.2.5. Ranching (R2)	56
	4.2.6. Forestry (F)	56
4.3.	Land suitability classes and land characteristics	57
4.4.	Land suitability in Dodoma Capital City District Conclusions and recommendations	64

TABLE OF CONTENTS

	PAGE
ABSTRACT	
REFERENCES	72
Technical Appendix I. SOIL SURVEY METHODS	73
AI.I. Field methods	73
AI.2. Office methods	73
AI.3. Laboratory methods	75
AI.4. Consulted documents	75
Technical Appendix 2. ASSESSMENT OF DEPENDABLE MOISTURE AVAILABILITY FOR MAIZE, SORGHUM AND GROUNDNUTS IN DODOMA CAPITAL CITY DISTRICT	79
A2.1. Introduction	79
A2.2. Principles	79
A2.3. The waterbalance model	81
A2.4. Results	84
Technical Appendix 3. DESCRIPTIONS AND ANALYTICAL DATA OF REPRESENTATIVE SOIL PROFILES	90

LIST OF TABLES

Table 1.	Average climatic data	7
Table 2.	Annual rainfall statistics (1939-1979)	7
Table 3.	Growing season rainfall statistics	8
Table 4.	Rainfall distribution (1939-1979)	8
Table 5.	Effective annual rainfall	9
Table 6.	Major relationships between physiography, vegetation, land use and soil erosion	18
Table 7.	Mapping units and soil associations	21
Table 8.	Soil units	24
Table 9.	Average soil characteristics	29
Table 10.	Yields of major crops	53
Table 11.	Relevant land qualities	59
Table 12.	Probability of crop failure by drought	61
Table 13.	Land suitability classification Dodoma Capital City District	65
Table 14.	Areal extent of land suitability units	67
Table 15.	Growth stages and yield response factors for maize, sorghum and groundnuts	83
Table 16.	Charateristics of the distributions of YWI	84
Table 17.	Yield-and-water indices per growing season	88
Table 18.	Relative changes in yield parameters from soil group 1 to 3	89
Table 19.	Physical properties of selected profiles	91

TABLE OF CONTENTS

ABSTRACT

PAGE

LIST OF FIGURES

Figure 1.	Cumulative frequency curves for yield-and - water indices for maize, groundnuts and sorghum on soil group 1 (AWC: 50 mm)	85
Figure 2.	Cumulative frequency curves for yield-and-water indices for maize, groundnuts and sorghum on soil group 2 (AWC: 100 mm)	86
Figure 3.	Cumulative frequency curves for yield-and-water indices for maize, groundnuts and sorghum on soil group 3 (AWC: 150 mm)	87

LIST OF MAPS

1.	Generalized Map of geology and geomorphology (scale 1:200,000)	10(b)
2.	Vegetation types, land use and soil erosion (scale 1:200,000)	17(b)
3.	Physiography and Soils (scale 1:50,000) 4 sheets	Vol. B
4.	Vegetation types, land use and soil erosion (scale 1:50,000) 4 sheets	Vol. B

SOIL MAP LEGEND Vol. B

ABSTRACT

This report describes a medium-intensity soil survey and land suitability evaluation of Dodoma Capital City District, Dodoma Region, which covers an area of 2500 sq. km. The survey and land suitability evaluation were carried out to assist the Capital Development Authority in planning future land use in the District. A soils and land use, vegetation and soil erosion map at scale 1:50,000 were prepared for the purpose.

The Capital City District can generally be described as a plateau with low relief intensity. Within the plateau a variety of landforms can be distinguished with different soils, vegetation types, land use and land degradation. Geographically the most important landform is an upland plain, covering about 52% of the area. Agriculturally the most important are the river valleys, intermediate plains and lowland plains covering about 14% of the area. The most degraded land is found on the footslopes and escarpments, covering about 24% of the area.

Soils of the survey area are characterized by a variety of textures, ranging from coarse sands to heavy clays. In general most soils of the area have a low nutrient status. Organic matter contents are very low. Also the structural properties of the Dodoma soils are poor: soil aggregates tend to be unstable and the soils are susceptible to erosion and surface sealing. Where the vegetative cover is poor and topsoil has been eroded, the exposed surface becomes very hard when dry giving the false impression of hardpans.

Land suitability for relevant landuse types: rainfed crop production, small-scale irrigated crop cultivation, improved natural grazing, ranching and forestry, were assessed in terms of the soils and major environmental factors of the area mainly, physiography and climate.

Major physical constraints for increased agricultural productivity in Dodoma Capital City District are inadequate moisture availability, low soil fertility status and soil erosion.

Inadequate moisture availability resulting from climatic constraints, notably low rainfall of high variability in a short rainy season and high
/of rates/potential evapotranspiration. Cultivation areas that are entirely rainfed and cannot benefit from other moisture additions have in general marginal suitability for crop production. In many parts of the District the inherent limitations imposed by climatic factors on biomass productivity are considerably worsened by land degradation, which is particularly evident from soil erosion and poor vegetation cover. These factors have decreased the rainfall absorptive capacity of the soils and made them drier than they would have been under well managed conditions.

In terms of the major fertility parameters, most soils of the area have a poor nutrient status. The limited fertility of soils in the District is to a very considerable extent attributed to erosion intensified by overgrazing. About 25% of the District is affected by gully and sheet erosion and about 35% of the area is particularly prone to sheet erosion. In only 20% of the District can soil erosion be dismissed as a negligible factor influencing crop productivity.

The main conclusion that can be drawn from the present study is that, Dodoma Capital City District is a marginal area for agriculture. Virtually no land can be considered highly suitable for any of the relevant agri-

cultural options. In most cases the land is marginally suitable or even unsuitable. Land with better potential is generally situated in lower-lying areas such as the lowland plains, the river valleys and the aggraded footslopes which receive run-off from higher ground.

On the basis of the land suitability study recommendations for land use in the District have been prepared.

Chapter I

INTRODUCTION

I.I. BACKGROUND AND IMPLEMENTATION

This report presents an account of the soil survey and land suitability study of Dodoma Capital City District, Dodoma Region, Tanzania. The survey, covering an area of 2500 sq. km, was undertaken by the National Soil Service at the request of and in co-operation with the Tanzania Capital Development Authority (C.D.A.). The objectives of the study were :

1) to prepare a soils map and land resources inventory of the area around the Capital and to evaluate the suitability of the mapped land/soil units for relevant agricultural land use alternatives (crop production, rangeland and forestry).

2) to identify the physical constraints for agricultural development of the area.

The field-work began in January 1979 and was completed in August 1979. A preliminary report, together with maps on soils, physiography, land use, vegetation and soil erosion, was submitted to the Capital Development Authority in October 1980. The final report shows no major changes apart from the inclusion of technical data and redrawn maps. The conclusions and recommendations of the preliminary report are basically unaltered.

The following staff of the National Soil Service and FAO personnel were responsible for the implementation of the soil survey and land suitability study, and for the preparation of the report:

National Soil Service

J.P. Magoggo, Agricultural Research Officer (Field work, Soil Correlation, report preparation);
S.E. Mugogo, Agricultural Research Officer (Field work, Soil Correlation);
Z. Mmari, Agricultural Field Officer (Field work);
A. Kiwelu, Agricultural Field Assistant (Field work);
L. Daggaa, Agricultural Field Assistant (Field work);
A. Kulugutu, Recorder (Field work, map drafting).

FAO Personnel (URT/73/006)

E. De Pauw, Soil Survey Expert (Field work, Soil Correlation, Map and report preparation);
E. Bomans, Associate Expert Soil Survey (Field work, Soil Correlation, Photo interpretation);
J. Hof, Associate Expert Soil Survey (Photo Interpretation, preparation of physiographic and slope maps);
J. Niemeyer, Associate Expert Soil Survey (Photo Interpretation, preparation of land use, vegetation and soil erosion maps).

Chemical analyses of representative profiles were carried out under the direction of Dr. R. Menon, FAO Soil Chemist, at the National Soil Service laboratory in Mlingano. The base maps were drawn by E. De Pauw, A. Kulugutu and J. Niemeyer and final fair drawing was done by Messrs. Hamisi and P. Lunkombe. The report was reviewed by Mr. J.F. Harrop, Project Manager.

Apart from field observations and soil analytical data, the present report and maps are based on a thorough analysis of existing aerial photographs, topographical maps, geological reports and computer-processed climatic data.

The report is prepared according to the following format: first the physical environment of the Capital City District is described (Chapter 2), then the mapping units and the soils (Chapter 3), followed by a description of the relevant agricultural options in the area, conclusions on agricultural potential and recommendations for future land use planning (Chapter 4). This constitutes the main part of the report and provides the information relevant for land use planners, extension staff and agriculturalists. The second part of the report is composed of technical appendices, which are destined for soil specialists. Appendix 3 contains descriptions and analytical data of representative soil profiles and may also be of particular interest to agronomists.

For the purposes of this soil survey it was found that information on physiography was as essential as soils information. For this reason, and certain limitations imposed by mapping scale, time and financial constraints, the Soils Map is actually a map of Soils and Physiography. Mapping units are therefore based on more or less uniform physiographic features characterized by particular soil associations, rather than by individual soils.

This survey would not have materialized without the assistance of the Capital Development Authority, who, apart from financing the survey, have been most co-operative in all matters. Our sincere thanks in this respect go to Mr. K. Hassan, Regional Planner, Mr. P. Shayo, Director of Physical and Social Planning Department and Mr. G. Kahama, Director General of C.D.A. Thanks are due as well to Mssrs. Mlay, Makalla and Mligo for their kind support. The soil survey team also wishes to acknowledge the kind services of the TIRDEP-office in Tanga for the stereo-plotter facility and the assistance of the Meteorological Department, Dar es Salaam in acquiring the climatic records for Dodoma.

1.2. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. The Capital City District can, in a general way, be described as a warped plateau with low relief intensity, broken up by steep escarpments, hills and occasionally mountains. Slight as the general topographical differences are, they have given rise to a variety of landforms, characterized by different soils, vegetation types and land use.

Following major landforms were recognized in the survey area:

1) Mountains
2) Inselbergs and hills
3) Footslopes
4) Upland plains
5) Lowland plains
6) Intermediate plains
7) Swamps
8) Lake
9) River valleys

Of these landforms the most important in area are the upland plains, covering about 52% of the survey area. The most important from an agricultural viewpoint are the river valleys, intermediate plains and lowland plains, covering about 14% of the survey area. The most degraded areas are the footslopes and escarpments, covering about 24% of the survey area.

2. The three main factors that govern the types of soils and their distribution are parent material, topography and antecedent tectonic movements.

Reddish clayey soils (Rc) occur on the footslopes of basic metamorphic hills of the Dodoma Formation. Reddish loamy soils (Rl) occur on the footslopes of granitic hills. Wherever the granite has been contaminated by basic inclusions of the Dodoma Formation, more reddish and clayey soils (Rc) may be present. Reddish, loamy or clayey soils are also associated with fault or shear zones within the basement complex. Such zones with red soils are common on the upland plains and along the escarpments.

Brown, loamy soils (Bl) and sandy soils (Bs) occupy the better drained parts of the upland plains. These areas are also characterized by the omnipresence of eroded or vegetated termite mounds.

Dark, sticky, cracking clays (V) and friable, calcareous clays (F) occupy the poorer drained parts of the area, such as the lowland plains and the swamps.

A brownish or reddish loamy colluvium overlies grey, heavy alluvium (C/A) in the river valleys. The colluvium originates mainly from the Dodoma Hills and appears to be the result of accelerated erosion in the area.

Virtually all soils in the survey area are characterized by a low nutrient status particularly with regard to phosphorus and exchangeable base content. Organic matter levels are low, which explains in part the poor structural properties of the soils and their susceptibility to erosion. Only in the dark cracking clays (V) and the friable clays (F), is the total exchangeable base content satisfactory.

A most surprising finding of the soil survey was the high acidity of many upland soils. Most upland soils have lower pH-levels than similar soils in higher rainfall areas. A possible explanation for this unexpected soil reaction might be that the extensive land degradation has exposed old weathered sub-soils which belong to an earlier weathering cycle.

The structural properties of the soils of the Capital City District are in general very poor. Aggregates are unstable and soils are susceptible to splash erosion or surface sealing. Due to the poor vegetative cover soils tend to become very hard when thoroughly dry, thus giving the false impression of 'hardpan soils'.

The suitability of the different soil types for the relevant land use alternatives can not be assessed independently from the other environmental factors. Most important in this respect appear the position of the different soils in the landscape, the degree of degradation to which the particular landscape has been subjected and the climatically determined growing season.

3. The land suitability classification refers to the following major land utilization types, that appear most relevant to the socio-economic conditions prevailing in the survey area :

1) Crop production systems :

   (CI) Smallholder rainfed crop production, low inputs
   (C2) Commercial rainfed crop production, moderate inputs
   (C3) Small-scale irrigated crop production

2) Rangeland systems :

   (RI) Unimproved natural grazing
   (R2) Ranching

3) Forestry (F)

4. The major physical constraints for increased agricultural productivity in Dodoma Capital City District are inadequate moisture availability, low soil fertility and soil erosion.

Water supply for plant growth under rainfed conditions is definitely limited by climatic constraints, particularly low rainfall with high variability, high potential evapotranspiration levels and a short rainy season. As a result, sites that are entirely rainfed and can not rely on water additions from other sources, have high probabilities of crop failure for drought-sensitive crops. Even drought-tolerant crops such as sorghum, are prone to regular crop failures under entirely rainfed conditions. If additional moisture is received from groundwater, seepage or run-off the likehood of crop failure is considerably reduced. This explains why most of the present farm land is situated in low-lying areas, particularly in the river valleys. In fact, the area presently under cultivation (25%) closely coincides with water-receiving areas (30%).

In many parts of the Capital City District the inherent and inescapable limitations imposed by climate on biomass production have been considerably worsened by land degradation, as expressed by soil erosion, surface capping, poor vegetative cover, low organic matter levels, poor structural properties. These factors to a large extent have decreased the rainfall absorptive capacity of the soils and made them drier than they would have been under well managed conditions. The areas most affected in this respect are the footslopes.

In terms of the major fertility parameters, most soils of the survey area have a poor nutrient status: organic matter levels are low, and unexpected high acidity occurs in many upland soils which constitutes a serious fertility limitation, particularly affected are Rc-soils, but also the Rs-, Bl- and Bs-soils, and some of the Rl- and A-soils. The most fertile soils in the area appear to be the V- and F-soils, covering about 5% of the District.

To a considerable extent, the limited soil fertility in the District can be attributed to soil erosion and overgrazing. The extent to which soil erosion has affected the District can best be appreciated by the actual figures : about 25% of the District is affected by gully and sheet erosion, particularly the footslopes on granitic rocks and the escarpments. About 34%

of the District is particularly prone to sheet erosion and, if cultivated, under risk of declining crop yields. In total, about 80% of the District is directly or indirectly influenced by the process of soil erosion. In only 20% of the District can the influence of the erosion factor on agricultural productivity be considered as minimal.

5. Dodoma Capital City District is a marginal area for agriculture. Virtually no land is highly suitable for any of the chosen land use alternatives. At best the land is moderately suitable, but in most cases the land is marginally suitable or even unsuitable. Even for drought resistant crops only 25% of the land appears to be suitable. The reasons for this generally poor agricultural potential are low rainfall and severe land degradation.

Land with better potential is generally situated in water receiving areas such as the lowland plains, the intermediate plains, the river valleys, the aggradational footslopes and the upland plain depressions. Better moisture availability in these areas is to a large extent due to the fact that the degraded upland areas are unable to absorb rainfall which passes to lowland sites as run-off, but other factors are also responsible such as heavier soils with good moisture holding capacity or the occurrence of perched watertables in old alluvium.

6. On the basis of the physical land suitability study the soil survey team has prepared land use recommendations for the District which are specified in Chapter 4.4.

Chapter 2

ENVIRONMENT

2.1. LOCATION, POPULATION AND COMMUNICATIONS

The survey area comprises Dodoma Capital District in Dodoma Region, Tanzania and lies approximately between latitudes and 5°30'S and longitudes 35°30'E and 36°10'E. It covers an area of 2636 sq. km. in a radius of about 40 km around Dodoma town. The average altitude is about 1100 m above sealevel.

The total population of the District was estimated in 1974 at 180,000. The average population density is 72 inhabitants per sq. km but population density varies considerably, from a minimum of 0-10 inhabitants per sq. km in some areas to more than 100 per sq. km in others. Apart from Dodoma town itself, centres of high population density are Kikombo, Bihawana and Mvumi.

The most important means of communications are the railway and roads. The Central Railway Line links Dodoma Town with Tabora and Kigoma to the west, Mwanza to the north and Morogoro and Dar es Salaam to the east. All-weather non-metalled roads link Dodoma with Arusha, Morogoro, Iringa and Singida. Numerous minor roads link villages with Dodoma town. In view of the low rainfall these roads are usually motorable even in the rainy season. Many new roads are being constructed. Other means of communications include the airport of Dodoma town and the airstrip at Hombolo Leprosarium.

2.2. CLIMATE

2.2.1. General

The observations which follow regarding climate are based on data from Dodoma meteorological station. It is assumed that most of the survey area is homogeneous in respect of climate and will be well represented by the data for Dodoma, although in the short term high rainfall variability may be expected from place to place. Consistently higher rainfall than in Dodoma can be expected on the southern footslopes of the Chenene mountains (Hombolo Makulu area). Long-term climatic data for this area are, however, not available.

Average climatic data on a monthly and yearly basis are given in table 1. It can be concluded that average temperatures are high and fairly uniform throughout the year. The coolest time of the year is the early dry season, the hottest time the end of the dry season, just before the onset of the rains. Daily temperature variations are moderate (11-14°C). Night frosts do not occur. The average annual rainfall is low and occurs normally for more than 90% during the rainy months of December, January, February and March. The transitional months April and November receive some rainfall, but the remainder of the year, between May and October, is virtually rainless. Evapotranspiration rates (according to Penman) are high.

Table 1. Average climatic data (°)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean temp. (°C)	24	24	24	23	22	21	20	21	22	24	25	25	23
Mean max. temp.	29	29	29	29	28	27	27	27	29	31	32	31	29
Mean min. temp.	18	18	18	18	16	14	13	14	15	16	18	19	16
Mean rainfall (51 years data)	151	115	123	51	5	1	0	0	1	5	20	106	578
Mean Penman evapotranspiration (*)	174	159	173	155	171	168	186	216	244	262	236	202	2346

(°) data from E. African Met. Dept. (1970)

(*) modified Penman estimates (calculated after Doorenbos and Pruitt, 1977)

2.2.2. Rainfall

Insufficient rainfall appears the most important limiting factor to crop production in the survey area.

Characteristic of the annual rainfall is the low average and the high variability (see table 2). This high variability makes the rainfall in Dodoma fairly unreliable. On a monthly basis this variability is even higher. In the more reliable rainfall months of December to March the rainfall may differ 50-70% from the average (see table 3) and in the transitional months October, November, April and May the rainfall is utterly unreliable. As a whole it may be concluded that only four months have significantly reliable rainfall to be of agricultural importance. The growing period for rainfed annual crops will therefore be confined to these four months or less.

Table 2. Annual rainfall statistics (1939 - 1979)

Average	556 mm
Standard deviation	170 mm
Coefficient of variation	31 %
80% probability rainfall (°)	410 mm
90% probability rainfall (°)	340 mm

(°) approximated

Table 3. Growing season rainfall statistics

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Average (mm)	4	26	110	136	112	112	152	5
Standard deviation (mm)	12	43	70	80	78	55	51	8
Coefficient of variation (%)	300	164	63	59	70	49	98	160
80% probability rainfall (mm)	0	0	51	68	46	66	9	0
90% probability rainfall (mm)	0	0	22	35	14	43	0	0

Another characteristic of the rainfall pattern is its positive skewness. This means that there is a higher chance that the rainfall will be below the average than above, but when below, it is likely to differ less from the average than when above. In addition the annual rainfall distribution is leptokurtic. This means that the annual rainfall shows a high tendency towards centrality around a value that, in view of the positive skewness, will be somewhat below the average.

The significance of these rainfall characteristics for crop production is that average rainfall data are likely to provide an overoptimistic picture of water availability and should therefore be supplemented with indicators that express likely conditions of moisture availability from rainfall.

Frequently used indicators of reliable rainfall are the 80% and 90% probability minimum rainfall. Those are the rainfall amounts that can be expected to be exceeded in 4 years out of 5, and 9 years out of 10 respectively. Alternatively these are the rainfall amounts that will probably not be exceeded in 1 year out of 5, and 1 year out of 10 respectively. 80% and 90% probability rainfall data in annual and monthly basis are given in tables 2 and 3.

From the analysis of daily rainfall records for the period 1939-79 it appears that the rainfall is rather well distributed. The average number of rainshowers during this period was about 50 per year, and only 13% had an intensity of more than 25 mm/day (table 4). Moreover the calculation of the effective rainfall (i.e. total rainfall minus estimated runoff) according to the Curve Number Method (Dastane, 1974) showed that the rainfall in Dodoma, on an annual basis, is about 94% effective (table 5).

Table 4. Rainfall distribution (1939 - 1979)

Average annual effective rainfall (standard deviation)	49 11
Average number of rainshowers per year with intensity 25 mm/day (standard deviation)	 6 2
% rainshowers with intensity 25 mm/day	13

Table 5. Effective annual rainfall

Average annual effective rainfall	522 mm
(standard deviation)	141 mm
80% probability effective rainfall	404 mm
90% probability effective rainfall	344 mm
Average annual effective/total rainfall	94%

In conclusion it would appear that the main climatic constraint for crop production in Dodoma Capital City District is the short duration of the growing period rather than a poor rainfall distribution. Contrary to common perceptions, the rainfall in Dodoma is largely effective and well distributed and can be optimally used by crops. Certainly high intensity rainstorms occur but they are comparatively rare. The fact that at present a higher fraction of the total rainfall is lost by runoff is not due to an alleged torrential character of the rainfall, but rather to the physical degradation of many soils in the area, which prevents them from absorbing the rainfall adequately (see chapter on soils).

2.3. GEOLOGY AND TECTONICS

Most of the area is underlain by intrusive Basement Complex rocks, mainly granites. The granites outcrop in scattered inselbergs, mainly in Dodoma Hills south of Dodoma and in the Chenene mountains in the north. The granitic rocks are believed to be of late Precambrian age (Wade and Oates, 1938) but their exact age, mode of emplacement and distribution in depth are so far unknown.

The granites enclose disconnected fragments of older Basement rocks, belonging to the Dodoma Formation. These fragments outcrop mainly in a series of low inselbergs south of the Chenene mountains. The rocks of these inselbergs are mainly amphibolites, schists and basic gneisses, and have in general a much more basic mineralogy than the granites. In addition basic and ultrabasic intrusive rocks may occur as younger dykes, penetrating the granite.

The most common granitic rocks are grey, non-schistose and rarely porphyritic granites. Near to the older basic rocks there is evidence of contamination, as expressed by an enrichment of dark minerals as well as an abundance of streaks and bands of dark schists. In addition inclusions of only partially digested basic rocks are often observed in the granite, for instance, at Mlimwa Hill near Dodoma.

A minor type of granitic rock recognized in the area is termed 'granitic gneiss'. This rock is characterized by a clear directional tendency but is otherwise very similar to the normal granite. It occurs mainly in the Dodoma Hills south of Bihawana.

In most of the survey area the Basement Complex rocks are covered by a mantle of loose or cemented superficial deposits, of alluvial, colluvial and residual origin and Tertiary or Quaternary in age.

The cemented superficial deposits include argillaceous or calcareous "cements". The argillaceous "cements" have a high clay content and are characteristically very hard and compact when dry, but soft when moist. They underlie large parts of the survey area and occur usually on the transition from hillslopes to lowland plains. They can often be observed underneath the present-day soils in riverbeds or erosion gullies draining from the hills. These "cements" are probably aggradation products formed on the Tertiary peneplain.

The cementing material is largely calcareous and the abundance of calcium is probably due to the persistance of the sites as freshwater swamps until the present day (Wade and Oates, 1938). Several of these calcareous deposits underlie the black clays of the lowland plains west of the Hombolo escarpment and are exploited as a source of building lime.

The loose superficial deposits include most of the present-day soils and are formed by residual weathering (soils of the upland plains) followed by colluvial transport (soils of the hill footslopes) or alluvial transport (soils of the lowland plains and river valleys).

There is ample evidence of (sub) recent tectonic movements in the survey area, probably related to the formation of the East African Rift Valley. These movements are visible in the landscape which has the general appearance of a warped plateau gently sloping to the East. The regularity of this warped plateau is interrupted by fault-like escarpments of which the most important one, the Hombolo escarpment, extends SW-NE from Hombolo Bwawani to Ntyuka over a distance of more than 30 km. Another important escarpment, the Kigwe escarpment, is located east of Kigwe village and forms the western boundary of the survey area. The geographical location of these escarpments is intermediate between the major fault scarps of Kilimatinde and Fufu, which are recognized in the geological literature as related to the formation of the Rift Valley.

The presence of numerous other faults and tectonic directions can be inferred from the abundance of linear features with general directions SW-NE and NW-SE. Examples are the alignment of the Little Kinyasungwe River upsteam lake Hombolo and of the Makutupora swamp. In some cases the linear features can be inferred from the soil distribution, for instance in the lowland plains west of the Hombolo escarpment. A very obvious linear feature is formed by the Chenene Mountains, which form an uplifted block extending in NW-SE direction over more than 100 km, iside an otherwise fairly uniform plateau.

2.4. PHYSIOGRAPHY

The bulk of the survey area can broadly be described as an warped, asymmetric plateau, with overall slope to the East and low relief intensity. This plateau is occacionally broken by steep escarpments and rectilinear slopes of tectonic origine, and isolated hills or hill ranges. The northern boundary of the survey area is formed by the Chenene Mountains, which form apparently an uplifted fault block. The Dodoma Hills form a continuous W-E aligned range of hills with associated footslopes.

A general map of major physiographic features in relation to geology at 1:200,000 scale is included in this report. The main physiographic features of the area are briefly described in the following paragraphs.

2.4.1. Mountains (M)

The only mountain range in the survey area is formed by the Chenene Mountains. The Chenene Mountains are an uplifted granitic fault block extending over more than 100 km in a NW-SE direction. They form the northern boundary of the survey area over a distance of about 25 km. The Chenene Mountains are characterized by their high altitude (1500-2000 m, 500-1000 m above the general plateau level), very steep slopes and table-top summits. There is little soil cover and therefore virtually no cultivation. Most of the Mountains are covered by natural vegetation, particularly thick bushland on the lower slopes and 'miombo' woodland at higher altitude. The Mountains have very limited footslopes. They cover about 81 sq. km.

2.4.2. Inselbergs and Hills (R)

Inselbergs are low, isolated rocky hills, scattered over the plateau, with or without distinct footslopes. They have steep slopes, no soil cover and usually a fairly intact thicket or bushland vegetation. Where rock outcrops occur close enough, their footslopes may join to form a hill range.

The most important hill range in the survey area is formed by the Dodoma Hills. This is a hilly area south of Dodoma, composed of granitic rocks rising about 200-300 m above the general plateau level. Slopes, soils and vegetation are similar to those on the inselbergs. These hills are surrounded by extensive footslopes which are described further.

According to geological composition the hills can be subdivided into two main groups, those formed by the basic metamorphic rocks of the Dodoma Formation (RB) and those formed by granitic (acid) rocks (RA). The former cover about 18 sq. km, the later 144 sq. km.

2.4.3. Footslopes (F)

Most of the hills and inselbergs are surrounded by apron-like footslopes, composed of weathering detritus and soil. The nature of the soil cover on footslopes is strongly determined by the underlying parent rock. Footslopes around hills formed by basic metamorphic rocks (FB) of the Dodoma Formation have reddish, usually clayey soils. Footslopes around hills formed by acid granitic rocks (FA) have brown, to red, usually loamy soils, occasionally sandy soils.

The footslopes are particularly extensive in the Dodoma Hills. The normal slope range is 1-12%. Characteristic for all footslope areas is the very strong soil and vegetation degradation: most areas are highly affected by sheet and gully erosion, and are often entirely denuded of natural vegetation.

The footslopes developed on granitic rocks cover about 476 sq. km, the footslopes on basic metamorphic rocks about 44 sq. km.

2.4.4. Upland plains (U)

The upland plains form the well-drained parts of the plateau. They have low relief intensity and are only slightly affected by recent incision.

Typical slopes on upland plains are 1-3%. They are affected by gully erosion to a limited extent only. The natural vegetation is usually bushland, more rarely bushed grassland.

According to the soil cover these upland plains can be separated into those with brown sandy and loamy soils (UB) and those with reddish, more clayey soils (UR). The latter upland plains are usually associated with tectonic features. A further peculiarity is the dense occupation of the UB-upland plains by eroded termite mounds, whereas UR-upland plains are usually free of mounds.

The upland plains are the most extensive physiographic unit in the survey area. They cover about 1364 sq. km, of which 91% are UB-plains and only 9% are UR-plains.

2.4.5. Lowland plains (L)

Lowland plains cover the less well drained parts of the plateau. In the survey area they probably originated from a former lake bottom. They have very low relief intensity and are virtually undissected or affected by erosion. Typical slopes are less than 1%. The soils of the lowland plains are heavy cracking black clays, or non-cracking brown clays, often saline and sodic. The natural vegetation is grassland or bushed grassland.

Lowland plains cover about 115 sq. km.

2.4.6. Intermediate plains (I)

Intermediate plains have soil and drainage characteristics that are intermediate between the footslopes and the lowland plains. They have low relief intensity, with a general slope range of 1-2% and with little evidence of soil erosion. The plains are well watered and are covered by moderately well drained loamy or clayey soils which are non-saline and non-sodic. The natural vegetation is non-degraded bushed or wooded grassland.

Intermediate plains cover about 47 sq. km.

2.4.7. Swamps (S)

Swamps cover the poorest drained parts of the survey area. They are usually waterlogged throughout the year and flooded in the rainy season. They are underlain by heavy cracking clay soils which are sodic and usually saline. The most important swamps of the survey area are the Singe and Makutupora swamps. It is probable that the tectonic movements in the survey area have played a major role in the formation of these swamps.

Swamps cover about 44 sq. km.

2.4.8. Lake (W)

The only lake in the survey area is Lake Hombolo which is man-made. It is slightly saline and sodic and very shallow (2.5 m maximum). Comparison of aerial photographs taken in 1960 with photos of 1978 indicates that half of the Hombolo Lake has already dried up and the emerged land is now under intensive cultivation.

The lake covers at present only 7.6 sq. km.

2.4.9. River valleys (V)

The river valleys include broad, poorly differentiated riverine plains with low relief intensity and strongly incised river beds. The river valleys are virtually free from flooding, except the river beds themselves. The river valleys are usually covered by colluvial loamy soils over alluvial clays; the river beds are covered by coarse sands.

According to the predominant geomorphic processes river valleys can be subdivided into aggradational valleys (VA), where deposition of water and sediments from higher land predominates, and erosional aggradational river valleys slope gradients are very low and moisture can readily be stored. These areas have a fair potential for agriculture and are entirely cultivated. In the erosional river valleys surplus moisture is drained off to lower land rather than stored. The agricultural potential of these valleys is much more restricted.

River valleys cover 201 sq. km, of which 62% are aggradational and 38% erosional.

2.4.10. Escarpments (E)

Escarpments are elongated, rectilinear landscape features with relatively steep slopes, of tectonic origin. They are usually severely degraded in terms of soils and vegetation, resulting in severe gully and sheet erosion with shallow soils, rock outcrops and poor bushland cover. The main escarpments in the survey area are the ones near Kigwe and Hombolo.

Escarpments cover 96 sq. km.

2.5. Drainage and Water resources

The main drainage ways of the survey area are the braided river channels in the river valleys. These channels are usually dry throughout the year, except during thunderstorms when they collect most of the runoff from the hills and footslopes and store this water in the sandy river beds or drain it into the swamps where it evaporates or feeds groundwater reservoirs. Permanent water is available in the riverbeds at shallow depth. Seasonal watertables occur in the riverain plains and eventually aggradational footslopes. The upland plains are in general droughty and lack clearly defined waterways. The hills, footslopes and escarpments are very droughty because rainwater can not be retained by them, due to shallow or compacted soils, poor vegetative cover and diversion by numerous gullies.

2.6. VEGETATION, LAND USE AND SOIL EROSION

2.6.1. General observations

In accordance with the physiognomic classification of Pratt et. al. (1966) following natural vegetation types are recognized in the survey area:

1) Woodland: a stand of trees, up to 18 m in height with open or continuous, but not thickly interlaced, canopy, and a canopy cover of more than 20%.

2) Bushland: an assemblage of woody plants, mostly of shrub habit, with a shrub canopy of less than 6 m height and a canopy cover of more than 20%.

Wooded bush: refers to bushland with 20 - 40% tree cover. Bushland thicket refers to a closed stand of shrubby woody plants, nearly impenetrable and therefore with little value for grazing.

3) Grassland: land dominated by grasses, sometimes with widely scattered or grouped trees and shrubs, the canopy cover of which does not exceed 2%. If the canopy cover exceeds 2%, the appropriate terms are wooded grassland (2-20% tree cover) and bushed grassland (2-20% shrub cover).

4) Permanent swamp vegetation: various plant communities associated with permanent standing water, such as aquatic grass species, trees or shrubs, reeds, sedges and rushes.

Of these types bushland is the most extensive in the survey area, covering about 50% of the land. This bush is usually of low, thorny shrub habit. The second most important vegetation type is bushed or wooded grassland (15% of the area), followed by pure grassland (5%). Woodland is very limited (0.5%) and confined to the highest levels of the Chenene Mountains and the Dodoma Hills. However, woodland 'islands' in various physiographic units indicate that it was probably much more extensive in the past and it is likely that its regeneration is prohibited by present overgrazing and cultivation practices. Swamp vegetation covers about 1% of the survey area.

The main land use types are grazing and smallholder cultivation. Grazing is the most extensive land use type. Virtually 70% of the area is used for seasonal or perennial grazing by individual cattle owners. Although grazing may occur on fallow land, it is usually not integrated with arable farming. Fodder is scarce and overgrazing is the rule rather than the exception. There are no state ranches in the area, no improved pastures for beef or dairy development, and few watering points.

Cultivation is mainly concentrated in low-lying areas, such as the river valleys in the south of the survey area, where seasonal water tables provide additional moisture to supplement the low and variable rainfall. Blockfarms (mostly vineyards) are also located in these areas. The main smallholder crops are sorghum, bulrush millet, maize, groundnuts, but also some cassava, vegetables and garden crops. Tomatoes are successfully grown by hand-irrigation from nearby river beds.

From recent aerial photographs (1978) it appears that about 25% of Dodoma Capital City District is cultivated at one time or another. If the total agricultural land area of Dodoma were distributed over the entire population of the District, an average family would have less than 1.5 ha. Considering the overall droughtiness of the survey area and the persistent risk of crop failures, this amount of land appears insufficient to support the population of the District. This general figure and the fact that at present many soils of inferior quality are cultivated indicate that suitable agricultural land is in short supply. This forces farmers to cut fallow periods below optimal levels and in the long run this situation may lead to exhaustion of the land and to complete soil and vegetation degradation. This is already evidenced by the spectacular soil erosion in the south of Dodoma Capital City District. The probably once productive footslopes of the Dodoma Hills have been coverted into gullied wastelands that are now unsuitable for cultivation. In view of the severe vegetation degradation the livestock carrying capacity is very low and natural regeneration is prevented by overgrazing.

The degradation and soil erosion in the upland areas is accompanied by siltation of reservoirs in the lower lying areas. This is one of the main reasons why large-scale irrigation from dams is impractical in Dodoma District. However, the fact that the upland areas, particularly the hill-footslopes, are unable to retain rainfall because of land degradation has one beneficial effect: the lower lying areas receive additional moisture from runoff and have for this reason a better moisture regime than would otherwise have been possible under the current low rainfall. This is probably the main reason for the intensive cultivation of the lower land, especially the river valleys.

Apart from the Soils Map one of the sources of information used for this exercise is a Map of Land Use, Vegetation Types and Soil Erosion at 1:50,000 scale. This map is reproduced on four sheets included in Volume B of this report.

The mapping units are:

1. Woodland
2. Wooded bushland or thicket
3. Bushland
4. Wooded or bushed grassland
5. Grassland
6. Swamp
7. Smallholder cultivation
8. Blockfarms (grapes)
9. Urban land

<u>Phases</u>

1. Moderate gully erosion (gullies 200 m apart)
2. Severe gully erosion (gullies 200 m apart)

<u>2.6.2. Distribution of vegetation, land use and soil erosion in relation to physiography</u>

Clear relationships can be observed in the survey area between physiography on the one hand and land use, natural vegetation types and soil erosion on the other. The most important physiographic elements are altitude, slope and topographical position. Altitude has a distinct influence on the natural vegetation: for example, significant 'miombo' woodland areas occur only above 1500 m. Slope characteristics strongly determine the nature and intensity of soil erosion. The topographical position influences the drainage and moisture regime and has therefore a direct bearing on agricultural potential and land use.

On the mountains, hills and inselbergs firewood collection and some extensive wet-season grazing are the only land use types. Cropland is non-existant in view of the virtual absence of a soil cover. The Chenene Mountains are the only area in the District with significant 'miombo' woodland cover. This woodland occurs mainly on the summits and upper slopes. The lower slopes have a dense thicket and wooded bushland cover. The hills and inselbergs have in general a dense cover of wooded bushland and thicket. Woodland is hardly preserved.

On the footslopes around the hills and inselbergs, and the escarpments bushland is the main natural vegetation type; bushed or wooded grassland occurs only in some scattered areas. Transitional to the hills, the upper parts of the footslopes are sometimes covered by thickets and wooded bushland. In terms of soils and vegetation, the footslopes are the most degraded parts of the survey area. In view of their higher slope gradients they are affected by severe gully and sheet erosion. Gully erosion is particularly evident on most footslopes around granitic hills: gullies up to 3-4 m deep and 100-200 m apart emerge from these hills in a radial pattern. The footslopes around basic metamorphic rocks appear severely affected by sheet erosion: bright-red subsoil comes at the surface and most of these areas are devoid of natural vegetation. As a result of the severe erosion and vegetation degradation on the footslopes the agricultural productivity is very low: virtually no cropland can be found on the footslopes and their livestock carrying capacity appears very low.

On the upland plains bushland is the main natural vegetation type, followed by bushed grassland. Bush thickets and wooded bushland may occur in scattered places, usually far away from villages. Cropland is fairly common in this unit, but the main land use is grazing. Cropland usually forms a complex network with bushed or wooded grassland in smallholder size units. This would indicate that the bushed grassland represents, in some places, a fallow-grazing rotational stage of former cropland. The main staple crops grown are bullrush millet, sorghum and maize. In view of their low relief intensity the upland plains are less affected by gully erosion than the footslopes, but sheet erosion appears considerable and vegetation degradation is obvious, especially in the neighbourhood of villages. The livestock carrying capacity of the upland plains appears in general low.

In some depressions in the upland plains with internal drainage permanent swamps occur with waterlogging for all or most of the year. They are characterized by aquatic or grassland vegetation and are mainly used for grazing. In some places paddy rice is grown during the rainy season and maize and sorghum during the dry season.

On the lowland and intermediate plains the dominant vegetation types are bushland and bushed or wooded grassland, while some smaller areas are covered by grassland. The lowland plains are intensively used in a rotational farming system, whereby large areas are under cultivation. The bushed/wooded grassland areas are left fallow or grazed and the bushland areas are used as grazing land. This intensive use of the lowland plains is largely made possible by a favourable moisture regime, resulting from runoff additions and soils that have a good moisture retention. In view of the very low slopes, their position in respect of the erosion base (Lake Hombolo) and the dense grass cover, there is very little erosion on the lowland plains.

The aggradational river valleys are the most densely cultivated parts of the survey area. Most riverine land is cultivated at one time or another and whatever natural vegetation remains is usually bushed or wooded grassland that represents the fallow stage of a cropping cycle. The main crops are also maize, sorghum, bullrush millet, groundnuts and tomatoes near river beds. Some areas are developed into block farms and produce mainly grapes. As for the lowland plains the intensive utilization of the aggradational river valleys can be attributed to the better moisture regime in these areas: because the degraded footslopes are unable to retain rainfall most of it will be drained off and makes very substantial contributions to the moisture regime of the river valleys.

A phenomenon that has not been mentioned thus far is the association of severe gully erosion with bushland vegetation. Most areas that are severely affected by gully erosion are also covered by bushland. This, and the fact that rocky hills have a wooded bushland or woodland vegetation, suggests that in the areas concerned bushland is a degraded vegetation type and not the natural climax.

The major relationships between physiography, vegetation, land use and soil erosion are summarized in table 6. A simplified map of land use, vegetation and soil erosion at scale 1:200,000 is included in this report. The above described relationships with physiography can readily be established by comparison with the generalized map of geology and geomorphology at the same scale.

Table 6. Major relationships between physiography, vegetation, land use and soil erosion

Map Symbol	Physiography	Natural vegetation	Land use	Soil erosion
M	Chenene mountains	Woodland	Limited firewood collection	Not applicable
R	Dodoma hills and Inselbergs	Wooded bushland and Thicket	Firewood collection. Some wet season grazing	Not applicable
F	Footslopes	Bushland	Wet season grazing. Some smallholder cultivation	Severe gully and sheet erosion
E	Escarpments	Bushland	Grazing	Severe gully and sheet erosion
UB + UR	Upland plains	Bushland	Grazing Smallholder cultivation	Moderate gully and sheet-wash erosion
		Bushed/wooded grassland	Intensive grazing	Some sheetwash, depending on density of grass cover
I	Intermediate plains	Bushed/wooded grassland	Intensive grazing Smallholder cultivation	Little erosion Some sheetwash
L	Lowland plains	Bushed/wooded grassland	Intensive grazing Smallholder cultivation	None, possibly some sheetwash
S	Swamps	Wet grasslands	Some grazing at swamp edges Some paddy cultivation	None
VA	River valleys: 1. Aggradational	Bushed/wooded grassland remains	Intensive smallholder cultivation	Mainly deposition from higher land
VE	2. Erosional	Bushed/wooded grassland	Grazing	Severe gully erosion

Chapter 3

SOILS

3.1. THE SOILS MAP LEGEND

Volume B of this report includes the Soils Map of Dodoma Capital City District at scale 1:50,000. The Soils Map is composed of four sheets which cover the north, the south, west and east of the survey area. The Legend of the Soils Map is also included on a separate sheet in Volume B.

It may be noted that the Soils Map is actually a Map of Physiography and Soils: information on physiography was considered to be as valuable for assessing the agricultural potential as soils information, while providing a very convenient framework for mapping purposes. The Legend of the Soils Map is thus composed of two distinct parts: the first part, covering the left-hand side of the sheet, lists the different physiographic units, mapping units and soil associations. The second half of the sheet lists the different soil units, gives a summary of their characteristics and classifies representative profiles of each soil unit in terms of the FAO/UNESCO World Soil Map Legend (1974) and the USDA Soil Taxonomy (1975).

The mapping units are the basic units of the Soils Map. They refer to areas with a fair homogeneity of physiography, parent material, slope class and are characterized by a particular soil association.

Under soil association is understood a group of defined soil units, that occur regularly together in a determined geographical pattern with certain proportions. The composition of a particular soil association is expressed by the relative occurrence of its component soils. Thus dominant soils are those that are most specific for the particular soil association. In general they occupy more than 50% of the mapping unit. Associated soils are also important and occupy on the average 20-50% of the mapping unit area. Inclusions are minor soils that occupy less than 20% of a given mapping unit. Where known, more exact proportions of the soil units are given in the report (see section 3.3.).

The soil units are the basic soil bodies recognized during the survey. Relevant descriptions of the different soil units are give in appendix 3.

The mapping units are identified on the Soils Map by a mapping unit symbol and a graphic symbol. The mapping unit symbol is mnemonic, e.g. M for mountains, UBb for Upland plains with Brown soils, bottom position, etc. Slope classes are indicated by a number, the steepest slopes having the higher figure, e.g. FAe2 stands for erosional footslopes on granitic rocks, 6-12% slopes. A phase is indicated by a figure between brackets, e.g. FAe2(s) stands for erosional footslopes on granitic rocks, 6-12% slopes, stony and rocky phase.

The graphic symbol is a shading, related to the physiography. The graphic symbol may be unique for a particular mapping unit, but is usually shared by several related mapping units, e.g. all footslope areas on granitic rocks have the same shading. The various graphic symbols used are explained on each Sheet of the Soils Map. Phases have their own graphic symbols and a particular mapping unit can therefore be represented on the Soils Map by an overlapping of different graphic symbols.

The different mapping units, soil associations and soil units are also given in tables 7 and 8.

3.2. GENERAL PROPERTIES AND DISTRIBUTION OF THE SOILS

The soil types and their general distribution in the survey area are essentially determined by parent material, topography and antecedent tectonic movements.

Reddish clayey soils (Rc) occur on the footslopes of basic metamorphic hills of the Dodoma Formation. Reddish loamy soils (Rl) occur on the footslopes of acid granitic hills. Wherever the intrusive granite has been contaminated by basic inclusions of the Dodoma Formation, more reddish and clayey soils (Rc) may be present. Reddish, loamy soils (Rl) occur on the footslopes of acid granitic hills. Wherever the intrusive granite has been contaminated by basic inclusions of the Dodoma Formation, more reddish and clayey soils (Rc) may be present. Reddish, loamy (or clayey) soils are also associated with fault or shear zones within the basement complex. Such zones with red soils are common on the upland plains and along the escarpments.

Brown, loamy soils (Bl) and sandy soils (Bs) occupy the better drained parts of the plateau areas, that are characterized by little relief, sluggish and poorly defined drainageways. As a result soils show little catenary differentiation. These areas are also characterized by the omnipresence of eroded or vegetated termite mounds.

Table 7. Mapping units and soil associations

MAPPING UNITS AND SOIL ASSOCIATIONS						
MAPPING UNIT		SOIL ASSOCIATION				
Symbol	Name	Area ha	Area %	Dominant Soils 50%	Associated Soils 20-50%	Inclusions 20%
M	MOUNTAINS	8,065	3.06	Not applicable		
	HILLS AND INSELBERGS	16,184	6.15	Not applicable		
RB	Hills and Inselbergs formed on basic metamorphic rocks	1,762	0.67	Not applicable		
RA	Hills and Inselbergs formed on granitic rocks	14,422	5.48	Not applicable		
	FOOTSLOPES	52,017	19.78			
	Footslopes developed on basic metamorphic rocks	4, 358	1.66			
FBe2	Erosional footslopes, strongly sloping, 6-12% slope	659	0.25	Rc		RI
FBel	Erosional footslopes, gently sloping, 1-6% slope	3,699	1.41	Rc		RI
	Footslopes developed on granitic rocks	47,659	18.12			
FAe2	Erosional footslopes, strongly sloping, 6-12% slope	17,394	6.61	RI		Rs
FAe2(s)	As above, stony and rocky phase	3,702	1.41	RI	L,G	Rs
FAe2(r)	As above, red topsoil phase	2,303	0.88	RI		Rs,Rc
FAel	Erosional footslopes, gently sloping, 1-6% slope	13,817	5.25	RI		Rs
FAel(s)	As above, stony and rocky phase	378	0.14	RI	L,G	Rs
FAel(r)	As above, red topsoil phase	1,813	0.69	RI		Rs,Rc
FAa	Aggradational footslopes, gently sloping, 1-6% slope	6,446	2.45	RI		C/A
FAa(r)	As above, red topsoil phase	700	0.27	RI		C/A
FAa(g)	As above, gully erosion phase	1,106	0.42	RI		G

Table 7 (contd.)

MAPPING UNITS AND SOIL ASSOCIATIONS						
M A P P I N G U N I T		SOIL ASSOCIATION				
Symbol	Name	Area ha	Area %	Dominant Soils 50%	Associated Soils 20-50%	Inclusions 20%
	ESCARPMENTS	9,587	3.63			
E	Escarpments, gently to strongly sloping, 8-12% slope	5,643	2.14	Bl,Bs	L	G
E(s)(r)	As above, stony, rocky and red topsoil phase	2,405	0.91	Rl	L,G	
E(g)	As above, gully erosion phase	1,539	0.58	Bl,Bs	L	G
	UPLAND PLAINS	136,378	51.82			
	Upland plains with brown soils and termite mounds	124,178	47.19			
UBt	Upland plains, almost flat top, 0-1% slope	41,660	15.83	Bl,Bs		
UBt(g)	As above, gully erosion phase	588	0.22	Bl	Bs	G
UBs2	Upland plains, sloping, 3% slope	8,070	3.07	Bl	Bs	
UBs2(g)	As above, gully erosion phase	451	0.17	Bl	Bs	G
UBsl	Upland plains, gently sloping, 1-3% slope	34,453	13.13	Bl	Bs	
UBsl(s)	As above, stony and rocky phase	446	0.17	Bl	Bs	L,G
UBsl(g)	As above, gully erosion phase	3,754	1.43	Bl	Bs	G
UBb	Upland plains, almost flat bottom, 0-1% slope	29,647	11.27	Bl	Bs	
UBb(g)	As above, gully erosion phase	401	0.15	Bl	Bs	G
UBb-VA	As above, transitional to aggradational valley	4,608	1.75	Bl	A	Rl
	Upland plains with red soils and without termite mounds	12,200	4.63			
URt	Upland plains, almost flat top, 0-1% slope	1,485	0.56	Rl		Rc
URt(s)	As above, stony and rocky phase	533	0.20	Rl	L,G	
URt(g)	As above, gully erosion phase	41	0.02	Rl	Rc	G

Table 7 (contd.)

MAPPING UNITS AND SOIL ASSOCIATIONS						
MAPPING UNIT		SOIL ASSOCIATION				
Symbol	Name	Area		Dominant Soils 50%	Associated Soils 20-50%	Inclusions 20%
		ha	%			
URs2	Upland plains, sloping, 3% slope	1,279	0.49	Rl		Rc
URs2(g)	As above, gully erosion phase	451	0.17	Rl		Rc, G
URsl	Upland plains, gently sloping, 1-3% slope	2,881	1.09	Rl		Rc
URsl(s)	As above, stony and rocky phase	346	0.13	Rl	L, G	
URsl(g)	As above, gully erosion phase	533	0.20	Rl		Rc, G
URb	Upland plains, almost flat bottom, 0-1% slope	4,620	1.76	Rl		Rc
URb(g)	As above, gully erosion phase	31	0.01	Rl		Rc, G
I	INTERMEDIATE PLAINS	4,667	1.77	D	Bl	Bs
	LOWLAND PLAINS	11,503	4.37			
LP	Lowland plains with poorer drainage	8,640	3.28	V		F
LB	Lowland plains with better drainage	2,807	1.07	F		V
LB(g)	As above, gully erosion phase	56	0.02	F		V
	RIVER VALLEYS	20,155	7.66			
VA	Aggradational river valleys	9,334	3.55	C/A	Rl	A
VA(r)	As above, red topsoil phase	3,165	1.20	Rl	C/A	
VE	Erosional river valleys	7,656	2.91	Rl, Bl	L	G
S	SWAMPS	4,438	1.69	V		
W	LAKE	759	0.29	Not applicable		

PHASES

(s) Stony and rocky phase/(r) red topsoil phase/(s)(r) stony, rocky and red topsoil phase/(g) gully erosion phase

Table 8 Soil Units

SOIL UNITS				
Soil Unit Symbol	Soil Unit	Main Soil Characteristics	Soil Classification	
			FAO/UNESCO Soil Map of the World	USDA Soil Taxonomy
	RED UPLAND SOILS			
Rc	Red friable clays on footslopes derived from basic metamorphic rocks	Well drained, (moderately) deep, (dark) reddish friable clays and sandy clays with weak blocky structure, low organic matter content, low base supply; very strongly acid, moderate available waterholding capacity.	Ferralic Cambisol	Ustoxic Dystropept Oxic Dystropept
Rl	Red sandy (clay) loams on granite derived footslopes and upland plains	Well drained, (moderately) deep, dark reddish brown or yellowish red, friable sandy clay loams and sandy clays with weak or moderate structure, low organic matter content, low base supply; moderately acid, moderate available waterholding capacity.	Dystric Cambisol Chromic Cambisol Eutric Cambisol	Typic or Ustic Dystropept Typic or Fluventic Ustropept As above
Rs	Red (loamy) sands on	Excessively drained, (moderately) deep yellowish red coarse (loamy) sands, structureless or with weak structure, very low base supply; strongly acid; very low available waterholding capacity.	Ferralic Arenosol	Ustoxic Quartzipsamment
	BROWN UPLAND SOILS			
Bl	Brown sandy (clay) loams on granite derived upland plains	Well drained, (moderately) deep yellowish brown or strong brown, friable and hard sandy loams and sandy clay loams (sandy clays), with weak or moderate structure, low organic matter content, low base supply, strongly acid, moderate available waterholding capacity.	Dystric Cambisol	Ustic or Typic Dystropept
Bs	Brown loamy sand on granite derived upland plains	Somewhat excessively drained, (moderately) deep yellowish brown loamy sands to sandy loams, friable and soft to slightly hard, with weak structure, low organic matter content and very low base supply; strongly acid, low available waterholding capacity.	Cambic Arenosol	" Ustic " Quartzipsamment

Table 8 (contd.)

	TRANSITIONAL SOILS			
D	Brown sandy clay loams and sandy clays of the intermediate plains	Moderately well drained, deep, brownish, friable sandy clay loams and sandy clays with weak structure, low organic matter content and moderate base supply; moderately to strongly acid, high available waterholding capacity.	Eutric Cambisol	Typic Ustropept
C/A	Colluvium over old, grey alluvium	Well drained, (moderately) deep, reddish or brownish sandy clay loams over grey, firm, sandy clays to clays with little structure; low organic matter content, low base supply; moderately acid, moderate available water-holding capacity.	Chromic Cambisol Dystric Cambisol	(Fluventic ?) Ustropept Fluventic Dystropept
	LOWLAND SOILS			
A	Acid, non-cracking (sandy) clays of the river valleys	Moderately well to imperfectly drained, deep greybrown (sandy) clays, friable to firm with weak structure or massive, low organic matter content; moderate base supply, moderately to strongly acid, non-saline, non-sodic; high available waterholding capacity.	Eutric Fluvisol	Typic Ustifluvent
F	Calcareous friable clays of the lowland plains	Well drained, deep, grey or brown, friable and soft clays, with moderate or strong blocky structure, moderate organic matter content, very high base supply; neutral to alkaline, non-sodic, usually non saline; with calcareous nodules; high available waterholding capacity.	Eutric Cambisol Haplic Phaeozem	(Vertic ?) Ustropept (Cumulic) Haplustoll
V	Dark cracking clays of the lowland plains	Moderately to poorly drained, (very) dark grey to black, very firm and very hard, cracking clays, without permanent structure, with low organic matter content, very high base supply; slightly acid to slightly alkaline; non to slightly calcareous; of variable salinity and alkalinity; high available waterholding capacity.	Pellic Vertisol	Entic or Typic Pellustert
L	UNDIFFERENTIATED VERY SHALLOW SOILS		Lithosol	-
G	UNDIFFERENTIATED ROCKS, BOULDERS, STONES AND GRAVELS		-	-

Dark cracking clays (V) occupy the poorer drained parts of the plateau, such as the bulk of the lowland plains and the swamps. Their distribution suggests that they are lacustrine deposits of a former lake, dammed by the Hombolo escarpment. Where this lake contained algae limestone, and friable calcareous clays (F) have developed.

Loamy, brownish or reddish colluvium covers grey, heavy alluvium (C/A) in the river valleys. The colluvium mainly originates from the Dodoma Hills and appears to be the result of accelerated erosion in this area.

Virtually all soils in the survey area are characterized by a low nutrient status and organic matter contents are low, which partly explains the poor structural properties of the soils and their susceptibility to erosion. Exchangeable K-levels are adequate, sometimes high, but available phosphorus levels are very low. Except for the dark cracking clays (V) and the friable clays (F) the total exchangeable base content tends also to be very low.

A most surprising finding of the survey was the high acidity of the upland soils. Most soils with upland characteristics have lower pH-values than similar soils in higher rainfall areas. The footslope soils on basic metamorphic rocks are even very strongly acid. At present there seems no adequate explanation to account for this phenomenon. However since erosion is widespread in the Region it may be due in part to exposure of old subsoils that were intensively leached during earlier weathering cycles.

The structural properties of the soils of Dodoma Capital City District are in general very poor. Aggregates are unstable and soils are susceptible to splash erosion or surface sealing. Due to the poor vegetative cover the soils tend to dry out rapidly at the surface and become very hard when thoroughly dry. However, after rewetting they become friable again and can easily be penetrated by roots. This characteristic of certain Dodoma soils may be the reason for the incorrect identification of so-called 'hardpan' soils by some workers. However, in a real 'hardpan' soil a hard layer should be obvious in the rainy season as well. The soil survey of Dodoma Capital City District has not revealed soils that meet the latter criterion.

Waterholding properties of the Dodoma soils are moderate; they are clearly related to the soil texture. Sandy soils have AWC-values of 30-70 mm/m, loamy soils 100-120 mm/m, kaolinite dominated clays have an AWC of about 120 mm/m, and montmorillonite dominated clays 150-200 mm/m. Infiltration rates of ploughed land were in general high.

Soils are generally not deep. Average depths are 1-2 m, often less. Inadequate moisture in the uplands often restricts effective soil depth.

A summary of the average characteristics of the various soil types is given in table 9.

3.3. DESCRIPTION OF THE SOILS

The soils of the survey area can be separated into groups according to their color and topographical position. The following main groups are recognized:

1) red upland soils
2) brown upland soils
3) transitional soils
4) lowland soils

3.3.1. Red upland soils

These soils occur in upland positions where drainage is unimpeded and where leaching is the dominant soil forming process.

3.3.1.1. Rc-soils : red friable clays on footslopes derived from basic metamorphic rocks

Rc-soils comprise well drained, deep or moderately deep, friable clays and sandy clays with (dark) reddish colours and weak blocky structure. Their organic matter content is low as well as the total exchangeable base content (TEB). The available waterholding capacity (AWC) is moderate but the soils appear strongly affected by surface sealing and it is likely that most of the rainfall can not be enter the soil and be made available to plants. Typical for these soils is their very strong acidity (pH-H20 is less than 5.0), which would pose a severe fertility limitation for most crops.

The Rc-soils occur mainly on the footslopes derived from basic metamorphic rocks. The main areas are located around the low hills of the Dodoma Formation south of and parallel to the Chenene Mountains. On these erosional footslopes their area is estimated as at least 80% of mapping units FBel and FBe2, or at least 3640 ha. Minor occurrences are located on the upland plains and escarpments and are related to the presence of fault or shear zones within the basement complex, or with basic contaminations in granitic rocks.

The natural vegetation is usually characterized by severe degradation: it is an open bushland or wooded bushland with very poor grass cover. Most of the land is bare and bright subsoil appears at the surface, evidence of severe sheet erosion. Gully erosion is less extensive. The Rc-soils appear to offer a very low potential for agriculture and for grazing, and effectively are little used as cropland.

Detailed descriptions of representative profiles (143/4/5 and 143/4/24) and analytical data re given in Technical Appendix 3.

3.3.1.2. Rl-soils : red sandy (clay) loams on granite derived footslopes and upland plains

Rl-soils comprise well drained, deep or moderately deep, dark reddish brown or yellowish red, friable sandy (clay) loams and sandy clays, often gravelly, with weak or moderate structure. The organic matter content is low, as well as the TEB. The AWC is moderate. The Rl-soils vary in acidity from slightly to strongly acid and in general soil acidity does not appear as serious a limitation for crop production as in the Rc-soils. The main differences between the Rl- and Rc-soils are therefore the generally heavier textures of the latter and their more pronounced acidity.

The Rl-soils occur on a variety of landforms and topographical positions. Within a particular landform they are usually associated with other soils. The main occurrence of Rl-soils is on the footslopes around granitic hills. They are estimated to cover at least 60% of these areas or more than 28,000 ha. They usually occur on slope and saddle positions and are in general severely affected by gully erosion, particularly where slopes exceed 6%. In these areas the topsoil has locally been washed away, leading to stony or rocky surfaces (stony or rocky phase), or to exposure of the subsoil (red topsoil phase). Rl-soils also occur on strongly eroded portions of the escarpments.

A second major occurrence of Rl-soils is on the upland plains. This is related to the presence of tectonic lines, such as fault or shear zones. It is unusual to find red soils, indicative of strong leaching conditions, in areas with low rainfall and very low relief intensity. It is likely that along the tectonic lines the permeability for water, and therefore the possibility of leaching, is substantially increased in comparison with other parts of the survey area. Upland plains with red soils are fairly homogeneous and are covered for more than 80% by Rl-soils.

A third occurrence of Rl-soils is in the river valleys. On sloping land their presence may be the result of sheet erosion (as in the erosional river valleys), on flatter land (as in the aggradational river valleys) Rl-soils are formed by accumulation of soil material eroded from higher ground. Finally Rl-soils may occur on upland plains with normally brown soils (UB-upland plains), but in areas that are too small to be mapped at the scale of the Soil Map. It is estimated that in these areas they occupy less than 1% of the terrain. In total Rl-soils are estimated to cover at least 43,000 ha or 16% of the survey area.

Table 9 Average soil characteristics

Characteristic (*)	SOIL UNIT									
	Rc	Rl	Rs	Bl	Bs	D	F	V	A	C/A
Drainage	Well dr.	Well dr.	Exc. dr.	Well dr.	S.ex.dr.	Mod.well drained	Well dr.	Mod.well to poor drained	Mod.well to imp. drained	Well dr.
Colour	Reddish	red.br. yel.red	yel.red	yel.br. str.br.	yel.br.	brownish	greyish brownish	d.grey-black	greyish brownish	reddish/ greyish
Texture	sc,c	sl,scl sc	s,ls	scl,(sc)	ls,sl	scl,sc	c	c	sc,c	sl-scl/ sc,c
Structure	w.sbk	w(m)sbk	no	w(m)sbk	w.sbk	w.sbk	m-str. sbk	massive	w.sbk	w.sbk/ massive
Consistence	fr.	fr.	v. fr.	fr., h-v.h.	w.sbk., v.fr.	w.sbk fr.	fr.	fi,v.h-	fr.-fi.	fr./fi
$pH(H_2O)$	4.7	6.1	5.2(°)	5.5	5.5	6.4	7.8	6.9	4.9	5.9
$pH(CaCl_2)$	4.2	5.3	4.2(°)	4.7	4.7	5.7	7.3	6.6	4.4	5.0
O.C.(%)	0.6	0.5	0.4(°)	0.7	0.8	0.9	1.5	0.5	0.7	0.3
N (%)	0.08	0.06	0.05(°)	0.12	0.10	0.09	0.10	0.07	0.25	0.04
P (ppm)	3	4	15 (°)	6	5	11	0.3	trace	8	5
K(meq/100g)	0.4	0.3	0.1(°)	0.3	0.1	0.4	N.D(+)	0.4	0.5	0.4
Sum bases (meq/100g)	6	6	2 (°)	4	3	12	50	61	14	9
Carbonates	-	-	-	-	-	-	variable	variable	-	-
Sodicity	-	-	-	-	-	-	-	variable	-	-
Salinity	-	-	-	-	-	-	variable	variable	-	-
AWC (mm/m)	120	120	30	100	70	150	160	-	-	-

(*) For pH, O.C.,N,P,K, sum of bases, data refer to the topsoil; colour texture, structure and consistence refer to the subsoil; drainage and AWC refer to the whole soil.

(°) Only data for one profile available. Wide deviation possible.

(+) N.D.: No data.

Depending on their position in the landscape, fertility status and the degree of land degradation, Rl-soils may vary in agricultural potential from moderate to very low. Most important in this respect appear the pH of the soil and the moisture regime at the given site. The most common land use is grazing, particularly on the footslopes, escarpments and erosional river valleys. In the aggradational river valleys and some parts of the upland plains they are usually cultivated, mainly for staple crops like bulrush millet, sorghum and maize and for grapes. Also vegetables, particularly tomatoes may be grown with some irrigation near river beds.

Detailed descriptions of representative profiles located on various physiographic units are given in Technical Appendix 3. Profile 162/1/2 is an example of an Rl-soil on an erosional footslope. Profile 162/2/19 is an example of a strongly acid Rl-soil on an upland plain; profile 143/4/13 is an example of an Rl-soil in a river valley.

3.3.1.3. Rs-soils : red (loamy) sands on granite derived footslopes

This soil unit comprises excessively drained, deep or moderately deep (yellowish) red coarse sands and loamy sands. These soils are structureless or weakly structured, they have a low organic matter content and are strongly acid. The AWC is very low. The main differences between the Rl and Rs-soils are the lighter textures, higher acidity and poor waterholding properties of the latter.

The Rs-soils are minor soils. They occur mainly as inclusions on the footslopes developed on granitic rocks. Their total extent is likely to be less than 20% of these areas or less than 8,000 ha (3% of the survey area). In view of the degradation of the landforms on which they occur, their poor water retention properties and low pH, the agricultural potential of these soils is considered to be very low. These soils are mainly utilized for extensive grazing, and are usually under degraded bushland vegetation.

Detailed descriptions of representative profiles (162/1/15 and 143/4/22) are given in Technical Appendix 3.

3.3.2. Brown upland soils

These soils are characterized by their occurrence in upland positions with unimpeded drainage. They occur usually on landforms that are characterized by very low relief intensity, very gentle slopes and sluggish drainage, conditions less conducive to leaching and formation of reddish soils.

3.3.2.1. Bl-soils : Brown sandy (clay) loams on granite derived upland plains

These soils are well drained, moderately deep or deep yellowish brown or strong brown, friable (moist) and hard (dry) sandy loams and sandy clay loams, sometimes sandy clays. They have a weak or moderate structure, a low organic matter content and low TEB. They are moderately to strongly acid. The AWC is moderate. The main differences between the Rl- and Bl-soils are the brownish colors and the stronger acidity of the latter. The soils are usually covered by termite mounds. They are little affected by gully erosion.

The Bl-soils are important soils that occur mainly on the upland plains. They form intimate complexes with the Bs-soils to the extent that it is usually not possible to separate homogeneous mapping units at the 1:50,000 scale. There is a tendency for the Bl-soils to occur mainly on slope and bottom positions of upland plains, and the Bs-soils to occur mainly on upper slopes and crests of upland plains. However this generalized pattern does not allow a high predictability and more observations are required to elucidate the actual soil distribution on the upland plains. In addition, many intergrades exist between the Bl- and Bs-soils with intermediate textures. It is therefore difficult to provide an exact area estimate of the Bl-soils : in all likelihood they cover at least 50% of the upland plains with termite mounds or at least 68,000 ha or 26% of the survey area.

The Bl-soils appear to have a low potential for agriculture in view of their low pH, a poor moisture regime resulting from inadequate rainfall and limited additions from run off, and the density of termite mounds. The main land use is therefore grazing and the soils are usually covered by bushland vegetation. However, notwithstanding the limited agricultural potential a fair proportion of these soils is at present cultivated, mainly for staple crops.

Detailed descriptions of representative profiles (162/1/14 and 143/4/14) are given in Technical Appendix 3.

<u>3.3.2.2. Bs-soils : Brown loamy sands on granite derived upland plains</u>

These soils are somewhat excessively drained, deep or moderately deep, yellowish brown loamy sands to sandy loams, friable (moist) and soft to slightly hard (dry). They have a weak structure, low organic matter content and a very low base supply. They may be gravelly at depth, especially on summit positions. They are moderately to strongly acid and have a low available waterholding capacity. Except for the colour and the fact that they occur on different landforms, the Rs- and Bs-soils show few differences that affect their use for agriculture. As with the Bl-soils, the Bs-soils are covered by termite mounds and are little affected by gully erosion.

As mentioned above, the Bs-soils occur in intimate association with the Bl-soils on the upland plains with termite mounds. They tend to occupy the upper, watershed positions on the upland plains but this generalized pattern has many exceptions. The Bs-soils are estimated to cover about 40% of the upland plains with termite mounds or 50,000 ha (19% of the survey area).

The potential of these soils for agriculture is definitely low in view of their acidity, poor nutrient supply, poor moisture retention properties, marginal rainfall and the presence of hard, infertile termite mounds. The main land use is therefore grazing and the natural vegetation is mainly bushland.

A detailed description of a representative profile (143/4/11) is given in Technical Appendix 3.

3.3.3. Transitional soils

These soils occur on landforms that are transitional between uplands and lowlands, such as the river valleys and intermediate plains, and have intermediate drainage and textural characteristics. They are non-saline and non-sodic.

3.3.3.1. D-soils : Brown sandy clay loams and sandy clays of the intermediate plains

These soils are moderately well drained, deep, brownish sandy clay loams and sandy clays with friable (moist) consistence and weak structure. Their organic matter content is low but the total exchangeable base content is moderate. These soils are moderately to strongly acid and have a high available waterholding capacity. The D-soils differ from the main upland soils (R1- and B1-soils) mainly by heavier textures, better base supply and higher AWC. They have no dense cover of termite mounds and sheet erosion appears less intensive than in most other parts of the survey area.

The D-soils occur on the intermediate plains, in which they occupy at least 50% or 2300 ha of the survey area. They are most extensive in the area surrounding the Hombolo Leprosarium. The D-soils are mainly covered by a well developed Acacia-Baobab wooded or bushed grassland. These soils have a moderate potential for agriculture and are commonly cultivated. The main land use is grazing and the livestock carrying capacity of the areas in which D-soils predominate appears good.

A detailed description of a representative profile (143/4/1) is given in Technical Appendix 3.

3.3.3.2. C/A-soils : reddish colluvium over old grey alluvium

These soils are well drained, deep or moderately deep, reddish or brownish sandy clay loams over grey, firm sandy clays to clays with massive structure. These soils have a low organic matter content and low base supply and are moderately to very strongly acid. The available waterholding capacity is moderate.

In these soils the upper part of the profile appears derived from loamy materials transported from upslope, whereas the lower part appears formed from a clayey material of alluvial origin. The C/A-soils therefore consist of two distinct layers, a colluvial layer (C) on top of an alluvial layer (A). The colluvial layer is usually thicker than 50 cm, whereas in the A-soils (see 3.3.4.1.) the C-layer is shallower than 50 cm or even absent. The clay layer exerts a favourable influence on the soil's moisture regime : it prevents deep percolation losses and allows maximum utilization by crops; being at moderate depth it does not cause waterlogging within the rooting zone.

These soils are most common in the aggradational river valleys, in which they are estimated to cover at least 50% of the land or 4700 ha (1.8% of the survey area). Where the acidity is not too high, these soils have a good potential for agriculture due to the favourable moisture regime. The flat land on which these soils occur is only slightly affected by erosion. The soils occur on some of the most intensively settled land in the survey area. The main staples grown are maize, sorghum, groundnuts and bulrush millet as well as grapes, tomatoes and garden crops.

Detailed descriptions of representative profiles (163/1/2) and (162/2/12) are given in Technical Appendix 3.

3.3.4. Lowland soils

These soils occur in lowland areas with very low relief intensity (slopes are less than 1%) and little or no erosion. Soil textures are more heavy and drainage is more impeded than on the upland areas.

3.3.4.1. A-soils : Acid, non-cracking (sandy) clays of the river valleys

These soils comprise moderately well to imperfectly drained, deep, grey brown sandy clays or clays. They are friable to firm (moist) and have a weak structure or are massive. The organic matter content is low, the base content is moderate. They are moderately to strongly acid and are non-saline and non-sodic. The available waterholding capacity is high. The soils are characteristically very hard when dry and are often confused with hardpans. They appear fairly impervious to water and become easily waterlogged.

They are minor soils and occur mainly as inclusions in aggradational river valleys. They are genetically linked with the C/A-soils but differ from the latter by the absence of the reddish colluvial layer of more than 50 cm thick. It is possible that the A-soils have developed directly in the argillaceous "cement" believed to be of Tertiary age and described in section 1.3.

In view of their limited extent these soils are of minor agricultural importance. Their agricultural potential appears low, mainly in view of the poor physical properties and waterlogging hazard. The main land use is grazing.

A detailed description of a representative profile (162/2/9) is given in Technical Appendix 3.

3.3.4.2. F-soils : Calcareous friable clays of the lowland plains

These soils are moderately well to well drained, deep, grey or brown, friable and soft clays. They have a moderate or strong structure, a moderate organic matter content and a very high exchangeable base content. The soils are neutral to alkaline, non-sodic and mainly non-saline, but strong salinity may be present locally. They may be calcareous and usually contain calcareous nodules at depth. The available waterholding capacity is high. Characteristic of these soils are high porosity and permeability and the good structure, promoted by the abundance of calcium in the soil. For these reasons the F-soils have a better drainage than would correspond with their position in water-receiving areas and upland crops can usually be safely grown on them.

These soils are minor soils and occur only on the better drained parts of the lowland plains west and south of Lake Hombolo. They are estimated to cover at least 80% of the lowland plains with better drainage or 2300 ha (0.9% of the survey area). It is suggested that the F-soils have developed on algal limestone deposits that originated in a former freshwater swamp (see section 1.3). Indeed the limestone has on occasion been observed within 1 m of the surface.

Except where salinity is locally very high, these soils have a good potential for agriculture in view of their favourable water retention properties, relative freedom from waterlogging and erosion, and good fertility status as expressed by the soil reaction, organic matter content and exchangeable base content. These soils are intensively cultivated, mainly for sorghum, bulrush millet and groundnuts, usually in rotation with grass fallows. Uncultivated areas and fallow land have a good grass cover and are intesively grazed.

Detailed description of representative profiles (143/4/17 and 162/2/18) are given in Technical Appendix 3.

3.3.4.3. V-soils : Dark cracking clays of the lowland plains

These soils comprise moderately to poorly drained, (very) dark grey to black, very firm and very hard, cracking clays, lacking a permanent structure. They have a low organic matter content and a very high base supply. The soil reaction ranges from slightly acid to slightly alkaline. The soils are non to slightly calcareous and have variable salinity and sodicity. In view of their heavy clayey textures they are also expected to have a high available waterholding capacity. Typical for these soils are the heavy, clayey textures, the very dark colors, very firm consistence the lack of a permanent structure and the very wide and deep cracks during the dry season. Their drainage is more impeded than for the F-soils.

The V-soils occur in the poorer drained parts of the lowland plains and in swamps. They are estimated to cover at least 11,000 ha or 4.3% of the survey area.

The suitability of these soils for agriculture is moderate. They have a favourable nutrient status, as expressed by the high exchangeable base content, and the high water retention capacity. Problems arise from the tendency of these soils to become waterlogged, the difficulty of cultivation with handtools and the salinity that affects them in many localities. Their potential for natural or improved grazing appears good. The soils are mainly used for grazing but are in some parts, particularly of the lowland plains, cultivated. The main crops are maize, sorghum and bulrush millet.

Detailed descriptions of representative profiles (143/4/18, 162/2/15 and 143/3/2) are given in Technical Appendix 3.

3.4. DESCRIPTION OF THE MAPPING UNITS

This section describes in some detail the mapping units that are shown on the Soils Map in terms of physiography, drainage, vegetation and soils. It also provides a brief evaluation of their potential for various land uses. For easy reference to the Soils Map all mapping units will be underlined.

3.4.1. Mountains (Mapping unit symbol : M)

Area : 8,065 ha; 3.06% of the survey area

Dominant slopes : 40%

Soils : virtually none

The only mountain range in Dodoma CCD are the Chenene mountains. They form the northern boundary of the survey area. They rise about 500 - 900 m above the level of the plateau (1600 - 2100 m above sealevel).

The Chenene mountains are formed by granitic rocks. Their very steep slopes, table-top summits and general direction at right angle to major tectonic alignments in the area, suggest that they are an uplifted plateau. The youthfulness of this mountain range is further evidenced by the lack of well developed footslopes and by the absence of a soil cover.

The lower slopes of the Chenene mountains are covered by a well preserved thorny woodland or bushland. At higher altitude there is 'miombo' wooland, also very well preserved and similar to the 'miombo' woodland of western Tanzania.

The area is very sparsely inhabited. It has no value for agriculture and limited value for grazing. Its potential for firewood appears high but exploitation on commercial scale will require very careful management to ensure that the area will not lose its watershed protection.

3.4.2. Hills and inselbergs

Hills of low or medium altitude occur as isolated features ('inselbergs') or in hill groups.

The most important group of hills is formed by the Dodoma hills south of Dodoma township. The Dodoma Hills are a west-east aligned range of medium altitude, steep hills with associated footslopes, rising about 100 - 300 m above the plateau level. The following paragraphs refer specifically to the hills sensu stricto. The footslope areas are described separately.

The hills are formed by granitic rocks and have almost no soil cover. They support a well preserved thicket or bushland vegetation and at the highest levels 'miombo' species may occur. The hills have no value for agriculture and very little value for grazing. Slopes are steep and the thicket is impenetrable to cattle. The potential for firewood is moderate but the best land use appears to be watershed moisture conservation.

On the basis of their lithological parentage the hills and inselbergs are subdivided into following mapping units :

Hills and inselbergs formed on basic metamorphic rocks (symbol : RB)

Area : 1,762 ha; 0.67% of the survey area

Dominant slopes : more than 30%

Soils : virtually none.

Hills and inselbergs formed on granitic (acid) rocks (symbol : RA)

Area : 14,422 ha; 5.48% of the survey area

Dominant slopes : more than 30%

Soils : virtually none.

3.4.3. Footslopes

The footslopes are the fan-shaped deposits of weathering materials and soil around the hills and inselbergs. They are extensive, especially in the Dodoma hills and have slopes in the range of 1-12%. The extent of footslopes is very limited around the Chenene mountains.

The footslopes developed on granitic rocks have mainly reddish, medium textured soils (R1) with moderate acidity. They are very often severely affected by gully erosion, with or without sheet erosion. On the basis of the dominant landscaping process the footslopes on granitic rocks can be subdivided into erosional and aggradational footslopes. On the former, erosion is the dominant landscaping process; on the latter deposition or 'aggradation' is the major landscaping process and colluvial deposits mainly cover these footslope areas.

The differentiation between erosional and aggradational footslopes has practical meaning for land use and land suitability. In general, the erosional footslopes on granitic rocks are not cultivated; they are usually reserved for grazing but due to overstocking their potential is at best marginal. The potential for crops is very low. The main constraints for cultivation are low moisture availability aggravated by severe gully erosion and poor structural properties. The fertility limitation is not so severe as in the footslopes on basic metamorphic rocks but the gully erosion problem is more acute. The gullies have lowered the watertable and prevent rainfall conservation by collecting the runoff from upslope.

In contrast, the aggradational footslopes have a far better moisture regime than the erosional footslopes and are in general not affected by erosion, due to their concave form at the lowest end of the footslopes. Their potential for agriculture, particularly for drought resistant crops, is therefore much better. They may also offer good grazing land.

The footslopes on granitic rocks are subdivided into following mapping units:

Characteristic of these areas is the severe degradation of soils and vegetation, as evidenced by gully and sheet erosion and the occurrence of many bare areas. The major vegetation type is bushland. Cultivation is rare, except in the lower lying parts of the footslopes that have not been affected by erosion and have a more favourable moisture regime.

Like the hills, the footslopes are primarily subdivided on the basis of the parent rock. Two basic groups of footslopes can be recognized:

1) footslopes developed on basic metamorphic rocks

2) footslopes developed on granitic rocks.

The footslopes developed on basic metamorphic rocks have mainly reddish clayey soils (Rc) with very high acidity (see 3.3.1.1.). They are somewhat affected by gully erosion, but severely affected by sheet erosion. On the basis of slopes these footslopes on basic metamorphic rocks are subdivided into following mapping units :

Erosional footslopes, strongly sloping, 6-12% slope (symbol : FBe2)

Area : 659 ha; 0.25: of the survey area

Dominant slopes : 6-12%

Soils : Rc is the dominant soil, with inclusion of Rl

Erosional footslopes, gently sloping, 1-6% slope (symbol : FBe1)

Area : 3699 ha; 1.41% of the survey area

Dominant slopes : 1-6%

Soils : Rc is the dominant soil, with inclusions of Rl.

The term 'erosional' emphasizes the fact that erosion is the dominant landscaping process in these areas.

The agricultural potential of the footslopes on basic metamorphic rocks is very low. The main constraints are the low water availability due to low rainfall, the inadequacy of the soils to capture rainfall or runoff because of surface compaction, soil erodibility and a very low fertility status. Due to overgrazing the potential for natural grazing is also very low.

The footslopes developed on granitic rocks have mainly reddish, medium textured soil (Rl) with moderate acidity. They are very often severely affected by gully erosion, with or without sheet erosion. On the basis of the dominant landscaping process, slopes and various phases, the footslopes on granitic rocks are subdivided into the following mapping units :

Erosional footslopes on granitic rocks, strongly sloping, 6-12% slope (symbol : FAe2)

Area : 17,394 ha; 6.61% of the survey area

Dominant slopes : 6-12%

Soils : Rl is the dominant soil, Rs occurs as inclusions.

This mapping unit covers usually the upper parts of extensive footslope areas.

As above, stony and rocky phase (symbol : FAe2(s))

Area : 3,702 ha; 1.41% of the survey area

Dominant slopes : 6-12%

Soils : Rl is the dominant soil, L and G occur as associated soils and rocks, Rs occurs as inclusions.

At least 10% of the surface is covered by rocks, boulders, stones of gravel.

As above, red topsoil phase (symbol : FAe2(r))

Area : 2,303 ha; 0.88% of the survey area

Dominant slopes : 6-12%

Soils : Rl is the dominant soil, RS and Rc occur as inclusions.

This soil variant is characterized by reddish colours as inferred from aerial photographs. The red topsoil phase can be the result of basic contamination of the granitic parent material, but is usually indicative of severe sheet erosion.

Erosional footslopes on granitic rocks, gently sloping, 1-6% slope (symbol : FAel)

Area : 13,817 hap 5.25% of the survey area

Dominant slopes : 1-6%

Soils : Rl is the dominant soil, Rs occurs as inclusions.

This mapping unit usually covers the lower, less sloping parts of extensive footslope area, or the gently sloping pediments around smaller rock outcrops.

As above, stony and rocky phase (symbol : FAel (s))

Area : 378 ha; 0.14% of the survey area

Dominant slopes : 1-6%

Soils : Rl is the dominant soil, L and G occur as associated soils and rocks, Rs occurs as inclusions.

<u>As above, red topsoil phase</u> (symbol : <u>FAel</u>(r))

Area : 1,813 ha; 0.69% of the survey area

Dominant slopes :1-6%

Soils : Rl is the dominant soil, Rs and Rc occur as inclusions.

<u>Aggradational footslopes, gently sloping, 1-6% slope</u> (symbol : <u>FAa</u>)

Area : 6,446 ha; 2.45% of the survey area

Dominant slopes : 1-6%

Soils : Rl is the dominant soil, C/A occurs as inclusions.

This mapping unit covers the lowest parts of extensive footslope areas and is transitional to the river valleys.

<u>As above, red topsoil phase</u> (symbol : <u>FAa</u>(r))

Area : 700 ha; 0.27% of the survey area

Dominant slopes : 1-6%

Soils : Rl is the dominant soil, C/A occurs as inclusions.

As in parts of some river valleys, the red colour indicates in these areas deposition of materials transported downhill.

<u>As above, gully erosion phase</u> (symbol : <u>FAa</u>(g))

Area : 1,106 ha; 0.42% of the survey area

Dominant slopes : 1-6%

Soils : Rl is the dominant soil, G occurs as inclusions.

Erosion gullies may extend downhill into parts of the aggradational footslopes, which, in contrast with the erosional footslopes are usually not affected by gully erosion.

In general the erosional footslopes on granitic rocks are not cultivated; they are usually reserved for grazing but due to overstocking their potential is at best marginal. The potential for crops is very low. The main constraints for cultivation are low available moisture agravated by severe gully erosion and poor structural properties. The fertility limitiation is not so severe as in the footslopes on basic metamorphic rocks but the gully erosion problem is more acute. The gullies have lowered the watertable and prevent rainfall conservation by collection of runoff from upslope. Due to their concave form at the lowest end of the footslopes, the aggradational footslopes have a far better moisture regime than the erosional footslopes and are in general not affected by erosion. Their pontential for agriculture, particularly for drought resistant crops, is therefore much better. They may also offer good grazing land.

3.4.4. Escarpments

The escarpments are rectilinear landscape features of tectonic origin, with relatively steep slopes (8-12%), that break up the regularity of the plateau. The main escarpments are the one bordering lake Hombolo, with an northeast trend, and the one near Kigwe with approximate northnorthwest trend.

The Hombolo escarpment is a relatively youthful landscape feature with fairly uniform height and slope and very little dissection by rivers. The distribution of the soils shows a very regular pattern, with shallow or stony and rocky soils at the upper part of the escarpment and reddish deeper soils at the base. The escarpment is severely affected by sheet and gully erosion. It is a true watershed : to the west rivers drain into the little Kinyasungwe downstream from lake Hombolo.

The escarpment near Kigwe is most likely an older tectonic feature. Its tectonic origin is not so obvious as is the case with the Hombolo escarpment, it is much more dissected by rivers and denuded with more rock outcrops and a less regular soils pattern.

The main vegetation type on the escarpments is bushland, in various degrees of degradation. The soil types that cover the escarpments are usually the same as those of the upland plains (see 3.4.5.). On the basis of the kind and intensity of erosion, following mapping units are recognized:

Escarpments, gently to strongly sloping, 8-12% slope (symbol : E)

Area : 5,643 ha; 2.14% of the survey area

Dominant slopes : 8-12%

Soils : Bl and Bs are dominant soils, L occurs as associated soil and G occurs as inclusions.

This mapping unit corresponds with the normal type of escarpment, as described above.

As above, stony, rocky and red topsoil phase (symbol : E(s)(r))

Area : 2,405 ha; 0.91% of the survey area

Dominant slopes : 8-12%

Soils : Rl is the dominant soil, L and G occur as associated soils and rocks.

A very high proportion of the land is covered by stones, rocks, boulders or gravels and shallow undifferentiated soils. Red topsoils usually reflect severe sheet erosion in the middle and lower parts of the escarpments, but also shearing in the granitic rock at the upper part of the escarpment.

As above, gully erosion phase (symbol : E(g))

Area : 1,539 ha; 0.58% of the survey area

Dominant slopes : 8-12%

Soils : Bl and Bs are dominant soils, L occurs as associated soil and G occurs as inclusions.

Gully erosion is particularly important on the Hombolo escarpment.

The agricultural potential of the escarpments is virtually nil. They are too rocky or affected by erosion for any agricultural use beyond subsistence level. Sometimes drought resistant crops are grown on the lower slopes with thicker soil cover, but the limitations of inadequate moisture, marginal soil fertility and por structural properties are as severe as on the eroded footslopes. Occasionally good grazing land can be found but in general the escarpments have only a marginal potential for this use.

3.4.5. Upland plains

Upland plains represent the well drained portions of the plateau that covers most of the survey area. They have an average altitude of 1060 - 1130 m, a low undulating relief with gentle slopes (1-3%) and an almost unnoticeable slope towards the east. The regularity of the plateau is occasionally broken by steep escarpments and rectilinear slopes of tectonic origin (sometimes more than 3%) and inselbergs. The upland plains are only slightly affected by recent incision. Drainage-ways have little gradient and are often poorly defined. Gully erosion is relatively rare. The vegetation is usually bushland and bushed grassland, often bushland thicket. Characteristic of many of these upland plains is the widespread occurrence of eroded termite mounds.

On the basis of soil types and the presence or absence of termite mounds, the upland plains are separated into two major groups :

1) Upland plains with brown soils and termite mounds
2) Upland plains with red soils and without termite mounds

The first group of upland plains is covered by brownish, medium textured (Bl) or coarse textured (Bs) soils, with strong acidity and very low nutrient status. Due to the low relief intensity there is little textural differentiation according to slope position. Coarse and medium-textured soils can be expected in any topographical position and it was not possible at the scale of the survey to map them out separately. In general, sandy soils take up a larger proportion of the higher watershed areas, whereas medium-textured to heavy-textured soils are more concentrated in the parts receiving surface runoff, but this general rule has many exceptions.

Typically these upland plains are eroded, with bare or covered termite mounds, usually a few meters across and 1-2 m high. Their occurrence is so universal that these uplands can be readily identified on aerial photographs.

Within the upland plains with brown soils and termite mounds, mapping units are separated on the basis of topographical position, slope and phases as follows :

Upland plains with brown soils and termite mounds, almost flat top, 0-1% slope (symbol : UBt)

Area : 41,660 ha; 15.83% of the survey area

Dominant slopes : 0-1%

Soils : Bl and Bs are dominant soils.

This mapping unit is the most extensive of the survey area. It covers the highest positions on the upland plains.

As above, gully erosion phase (symbol : UBt(g))

Area : 588 ha; 0.22% of the survey area

Dominant slopes : 0-1%

Soils : Bl is the dominant soil, Bs occurs as associated soil and G occurs as inclusions.

Upland plains with brown soils and termite mounds, sloping, 3% slope (symbol : UBs2)

Area : 8,070 ha; 3.07% of the survey area

Dominant slopes : 3-6%

Soils : Bl is the dominant soil, Bs occurs in association.

This mapping unit covers the sloping parts of the upland plains, usually associated with the presence of tectonic lines, such as shear zones, and faults, recognizable from their linear pattern.

As above, gully erosion phase (symbol : UBs2 (g))

Area : 451 ha; 0.17% of the survey area

Dominant slopes : 3-6%

Soils : Bl is the dominant soil; Bs occurs as associated soil; G occurs as inclusion.

Upland plains with brown soils and termite mounds, gently sloping, 1-3% slope (symbol : UBs1)

Area : 34,553 ha; 13.13% of the survey area

Dominant slopes : 1-3%

Soils Bl is the dominant soil, Bs occurs as associated soil.

This mapping unit is one of the most common in the survey area and covers gently sloping parts of the upland plains.

As above, stony and rocky phase (symbol : UBsl(s))

Area : 446 ha; 0.17% of the survey area

Dominant slopes : 1-3%

Soils : Bl is the dominant soil, Bs occurs as associated soil, L and G occur as inclusions.

A high proportion of the terrain is covered by rocks, stones, boulders or gravel.

As above, gully erosion phase (symbol : UBsl(g))

Area : 3,754 ha; 1.4% of the survey area

Dominant slopes : 1-3%

Soils : Bl is the dominant soil, Bs occurs as associated soil, G occurs as inclusion.

Upland plains with brown soils and termite mounds, almost flat bottom, 0-1% slope (symbol : UBb(g))

Area : 29,647 ha; 11.27% of the survey area

Dominant slopes : 0-1%

Soils : Bl is the dominant soil, Bs occurs as associated soil.

This mapping unit is one of the most common in the survey area and covers the water-receiving bottom parts of the upland plains.

As above, gully erosion phase (symbol : UBb(g))

Area : 401 ha; 0.15% of the survey area

Dominant slopes : 0-1%

Soils : Bl is the dominant soil, Bs occurs in association and G as inclusions.

Upland plains with brown soils and termite mounds, almost flat bottom, transitional to aggradational valley (symbol : UBb-VA)

Area : 4,608 ha; 1.75% of the survey area

Dominant slopes : 0-1%

Soils : Bl is the dominant soil, A occurs in association and Rl as inclusions.

This mapping unit covers bottomlands that are transitional to the aggradational river valleys and are characterized by a higher proportion of clayey soils, similar to the alluvial soils underlying the river valleys.

Although erosion is relatively slight, the agricultural potential of the upland plains with brown soils and termite mounds is very low. The main constraints are the low water availability and low fertility. The higher positions especially appear less suitable due to the higher proportion of sandy, strongly leached soils with low moisture retention capacity. The bottom positions appear more suitable for cultivation, particularly of drought resistant crops because virtually all rainfall is effective and because they also benefit from water additions from higher ground. However, these runoff or seepage additions may vary considerably in function of the runoff potential of the higher land (which is largely determined by the quality of the vegetation cover) and the size of the bottomlands (wide bottomlands will receive per surface unit less runoff than narrow bottomlands). Another severe handcap is the omnipresence of termite mounds. Their fertility status appears even worse than that of the surrounding land and their hardness makes mechanized farming an ordeal.

The upland plains with brown soils and termite mounds offer probably a better potential for natural grazing, but considering the overgrazing in the survey area, destocking appears a 'must' for any serious rangeland development scheme.

2. The second group of upland plains is mainly covered by reddish, medium textured soils (Rl) with moderate acidity and low to moderate nutrient status. Occasionally reddish clayey soils (Rc) occur as well. The termite mounds, so characteristic of the first group of upland plains, are, inexplicably, almost entirely absent here.

Within the upland plains the red soils have a seemingly random distribution. However, on closer examination it becomes obvious that their distribution is usually linked with the presence of linear landscape features that are most likely the result of tectonic disturbances in the underlying granitic rocks, such as shear zones, fault lines etc. However, this pattern only becomes evident from aerial photographs and cannot be inferred from topographical considerations only.

In analogy with the first group of upland plains, differentiation of mapping units is based on topographical position, slope and some phases.

Upland plains with red soils and without termite mounds, almost flat top, 0-1% slope (symbol : URt)

Area : 1,485 ha; 0.56% of the survey area

Dominant slopes : 0-1%

Soils : Rl is the dominant soil with Rc as inclusions.

As above, stony and rocky phase (symbol : URt(s))

Area : 533 ha; 0.2% of the survey area

Dominant slopes : 0-1%

Soils : Rl is the dominant soil, L and G occur as associated soils together with rock outcrops.

As above, gully erosion phase (symbol : URt(g))

Area : 41 ha; 0.02% of the survey area

Dominant slopes : 0-1%

Soils : Rl is the dominant soil, Rc occurs in association, and G as inclusions.

Upland plains with red soils and without termite mounds, sloping, 3% slope (symbol : URs2)

Area : 1,279 ha; 0.49% of the survey area

Dominant slopes : 3-6%

Soils : Rl is the dominant soil, with Rc as inclusions.

As above, gully erosion phase (symbol : URs2(g))

Area : 451 ha; 0.17% of the survey area

Dominant slopes : 3-6%

Soils : Rl is the dominant soil, Rc and G occur as inclusions.

Upland plains with red soils and without termite mounds, gently sloping, 1-3% slope (symbol : URsl)

Area : 2,881 ha; 1.09% of the survey area

Dominant slopes : 1-3%

Soils : Rl is the dominant soil, Rc occurs as inclusions.

As above, stony and rocky phase (symbol : URs(s))

Area 346 ha; 0.13% of the survey area

Dominant slopes : 1-3%

Soils : Rl is the dominant soil, L and G occur as associated soils and rock outcrops.

As above, gully erosion phase (symbol : URsl(g))

Area : 533 ha; 0.20% of the survey area

Dominant slopes : 1-3%

Soils : Rl is the dominant soil, Rc and G occur as inclusions.

Upland plains with red soils and without termite mounds, almost flat bottom, 0-1% slope (symbol : URb)

Area : 4,620 ha; 1.76% of the survey area

Dominant slopes : 0-1%

Soils : Rl is the dominant soil, Rc occurs as inclusion.

As above, gully erosion phase (symbol : URb(g))

Area : 31 ha; 0.01% of the survey area

Dominant slopes : 0-1%

Soils : Rl occurs as dominant soil, Rc and G occur as inclusions.

The agricultural potential of the upland plains with red soils and without termite mounds is low in view of the above discussed constraints of low moisture availability and low soil fertility. However the fertility limitation is less severe than in the first group of upland plains and in the water receiving areas moisture should be more adequate. Erosion may be a problem on the steeper slopes (more than 3%), but it is considered that in flatter land with sound fertility and water conservation techniques these areas are able to produce reasonable yields of shortmaturing, drought resistant crops such as sorghum, millet, grapes.

Depending on the intensity of overgrazing, the potential for grazing appears moderate to marginal on the flatter land, and marginal on the sloping land.

3.4.6. Intermediate plains (symbol: I)

Area : 4,667 ha; 1.77% of the survey area

Dominant slopes : 0-2%

Soils : D is the dominant soil, Bl occurs as associated soil and Bs occurs as inclusion.

The intermediate plains form a tract of almost flat land between the Hombolo lake and the hills north of Hombolo Makulu. They are characterized by a network of parallel, clearly incised, small rivers and rivulets with seasonal flow and by moderately well drained medium to fine-textured soils (D) with good waterholding properties and moderate nutrient status.

The term 'intermediate' refers to the drainage and soil characteristics of this mapping unit, which are intermediate between those of the footslopes, the upland plains and the lowland plains (3.4.7). The intermediate plains differ from the upland plains by soils with finer textures, more brownish colours and mottling, and by the absence of termite mounds. They differ from the lowland plains by better drainage and less heavy, non-saline and non-sodic soils. They differ from the footslopes by lack of erosion.

The vegetation is in general a well-developed Acacia-Baobab wooded or bushed grassland. The mapping unit is not entirely homogeneous and contains some stretches of upland plains with medium-textured or sandy soils and termite mounds.

The intermediate plains appear to have a moderate potential for drought resistant crops and possibly in good rainfall years, maize.

They are not as strongly affected by lack of moisture and fertility as the other upland areas, while on the other hand they do not have the drainage and salinity problems associated with the lowland plains and swamps.

Overgrazing does not appear a major problem in this area and the potential for natural grazing is considered high. Dairy development in the neighbourhood of lake Hombolo could be given serious consideration subject to the availability of irrigation water.

3.4.7. Lowland plains

The lowland plains are tracts of low-lying land bordered by higher land from which they receive surface runoff and seepage water. They are covered by grassland or bushed grassland. Soils are cracking or non-cracking clays. Termite mounds are absent and this unit is free from erosion.

The main lowland plain area occurs west of lake Hombolo. Its shape, confinement below the 3400 ft contour and clayey sediments suggest that this area was a former swamp, impounded against the Hombolo escarpment, probably under a wetter climate than the present. This assumption is further corroborated by the occurrence of shallow lacustrine limestone.

The actual drainage conditions within the lowland plains are largely determined by the soil type. Drainage is restricted in the dark cracking clays (V), but for the brown, friable, calcareous clays (F) drainage is good. Even on the cracking clays waterlogging during the rainy season is not as frequent as in other lowland areas with similar soils ('mbuga') because the rainfall is low and also because surface runoff can find an outlet to lower sites, such as the Hombolo lake, incised river beds or swamps.

In respect of drainage and soils, the lowland plains have been subdivided into the following mapping units :

Lowland plains with poorer drainage (symbol : LP)

Area : 8,640 ha; 3.28% of the survey area

Dominant slopes : 0-1%

Soils : V is the dominant soil, F occurs as inclusions.

Lowland plains with better drainage (symbol : LB)

Area : 2,807 ha; 1.07% of the survey area

Dominant slopes : 0-1%

Soils : F is the dominant soil, V occurs as inclusions.

<u>As above, gully erosion phase</u> (symbol : <u>LB</u>(g))

Area : 56 ha; 0.02% of the survey area

Dominant slopes : 0-1%

Soils : F is the dominant soil; V occurs as inclusions.

The lowland plains with poorer drainage (<u>LP</u>) are covered by moderately to imperfectly drained, very sticky, dark cracking clays (V). These soils are very high in bases, but nitrogen may be deficient, as well as phosphorus. They have a very good moisture retention capacity but structural properties are poor. They are very difficult to cultivate by hand and their potential for smallholder farming is marginal. They appear suitable for mechanized farming of drought resistant crops that can withstand occasional waterlogging such as sorghum. Physically the soils are very suitable for irrigation, but at present irrigation water is not available. Moreover, some of these soils are saline and salinity survey may be required before embarking on capital-intensive projects.

These areas also have a good potential for natural or improved grazing. They have a good grass cover that persists for some time into the dry season and overgrazing is uncommon.

The lowland plains with better drainage (<u>LB</u>) are covered by friable clays with strong, crumb structure and good drainage (F). These soils are also high in nutrients, except phosphorus and nitrogen. They are calcareous, often saline, and have a very good moisture retention capacity. They are suitable for smallholder cultivation of drought resistant and salt tolerant crops such as sorghum. They are less suitable for salt-sensitive crops, such as grapes or maize. They appear unsuitable for mechanized farming because the structure can be irreversibly destroyed by heavy machinery.

These areas have a good grass cover and can be grazed under appropriate stocking rates, but overstocking may lead to structural deterioration.

<u>3.4.8. Swamps</u> (symbol : <u>S</u>)

Area : 4,438 ha; 1.69% of the survey area

Dominant slopes : 0%

Soils : V is the dominant soil.

The swamps are tracts of low-lying land characterized by permanent soil moisture saturation, temporary or permanent flooding and a vegetation of predominantly grassland, often with aquatic species. They are the poorest drained parts of the plateau, with virtually no relief. They are differentiated from the poorly drained lowland plains by longer periods of waterlogging and by lack of external drainage. Swamps can only lose excess water by evaporation and to a very minor extent by seepage downwards. The main landscaping process is deposition. Erosion is non-existant.

The main swamps in the survey area are the Makutupora and Singe swamps. These are underlain by dark, cracking clays (V), which are often saline and sodic. Due to waterlogging problems these areas are unsuitable for upland crops. They are moderately suitable to unsuitable for rice, depending on the depth of flooding and the severity of the salinity limitation. In any case, the area where rice could be grown appears to be confined to a small border zone at the swamp edges. The swamps probably offer good dry season grazing land.

3.4.9. River valleys

The river valleys are the major drainage-ways of the survey area. They are usually low-lying areas with little relief intensity and strongly incised river-beds. Most rivers originate in the Dodoma hills or the Chenene mountains.

The river valleys are essentially composed of two major landscape features : the riverbeds and the valleyfloors.

The riverbeds are narrow or wide, sandy or stony drainage channels incised into the valley floor, often forming a braided pattern of interconnecting channels. They are usually dry, even during the rainy season, but during and immediately after heavy showers in the catchment areas they become torrential and transport large amounts of runoff and sediment from the hills and footslopes in a very short time. The runoff is stored at shallow depth in the sandy bed, the coarse sediments are deposited in the river bed, often in fan-like accumulations, while the finer sediment is either drained off to the swamps or deposited in reservoirs, where it causes gradual siltation, for instance in lake Hombolo.

The valleyfloors are rather flat bottom-lands covered by medium textured colluvium from the footslopes, underlain by a clayey alluvial sediment (C/A soils). Soils developed on this colluvium have low to moderate fertility status and moderate moisture retention capacity. The presence of clayey alluvium at moderate depth is an important factor in the water economy of the valley floors. Rain and seepage water from uphill are effectively stored above the clay layer, without causing serious drainage problems, and for this reason the valley floors have by far the best moisture availability in the survey area. Moreover they experience no salinity problems.

The valley floors therefore seem to offer the best potential for crop production in the survey area. The most suitable crops must be drought resistant and short-maturing, such as sorghum, millet, grapes, although maize is expected to perform reasonably well in most except the driest years. These areas appear suitable for capital intensive undertakings such as large-scale grape production. Moreover they are also suitable for small-scale irrigated cultivation of garden crops nearby river beds or where permanent groundwater is available.

Farmers recognize the high potential of the valley floors which are the most densely settled and utilized areas within Dodoma Capital City District.

According to the dominating landscaping process the river valleys have been differentiated into following mapping units:

Aggradational river valleys (symbol : VA)

Area : 9,334 ha; 3.55% of the survey area

Dominant slopes : 0-1%

Soils : C/A is the dominant soil, Rl occurs as associated soil and A occurs as inclusion.

This mapping unit covers the water-receiving areas in which the incised river beds with unsuitable agricultural land cover only a small area. Deposition of sediment and water from higher land is the predominant process. The slope gradients are very low and moisture availability is optimum under the given climatic conditions. The potential for agriculture outlined above is entirely applicable to this mapping unit.

As above, red topsoil phase (symbol : VA(r))

Area : 3,165 ha; 1.20% of the survey area

Dominant slopes : 0-1%

Soils : Rl is the dominant soil, C/A occurs in association.

This mapping unit covers areas in the aggradational river valleys where reddish colluvium from upslope has accumulated to greater depth.

Erosional river valleys (symbol : VE)

Area : 7,656 ha; 2.91% of the survey area

Dominant slopes : 1-2%

Soils : Rl and Bl are dominant soils, L occurs in association and G as inclusions.

These valleys act more as watershedding areas. Valleys gradients are steeper and the proportion of land occupied by incised river beds or gullies is higher. Surplus moisture tends to be drained off to lower land rather than stored locally. These erosional valleys have a much more restricted potential for agriculture.

Chapter 4

LAND SUITABILITY EVALUA

4.1. GENERAL CONSIDERATIONS

In this chapter the practical significance of the soil differences, recognized during the soil survey are assessed in respect of various productive land use types, together with other important environmental factors, such as physiography, climate, drainage, soil degradation processes etc.

To develop the land suitability classification for Dodoma Capital City District, the principles and methods given by "A framework for land evaluation" (FAO, 1976) have been followed. The different mapping units of the Soils Map were evaluated in terms of land suitability ratings in respect of specific land use alternatives, which will be discussed in section 4.2. The suitability ratings were determined by rating individual land qualities such as moisture availability, soil fertility, erosion hazard, drainage etc. The meaning of the concept "land quality" and the significance of the land qualities used for the present study is explained in section 4.3.

The land suitability classification adopted for Dodoma Capital City District is a physical one. This means that the relative suitability of the different mapping units recognized during the survey, is assessed purely on the basis of physical land characteristics, without analysis of social and economic costs and benefits. It is therefore perfectly possible that land may be suitable for a particular use, but that such use would be unrealistic within the socio-economic context of the area.

The land suitability ratings refer to current suitability, i.e. the suitability for a defined use of land in its present condition, with allowance for improved management. This means that the suitability ratings refer specifically to properly managed land, within the limitations imposed by the agricultural system, and assume that, where required, minor land or land use improvements will be carried out. Examples of such improvements are the use of fertilizer or manure, elementary soil conservation, timely planting, bush control. In some cases these improvements are within the financial and technical capability of smallholders, but their implementation is blocked by tradtion imposed attitudes, poor extension services, limited marketing or credit services or inadequate distribution systems. A case in point is the reduction of stock numbers, which is feasible and desireable from a technical viewpoint, but is resisted by traditional perceptions of the utility of livestock. In such cases where the socio-cultural environment is the major constraint, and not the lack of capital or skills, suitability ratings are given with and without improvements.

It should also be noted that the present land suitability classification is to a large extent qualitative, with land suitability expressed in qualitative terms. An exception is the assessment of dependable moisture availability which is based on a probability estimate of the hazard of crop failure (see 4.3.).

4.2. RELEVANT LAND USE ALTERNATIVES

Following productive land utilization types appear relevant for Dodoma Capital City District :

(C1) Smallholder rainfed crop production, low inputs	)	
(C2) Commercial rainfed crop production, moderate inputs	)	Crop pro-
(C3) Small-scale irrigated crop production	)	duction systems
(R1) Unimproved natural grazing	)	
(R2) Ranching	)	Rangeland
(F) Forestry	)	systems

Mixed farming systems with integration of livestock and crop production on individual holdings are not considered for the present evaluation. In the survey area such systems have not developed sufficiently to present a viable alternative in the present socio-economic context.

4.2.1. Smallholder rainfed crop production, low inputs (C1)

This smallholder-based land utilization type is characterized by low inputs of capital and labour, and by low yields. Rainfall, often supplemented by runoff or groundwater additions is the sole source of soil moisture for upland crops. Bush fallows are the normal means to restore soil fertility. Although not actually integrated with livestock, this land utilization type derives its viability in part from the large livestock population in the area, which helps to overcome the nutritional deficits in drought years. Still the system is very vulnerable to the impact of drought. Periodic droughts have in the past resulted in famines and famine relief is still regularly required to overcome frequent shortfalls in food production.

This land utilization type is the most important one in Dodoma Capital City District. It is estimated that about 25% of the survey area is under this form of cultivation at one time or another, which is probably the maximum acreage that allows profitable cultivation in normal rainfall years. The opportunities for acreage expansion appear very limited and can only be achieved by bringing marginally suitable or unsuitable land under cultivation, resulting in a fruitless competition with already scarce grazing land.

The main crops grown are sorghum, bulrush millet, maize and groundnuts. These crops may be grown pure or in mixtures. Improved seeds are mainly used for cultivation of maize (Katumani) and sorghum (Serena and Lulu), but for sorghum and other crops local varieties are also important.

All these crops have approximate growth cycles of 3½ months. Sorghum and millet are mainly grown for subsistence, maize frequently for sale and groundnuts mainly as cash crop. Minor crops in the area are grapes, grown as a garden crop, and vegetables.

Surprising is the virtual absence of cassava as a food crop, since there appear no climatic or soil constraints for growing this crop and alternative to low-yielding sorghum and millet as a source of carbohydrate. It is not known whether this situation is due to a traditional taste preference. Unexpected as well, in view of the low rainfall and the crop's susceptibility to drought, is the importance of maize, even in areas that appear entirely unsuitable for the crop. This insistence on maize may also be a matter of palate; the infestation of small grain crops by birds may be an additional reason.

Crop yields are generally low, with large fluctuations according to the adequacy of rainfall. Drought years may lead to complete crop failures, particularly of maize. Following table gives some yield data compiled by PPAL (1976).

Table 10. Yields of major crops

Crop	(1)	(2)
Maize	939	1000
Bulrush millet	934	270
Sorghum	857	373
Groundnuts	573	114

(1) data from 11 villages in Dodoma CCD (PPAL, Tec. Sup. 6, 1976)

(2) data for season 1971-72 in villages of Dodoma Region (PPAL, Tec. Sup. 2, 1976).

The first set of yild data can be considered as fairly representative yields during normal rainfall years on cropland with average suitability. The second set, with the exception of the maize yield data, may be representative for yields in drought years.

Natural fertility is usually restored by bush fallows. The duration of the cultivation/fallow cycle has been estimated by Brown (1977) at 6-7 years, with 4 years cultivation followed by 2 years fallow. Reports of declining yields (Brown, 1977) in the area would indicate that the duration of the fallow period is inadequate to restore natural fertility. Fertilizer use is minimal. In a CDA-survey of 78 Ujamaa villages, reported by PPAL (1976) farmyard manure was reported by almost 80% of the villages, but it was only sporadically applied and in indeterminate quantities. Considering that the Capital City District has a livestock population that exceeds about four times the carrying capacity of the area, this minimal use of manure is all the more regrettable since large areas have been abandoned for cultivation because of land degradation. The use of artificial fertilizers, insecticides and pesticides is virtually non existing.

The timing of agricultural operations is fairly simple and clearly regulated by the onset and duration of the rains. As the growing season is short, it is normal practise to plant as soon as possible after the onset of the rains, which is usually December or January. Cultivation is by handtools mainly, virtually no oxen are used. Capital assets of smallholders consist of elementary farm implements and of livestock. Livestock assets (cattle, goats, sheep, donkeys) are highly variable in quantity among households.

Little information is available about the size of the holdings. From recent population and acreage data the average holding is estimated at 4-5 ha per household. These data suggest overpopulation of the area. Brown (1977) for instance, estimates the carrying capacity of average arable land in the area as 1 household per 15 ha.

4.2.2. Commercial rainfed crop production, medium inputs (C2)

This land utilization type mainly refers to medium-or large scale grape cultivation, but may also include mechanized farming of other drought resistant crops, such as sorghum and millet. The main characteristic is that the crops are grown for sale and not for local consumption. This land utilization type is still largely rainfed but differs from C1 by its requirement for substantial capital inputs and improved skills and management.

This land utilization type is at present a minor one in Dodoma Capital City District and covers less than 5% of the are, but it offers scope for considerable expansion and raises hope for a substantial cash income increase for the rural population. Particularly grapes are becoming increasingly attractive in view of high producer prices in comparison with other crops. In addition, grapes are drought resistant, produce good yields under good management and are perennials that require relatively simple care.

However, to achieve optimal yields proper management, skills and inputs are required such as fertilizers, manure, modern farm machinery, fencing, additions of irrigation water, hired labour etc. Particularly initial land preparation for vineyards requires a substantial investment in manure, trench digging, lime, poles, fences. Irrigation additions may be a prerequisite to achieve a second crop in the dry season.

At present grape yields vary tremendously in response to management level and site conditions. Grape productivity figures may vary from 1 to 11 tons/ha. Taking into account the high spatial variability, recent estimates (Schaeffer, personal communication) put grape productivity on average at about 1 ton/ha, which, by world standards, is a low yield.

Under the same land utilization type the large-scale mechanized production of the main drought-resistant staples of the area, sorghum and millet, has been included, although these crops are at present not grown mechanized.

Land suitability is evaluated for grapes and sorghum, millet separately. It should be stressed that this land suitability assessment is of a very qualitative nature and that only crude considerations of economic feasibility are included. It should also be noted that the suitability evaluation is of necessity fairly generalized, and applies to whole mapping units. However, particularly for grapes, better moisture supply by springs or groundwater, may locally improved suitability of small areas within some mapping units.

4.2.3. Small-scale irrigated crop production (C3)

This land utilization type refers to the cultivation of garden crops, such as tomatoes, onions, green vegetables, grown by smallholders by means of irrigation powered by hand, small pumps or windmills. This system is highly labour intensive and requires for the achievement of high yields substantial capital investment, mainly for fertilizer, manure, agrochemicals, pumps, windmills, and land preparation costs, and good management.

Only very small areas in the Capital City District (less than 1%) are at present under this land utilization type, usually in the river valleys where water is available from river beds or can be easily pumped.

High yields of garden crops can and have been achieved. Estimates of tomato productivity by eight villages range from 2250 kg/ha to 12,800 kg/ha, with an overall mean of 8232 kg/ha. Under low levels of management vegetable yields would probably not exceed 2000 kg/ha (PPAL,1976).

It should be noted that at the scale of the survey it was only possible to identify those mapping units in which areas suitable for small-scale irrigated farming are likely to occur. The hectarage estimates of suitable areas given in table 13 are therefore tentative and need to be verified by more detailed surveys.

4.2.4. Unimproved natural grazing (R1)

This land utilization type refers to the natural grazing of livestock on unutilized land for agriculture in its present degraded condition. It is the most important land utilization type in the survey area, practised on at least 50% of the survey area. It is practised mainly by pastoralists and is characterized by low capital and labour inputs. Livestock is mainly perceived as a "bank" and high livestock populations are considered essential to overcome high mortality in drought years. As a result overstocking is the rule and most rangelands are overgrazed. Herds are usually of poor milking quality and low weight and subject to high mortality. Watering points are few and overused and considerable movement of cattle between watering points and grazing areas results. Disease and parasite protection is non-existing. Browsing plays a considerable role in herd nurtition.

In the qualitative land suitability evaluation for this land utilization type, consideration has been given to the relative abundance of grasses in the mapping unit concerned, the degree of land degradation, the penetrability of the area as influenced by the density of thickets, the persistence of green vegetation into the dry season, and the proximity of watering points.

4.2.5. Ranching (R2)

This land utilization type refers to an improved natural grazing on demarcated areas, characterized by high capital costs for development and maintenance. Profitable ranching, either as a commercial or as a co-operative enterprise requires rangeland in good condition, adapted stocking rates, high offtake from the herd, adequate provision of watering points, dips, fire-protection and good management. In the degraded condition of many rangelands in Dodoma Capital City District reseeding may also be required as well as bush control.

This land utilization type is at present not practised in the survey area but appears a relevant option. Its inclusion in the present land suitability evaluation does not imply, however, that ranching schemes in Dodoma Capital City District are economically viable. The potential viability of such units can only be established after an specific feasibility study to which the present physical land suitability classification may serve as an input.

4.2.6. Forestry (F)

This land utilization type refers to non-irrigated, planted forests or improved natural woodlands for the production of firewood and building materials. Afforestation is a priority of agricultural policy in Dodoma Capital City, both to meet a rising need for fuelwood and construction materials for the Capital and for the reclamation of eroded lands. Afforestation of eroded areas in a semi-arid climate is a highly capital- and labour intensive undertaking; particularly in the establishment stage whereas afterwards very strict control over felling and adequate replanting are essential to maintain the forests.

The main natural vegetation communities that can produce fuelwood and building materials are woodland and bushed woodland. The former is rather limited in the survey area (about 1300 ha), the latter is more extensive (about 22,000 ha) but the wood yield is low and a commercial exploitation would suffer from severe accessibility problems as most of these woods are located on steep hills and mountains. Planted forests are therefore an obvoius solution: at present several thousand hectares have been planted in the District, but have not yet reached an exploitation stage.

4.3. LAND SUITABILITY CLASSES, LAND QUALITIES AND LAND CHARACTERISTICS

Land suitability classification is the appraisal and grouping of land in terms of suitability for specific uses, such as the one described in section 4.2. The suitability classes which are used in this report are as follows :

Class S1 : Highly suitable land

Land having no significant limitations to sustained application of the considered use; or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2 : Moderately suitable land

Land having limitations which in aggregate are moderately severe for sustained application of the considered use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall avantage to be gained from the use, although still attractive, will be appreciably inferior to that in class S1- land.

Class S3 : Marginally suitable land

Land having limitations which in aggregate are severe for sustained application of the considered use and will reduce productivity or benefits or increase required inputs, that this expenditure will be only marginally justified.

Class N : Unsuitable land

Land having limitations which appear so severe as to preclude any possibilities of succesful sustained use of the land in the given manner; or the limitations may be surmountable in time but cannot be corrected with existing knowledge at currently acceptable cost.

These definitions are somewhat difficult to use for the evaluation of rangeland (R1 and R2) and for forestry. For the latter the definitions of suitable and unsuitable land are adapted as follows (Van der Kevie,1976):

Class S1 : Highly suitable rangeland

Land which is expected to produce large amounts of fodder and animal products, and which can sustain a high rate of stocking for a prolonged period of the year.

Class S2 : Moderately suitable rangeland

Land which is expected to support fewer animals or for a shorter season than Class S1- land.

Class S3 : Marginally suitable rangeland

Land on which it is expected that animals can survive but cannot be kept in good condition except for short periods.

Class N : Unsuitable rangeland

Land which is expected to produce too little fodder for animals to survive or too little to be worth grazing.

For forestry evaluations following suitability classes may be distinguished:

Class S1 : Highly suitable land for forestry

Land which is expected to have a high production capacity for woodland types with many desirable tree species.

Class S2 : Moderately suitable land for forestry

Land which is expected to have a moderate production capacity for the forest type and tree species under consideration.

Class S3 : Marginally suitable land for forestry

Land which is expected to have only a marginal production capacity. Productivity is low and the number of desirable species that can be grown is small.

Class N1 : Currently unsuitable land for forestry

Land with very severe limitations for forestry which at present cannot be corrected economically and which preclude succeful sustained use for land for forestry (usually rock outcrops).

The process of land suitability classification goes through an intermediate interpretation stage by means of the "land quality" concept. A land quality is a complex attribute of the land with a distinct and individual influence on the suitability of land for a specific use. Examples of major land qualities are : moisture availability, flooding hazard, erosion hazard etc. Land qualities are evaluated on the basis of land characteristics, which, in contrast with land qualities, are measurable and can be quantified. Examples of land characteristics are rainfall amounts, soil texture, slope etc. The integration of land characteristics into land qualities is usually done by conversion tables. The conversion of land qualities into land suitability is done by various quantified approaches or by an empirical interpretation.

The suitability assessment of land is made on the basis of those land qualities that are most relevant for the land use types considered. The land qualities that are considered most relevant in the surveyed area are given in table 11.

Table 11. Relevant land qualities

LAND QUALITY	LAND UTILIZATION TYPE								
	C1			C2		C3	R1	R2	F
	Maize	Sorghum millet	Ground-nuts	Grapes	Sorghum millet				
1. Moisture availability				*					*
2. Dependable moisture availability	*	*	*		*				
3. Conditions for seedling establishment	*								*
4. Soil fertility	*	*	*	*	*	*			*
5. Drainage conditions in the growing season	*	*	*	*	*				*
6. Workability	*	*	*						
7. Possibilities for mechanization					*				
8. Salinity	*	*	*	*	*	*			*
9. Sodicity	*	*	*	*	*	*			*
10. Erosion hazard	*	*	*	*	*	*			*
11. Drainability for irrigated agriculture						*			

It is clear from the table that the selection of land qualities depends on the particular land utilization type for which the suitability assessment is made. For certain land utilization types other land qualities need to be considered but can, however, not be rated at present because of insufficient data. For instance, a useful land quality for small-scale irrigated crop production (C3) "proximity of irrigation water" could not be assessed by lack of relevant data. For the same reason the land quality concept could not be applited to rangeland types (R1 and R2) because it requires a detailed knowledge of the plant communities, availability of water sources etc.

Brief explanations of the meaning of selected land qualities are given below, as well as a summary evaluation of the survey area in terms of land qualities.

Moisture availability

This land quality refers to the availability of moisture for plant growth, as determined by the water supply, the water storage capacity of soils and the water consumption by evapotranspiration. Under rainfed conditions the water supply depends on the total amount of rainfall, the length of the rainy season and the potential evapotranspiration. Soil characteristics that modify the water supply by rainfall are texture, structure, organic matter content, depth, amount of gravels and stones in the profile and the capability of the soils to absorb rainfall.

In the section on climate (1.2) it was pointed out that certain climatic factors impose very definite limitations on the water supply for plant growth. These factors are low rainfall with high variability, high potential evapotranspiration rates and a short rainy season. It was also observed (section 3.2) that in large parts of the Capital City District these limitations to moisture availability are considerably enhanced by land degradation, as expressed by soil erosion, surface capping, poor vegetative cover, low organic matter levels, poor structural properties. These factors to a large extent decrease the rainfall absorption capacity of the soils and make them drier than they would be under well managed conditions. The areas most affected in this respect are the erosional footslopes.

In conclusion it may be stated that moisture availability for plant growth is generally poor in Dodoma Capital City District, especially in well drained upland areas. The areas with a better moisture regime are situated in water-receiving sites, which cover about 30% of the District. This figure, not surprisingly, agrees closely with the area under crop production (25%).

Dependable moisture availability

Dependable moisture availability refers to the moisture available to plants that can reasonably be expected over a long series of growing periods. In constrast with the previous land quality, it takes into account the variability of the water supply, both in amount as in distribution. Dependable moisture availability is assessed by estimating the probability of crop failure by drought. This is done by means of a methodology which is explained in Technical Appendix 2. The land quality has only been applied to assess land suitability for maize (Katumani), sorghum (Serena) and groundnuts, which are important crops in the area and lend themselves well to this particular analysis. The results of this study are summarized in the following table:

Table 12. Probability of crop failure by drought

Crop	Soil group (°)		
	1	2	3
Maize (Katumani)	64	63	59
Groundnuts (Erect bunch)	54	46	39
Sorghum (Serena)	32	29	24

(°) Soil group 1 (Rs, Bs): AWC of about 50 mm/m
Soil group 2 (Rl, Bl, Rc, C/A, D *): AWC of about 100 mm/m
Soil group 3 (F, V, A, D*): AWC of about 150 mm/m

(*) pro partim

These results indicate that in Dodoma watershedding sites that are entirely rainfed without other water additions, have very high probabilities of crop failure for maize and groundnuts. Even drought-resistant sorghum is prone to regular crop failures under these conditions. In this respect it should be noted that "crop failure" means here a 50% yield decrease compared with the yield under full moisture supply. An increase of soil moisture capacity reduces the risk of crop failure but not much. Probabilities of crop failure are likely to be reduced more substantially if additional moisture is received from groundwater, seepage or runoff. Again, this confirms the general pattern of intensive cultivation of the lower-lying areas, particularly the river valleys.

Soil fertility

This land quality refers to the presence and availability of plant nutrients in the soil, as determined from soil chemical data. The major parameters to assess soil fertility are soil reaction (pH), organic carbon content, total nitrogen content, available phosphorus, exchangeable potassium, cation exchange capacity (or in absence of the latter, sum of exchangeable bases) and base saturation. No information is available on the status of micro-elements for the soils of the survey area and they are therefore not considered in the rating.

In terms of the major fertility parameters most soils of the survey area have a low nutrient status. Especially organic matter levels are low. Total nitrogen and exchangeable K-levels are adequate or even high. The CEC (or sum of bases) is low except for the V- and F-soils. Unexpected is the high acidity of many upland soils in this dry area (section 3.2.). Most affected in this respect are the Rc-soils, but also the Rs-, and Bs-soils, and some of the Rl- and A-soils. The most fertile soils appear the V- and F-soils, covering about 5% of the survey area.

To a considerable extent the limited soil fertility in the survey area should be attributed to soil erosion and overgrazing.

Erosion hazard

As used here this land quality refers to the risk of soil erosion by water mainly. Although there is evidence of wind erosion in Dodoma Capital City District this factor remains minor in comparison with the considerable water erosion that has affected large parts of the survey area.

The erosion hazard is assessed on the basis of actual soil erosion, topography, inherent soil erodibility and rainfall erosivity.

Erosion hazard is determined both by past soil erosion as by the susceptibility of the soil to erosion. Past erosion in its most conspicuous form, gully erosion, has had a significant impact in large parts of the survey area (25%), particularly the footslopes on granitic rocks, and the escarpments. Sheet erosion refers to a fairly uniform stripping of soil particles and transportation downslope by surface run-off. Although less spectacular than gully erosion, it is in some ways more damaging because it covers more land and because most of the soil fertility is stored in the surface layers. In areas subject to sheet erosion crop yields are therefore bound to decline gradually. Most parts of the footslopes and the escarpments are severely affected by sheet erosion, but also the top and slope positions of upland plains are reckoned to be particularly prone, in view of the severe vegetation degradation in these area. Where the grass cover is poor and soil aggregates unstable, even modest slopes (a few percent) are sufficient to allow transportation of detached topsoil particles.

In conclusion it is estimated that about 26% of the survey area is considerably affected by past erosion and 34% of the area is under a considerable risk of soil erosion. The transported products of soil erosion accumulate downslope and cover large parts of the river valleys. Thus in about 80% of the survey area soils and agricultural potential are influenced by the process of accelerated soil erosion. In only 20% of the area the influence of the erosion factor is minimal.

Conditions for seedling establishment

This land quality refers to the suitability of the cultivated topsoil for germination of seeds and emergence and initial root development of plants. This depends on the consistence of the topsoil, kind and stability of the surface aggregates and the susceptibility of the soil to surface sealing. Soils that seal easily tend to form crusts which form a mechanical hindrance to emergence and at the same time reduce the moisture availability to plants by increased surface runoff. Soils that are low in organic matter are particularly prone to surface sealing. This is particularly the case with the Rc-soils, which cover mainly the footslopes derived from basic metamorphic rocks, and to a lesser extent with the Rl-soils which cover the granitic footslopes.

Drainage conditions in the growing season

This land quality refers to the drainage condition of a soil, estimated by the frequency and duration of the periods when the soil is saturated with water. These conditions are seldom accurately measured but can be inferred from soil characteristics such as texture, colour, mottling, quality and kind of organic matter and groundwater levels.

There exist no drainage limitations for cultivation in the upland areas such as footslopes, river valleys, upland plains, intermediate plains. Drainage limitations may exist on the lowland plains with poorer drainage, covered by the V-soils. Yet the risk of waterlogging is not as severe as on similar soils in higher rainfall areas, because of low rainfall and because surface runoff can drain off to lower land. In the swamps poor drainage and ponding water severely restrict cultivation.

Workability

This land quality refers to the ease with which a soil can be worked with handtools or animal drawn ploughs and is therefore only applicable to agricultural systems without mechanization. It is estimated on the basis of stoniness and consistence.

Workability for most soils in the survey area is good, except for the V-soils. These soils are very difficult to cultivate by handtools because they are very hard when dry, and very sticky when wet. Mapping units including a stony and rocky phase (s) have also a poor workability rating.

Possibilities for mechanization

This land quality refers to the physical feasibility of the use of tractors and modern agricultural implements, as estimated from topography, stoniness and soil conditions. It is only applicable to mechanized farming systems.

Apart from the hills, mountains and swamps considerable constraints to mechanization exist on the sloping terrain of the escarpments and on areas affected by rockiness, stoniness and gully erosion. The termite mounds that cover most of the upland plains are bound to increase significantly the development costs of mechanized schemes in these areas. It is estimated that the total area with moderate to severe constraints for mechanization is about 216,000 ha or 82% of the survey area. The affected areas are the mountains, hills and inselbergs, erosional footslopes, escarpments, upland plains with termite mounds and swamps.

Salinity and sodicity

Salinity refers to the presence of salts in the soil in quantities that may have a harmfull effect on plant growth. Sodicity refers to the unbalanced presence of sodium salts in the soil. Salinity and sodicity are often found together in the same soils. This is the case in part of the V-soils on the lowland plains, which are often saline and sodic. The exact extent of the saline and sodic areas could not be established at the scale of the survey but in all likelihood salinity and sodicity affect less than 20% of the lowland plains, or less than 1% of the survey area.

Drainability for irrigated agriculture

This land quality refers to the ability of a soil to be drained. This is an important factor in irrigated agriculture in order to leach out harmful salts, lower the groundwater table or to drain excess water.

It is considered that only the V-soils in the lowland plains present serious drainability problems that require correction. Drainability in these soils is impeded by heavy textures and montmorillonitic clay mineralogy, and artificial drainage may need to be provided if they are to be developed for small-scale irrigation of garden crops.

4.4. LAND SUITABILITY IN DODOMA CAPITAL CITY DISTRICT CONCLUSIONS AND RECOMMENDATIONS

In table 13 the different mapping units recognized during the survey and shown on the Soils Map are rated in terms of suitability classes in respect of the land use alternatives considered in section 4.2. Some of the land utilization types have been split up according to relevant crops. Where no improvements are suggested for a particular land utilization type, one rating is given only. A rating between brackets applies to a minor part of the mapping unit (less than 50%). Where improvements are recommended, the symbol for current suitability is shown on the left, the proposed improvement in the middle and the symbol for potential suitability is given on the right.

The main improvement that is considered relevant, technically feasible and desirable is stock reduction. It is suggested that for a very large part of the survey area stock reduction to levels within the carrying capacity of the land would significantly improve suitability for natural, unimproved grazing (table 14).

Table 14 gives the areas of land suitability in respect of the considered land utilization types. From table 13 and 14 some general conclusions can be drawn about land suitability in the District.

1. Most of the mapping units are currently poorly suited for the considered land utilization types. In fact, there is no land that is highly suitable for any of the alternatives; at best the land is 'moderately suitable'. In most cases the land is either marginally suitable or unsuitable. The reasons for this generally poor potential are twofold. First, rainfall is low and the growing season is short, therefore potential biomass production is considerably reduced. A second, and more important, reason appears to be the severe land degradation that has affected the upland areas, especially the more sloping ones.

Table 13. Land suitability classification Dodoma Capital City District

Mapping Unit	Land utilization types								
	C1			C2		C3	R1	R2	F
	Maize	Sorghum Millet	Ground-nuts	Grapes	Sorghum Millet				
M	N	N	N	N	N	N	N	N	N
RB	N	N	N	N	N	N	N(S3)	N	N
RA	N	N	N	N	N	N	N(S3)	N	N
FBe2	N	N	N	N	N	N	S3	N	N
FBe1	N	N	N	N	N	N	S3	N	N
FAe2	N	N	N	N	N	N	S3	N	N
FAe2(S)	N	N	N	N	N	N	S3	N	N
FAe2(r)	N	N	N	N	N	N	S3	N	N
FAe1	N	N	N	N	N	N	S3	N	S3
FAe1(S)	N	N	N	N	N	N	S3	N	N
FAe1(r)	N	S3	N	N	N	N	S3	N	S3
FAa	S3	S2	S3	S2(S3)	S3	N	S3/R/S2	N	S2
FAa(r)	S3	S2	S3	S2/S3)	S3	N	S3/R/S2	N	S2
FAa(g)	S3(N)	S2(S3)	S3(N)	N	N	N	S3	N	S3(S2)
E	N	N(S3)	N	N	N	N	S3	N	N(S3)
E(S)(r)	N	N	N	N	N	N	S3	N	N
E(g)	N	N	N	N	N	N	S3	N	N
UBt	N	S3	N	N	N	N	S3/R/S2	S3	N
UBt(g)	N	S3(N)	N	N	N	N	S3	N	N
UBS2	N	S3	N	N	N	N	S3/R/S2	S3	N
UBS2(g)	N	S3(N)	N	N	N	N	S3	N	N
UBS1	N	S3	N	N	N	N	S3/R/S2	S3	N
UBS1(S)	N	N	N	N	N	N	S3	N	N

Table 13. (Cont.)

UBs1(g)	N	S3(N)	N	N	N	N	S3	N	N
UBb	S3(N)	S2(S3)	S3	S3(S2)	N	N	S3/R/S2	S3	S3
UBb(g)	N	S2(N)	S3(N)	N(S3)	N	N	S3	N	N
UBb-VA	S3	S2	S3	N	N	N	S3/R/S2	S3	S3
URt	N	S3	N	N	S3	N	S3/R/S2	S3(S2)	S3
URt(S)	N	N	N	N	N	N	S3	N	N
URt(g)	N	S3(N)	N	N	N	N	S3	N	N
URs2	N	S3	N	N	S3	N	S3/R/S2	S3	S3
URs2(g)	N	S3(N)	N	N	N	N	S3	N	N
URs1	N	S3	N	N	S3	N	S3/R/S2	S3	S3
URs1(S)	N	N	N	N	N	N	S3	N	N
URs1(g)	N	S3(N)	N	N	N	N	S3	N	S3
URb	S3(N)	S2	S3	S2(S3)	S3	N	S3/R/S2	S2	S2
URb(g)	N	S2(N)	S3(N)	N(S2)	N	N	S3	N	S3
I	S3	S2	S2(S3)	S2(S3)	S3	N(S2)	S2	S2	S2
LP	S3(N)	S2(N)	N	N	S2(N)	N(S2)	S2	S2	S2(S3)
LB	S3	S2	S2	N(S2)	N	N	S2(S3)	S2(S3)	S2(S3)
LB(g)	S3(N)	S2(N)	S2(N)	N(S2)	N	N	S3	N	S3
VA	S3	S2	S3	S2(S3)	S2(S3)	S3(S2)	S3/R/S2	S2	S2(S3)
VA(r)	S3	S2	S3	S2(S3)	S2(S3)	S3(S2)	S3/R/S2	S2	S2
VE	N(S3)	S3(S2)	N(S3)	N(S2)	N	N	S3	N	N
S	N	N	N	N	N	N	S2(N)	N	N
W	N O T A P P L I C A B L E								

Notes: (Table 13)

1. Abbreviations:

   C1 : Smallholder rainfed crop production, low inputs

   C2 : Commercial rainfed crop production, medium inputs

   C3 : Small-scale irrigated crop production

   R1 : Unimproved natural grazing

   R2 : Ranching

   F : Forestry

2. Suitability ratings between brackets apply to small (50%), undifferentiated parts of the mapping units. The first rating applies to most of the mapping unit.

3. R : Stock reduction.

Table 14. Areal extent of land suitability units

Land utilization type	Crops	Suitability areas							
		S1		S2		S3		N	
		ha	%	ha	%	ha	%	ha	%
C1	Maize	0	0	0	0	64,098	24	199,956	76
	Sorghum Millet	0	0	66,539	25	111,725	42	84,888	27
	Ground-nuts	0	0	6,113	2	61,893	24	195,146	74
C2	Grapes	0	0	44,170	17	29,553	11	189,429	72
	Sorghum Millet	0	0	14,797	6	25,828	10	222,527	84
C3		0	0	7,741	3	8,749	3	246,662	94
R1	(a)	0	0	18,785	7	223,890	85	20,725	8
	(b)	0	0	158,186	60	84,489	32	20,725	8
R2		0	0	32,836	12	124,480	47	106,084	41
F		0	0	29,809	11	63,159	24	170,432	65

Notes:

1. R1(a) : without stock reduction

   R1(b) : with stock reduction

This has resulted in low soil fertility, soil erosion and poor structural properties, which directly affect crop productivity, and vegetation degration which affects livestock carrying capacity. Indeed table 14 clearly illustrates the role of land degradation in a comparison between suitability levels for natural grazing (R1) before and after stock reduction. The estimates indicate a dramatic improvement in land suitability could be expected by mere stock reduction.

2. Land with a better potential is generally situated in lower, water receiving areas such as the lowland plains, the intermediate plains, the river valleys, the aggradational footslopes and the upland plain bottoms. Better moisture availability in these areas is to a large extent due to the fact that the degraded upland areas are unable to retain moisture and produce a lot of runoff, but also to other factors such as heavier soils with good moisture holding capacity or the occurrence of perched watertables over old alluvium.

In the following paragraphs the physical suitability of Dodoma Capital City District for the land use types considered can be summarized as follows:

Smallholder rainfed crop production, low inputs (C1)

The best areas for this land utilization type appear the aggradational footslopes, the intermediate plains, the lowland plains; the aggradational river valleys and the upland plain bottomlands with red soils.

It should be noted that even these better areas are at best rated as 'moderately suitable'. In the case of the maize crop there is not even moderately suitable land, while only 2% of the survey area appears moderately suitable for groundnuts. Most of the land is either marginally suitable or unsuitable for this land utilization type (table 14).

Commercial rainfed crop production, moderate inputs (C2)

The best areas for this kind of land use are again the aggradational footslopes, the intermediate plains, the lowland plains, the aggradational river vallyes and the upland plain bottoms with red soils.

A distinction has been made between suitability for mechanized farming of drought resistant staples and for grape farming. In general the indicated areas are considered more suitable for grape farming than for mechanized farming of staple crops in view of the higher market value for grapes. As a matter of fact it is thought that in most areas, with the possible exception of the river valleys and parts of the lowland plains, the expenditure on mechanized farming is only marginally justified. As for the previous land utilization type, most of the survey area is considered unsuitable for the given use (table 14).

Small-scale irrigated crop production (C3)

In view of the inadequacy of the existing reservoirs to provide irrigation water for large areas, large-scale irrigation is considered unfeasible in the survey area. The emphasis of future irrigation development is therefore on small-scale irrigation of high-priced and high-yielding garden crops with moderate capital investment and high labour inputs. Only parts of the river valleys, the intermediate plains and the lowland plains seem to offer a moderate potential for small-scale irrigated agriculture. The main limitation elsewhere is the lack of irrigation water. In all, about 3% of the District or about 7700 ha appears to have a moderate potential for irrigation development.

Unimproved natural grazing (R1)

This is the main land use type in the survey area. Where cultivation is unfeasible, as in the eroded hillslopes, grazing still offers marginal returns. The suitability of those and other upland areas for this land use type strongly depends on the extent of overgrazing. Indeed a comparison of suitability, before and after destocking, (table 14), provides estimates of moderately suitable rangeland of respectively 7% and 60% of the District. The best lands for unimproved natural grazing are again situated in lower, water receiving land such as the intermediate plains, the lowland plains and the aggradational river valleys.

Improved natural grazing (ranching) (R2)

It is considered that for most of the survey area the investiment required for this land use type are not or are at best marginally justified by the potential benefits. The main limitations in this respect are the lack of watering points, the drought hazard and to a lesser extent the predominance of thornbush. The most suitable areas for ranching are located in the aggradational plains, the poorly drained lowland plains, where good grazing grounds are available and water is nearby. A total of about 32,800 ha or 12% of the survey area is considered moderately suitable for ranching. Substantial homogeneous blocks occur only in the lowland plains with poorer drainage.

Forestry

Most of the survey area is considered unsuitable or marginally suitable for afforestation. In only 11% of the District afforestation for commercial production appears to offer a moderate potential. This is a disappointing conclusion, since afforestation of the eroded hillslopes would be the most sensible use for them. However, the limitations of soil depth, droughtiness and poor fertility may prove so severe as to make expenditures for afforestation economically unjustified.

The best areas for afforestation are those that do not need it, such as the aggradational footslopes and the intermediate plains. It may be envisaged to locate in these areas tree plantations for firewood production.

The above findings can be used as a basis for the preparation and implementation of a land use plan for the District. Sound land use planning is all the more required in Dodoma Capital City District because certain areas offer potential for several alternatives while others are suited to none.

The present land suitability study recognizes the fact that the Capital City District is a marginal area for crop production. Even for drought resistant crops at best 25% of the land appears suitable. The main constraints for crop development in the District are low and unreliable rainfall and severe land degradation, as expressed by low soil fertility, sheet and gully erosion, poor structural properties and vegetation degradation. Whereas climate is beyond human control, the other limitations can be corrected by improved management.

The correction of soil limitations appears technically and economically feasible but is clearly a long-term job. Proper crop management should be directed towards optimal moisture conservation, enhanced soil fertility and reduce erosion hazard. Especially soil fertility needs to be improved throughout the survey area, preferably by generous applications of manure as this is likely to improve soil structure and moisture conservation, and reduce soil erodibility as well. However, this would require a more thorough integration of the large livestock population into the farming system. Also specific techniques for soil and moisture conservation that are best adapted to this dryland area need to be worked out by agronomists and extension workers. The potential for irrigated development and grape cultivation deserves further study in the designated areas.

Some areas with apparently vigorous grass cover and nearby water sources exist in the survey area. Their potential for rangeland development deserves further study by range specialists. In the degraded upland areas the major constraint for rangeland development, overstocking, is technically easy to overcome but probably socially unacceptable, as it would involve large-scale stock reduction.

With some exceptions, the potential for forestry in Dodoma Capital City District, aimed at commercial production, is very limited. In view of the harsh conditions prevailing on the eroded hillslopes, afforestation efforts to rehabilitate badlands are bound to run into trouble where they are most needed. In respect of forestry development in the District following observations are suggested for consideration :

1. Large-scale afforestation of eroded lands with climax species may prove technically unfeasible and economically unjustified. It might be more appropriate to allow regeneration of the natural vegetation through the various successional stages, since pioneer species are more exposure and harsh sites. This long-term strategy would necessitate protection from grazing and fire.

2. The choice of species for afforestation is critical. Selection of unsuitable species may result in much wasted effort, time and money. Local tree species should be given first consideration.

3. Afforestation for commercial firewood production appears economically justified in restricted areas with good, deep soils and favourable moisture conditions. Careful site selection is required. In this respect further study of the aggradational footslopes and the intermediate plains can be recommended.

On the basis of its physical land suitability study the soil survey team would recommend following land uses for the major land types of Dodoma Capital City District :

Mountains:

Forest and game reserve. Protected woodland for watershed conservation.

Hills and inselbergs:

Protective vegetation cover.

Footslopes:

a. Erosional footslopes : protection from grazing to promote rehabilitation of the natural vegetation.

b. Aggradational footslopes :

- smallholder cultivation of drought resistant crops, possibly grapes.
- afforestation for commercial firewood production.

Upland plains:

a. Upland plains with brown soils and termite mounds : unimproved natural grazing.

b. Upland plains with red soils and without termite mounds :

- water-receiving positions (bottomlands) : smallholder cultivation drought resistant crops, possibly grapes.
- watershedding positions (slopes and crests) : unimproved natural grazing.

Intermediate plains:

- smallholder cultivation of drought resistant crops, possibly grapes
- ranching
- unimproved natural grazing
- afforestation for commercial firewood production

Lowland plains:

- mechanized cultivation of drought resistant crops
- ranching
- unimproved natural grazing

River valleys:

a. aggradational valleys :

- smallholder cultivation of drought resistant crops, possibly maize
- grapes

b. Erosional valleys : protective vegetation cover.

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Technical Appendix I

SOIL SURVEY METHODS

The soil survey of Dodoma Capital City District was carried out on the basis of field observations, together with interpretation of aerial photographs, topographical maps, geological maps and climatic data. The survey methods comprise a set of interactive operations which can conveniently be grouped into Field Methods, Office Methods and Laboratory Methods.

AI.I. FIELD METHODS

Fieldwork was started in January 1979 and completed in August 1979. The number of field parties carrying out the survey varied from three to four. One party was in charge with the correlation of incoming field data and the interpretation of aerial photographs at the field office in Dodoma. In the last month of the fieldwork one party was continuously devoted to the identification and mapping of land use, vegetation and soil erosion, through aerial photo-interpretation supported by field observations. The photo-interpretation was later continued at the National Soil Service offices in Mlingano. Another field party carried out infiltration rate measurements at 9 sites on representative soils with self-made double ring infiltrometers. These tests were run in triplicate.

Initially reconnaissance trips were undertaken throughout the area and soil observations were mainly made along roads. Preliminary physiographic and soils legends were then prepared and on the basis of the provisional physiographic units field traverses were selected. The traverses were covered on foot or where possible by car, and soil observations made by spade and auger. Major soils were described in detail from pits and samples were taken for laboratory analysis and soil correlation. Notes on land use, geology, natural vegetation, relief, soil erosion etc. were also taken. As field work progressed the physiographic and soils legends were gradually improved and the mapping updated.

A total of 500 soil observations were made of which 103 were profile pits and 350 soil samples were collected for analysis. Partitioned boxes made of galvanized ironsheeting were used for soil correlation at the field office. From some of thsse representative profile pits an additional total of 30 samples were taken for determinations of available waterholding capacity.

AI.2. OFFICE METHODS

Following a preliminary visit to the area, existing information on climate, geology, vegetation and soils was compiled and studied. A full list of consulted literature and base documents with particular relevance to the Dodoma area is included at the end of this Appendix.

The main base documents were 1:50,000 topographic maps prepared by the Survey and Mapping Division, Dar es Salaam and aerial photographs at 1:40,000 and 1:25,000 scale. The first set of photographs, dating from 1969, was obtained from the Survey and Mapping Division, the second set dating from 1978 from the Ministry of Capital Development. Other available base materials included geological reports and maps (at scales 1:250,000 and 1:125,000) and a complete record of daily rainfall at Dodoma town for the years 1939-79 obtained from the Meteorological Department, Dar es Salaam.

Interpretation of aerial photographs and topographic maps was undertaken in the field office and continued at the main office in Mlingano. On the basis of the 1:50,000 topographical maps a slope map was prepared at the same scale, which proved very useful in the delineation of physiographic units and in the identification of linear features on the otherwise uniform upland plains.

On the basis of the 1:40,000 aerial photographs a physiographic map was prepared which served as a framework for soils mapping. By means of a stereoscope the boundaries of the mapping units were traced on transparent overlays and later transferred on the 1:50,000 topographical maps by means of a stereoplotter.

The 1:25,000 scale photographs were very practical for the selection of sampling sites and orientation in the field. In view of the visual quality and very recent nature of the photographs it was considered feasible to prepare a detailed map of land use, vegetation types and soil erosion, which served as an input to the land suitability evaluation. This map was prepared in a similar manner by means of a stereoscope by tracing on transparent overlays and subsequent reduction to 1:50,000 scale by means of a stereo-plotter.

The 1:25,000 photographs were less useful for physiographic mapping because of the excessive detail provided by the larger scale and the high time requirements for their interpretation. However, certain soil patterns which were difficult to map in a consistent manner from the 1:40,000 photographs, could be easily observed and mapped from the larger-scale photographs. This applies particularly to the red soils on the upland plains which were characterized by an abrupt, smooth, dark tone. Also some soil units (V-soils) in the lowland plains could be more easily recognized, as well as gully erosion.

After completion of the field work a final correlation and mapping of the soils recognized in the area was carried out at the main office in Mlingano, on the basis of all available field and soil analytical data. To assist in the correlation process the soils were classified in terms of both the FAO/UNESCO Legend of the Soil Map of the World and the USDA Soil Taxonomy.

Following a detailed review of the mapping units established in the field and transferred from the aerial photographs onto the 1:50,000 topographical maps, a final legend for the Soils and Physiography Map was prepared. Due to the complexity of the soil pattern and the restricted amount of observations, individual soils could usually not be mapped separately. Instead soil associations were delineated which include one or more soils as the most common within a specific mapping unit.

AI.3. LABORATORY METHODS

The soil samples were analyzed in the Central Soils Laboratory of the Agricultural Research Institute, Mlingano using internationally accepted methods.

Particle size distribution was estimated by the Bouyoucos hydrometer method using Calgon as dispersing agent.

Soil pH was measured in water and 0.01 M calcium chloride suspension using a pH-meter with glass and reference electrodes. A soil:solution ration of 1:2.5 was used.

Walkley and Black's chromic acid oxidation method was used in determining organic carbon. Nitrogen was estimated by the semi-micro Kjeldahl method.

Available phosphorus was extracted with 0.03 M ammonium fluoride in 0.025 M hydrochloric acid (Bray and Kurtz I solution) and estimated colorimetrically by the molybdenum blue method.

Exchangeable bases were extracted with neutral, normal ammonium acetate solution. Sodium and potassium were estimated using flame photometer. Calcium and magnesium were estimated by complexometric titration with EDTA using calcon and crichrome black T as indicators.

Where analyzed, CEC was determined by saturation with IN NH_4Ac at pH 7 followed by replacement with 4% KCl and distillation of the absorbed ammonia.

AI.4. CONSULTED DOCUMENTS (excluding references)

Base maps and aerial photography

Topographical maps :

1:50,000 : 143/III (Mundemu)
143/4 Hombolo
144/3 Dabalo
162/I Dodoma West
162/2 Dodoma East
163/I Chilonwa
162/3 Iuatu
162/4 Mvumi
163/I Chilonwa

1:25,000 : enlargements prepared by CDA from 1:50,000 topographical maps. 3 big sheets covering about 70% of the survey area, complete in the west, covering the east up to 32°E, complete in the south, covering the N up to 36°N.

Geological maps :

142: Bahi (5°30'S to 6°00'S; 35°00'E to 35°30'E): scale 1:125,000

143: Meia Meia ($5^{o}30'S$ to $6^{o}00'S$; $35^{o}30'E$ to $36^{o}00'E$): scale 1:125,000

144: Zoissa ($5^{o}30'S$ to $6^{o}00'S$; $36^{o}00'E$ to $36^{o}30'E$): scale 1:125,000

52: Dodoma ($6^{o}S$ to $7^{o}S$; $35^{o}E$ to $36^{o}E$): scale 1:250,000 (with explanatory text)

Aerial photographs :

1:12,500 + mosaics : excellent quality; covering whole CCD (1974)

1:25,000 (Geosurvey): excellent quality, covering about 75% of Dodoma Region and whole CCD (1978).

1:40,000 (Lands and Survey Division): good quality, covering whole CCD(1960)

Map of physiography :

(1:50,000): draft map prepared by Project Planning Associates as a basis for their map of "Physiography/Terrain Units" in Tec. Suppl.62 (1976).

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Technical Appendix 2

ASSESSMENT OF DEPENDABLE MOISTURE AVAILABILITY FOR MAIZE, SORGHUM AND GROUNDNUTS IN DODOMA CAPITAL CITY DISTRICT

A2.1. INTRODUCTION

Dodoma Capital City District is one of the driest areas in Tanzania. The average annual rainfall is low (about 570 mm) and occurs for more than 90% during four rainy months (December to March). The rainy season is monomodal without well pronounced maxima. Rainfall variability is high and the distribution is positively skewed, in other words there is more chance that rainfall will be below the average than above. Only four months have significant reliable rainfall and the growing season for rainfed annual crops will therefore be confined to these four months.

It is clear that with the short growing season and the considerable variability that may affect it, the prime requirements for successful rainfed crop production in the District are that the crops or crop varieties have growth cycles that are matched to the short season, that the crops are drought tolerant and are planted as soon as possible to make optimal use of the rainfall. Yet, experience in the area shows that even under these conditions drought resistant crops fail periodically and the question thus arises whether rainfed crop production in the District that does not benefit from other moisture additions, does not entail unacceptable risks of crop failure. To answer this question it is essential that the hazards to crops due to inadequate moisture availability are correctly perceived and, if possible, quantified. Thus the basic question that needs to be answered is:

"What is the probability of a crop failure by inadequate moisture availability?"

This question will be addressed by means of a crop-specific water-balance model that is explained in following section.

A2.2. PRINCIPLES OF THE METHOD

As indicated in Chapter 2.2, moisture availability for plants is subject to considerable year-by-year fluctuations. It can therefore not be analyzed through average data. To make this point clear 'moisture availability' as a land quality has been replaced in the present study by the concept of 'dependable moisture availability'. While the former refers to the average amount of soil moisture available to plants, the latter refers to the amount of moisture that can reasonably be expected over a long series of growing periods.

The new land quality "dependable moisture availability" is assessed by a method which is basically a waterbalance study based on following principles :

a. A waterbalance is crop-specific. Water demand is expressed by the crop water requirement or maximum crop evapotranspiration (ETm), not by the potential evapotranspiration (ETo). The crop water requirement is estimated by multiplying the Penman-potential evapotranspiration estimates with crop coefficients, which are crop-specific and vary according to the growth stage of the crop. Moreover the waterbalance model considers specific crop characteristics related to moisture needs, such as the length of various growth stages, the degree of effect of moisture stress at these growth stages and the rooting habits.

b. A waterbalance is based on the comparison of actual rainfall figures with ETm-normals. This implies that a long series of years have to be considered, a waterbalance prepared for each growing season followed by probability estimates of moisture availability over the period.

c. The growing season is divided into a number of time periods (months, weeks or days). The major parameter to assess moisture availability in each time period is the ratio of actual crop evapotranspiration (ETa) to crop water requirement (ETm). It is hereby assumed that an evapotranspiration deficit will express itself by a yield reduction when comparised with a theoretical, water-constraint-free yield.

d. Each growing season is characterized by a moisture index, obtained from a crop-specific and cumulative combination of the ETa/ETm-ratios of the individual time periods. When this moisture index for the growing season concerned is less than 50%, a crop failure is assumed; the probability that such crop failure could occur over the long term is then assessed by means of a cumulative frequency distribution.

e. From the probabilities of not exceeding the critical value (50%), dependable moisture availability is assessed as follows :

Probability of crop failure by inadequate moisture availability	Degree of limitation
0-10% probability of crop failure	No or slight limitation
11-20% probability of crop failure	Moderate limitation
21-40% probability of crop failure	Severe limitation
40% probability of crop failure	Very severe limitation

Other class intervals may be adopted in function of the land use type or management level under consideration.

A2.3. THE WATERBALANCE MODEL

For Dodoma town daily rainfall records were compiled covering 41 years (1939-80). Long-term records for other stations being incomplete or too short, it was assumed that most of the District is homogeneous in terms of rainfall and well represented by the data for Dodoma town.

The daily rainfall data for the growing period were grouped into weekly amounts and matched in a waterbalance with weekly crop water requirement normals, for three crops in relation to the storage capacity within rooting depth for three soil groups.

The crops and crop varieties selected for this study are Katumani maize, groundnuts of the erect bunch habit, and Serena sorghum. All these crops have short growth cycles of approximately 15 weeks that match closely the reliable growing season of approximately 4 months.

The soils of the survey area were classified into three categories according to their waterstoring properties (AWC) as follows :

Soils	Soil group		
	(1)	(2)	(3)
Rc		x	
Rl		x	
Rs	x		
Bl		x	
Bs	x		
D		x(°)	x(°)
C/A		x	
A			x
F			x
V			x

Soil group 1 : AWC approx. 50 mm/m
Soil group 2 : AWC approx. 100 mm/m
Soil group 3 : AWC approx. 150 mm/m
(°) pro partim

On the basis of the waterbalance a moisture index was calculated for each growing season. The set of moisture indices was then plotted in a cumulative frequency diagram and from the curve "probabilities of crop failure" could be derived.

The model has following specifications :

a. The waterbalance model is a very simple one, adopted from Thornthwaithe and Mather (1957) and Sansom (1954) with one notable difference: instead of potential evapotranspiration (ETo), the crop water requirement (ETm) represents the water demand. The basis equations of this waterbalance model are :

if $R_i + (Sa)_{i-I} \quad (ETm)_i$ then $(ETa)_i = (ETm)_i$

$(Sa)_i = R_i + (Sa)_{i-I} - (ETm)_i \quad (Smax)_i$

if $R_i + (sa)_{i-I} \quad (ETm)_i$ then $(ETa)_i = R_i + (Sa)_{i-I}$

$(Sa)_i = 0$

in which ETm : crop water requirement
R : rainfall
Sa : actual soil moisture storage
ETa : actual crop evapotranspiration
Smax : maximum soil moisture storage = AWC x d with
AWC : available waterholding capacity (mm/m)
d : rooting depth
$(ETa)_i$, $(ETm)_i$, etc.... : actual evapotranspiration, crop water requirement etc. during week i.
$(Sa)_{i-I}$: actual soil moisture storage in week immediately preceding week i.

The shortest period considered for the waterbalance calculations is a week. The available waterholding capacities for the different soil groups are measured averages. Rooting depths of the selected crops were considered to vary over the length of their growth cycle as follows :

Crop	Weeks of the growth cycle	Rooting depth (cm)	Maximum moisture storage capacity within rooting depth (Smax) (mm) soil group		
			1	2	3
Serena sorghum	1-3	30	15	30	45
	4-7	100	50	100	150
	8-15	150	75	150	225
Katumani maize	1-3	30	15	30	45
	4-7	80	40	80	120
	8-16	120	60	120	180
Groundnuts	1-3	30	15	30	45
	4-7	60	30	60	90
	8-15	100	50	100	150

Inherent assumptions in this model are :

1) all rainfall infiltrates into the soil and is 100% effective.
2) the soils have no other sources of additional moisture such as groundwater, lateral seepage or runoff.
3) actual evapotranspiration is not affected by depletion of soil moisture.

b. In analogy with actual farming practices, planting starts when there is enough moisture by rain or storage. If the earliest considered planting time is virtually rainless, planting is automatically postponed until enough moisture is available. The decision to postpone planting to a later date than the considered planting week is taken if rainfall plus storage do not exceed 20 mm. As earliest planting week has been taken the week of 1-7 December.

c. The moisture index selected to characterize moisture availability in a particular growing season is the Yield and Water Index. This index was introduced in Tanzania by the FAO Early Warning and Crop Monitoring Project (EWCMP, 1980) on the basis of the work of Doorenbos and Kassam (1979).

Doorenbos and Kassam state that the effect of waterstress on yield can be quantified by the following relationship between relative yield reduction and relative evapotranspiration deficit :

$$(I - Ya/Ym) = ky(I - ETa/ETm)$$

in which Ya is the actual yield, Ym the water constraint-free yield and ky is the empirically derived yield response factor. This factor quantifies the sensitivity of a crop or crop growth stage to water-stress.
For the selected crops the values of ky per growth stage are given in table 15.

Table 15. Growth stages and yield response factors for maize, sorghum groundnuts

Growth stage	Crop					
	Sorghum		Maize		Groundnuts	
	Length	ky	Length	ky	Length	ky
Vegetative stage	1-6	.2	1-6	.4	1-5	.2
Flowering stage	7-8	.55	7-8	1.5	6-9	.8
Yield formation stage	9-13	.45	9-13	.5	10-13	.6
Ripening stage	14-15	.2	14-16	.2	14-15	.2

The YWI indicates to what extent the actual yield may approach the water constraint-free yield if other agronomic factors are not limiting. It is calculated by setting its value at planting time at 100 and successively reducing this value by the percentage yield reductions occurring at successive growth stages as follows :

1) for each growth stage the arithmetic mean of weekly ETa/ETm-ratios is taken : (ETa/ETm) with j= 1, 2, 3, or 4.
2) the yield reduction % at stage j is calculated as $R_j = (100 - (ETa/ETm)_j)ky_j$
3) the YWI at stage j is calculated by following iterative equation : $I_j = I_{j-I}\ (I - R_j/100)$.

The major significance of the YWI is that it establishes a relationship, albeit approximate with yields.

d. The cumulative frequency distribution of YWI-values for all cropping seasons is plotted on probability graph paper, using the formula of Weibull to estimate the cumulative frequencies.

$$\text{cumulative frequency} = \frac{100\ m}{N + I}$$

with N : total number of data and m : rank number with m + I for the highest value.

A2.4. RESULTS

Yield and Water Indices for the considered crops grown on particular soil types are given for each analyzed cropping season in table 17. Table 16 gives some characteristics of the distributions of YWI-values for the considered crops and soil types. The frequency distribution curves are shown in figure 1 - 3.

Table 16. Characteristics of the distributions of YWI

Parameter	Crop								
	Maize			Groundnut			Sorghum		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Average YWI	31	37	40	44	50	52	58	60	61
Standard deviation YWI	27	29	29	18	20	21	17	18	18
80% probability minimum yield (%)	0	3	6	29	32	32	40	40	40
Coeff. variation YWI (%)	85	77	72	40	40	40	30	30	30
Probability of crop failure	66	62	57	54	48	40	33	31	29

(1) Soil group 1 : AWC approx. 50 mm/m (soils Rs, Bs)
(2) Soil group 2 : AWC approx. 100 mm/m (soils Rc, Rl, Bl, D, C/A)
(3) Soil group 3 : AWC approx. 150 mm/m (soils D, A, V, F)

From these tables it is obvious that the variability of moisture availability among seasons is considerable and may affect crop yields seriously in relation to water constraint-free yields.

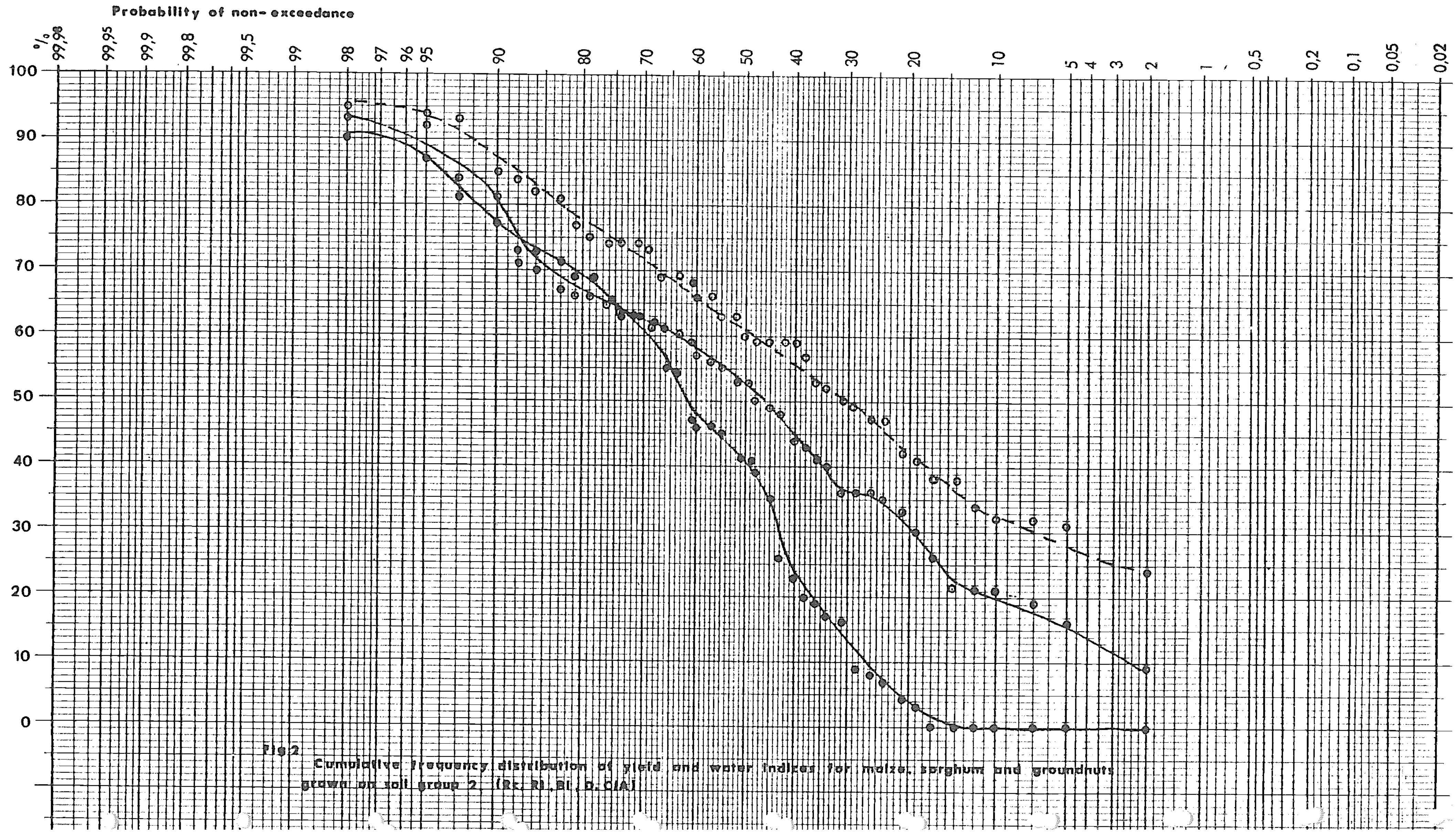

Fig 2

Cumulative frequency distribution of yield and water indices for maize, sorghum and groundnuts grown on soil group 2. (Rc, Rl, Bl, D, OIA)

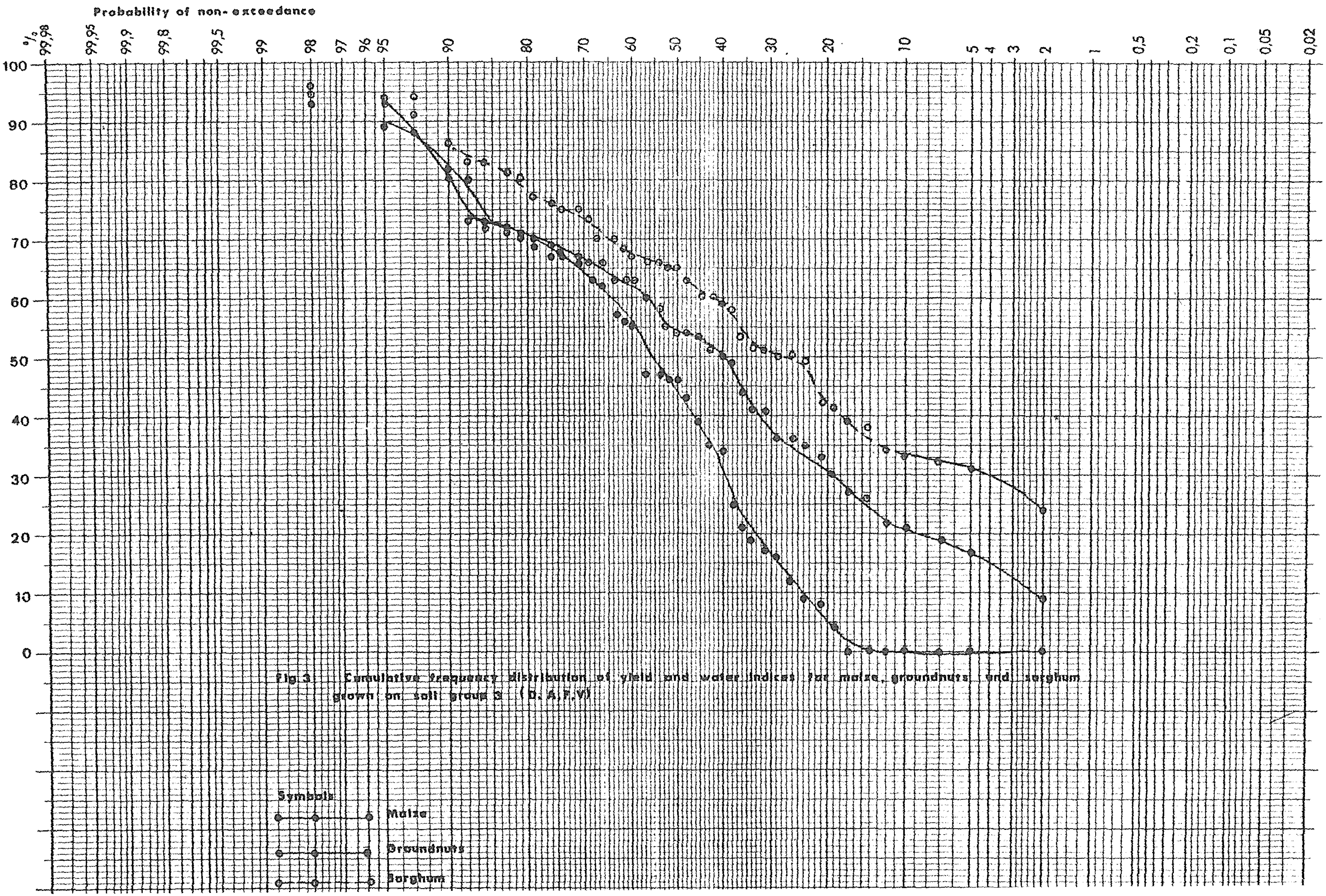

Fig.3 Cumulative frequency distribution of yield and water indices for maize, groundnuts and sorghum grown on soil group 3 (D. A. F. V)

Table 17. Yield and Water Indices per growing season

Growing season	Crop								
	Maize			Groundnuts			Sorghum		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
1939-40	53	55	57	54	63	71	80	82	83
1940-41	69	77	80	64	81	82	81	85	86
1941-42	62	69	69	48	56	63	70	73	73
1942-43	25	47	47	57	70	72	66	68	68
1943-44	40	41	43	64	66	67	65	66	67
1944-45	42	45	46	52	53	54	67	69	70
1945-46	3	3	4	16	16	17	33	34	34
1946-47	73	81	88	75	84	92	84	94	94
1947-48	15	16	16	28	33	33	41	42	42
1948-49	52	54	55	48	49	49	62	63	63
1949-50	40	41	46	64	65	70	69	69	70
1950-51	35	35	35	56	56	56	59	59	59
1951-52	0	4	25	37	48	58	43	47	51
1952-53	0	0	0	9	9	9	23	24	24
1953-54	0	0	0	17	21	26	30	31	31
1954-55	0	0	0	35	36	36	51	52	52
1955-56	65	71	72	52	62	66	71	74	75
1956-57	20	20	21	52	53	54	56	57	58
1957-58	86	90	93	92	93	95	93	95	96
1958-59	13	26	34	53	57	63	59	59	66
1959-60	78	87	89	79	92	93	89	93	94
1960-61	20	39	39	35	43	44	52	53	53
1961-62	64	73	80	52	61	70	67	74	80
1962-63	19	46	56	35	44	51	53	59	65
1963-64	68	73	73	53	63	63	83	84	83
1964-65	18	19	19	43	50	50	59	60	60
1965-66	0	23	67	30	41	53	39	63	65
1966-67	7	7	9	21	21	21	38	38	38
1967-68	9	9	12	35	36	41	48	48	50
1968-69	17	17	17	22	22	22	41	41	41
1969-70	44	46	47	39	40	41	58	59	60
1970-71	62	62	62	67	67	67	81	81	81
1971-72	18	65	67	48	59	69	63	77	77
1972-73	64	69	71	54	66	66	72	74	75
1973-74	0	0	0	19	19	19	32	32	33
1974-75	0	0	0	32	35	35	50	50	50
1975-76	0	0	0	30	30	30	32	32	32
1976-77	62	63	63	54	60	60	66	66	66
1977-78	0	0	0	25	26	27	37	38	39
1978-79	96	63	66	53	71	73	71	75	76
1979-80	8	8	8	36	36	36	48	49	49

(1) Soil group 1 : AWC approx. 50 mm/m
(2) Soil group 2 : AWC approx. 100 mm/m
(3) Soil group 3 : AWC approx. 150 mm/m.

This effect is most pronounced om maize, whereas for groundnuts and particularly sorghum the yield reductions caused by moisture stress, although still considerable are much less. Maize is therefore an unsuitable crop in the District under entirely rainfed conditions. Of the three crops, the probability of crop failure is the highest for maize, and the average yield over the return period is estimated at 30-40% of the water-constraint-free yield. In additon, it seems likely that in one year out of five the yield will be virtually nil. A final handicap is that these drought or 'famine years' tend to persist over consecutive seasons (see table 17).

Groundnuts also have a very high probability of crop failure, but the average yield that can be expected over a 40-year return period is higher (44-52% of the water constraint-free yield) and in most years (4 out of 5) the expected yield is likely to exceed 30% of the constraint-free yield.

Sorghum yields are least affected by rainfall variability : the average yield over the return period is about 60% of the water constraint-free yield, in 4 years out of 5 at least 40% of the constraint-free yield can be expected, and the probability of crop failure is the lowest of the selected crops. Although maize is still likely to outyield sorghum in rainfall years, sorghum will have the most stable crop performance over the long term and will be least affected by the climatic vagaries.

Under the climatic conditions prevailing in the Capital City District the role of soils as a moisture storage bank to alleviate rainfall deficiencies, appears minor. Table 18 indicates that high relative increases in the AWC from soil group I (AWC : 50 mm) to soil group 3 (AWC : 150 mm) only results in modest changes of the main yield parameters. The moisture storage properties of the soil type appear more crucial for maize and groundnuts, than for drought resistant sorghum.

Table 18. Relative changes in yield parameters from soil group I to 3

	Relative increase/decrease (%)		
	Maize	Groundnut	Sorghum
AWC (+300%)			
Average YWI	+29	+18	+ 5
80% probability min. yield	-	+10	+ 5
Probability crop failure	-14	-26	-13

A general conclusion from this analysis is that rainfed cultivation in the Capital City District without moisture additions from other sources entails high probabilities of crop failure and considerable yield reductions, even for drought-resistant crops. Soil moisture properties influence these risks to a minor extent only. These results are in conformity with present land-use patterns, whereby intensive cultivation is concentrated in lower-lying water-receiving areas and little cultivation occurs on watershedding uplands.

Technical Appendix 3

DESCRIPTIONS AND ANALYTICAL DATA OF REPRESENTATIVE SOIL PROFILES

Profile number	Soil unit	Mapping unit	Soil classification	
			FAO	USDA
143/4/5	Rc	FBeI	Ferralic Cambisol	Oxic Dystropept
162/1/2	Rl	FAe2	Dystric Cambisol	Typic Dystropept
162/2/19	Rl	UBt	Dystric Cambisol	Ustic Dystropept
143/4/13	Rl	VA(r)	Chromic Cambisol	Typic Ustropept
162/1/15	Rs	FAeI	Ferralic Arenosol	Ustoxic Quartzipsamment
143/4/22	Rs	UBt	(Ferralic?) Arenosol	('Ustic'?) Quartzi-psamment
162/1/14	Bl	UBb	Dystric Cambisol	Ustic (Fluventic) Dystropept
143/4/14	Bl	UBb	Dystric Cambisol	Typic Dystropept
143/4/11	Bs	UBt	Cambic Arenosol (petric phase)	'Ustic' Quartzipsamment
143/4/1	D	I	Eutric Cambisol	Typic Ustropept
162/2/9	A	UBb-VA	Eutric Fluvisol	Typic Ustifluvent
163/1/2	C/A	VA	Chromic Cambisol	(Fluventic?) Ustropept
162/2/12	C/A	VA	Dystric Cambisol	Fluventic Dystropept
143/4/17	F	LB	Haplic Phaeozem	(Cumulic) Haplustoll
162/2/18	F	LB	Eutric Cambisol	(Vertic?) Ustropept
143/4/18	V	LP	Pellic Vertisol	Entic Pellustert
162/2/15	V	LP	Pellic Vertisol	Entic Pellustert
143/3/2	V	S	Pellic Vertisol	Entic Pellustert

Table 19. Physical properties of selected profiles

Profile No.	Soil Unit	Soil Classification		Texture		Bulk density		Available water
		FAO	Soil Taxonomy	Topsoil	Subsoil	Topsoil	Subsoil	mm/m
143/4/5	Rc	Ferralic Cambisol	(Oxic) Dystropept	C	C	1.21	1.24	119
143/4/6A				SCL	SCL	1.41	1.39	152
143/4/14	Bl	Dystric Cambisol	Ustic Dystropept	LS-Sl	SL-SCL	1.46	1.47	98
143/4/13	Rl	Chromic Cambisol	Typic Ustropept	SL-SCL	SCL	1.38	1.37	116
143/1/6A		Arenosol	Quartzipsamment	LS	SL	-	1.53	71
162/1/14	Bl	Dystric Cambisol	Ustic Dystropept	SL	SCL	-	1.60	91
162/1/15	Rs	Ferralic Arenosol	Ustoxic Quartzipsa-mment	LS	LS	1.58	1.61	30
162/2/18	F	Eutric Cambisol	(vertic) Ustropept	C	C	0.98	0.92	164

Profile number: 143/4/5

Map number: 143/4

Location: about 0.5 km from Hombolo Makulu village, along Meia-Meia road, 30 m north of road; (coordinates ZJ 264 483)

Soil unit: Rc

Mapping unit: FBel

Date of examination: 2/3/79

Surveyors: Mmari/Kiwelu

Classification: FAO: Ferralic cambisol
USDA: (oxic) Dystropept

Climate: Bsh (Köppen)

Landform: almost flat, pediment

Site: almost flat, slope 1.7%

Microrelief: None

Parent material: colluvium derived from schists

Vegetation: Tree spp, Baobab, Mhogolo, Mtumba, acacia Muyinga, msele Mtambala. Grass and herbs mbigili.

Land use: Grazing at the site of observation, crop land on the adjacent land:- maize, sorghum, bulrush millet.

Drainage: well drained; run-off and internal drainage both medium.

Moisture condition: Dry throughout the profile

Ground water: Nil

Rock outcrop/surface stones: None

Erosion/deposition: Sheet erosion

Others: None.

Brief profile description:

Deep, porous well drained dark red clay with moderate to strong sub-angular blocky structure, developed on colluvial material derived from schist; very strongly acid.

Individual horizon description:

0-14 cm	Dark red (2.5 YR 3/6) moist, dark reddish brown (2.5YR 3/4) dry; fine clay: moderate find and medium, sub-angular blocky; sticky and plastic wet; friable moist; hard dry; few very fine and fine tubular pores; many fine roots; pH 4.8; gradual smooth boundary.
14-33 cm	Dark red (2.5 YR 3/5) moist, dark red 2.5YR 3/6) dry; fine clay; strong, medium and coarse subangular blocky; sticky and plastic wet, friable moist, slightly hard dry; common very fine and fine tubular pores; many fine roots; pH 4.4; gradual, smooth boundary.
33-192 cm	Dark red (2.5 YR 3/6) moist, red 2.5YR 4/6) dry; fine clay; moderate fine and medium, subangular blocky; sticky and plastic wet, friable moist, slightly hard dry; common very fine and fine, tubular pores; few fine and medium roots; pH 3.8.

SOIL ANALYTICAL DATA

Mapping unit: FBel
Date of sampling: 2/3/1979
Soil unit: Rc

Profile No.: 143/4/5
Surveyor(s): Mmari, Kiwelu

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8352	0-14	4.8	4.6	36.8	9.6	4.4	49.2
53	14-33	4.4	4.2	32.8	7.0	5.0	55.2
54	33-70	3.8	3.7	33.2	7.6	6.6	53.2
55	70-192	3.6	3.5	31.8	7.0	8.0	53.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (sum)
0.98	0.085	12	0.1	0.7	4.4	8.0	13.2	18.00
0.59	0.050	12	0.2	0.3	4.0	2.4	6.2	13.00
0.49	-	-	0.2	0.2	2.8	4.0	7.2	15.00
0.20	-	-	0.2	0.2	2.4	7.2	10.0	12.00

Texture class	Silt/ clay	CEC meg/ 100g clay	ESP	base saturation %	P ppm
C	0.3	36.6	0.6	73	Trace
C	0.2	23.6	1.3	53	1
C	0.3	28.2	1.3	48	Trace
C	0.3	22.6	1.7	83	1

Profile number: 162/1/2
Map number: 162/1
Location: Kikuyu Hill, about 4 km. southwest of Dodoma, 500 m upslope from Iringa road; coordinates ZJ 013 139
Date of examination: 23/2/1979
Surveyors: De Pauw
Soil unit: R1
Mapping unit: FAe1
Soil classification: FAO: Eutrict cambisol
USDA: Typic Ustropept
Landform: Pediment, middle slope
Site: Undulating, slope 5%
Microrelief: -
Elevation: 3900'
Climate: Bsh (Köppen)
Parent material: Granite
Land use/Vegetation: Fallow land, many low acacia bushes, dense grass and herb cover. Maize plots interspersed with groundnuts. Fields well weeded
Moisture condition: Moist throughout
Ground water: -
Drainage class: Well drained: Runoff-medium on Fallow-land-rapid on cultivated slopes
Rock outcrops/surface stones: Farther on up-slope
Erosion/Deposition: Several rills in cultivated fields. Sand deposition on surface
Others: -

Brief Profile Description:

Moderately deep, dark reddish brown sandy clay. Bedrock at about 77 cm.

Individual horizon description:

0-10/15 cm	Dark reddish brown (5YR3/3.5) moist; sandy clay loam; weak, medium to coarse crumbs; moist friable, wet non-sticky non-plastic; common fine and many fine pores; common very fine roots; some smooth tunnel linings due to termited; pH 5.6; abrupt wavy boundary.
10/15-60/65 cm	Dark red to red (2.5YR3.5/6) moist sandy clay; moderate fine angular blocks; moist friable, wet slightly stickly slightly plastic; many fine and very fine pores; few coarse and medium and common fine and very fine roots; smooth linings on aggregated surfaces; pH 6.0; clear wavy boundary.
60/65-77 cm	Dark reddish brown (5YR3/4) moist; sandy clay; moderate fine angular blocks; moist friable, wet slightly sticky slightly plastic; many fine and very fine pores; common fine and very fine roots; smooth linings on aggregated surfaces; pH 6.1.
77 cm +	(Granite) rock + thin gravelly layer.

SOIL ANALYTICAL DATA

Mapping unit: FAel | Profile No.: 162/1/2
Date of sampling: 23/2/1979 | Surveyor(s): De Pauw
Soil unit: R1

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution Sand	Silt 50-20m	Silt 20-2m	Clay
11.8304	0-10/15	5.6	4.8	66.0	3.0	2.4	28.6
05	10/15-60/65	6.0	5.2	50.2	6.8	1.2	41.8
06	60/65-77	6.1	5.5	47.2	8.6	6.0	38.2

O.C. %	N %	C/N	Exchangeable cations (meg/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (sum)
0.49	0.080	6	0.1	0.1	2.8	3.2	6.2	-
0.36	0.065	6	0.1	0.1	5.2	5.6	11.0	-
0.20			0.2	0.3	7.6	4.8	12.9	-

Texture class	Silt/ clay	Sum bases clay meq/100g ( )	CEC meq/100g clay	ESP	base saturation	P ppm
Scl	0.19	22	-	-	-	3
sc	0.19	26	-	-	-	Trace
sc	0.38	34	-	-	-	1

Profile number: 162/2/19
Map number : 162/2
Location: Road Kitelela - Msalato, 1.5 km from Kitelela, 30 m east of road (coordinates ZJ 130 288)
Date of examination: 10/4/1979
Surveyor(s): Mgogo, Kiwelu
Soil unit: R1
Mapping unit: UBt
Soil classification: FAO: Dystric cambisol
USDA: Ustic Dystropept
Land form: Upland plain, summit
Site: Undulating, slope 2%
Microrelief: None
Elevation: 3480'
Climate: Bsh (Köppen)
Land use/Vegetation: Natural rangeland; grassland with bushes; bare spots
Moisture condition: moist throughout
Ground water: -
Drainage class: Well drained: Run-off: medium; internal: medium
Rock outcrops/Surface stones: -
Erosion/Deposition: Surface wash
Others: -

Brief Profile Description:

Deep, well drained, dark red sandy clay with good structural development, structural grade becoming weak down the profile.

Individual horizon description:

0-23 cm	Dusky red (10R3/3) moist; sandy clay; strong fine and medium sub-angular blocks; moist friable, wet sticky and plastic; many fine roots; pH 6.0; clear smooth boundary.
23-50 cm	Dusky red (10R3/4) moist; sandy clay; strong fine and medium sub-angular blocks; moist friable, wet sticky and plastic; many fine and few medium roots; pH 6.3; gradual smooth boundary.
50-79 cm	Dark red (10R3/6) moist; sandy clay; moderate fine and medium sub-angular blocks; moist friable, wet sticky and plastic; many fine roots; pH 5.9; gradual smooth boundary.
79-130 cm+	Dark red (10R3/6) moist; sandy clay; weak fine and medium sub-angular blocks; moist friable, wet sticky and plastic; many fine roots; pH 6.0

SOIL ANALYTICAL DATA

Mapping unit: UBt

Date of sampling: 10/4/1979

Soil unit: R1

Profile No.: 162/2/19

Surveyor(s): Mugogo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8274	0-23	6.0	5.2	52.8	3.6	3.2	40.4
75	23-50	6.3	5.6	49.8	2.0	1.2	47.0
76	50-79	5.9	5.1	47.8	2.6	3.2	47.4
77	79-130	6.0	5.4	45.8	2.0	4.2	48.0

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (NH_4OAc)
0.85	0.09	9	0.1	0.1	0.4	1.2	-	1.8	12.0
0.60	0.07	9	0.1	0.1	1.2	0.8	-	2.2	-
0.36			0.1	0.1	1.6	0.4	-	2.2	13.0
0.56			0.1	0.1	0.4	1.6	-	2.2	-

Texture class	Silt/ clay	Sum bases meq/100g clay	CEC meq/ 100g clay	ESP	base saturation %	P ppm
Sc	0.17	4	30	0.8	15	1
Sc	0.07	5	-	-	-	Trace
Sc	0.13	5	28	0.8	17	Trace
Sc	0.13	5	-	-	-	Trace

Profile number: 143/4/13
Map number: 143/4
Location: ZJ 304 400, (500 m south of Hombolo experimental station)
Date of examination: 9/3/1979
Surveyor(s): Bomans, Magoggo
Soil unit: R1
Mapping unit: VA(r)
Soil classification: FAO: Chromic Combisol
USDA: Typic Ustropept
Landform: Upland plain, bottom
Site: Flat to almost flat, 1% slope
Microrelief: -
Elevation: 3390'
Climate: Bsh (Köppen)
Parent material: Gneissic regolith
Land use/Vegetation: Tall, dense grass, few baobab trees
Moisture condition: Moist throughout
Ground water: -
Drainage class: Well drained
Rock outcrops: Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, porous and well drained dark red to red sandy loam to sandy clay loam, with slightly acid reaction.

Individual horizon description:

0-13 cm	Dark reddish brown (5YR3/4) moist; sandy loam; moderate medium crumbs; moist friable, wet slightly sticky slightly plastic; many coarse and fine tubular pores many fine roots; pH 6.6; clear smooth boundary.
13-29/30 cm	Dark red (2.5YR2.5/6) moist; sandy clay loam; moderate fine sub-angular blocks; moist friable, wet slightly sticky slightly plastic; common fine tubular pores; common fine roots; pH 6.3; clear smooth boundary.
29/30-51 cm	Dark red (2.5YR3/6) moist, sandy clay loam; moderate fine and medium sub-angular blocks; moist friable, wet slightly sticky, slightly plastic; common fine tubular pores; common fine roots; pH 6.0; clear smooth boundary.
51-110 cm +	Red (10R4/8) sandy clay loam to sandy clay; weak medium subangular blocks; moist friable, wet slightly sticky slightly plastic; common fine tubular pores; pH 6.5 - 6.0.

SOIL ANALYTICAL DATA

Mapping unit: VA (r)
Date of sampling: 9/3/1979
Soil unit: R1

Profile No.: 143/4/13
Surveyor(s): Magoggo, Bomans

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution Sand	Silt 50–20m	Silt 20–2m	Clay
11.8333	0-13	6.6	5.7	76.8	3.0	2.0	18.2
34	13-29/30	6.3	5.6	69.8	2.8	3.0	24.4
35	29/30-51	6.0	5.8	65.2	1.6	1.2	32.0
36	51-80	6.5	6.5	59.2	3.2	3.2	34.4
37	80-110	6.0	5.0	60.8	4.8	1.4	33.0

O.C. %	N %	C/N	Exchangeable cations meq/100g Na	K	Ca	Mg	H	Sum bases	CEC soil (NH_4OAc)
1.37	0.065	21	0.1	0.7	4.0	1.2	-	6.0	14.00
0.69	0.070	10	0.1	0.7	4.8	1.6	-	7.2	-
0.59	0.055	11	0.1	0.7	5.2	2.0	-	8.0	-
0.10			0.1	0.9	5.2	5.6	-	11.8	15.00
0.20			0.1	0.7	3.2	2.8	-	6.8	-

Texture class	Silt/ clay	Sum bases meq/100g clay	CEC meq/100g clay	ESP	base saturation %	P ppm	cm
sl	0.27	33	77	0.7	43	7	.247
scl	0.24	30	-	-	-	2	.200
scl	0.09	25	-	-	-	1	.196
scl	0.19	34	44	-	79	2	.147
scl	0.19	21	-	-	-	2	.196

Profile number: 162/1/15
Map number: 162/1
Location: About 5 km from Zuzu brick factory on road to Bihawana, 20 m west of road; coordinates YJ 928 103
Date of examination: 03/04/1979
Surveyor(s): Mgogo, Kiwelu
Soil unit: Rs
Mapping unit: FAel
Soil classification: FAO: Ferralic Arenosol
USDA: Ustoxic quartzipsamment
Landform: Pediment
Site: undulating, slope 2%
Microrelief: Few termite mounds, up to 1.5 m high
Elevation: 3700'
Climate: Bsh (Köppen)
Parent material: Granitic colluvium
Land use/Vegetation: Abandoned cropland
Moisture condition: Moist from surface
Ground water: -
Drainage class: Somewhat excessively drained. Runoff: medium, internal: rapid
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, yellowish red loamy sand with weak structure and strongly acid reaction.

Individual horizon description:

0-12 cm	Dark reddish brown (YR3/2) moist; loamy sand; weak fine and medium subangular blocks; moist very friable wet non-sticky non-plastic; common fine and medium roots; pH 5.4 clear smooth boundary.
12-28 cm	Dark reddish brown (5YR3/3) moist; loamy sandy; weak fine and medium subangular blocks; moist very friable, wet non-sticky non-plastic; common fine and medium roots; pH 4.9; gradual smooth boundary.
28-57 cm	Yellowish red (5YR3/4) moist; loamy sand; weak fine and medium subangular blocks; moist very friable, wet non-sticky non-plastic; few fine roots; pH 4.9; gradual smooth boundary.
57-88 cm	Yellowish red (5YR4/4) moist; loamy sand; moist very friable, wet non-sticky non-plastic; few fine and medium roots; pH 5.2; gradual smooth boundary.
88-115 cm	Yellowish red (5YR4/6) moist; loamy sand; moist very friable; few fine and medium roots; pH 5.0; gradual smooth boundary.
115-127 cm	Strong brown (7.5YR5/6) moist; loamy sand; moist very friable, wet non-sticky non-plastic; few fine and medium roots; pH 4.8.

SOIL ANALYTICAL DATA

Mapping unit: FAel

Date of sampling: 3/4/1979

Soil unit: Rs

Profile No.: 162/1/15

Surveyor(s): Magoggo/Kiwelu

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8149	0-12	5.4	4.3	87.2	1.0	0.6	11.2
50	12-18	4.9	4.1	88.2	1.0	0.6	10.2
51	28-57	4.9	4.0	86.2	1.0	1.6	11.2
52	57-88	5.2	4.0	86.2	1.0	1.6	11.2
53	88-115	5.0	4.0	86.2	1.0	1.6	11.2
54	115-127	4.8	4.0	83.2	2.0	1.6	13.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
0.49	0.050	10	0.1	0.1	0.8	Trace	1.0	-
0.39	0.030	13	0.1	0.1	1.2	"	1.4	-
0.20	-	-	0.1	0.1	1.2	"	1.4	-
0.29	-	-	0.1	0.1	0.8	"	1.0	-
0.39	-	-	0.1	0.1	0.8	1.6	2.6	-
0.20	-	-	0.1	0.1	0.8	0.4	1.4	-

Texture class	Silt/ clay	Sum bases meq/100g clay	P ppm
ls	0.14	9	16
s-ls	0.16	14	14
ls	0.23	13	11
ls	0.23	9	9
ls	0.23	23	12
ls	0.27	11	7

Profile number: 143/4/22
Map number: 143/4
Location: 1.5 km from junction Hombolo - Meia road to Makutopora
(coordinates ZJ 157 498)
Date of examination: 24/3/1979
Surveyor(s): Mgogo, Kiwelu
Soil unit: Rs
Mapping unit: Ubt
Soil classification: FAO: (Ferralic?) Arenosol
USDA: ("Ustic"?) Quartzipsamment
Landform: Upland plain, slope
Site: Undulating, slope 2.6%
Microrelief: Few scattered termite mounds up to 1 m high
Elevation: 3650'
Climate: Bsh (Koppen)
Parent material: Colluvium
Land use/Vegetation: Maize, sorghum, bulrush millet, groundnuts,
Bushland
Moisture condition: Moist throughout
Ground water: -
Drainage class: Somewhat excessively drained. Run-off: slow;
Internal:rapid
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, somewhat excessively drained, yellowish red strongly acid loamy sand.

Individual horizon description:

0-16 cm	Brown to dark brown (7.5YR4/4) moist; very coarse sand to loamy sand; weak fine sub-angular blocks; friable moist, non-plastic wet; common fine roots; pH 5.1; clear smooth boundary.
16-35 cm	Yellowish red (5YR4/6) moist; very coarse loamy sand; weak fine sub-angular blocks; friable moist, non-sticky non-plastic wet; few fine roots; pH 5.0; clear smooth boundary.
35-58 cm	Reddish brown (5YR4/4) moist; very coarse loamy sand; weak fine sub-angular blocks; friable moist, non-sticky non-plastic wet; few fine roots; pH 4.9; clear smooth boundary.
58-87 cm	Yellowish red (5YR4/6) moist; very coarse to medium loamy sand; structureless single-grain; friable moist, non-sticky non-plastic wet; few fine and medium roots; pH 4.9; clear smooth boundary.
87-140 cm+	Yellowish red (5YR5/6) moist; very coarse to medium sandy loam; structureless single-grain; friable moist, non-sticky non-plastic wet; few fine roots; pH 5.0.

SOIL ANALYTICAL DATA

Mapping unit: UBt
Date of sampling: 24/3/1979
Soil unit: Rs

Profile No.: 143/4/22
Surveyor(s): Magoggo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8190	0-16	5.1	4.2	87.8	1.0	2.2	9.0
91	16-35	5.0	4.2	85.4	2.0	1.6	11.0
92	35-58	4.9	4.2	83.4	3.0	1.6	12.0
93	58-87	4.9	3.6	84.4	1.0	1.6	13.0
94	87-140	5.0	4.2	81.4	3.0	1.6	14.0

O.C. %	N %	C/N	Na	K	Ca	Mg	H( )	Sum bases	CEC soil (NH_4OAc)
0.44	0.045	10	0.1	0.2	0.8	Trace	-	1.1	-
0.45	0.040	11	0.1	0.1	0.8	0.8	-	1.8	-
0.32	0.030	11	0.1	0.1	0.4	0.4	-	1.0	-
0.32	0.030	11	0.1	0.1	0.4	0.4	-	1.0	-
0.19	0.020	10	0.1	0.1	0.8	0.8	-	1.8	-

Exchangeable cations (meq/100g soil): Na, K, Ca, Mg, H( )

Texture class	Silt/clay	Sum bases meq/100g clay	CEC meq/100g clay	ESP	base saturation %	P ppm
ls	0.36	12	-	-	-	3
ls	0.33	16	-	-	-	6
ls	0.38	8	-	-	-	2
ls	0.20	8	-	-	-	2
sl	0.33	13	-	-	-	8

Profile number: 162/1/14
Map number: 162/1
Location: About 4 km from Zuzu brick factory on road to Bihawa, 10 m. E. of road, coordinates YJ 934 127
Date of examination: 03/04/79
Surveyor(s): Mgogo, Kiwelu
Soil unit: B1
Mapping unit: UBb
Soil classification: FAO: Dystric cambisol
USDA: Ustic (Fluventic) Dystropept
Landform: Upland plain, bottom
Site: Almost flat, slope ½%
Microrelief: -
Elevation: 3650'
Climate: Bsh (Köppen)
Parent material: Granitic regolith
Land use/Vegetation: Adjacent land cultivated for maize, sorghum and bulrush millet
Moisture condition: Moist throughout
Groundwater: -
Drainage class: Well drained. Run-off: medium, internal: medium
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: Termite burrows and nest throughout the profile.

Brief Profile Description:

Deep, brownish sandy loam to sandy clay loam wet moderate structure, strongly acid.

Individual horizon description:

0-15 cm	Dark brown (7.5YR3/2) moist; sandy loam; weak fine and medium subangular blocks; moist friable, non-sticky non-plastic wet; common fine roots; pH 5.4, clear smooth boundary.
15-28 cm	Brown to dark brown (7.5YR4/4) moist; sandy clay loam moderate fine and medium subangular blocks; moist friable: wet non-sticky non-plastic; common fine roots; pH 4.3 gradual smooth boundary.
28-51 cm	Brown to dark brown (7.5YR4/4) moist; sandy clay loam strong fine subangular blocks, moist friable, wet slightly sticky; slightly plastic; few fine roots; pH 4.7; gradual smooth boundary.
51-77 cm	Strong brown (7.5YR5/6) moist; sandy clay loam; strong fine subangular blocks; moist friable, wet slightly sticky slightly plastic; pH 4.8 gradual smooth boundary.
77-125 cm	Strong brown (7.5YR5/6) moist; slightly gravelly sandy clay loam; strong fine subangular blocks, moist friable, wet slightly sticky, slightly plastic; few fine roots; about 10% fragments-qualrtz (0.2 - 0.4 cm); pH. 5.3; gradual smooth boundary.
125-175 cm+	Reddish yellow (7.5YR6/8) moist; slightly gravelly sandy clay loam; strong fine sub-angular blocks; moist friable; wet sticky and plastic; few fine roots; about 10% fragments of quartz (0.2 - 0.4 cm); pH 5.2.

SOIL ANALYTICAL DATA

Mapping unit: UBb

Date of sampling: 3/4/1979

Soil unit: Bl

Profile No.: 162/1/4

Surveyor(s): Mugoggo, Kiwelu

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution Sand	Silt 50-20m	Silt 20-2m	Clay
11.8178	0-15	5.9	5.0	80.8	4.0	2.0	13.2
79	15-28	4.3	3.7	73.4	5.4	2.0	19.2
80	28-51	4.7	4.0	65.8	5.0	4.0	25.2
81	51-77	4.8	4.2	60.8	6.0	4.0	29.2
82	77-125	5.3	4.6	61.8	5.0	5.6	27.6
83	125-175+	5.2	4.3	61.0	6.0	6.8	26.2

O.C. %	N %	C/N	Exchangeable cations meq/100g Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
0.50	0.045	11	0.1	0.5	1.2	1.6	3.4	-
0.44	0.050	9	0.1	0.4	1.6	3.2	5.3	-
0.50	0.050	10	0.1	0.5	2.0	3.2	9.8	-
0.44	0.050	9	0.1	0.7	2.0	3.6	6.4	-
0.25	-	-	0.1	1.0	2.0	1.6	4.7	-
0.38	-	-	0.1	1.0	2.0	2.8	5.9	-

Texture class	Silt/ clay	Sum base meq/100g clay	P ppm
sl	0.45	26	4
sl	0.39	28	2
scl	0.36	23	3
scl	0.34	22	1
scl	0.38	17	3
scl	0.49	23	2

Profile number: 143/4/14
Map number: 143/4
Location: 200 m south of offices Hombolo Research Station, 5 m west of road, coordinates ZJ 296 401
Date of examination: 09/03/79
Surveyor(s): Bomans/Magoggo
Soil unit: B1
Mapping unit: UBb
Soil classification: FAO: Dystric Cambisol
USDA: Typic Dystropept
Landform: Upland plain, lower slope
Site: Undulating
Microrelief: -
Elevation: 3450'
Climate: Bsh (Köppen)
Parent material: -
Land use/Vegetation: Fallow, Dense grass, medium height
Moisture condition: Moist to 80 cm, wet below
Ground water: 95 cm
Drainage class: moderately well drained
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, porous brown to dark brown sandy clay loam with weak structural development.

Individual horizon description:

0-10 cm	Brown to dark brown (10YR4/3) moist; loamy sand; weak coarse crumbs; moist very friable; wet non-sticky non-plastic; many fine and fine medium tubular pores; many fine roots; pH 5.3; clear smooth boundary.
10-19 cm	Brown to dark brown (10YR4/3) moist; sandy loam; weak coarse and medium subangular blocks; moist friable wet slightly sticky, slightly plastic; many fine and few medium tubular pores; common fine roots; pH 5.0; clear smooth boundary.
19-38 cm	Brown to dark brown (10YR4/3) moist; sandy loam to sandy clay loam; weak medium and coarse subangular blocks; moist friable, slightly sticky, slightly plastic wet; many fine tubular pores; common fine roots; pH 4.6; clear smooth boundary.
38-100 cm+	Dark yellowish brown (10YR4/4) moist; sandy loam to sandy clay loam; weak medium and coarse subangular blocks; moist friable, slightly sticky; slightly plastic wet; many fine tubular pores; common fine roots; pH 4.6.

SOIL ANALYTICAL DATA

Mapping unit: UBb
Date of sampling: 9/3/1979
Soil unit: Rl

Profile No.: 143/4/14
Surveyor(s): Bomans, Magoggo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution Sand	Silt 50-20m	Silt 20-2m	Clay
11.8338	0-10	5.3	4.2	83.8	4.0	2.0	10.2
39	10-19	5.0	4.3	74.8	6.0	2.4	16.8
40	19-39	4.6	3.8	73.8	4.0	3.0	19.2
41	38-100(a)	4.6	3.8	72.8	5.0	2.0	20.2
42	38-100(b)	4.7	4.0	65.8	5.0	3.0	26.2

O.C. %	N %	C/N	Exchangeable cations meq/100g soil Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
0.88	0.085	10	0.1	0.3	1.2	0.4	2.0	-
0.49	0.075	6	0.1	0.3	1.2	0.4	2.0	-
0.29	-	-	0.1	0.3	1.2	1.2	2.8	-
0.49	-	-	0.1	0.2	0.4	2.4	3.1	10.00
0.39	-	-	0.1	0.2	1.2	1.2	2.7	

Texture class	Silt/clay	Sum bases meq/100g clay	CEC clay meq/100g	P ppm
LS	0.6	19.6	-	4
SL	0.5	11.9	-	12
SL	0.4	14.6	-	3
SCL	0.3	15.3	49.5	2
SCL	0.3	10.3	-	2

Profile number: 143/4/11
Map number: 143/4
Location: Hombolo Bwawani Research station, near office building, coordinates ZJ 297 409
Date of examination: 8/3/1979
Surveyor(s): Magoggo et al
Soil unit: Bs
Mapping unit: UBt
Soil classification: FAO: Cambic arenosol (petric phase)
USDA: "Ustric" quartzipsamment
Landform: Upland plain, slope, near rock outcrop
Site: Undulating; slope 4%
Microrelief: -
Elevation: 3450'
Climate: Bsh (Köppen)
Parent material: Granitic rock
Land use/Vegetation: Housing. Maize fields
Moisture condition: Dry to 35 cm., moist below
Ground water: -
Drainage class: Somewhat excessively drained
Rock outcrops/Surface stones: -
Erosion/Depostion: Deposits of unearthed material on top of the A-horizon
Erosion not evident
Others: Profile described of a trench near a septic tank; the first horizon is a sand deposit from the bottom of the pit and is not part of the profile.

Brief Profile Description:

Deep, somewhat excessively drained loamy sand becoming gravely beyond 1 m depth. Structure is weak and even absent at depth. The profile is a trench near a septic tank and the top materia is evidently unearthed material from elsewhere.

Individual horizon description:

0-15/18 cm	Strong brown (7.5YR5/6) moist; light yellowish brown (10YR6/4) dry; sand; dry loose, moist very friable, wet non-sticky non-plastic; many very fine roots; pH 6.0; abrupt smooth boundary.
15/18-21/25 cm	Brown to dark brown (10YR4/3) moist, brown (10YR5/3) dry; sand to loamy sand; weak medium sub-angular blocks; soft to slightly hard dry, very friable moist, non-sticky non-plastic wet; many very fine roots; pH 5.6; abrupt smooth boundary.
21/25-35/38 cm	Brown to dark brown (10YR4/3) moist, brown (10YR5/3) dry; loamy sand; weak fine and medium sub-angular blocks; moist very friable, wet non-sticky non-plastic few very fine roots; pH 5.1; clear smooth boundary.
35/38-69 cm	Brown (10YR4.5/3) moist, brown (10YR5/3) dry; loamy sand; single grain; dry loose, moist very friable wet non-sticky non-plastic; few very fine roots; pH 5.0; gradual smooth boundary.
69-102 cm	Brown (10YR5/3) moist, light yellowish brown (10YR6/4) dry; loamy sand; single grain; dry loose, moist very friable, wet non-sticky non-plastic; few very fine and fine roots; pH 5.0; clear smooth boundary.

(continued opposite)

SOIL ANALYTICAL DATA

Mapping unit: UBt
Date of sampling: 8/3/1979
Soil unit: BS

Profile No.: 143/4/11
Surveyor(s): Magoggo et al

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8325	15/18-21/25	6.0	5.0	86.8	3.0	1.0	9.2
26	21/25-35/38	5.6	4.2	87.8	2.8	1.4	8.0
27	35/38-69	5.1	4.0	86.8	2.0	1.2	10.0
28	69-102	5.0	4.0	82.8	2.0	4.2	11.0
29	102-120	5.0	4.4	83.8	2.8	1.4	12.0

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
0.69	0.080	9	0.1	0.1	0.8	0.8	1.8	-
0.20	0.035	6	0.1	0.1	0.8	0.8	1.8	-
0.29	0.020	14	0.1	0.1	0.4	0.4	1.0	-
0.20	-	-	0.1	0.1	0.4	0.4	1.0	15.00
0.39	-	-	0.1	0.1	0.4	0.4	1.0	-

Texture class	Silt/clay	Sum bases meq/100g clay	CEC meq/100g clay	ESP	P ppm
ls	0.43	20	-	-	6
ls	0.53	23	-	-	6
ls	0.32	10	-	-	3
ls	0.56	11	(136)	0.7	4
ls	0.35	8	-	-	3

102-120 cm **Brown to strong brown (7.5YR5.5) moist; very gravelly loamy sand; single grain; dry loose, moist very friable, wet non-sticky non-plastic; common very fine roots; about 30 - 40% granite and quartzite gravels; pH 5.0.**

Profile number: 143/4/1
Map number: 143/4
Location: Zepisa, about 2 km west of leprosarium, 25 m E. of road,
coordinates ZJ 259 419
Date of examination: 1/3/1979
Surveyors: Mmari, Kiwelu
Soil unit: D
Mapping unit: 1
Soil classification: FAO: Eutric Cambisol
USDA: Typic Ustropept
Landform: Intermediate plain
Site: Almost flat slope 1%
Microrelief: -
Elevation: 3400'
Climate: Bsh (Köppen)
Parent material: Granitic colluvium
Land use/Vegetation: maize, sorghum millet weet potatoes, rice, finger millet, baobab, acacia species; also grazing.
Moisture condition: Moist throughout
Ground water: -
Drainage class: imperfectly drained. Run-off slow; Internal slow.
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: high biological activity in top two horizons.

Brief Profile Description:

Deep imperfectly drained but porous dark greyish to yellowish brown, sandy clay loam. A fluctuating temporarily high water table is reflected in the mottling.

Individual horizon description:

0-10 cm	Dark grey (10YR4/1) moist; sandy clay loam; weak fine and medium subangular blocks; moist friable; sticky and plastic wet; few very fine and fine tubular pores; many very fine and fine roots; pH 6.2 smooth abrupt boundary.
10-27 cm	Very dark greyish brown (10YR3/2) moist; many medium distinct and sharp dark yellowish brown (10YR3/4) mottles; sandy; clay loam; weak fine and medium subangular blocks; moist friable, wet sticky and plastic; common very fine and fine tubular pores; many very fine and fine roots; pH 6.4; clear smooth boundary.
27-60 cm	Yellowish brown (10YR5/4) moist; few medium faint diffuse very dark grey (10YR3/1) mottles; sandy; clay loam; weak medium and fine subangular blocks; moist friable; wet sticky and plastic; many fine and medium tubular pores; common coarse, fine and very fine roots; pH 6.2; clear smooth boundary.
60-120+ cm	Yellowish brown (10YR5/4) moist; sandy clay loam; moderate medium and coarse subangular blocks; moist friable, wet very sticky very plastic; many fine and medium tubular pores; few fine and medium roots; pH 5.6.

SOIL ANALYTICAL DATA

Mapping unit: 1
Date of sampling: 1/3/1979
Soil unit: D

Profile No.: 143/4/1
Surveyor(s): Mmari/Kiwelu

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8343	0-10	6.2	5.8	55.8	14.0	8.0	22.2
44	10-27	6.4	5.9	55.8	14.0	9.0	23.2
45	27-60	6.2	5.8	54.8	9.0	9.0	27.2
46	60-120+	5.6	4.5	52.8	7.0	8.0	32.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
1.18	0.100	12	0.1	0.6	7.6	5.6	13.00	16.00
0.59	0.065	9	0.1	0.4	6.8	4.0	11.30	-
0.88	0.090	10	0.3	0.3	6.8	6.0	13.40	17.00
0.20	-	-	0.4	0.4	6.0	7.2	14.00	16.50

Texture class	Silt/ clay	Sum bases clay meq/ 100g	CEC meq/100g clay	ESP	base saturation %	P ppm
Scl	0.99	63	72	0.6	87	8
Scl	0.91	49	-	-	-	3
Scl	0.66	49	63	1.8	79	3
Scl	0.47	43	51	2.4	85	3

Profile number: 162/2/9
Map number: 162/2
Location: North of road to Morogoro, 2.5 km East of Dodoma; coordinates ZJ 100 200
Date of examination: 01/03/1979
Surveyor: Magoggo
Soil unit: A
Mapping unit: UBb - VA
Soil classification: FAO: Eutric Fluvisol
USDA: Typic ustifluvent
Landform: Better drained lowland plain
Site: Flat to almost flat
Microrelief: None
Elevation: 3580'
Climate: Bsh (Köppen)
Parent material: alluvium
Land use/Vegetation: Maize. Grassland. Grazing (cow and goat)
Moisture condition: Moist throughout
Ground water: -
Drainage class: Imperfectly drained
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, brownish to greying brown sandy clay loam to clay with moderate structure. The deeper horizons are very hard to work even when moist. (Hardpan' soil?)

Individual horizon description:

0-13 cm	Brown to dark brown (10YR4/3) moist; and brown (7.5YR5/4) dry; sandy clay loam; moderate medium subangular blocks; dry very hard; moist friable, wet very sticky and plastic; common fine tubular pores; many fine and very fine roots pH 5.3; smooth abrupt boundary.
13-50 cm	Dark greyish brown (10YR4/2) sandy clay to clay; massive structure; dry very hard, moist firm, wet sticky and plastic; few very fine tubular pores; few fine roots; pH 5.9; clear smooth boundary.
50-70 cm+	Greyish brown (10YR5/2) moist; clay; massive; dry very hard, moist frim, wet sticky and plastic; few very fine tubular pores; very few fine roots; pH 6.2.

SOIL ANALYTICAL DATA

Mapping unit: UBt-VA
Date of sampling: 1/3/1979
Soil unit: A

Profile No.: 162/2/9
Surveyor(s): Magoggo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Cla;
				Particle size distribution			
11.8381	0-13	5.3	4.9	44.8	12.0	17.0	26.2
82	13-50	5.9	5.6	48.8	4.8	5.4	45.0
83	50-70	0.2	5.8	48.4	3.4	12.2	42.0

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases
0.58	0.050	12	0.2	0.5	5.2	3.2	9.1
0.45	-	-	0.9	0.1	8.8	7.2	17.0
0.53	-	-	1.6	0.1	8.8	7.5	10.1

Texture class	Silt/ clay	Sum bases meq/100g clay	P ppm
L	1.11	35	8
Sc	0.36	38	1
C	0.37	24	1

Profile number: 163/1/2
Map number: 163/1
Location: About 150 m North of Mwitikira river and 40 m West of road to Buigiri; coordinates AD 682 197
Date of examination: 23/4/1979
Surveyors: Mgogo/Mmari
Soil unit: C/A
Mapping unit: VA
Soil classification: FAO : Chromic cambisol
USDA: (Fluventic?) Ustropept
Landform: Valley floor
Site: Almost flat, slope less than 1%
Microrelief: -
Elevation: 3550'
Climate: Bsh (Köppen)
Parent material: Colluvium/Alluvium
Land use/Vegetation: Range land. Open grassland.
Moisture condition: Moist up to 22 cm, dry below.
Ground water: -
Drainage class: Well drained. Internal: medium; run-off: slow
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, well drained sandy clay loam to clay with yellowish red to greyish brown colours in the B-horizon.

Individual horizon description:

0-22 cm	Dark reddish brown (5YR3/4) moist; sandy clay loam; moderate fine and medium sub-angular blocks; moist friable, wet sticky and plastic; many fine + few medium and coarse roots; pH 5.1; abrupt smooth boundary.
22-70 cm	Yellowish red (5YR4/6) moist and 5YR5/6 dry); sandy clay strong medium and fine sub-angular blocks; dry hard, moist friable, wet very sticky and very plastic; few fine and medium roots; pH 6.0; abrupt smooth boundary.
70-110 cm+	Greyish brown (10YR5/2) moist; dark greyish brown (10YR4/2) dry; fine clay; strong medium and fine sub-angular blocks; dry very hard, moist very firm, wet very sticky and very plastic; very few fine roots; pH 5.4.

SOIL ANALYTICAL DATA

Mapping unit: VA

Date of sampling: 23/4/1979

Soil unit: C/A

Profile No.: 163/1/2

Surveyor(s): Mmari

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Particle size distribution Silt 50-20m	Silt 20-2m	Clay
11.8210	0-22	5.1	4.1	62.8	5.8	6.2	25.2
11	22-70	6.0	5.5	51.8	4.0	4.0	40.2
12	70-110	5.4	4.8	41.8	4.0	7.0	47.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases
0.63	0.075	8	0.2	0.4	3.2	2.8	6.6
0.44	0.060	7	0.5	0.2	4.0	4.4	9.1
0.38			0.9	0.3	6.0	6.0	13.2

Texture class	Silt/ clay	Sum bases meq/100g clay	P ppm
SCL	0.5	26.2	1
SC	0.2	22.6	1
C	0.2	28.0	3

Profile number: 162/2/12
Map number: 162/2
Location: ZJ 088 199 about 6 km from Dodoma along Morogoro road; 2 km North of afforestation area
Date of examination: 9/3/1979
Surveyors: Z. Mmari/A. Kiwelu
Soil unit: C/A?
Mapping unit: Va?
Soil classification: FAO: (Dystric?) Cambisol
USDA: Fluventic Dystropept
Landform: Better drained lowland plain
Site: Almost flat, slope 1%
Microrelief: -
Elevation: 3350'
Climate: Bsh (Köppen)
Parent material: Granitic colluvium
Land use/Vegetation: Clearing of natural trees for afforestation. Acacia, baobab
Moisture condition: Dry to 12 cm, moist to 89 cm, wet below
Ground water: 89 cm
Drainage class: Imperfectly drained
Rock outcrops/Surface stones: -
Erosion/Deposition: Water deposition
Others: Surface sealing: -

Brief Profile Description:

Deep, imperfectly drained but very strongly acid sandy clay to clay with mottles right from the surface horizon. Structure development is strong to moderate.

Individual horizon description:

0-12 cm	Brown to dark brown (7.5YR4/4) dry and 10YR4/4 moist); few, fine, diffuse brown (10YR4/3) mottles; clay loam to clay; strong fine and medium sub-angular blocks; dry slightly hard, moist friable, wet sticky and plastic; many very fine roots; pH 4.5; clear smooth boundary.
12-43/61 cm	Reddish brown (5YR4/4) moist; common, fine and medium faint, diffuse brown (10YR4/3) mottles; sandy clay to clay; moderate, fine medium and coarse sub-angular blocks; friable moist, sticky and plastic wet; few very fine and fine roots; pH 4.3; clear wavy boundary.
43/61 + 89 cm	Mixed Reddish and greyish brown (5YR4/4 and 10YR5/2) moist; mottles; sandy clay to clay; moderate fine, medium and coarse sub-angular blocks; moist friable, wet sticky and plastic; few very fine and fine roots; pH 4.6; clear smooth boundary.
89-116 cm+	Greyish brown (10YR5/2) moist; faint medium, prominent clear strong brown (7.5YR5/6) mottles; sandy clay to clay; structureless massive; friable moist, very sticky very plastic wet; few very fine roots; pH 4.7.

SOIL ANALYTICAL DATA

Mapping unit: VA

Date of sampling: 9/3/1979

Soil unit: C/A

Profile No.: 162/2/12

Surveyor(s): Kiwelu/Mmari

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8977	0-12	4.5	3.9	40.8	8.4	32.6	40.2
78	12-43/61	4.3	3.5	44.8	3.8	9.4	48.0
79	43/61-89	4.6	3.7	44.6	3.6	4.8	47.0
80	89-113	4.7	3.7	45.8	2.4	3.6	46.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H( )	Sum bases	CEC soil (NH_4OAc)
0.85	0.050	17	0.2	0.4	1.6	1.6		3.8	-
0.32	-	-	0.3	0.2	2.9	6.4		9.7	-
0.13	-	-	0.5	0.2	2.4	6.0		9.1	-
0.26	-	-	0.8	0.2	2.8	5.2		9.0	-

Texture class	Silt/ clay	Sum bases meq/100g clay	CEC meq/ 100g clay	ESP	base saturation	P ppm
C	0.5	9.5	-	-	-	7
C	0.2	21.1	-	-	-	Trace
C	0.2	19.4	-	-	-	"
C	0.2	19.5	-	-	-	"

Profile number: 143/4/17
Map number: 143/4
Location: ZJ 199 371 about 3½ km SE of corner at Ipampa
Date of examination: 20/03/1979
Surveyors: AK/JPM
Soil unit: F
Mapping unit: LB
Soil classification: FAO: Haplic phaeozem
USDA: (Cumulic) haplustoll
Landform: Better drained lowland plain
Site: Flat, slope 0%
Microrelief: -
Elevation: 3410'
Climate: Bsh (Köppen)
Parent material: -
Land use/Vegetation: wooded bushland
Moisture condition: Dry to 9 cm, slightly moist to 60 cm, moist below.
Ground water: -
Drainage class: Imperfectly drained. Run-off slow, internal: medium
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, brown to dark brown clay, strong structure, slightly to moderately alkaline reaction. At 1 m depth calcareous nodules.

Individual horizon description:

0-31 cm	Dark brown (7.5YR3/2) moist; fine clay; moderate and medium subangular blocks; dry soft, moist friable, wet slightly sticky, slightly plastic; common fine pores; many fine and common coarse roots; pH 8.2; clear smooth boundary.
31-59 cm	Dark brown (7.5YR3/2) moist; fine clay; strong coarse subangular blocks; moist friable, wet slightly sticky slightly plastic; many fine pores; few fine roots; pH 7.8; clear smooth boundary.
59-76 cm	Brown to dark brown (10YR4/3) moist; fine clay; strong coarse subangular blocks; moist friable, wet slightly sticky slightly plastic; many fine pores; few fine roots; pH 8.1; clear smooth boundary.
76-101 cm	Brown to dark brown (10YR4/3) moist; fine clay; strong medium subangular blocks; moist friable wet slightly sticky, slightly plastic; many fine pores; few fine and few medium roots; some whitish coating on ped surface but not of clay; pH 8.4; clear smooth boundary.
101 cm+	As horizon 4 but contains slightly calcareous nodules that give slight effervescence with conc. HCl.

SOIL ANALYTICAL DATA

Mapping unit: LB
Date of sampling: 20/3/1979
Soil unit: F

Profile No.: 143/4/17
Surveyor(s): Magoggo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8230	0-31	8.2	7.6	42.8	3.6	4.0	49.6
31	31-59	7.8	7.5	35.8	4.6	14.0	45.6
32	59-76	8.1	7.7	34.8	5.6	12.0	47.6
33	76-101	8.4	8.0	30.6	3.6	9.6	56.6

(Particle size distribution: Sand, Silt, Clay)

O.C. %	N %	C/N	Na	K	Ca	Mg	Sum bases
1.95	0.130	15	0.1	14.3	38.8	4.4	57.6
1.28	0.080	16	0.8	0.6	35.2	11.6	48.2
0.98	0.055	17	0.7	0.3	30.0	16.0	47.0
0.73	0.055	13	2.9	0.4	23.6	16.0	42.9

(Exchangeable cations (meq/100g soil): Na, K, Ca, Mg)

Texture class	Silt/ clay	Sum bases meq/100g clay	P ppm
C	0.2	116.1	Trace
C	0.4	105.7	"
C	0.4	98.7	"
C	0.2	86.9	"

Profile number: 162/2/18
Map number: 162/2
Location: About 1.2 km from Katelela, along road Katelela - Mahomamakulu, 10 m North East of road; coordinates ZJ 152 290
Date of examination: 10/4/1979
Surveyors: Mgogo, Kiwelu
Soil unit: F
Mapping unit: 1B
Soil classification: FAO: Eutric cambisol
USDA: (Vertic?) Ustropept
Landform: Better drained lowland plain
Site: Flat to almost flat
Microrelief: -
Elevation: 3400'
Climate: Bsh (Köppen)
Parent material: Alluvium
Land use/Vegetation: Grazing; presence of perennial crops. A little cultivation on adjacent land.
Moisture condition: Moist throughout
Ground water: -
Drainage class: Well-drained. Run-off: Slow; internal; medium
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: -

Brief Profile Description:

Deep, dark grey to greyish brown friable clay with strong structure and slightly alkaline reaction, non calcareous.

Individual horizon description:

0-18 cm	Very dark grey (10YR3/1) moist, fine clay; strong subangular blocks; moist friable wet sticky and plastic; many fine roots; pH 6.9; clear smooth boundary.
18-46 cm	Dark grey (10YR4/1) moist; fine to very fine clay; strong subangular blocks; moist friable, wet sticky and plastic; common fine roots; pH 7.6; clear smooth boundary.
46-79 cm	Grayish brown (10YR5/2) moist; very fine clay; subangular blocky; moist friable, wet sticky and plastic; few fine roots; about 1% irregular, hard, white calcareous nodules, pH 8.0; clear smooth boundary.
79-110 cm	Grayish brown (2.5YR5/2) moist; very fine clay; moderate fine and medium subangular blocks; moist friable, wet sticky and plastic; few fine roots; about 10% irregular, hard, white calcareous nodules.

SOIL ANALYTICAL DATA

Mapping unit: LB
Date of sampling: 10/4/1979
Soil unit: F

Profile No.: 162/2/18
Surveyor(s): Kiwelu, Mugoggo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution Sand	Silt 50-20m	Silt 20-2m	Clay
11.8155	0-18	6.9	6.3	21.2	6.0	19.6	53.2
56	18-46	7.6	7.4	21.2	3.0	16.6	59.2
57	46-79	8.0	7.9	21.2	3.6	13.0	62.2
58	79-110+	8.0	7.9	23.8	1.0	9.0	66.2

O.C. %	N %	C/N	Exchangeable cation meq/100g Na	K	Ca	Mg	H	Sum bases	CEC soil (NH_4OAc)
0.88	0.105	8	0.4	4.2	20.4	9.6	-	34.60	54.0
0.78	0.075	10	0.5	2.6	22.1	12.4	-	37.60	-
0.20	-	-	0.2	2.6	26.4	12.8	-	42.00	-
0.25	-	-	0.3	2.6	27.2	11.6	-	41.70	-

Texture class	Silt/ clay	Sum bases meq/100g	CEC meq/100g clay	ESP	base saturation	P ppm
C	0.48	65	101	0.01	64	1
C	0.33	64	-	-	-	2
C	0.27	68	-	-	-	1
C	0.15	63	-	-	-	1

Profile number: 143/4/18
Map number: 143/4
Location: ZJ 215 368 about ½ km West of Hombolo lake and ¼ km
S.E. of the river little Kinyasungwe
Date of examination: 20/03/1979
Surveyors: ZAM et al
Soil unit:
Mapping unit: LP
Soil classification: FAO: pellic vertisol
USDA: Entic pellustert
Landform: Lowland plain with restricted drainage
Site: Flat to almost flat
Microrelief: ?
Elevation: 3400'
Climate: Bsh (Köppen)
Parent material: Colluvium/alluvium?
Land use/Vegetation: Grazing - Maize nearby
Wooded bushland, short grass
Moisture condition: Top horizon dry, moist below
Ground water: -
Drainage class: Moderately well drained. Run-off; rapid; internal; very slow
Rock outcrops/Surface stones: -
Erosion/Deposition: Sandy overwash
Others: Cracks up to 0.5 cm wide, 38 cm deep

Brief Profile Description:

Deep dark grey cracking clay with slightly to moderately acid reaction.

Individual horizon description:

0-12 cm	Grey (10YR5/1) moist; dark grey (7.5YR4/0) dry; fine to very fine clay; strong medium and coarse subangular and angular blocky; dry extremely hard, moist firm, wet very sticky and very plastic; common fine and medium, few coarse roots; pH 5.9; gradual smooth boundary.
12-38 cm	Dark grey (10YR4/1) moist; fine to very fine clay; strong medium and coarse subangular blocks; dry extremely hard, moist firm, wet very sticky and very plastic; common fine and medium roots; pH 6.3 gradual smooth boundary.
38-74 cm	Dark grey (7.5YR4/0) moist; very fine clay; strong medium and coarse parallel epidedon; dry extremely hard, moist very firm, wet very sticky and very plastic few fine and medium roots; pH 6.5.

SOIL ANALYTICAL DATA

Mapping unit: 4
Date of sampling: 20/3/1979
Soil unit: V

Profile No.: 143/4/18
Surveyor(s): Mmari

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution Sand	Silt 50-20m	Silt 20-2m	Clay
11.8289	0-12	5.9	5.3	23.2	3.0	14.2	59.6
90	12-38	6.3	5.8	24.8	1.6	14.0	59.6
91	38-74	6.5	6.0	20.2	3.0	14.0	62.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
0.75	0.070	10	0.2	0.1	2.0	2.8	5.1	28.0
0.85	0.055	15	0.1	0.2	0.8	0.4	1.5	-
0.38	0.045	8	0.1	0.2	1.2	0.8	2.3	32.0

Texture class	Silt/clay	Sum bases meq/100g clay	CEC meq/100g clay	ESP	base saturation %	P ppm
C	0.3	8.6	47.0	0.7	18.2	
C	0.3	10.7	-	-	-	
C	0.3	3.7	51.4	0.3	7.2	Trace

Profile number: 162/2/15
Map number: 162/2
Location: ZJ 174 290 About 3½ km from Katelela on the road to Mahomakulu, 50 m North of the road
Date of examination: 10/4/1979
Surveyors: S. Mugogo, A. Kiwelu
Soil unit: V
Mapping unit: LP
Soil classification: FAO: Pellic vertisol
USDA: Entic Pellustert
Landform: Better drained lowland plain
Site: Flat to almost flat, slope 1%
Elevation: 3400'
Microrelief: -
Climate: Bsh (Köppen)
Parent material: Alluvium
Land use/Vegetation: Bushed grassland. Grazing. Maize, sorghum, bulrush millet
Moisture condition: Moist throughout
Ground water: -
Drainage class: Moderately well drained
Rock outcrops/Surface stones: -
Erosion/Deposition: Erosion along cattle tracks
Others: Salt accumulation on the surface

Brief Profile Description:

Deep, dark grey moderately alkaline clay. The profile contains about 5% white hard nodules about 1 to 5 mm size.

Individual horizon description:

0-8 cm	Very dark grey (10YR3/1) moist; very fine clay; moderate fine sub-angular blocks; very friable moist, sticky and plastic wet; many fine roots; 5% hard irregular white nodules (1-5 mm); pH 8.4; abrupt smooth boundary.
8-21 cm	Dark grey (10YR4/1) moist; very fine clay; strong medium and coarse prismatic structure; moist firm, wet sticky and plastic; common fine roots; 5% hard irregular white nodules (1-5 mm); pH 8.2; abrupt smooth boundary.
21-42 cm	Dark grey (10YR4/1) moist; very fine clay; strong medium and coarse prismatic structure; moist firm, wet sticky and plastic; few fine roots; broken, moderately thick cutans of clay minerals on horizontal and vertical surfaces; 5% hard irregular white nodules (1-5 mm); pH 8.2; gradual smooth boundary.
42-60 cm	Grey (10YR5/1) moist; very fine clay; moderate medium prismatic structure; moist firm, wet sticky and plastic; broken, moderately thick cutans of clay minerals on horizontal and vertical surfaces; 5% hard irregular white nodules (1-5 mm); pH 8.3; gradual smooth boundary.
60-95 cm+	Grey (10YR5/1) moist; very fine clay; structureless massive; moist firm, wet slightly sticky and plastic; 5% hard irregular white nodules (1-5 mm); pH 8.1.

SOIL ANALYTICAL DATA

Mapping unit: LP
Date of sampling: 10/4/1979
Soil unit: V

Profile No.: 162/2/15
Surveyor(s): Kiwelu/Sem

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Sand	Silt 50-20m	Silt 20-2m	Clay
11.8225	0-8	8.4	8.0	22.6	3.2	7.2	67.0
26	8-21	8.2	7.8	24.8	1.6	8.0	65.6
27	21-42	8.2	7.7	21.8	2.0	9.6	66.6
28	42-60	8.3	7.8	23.4	2.4	5.6	68.6
29	60-95	8.1	7.6	19.8	2.6	11.8	65.8

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	Sum bases	CEC soil (NH_4OAc)
2.01	0.165	12	1.6	2.1	36.4	7.6	47.7	-
1.28	0.115	11	1.9	0.9	34.8	9.2	47.8	-
0.85	0.085	10	12.0	1.3	33.2	13.2	59.7	-
0.79	0.060	13	13.0	0.5	32.8	15.6	61.9	-
0.67	0.060	11	11.6	0.3	30.0	18.0	59.9	-

Texture class	Sum bases meq/100g clay	P ppm
C	71.2	Trace
C	71.3	"
C	89.6	"
C	90.2	"
C	91.0	"

Profile number: 143/3/2
Map number: 143/3
Location: Makutupora; road Mzabwe - Dodoma, 100 m West of road, (coordinates ZJ 033 395)
Date of examination: 13/3/1979
Surveyors: Magoggo
Soil unit: V
Mapping unit: S
Soil classification: FAO: Pellic vetisol
USDA: Entic Pellustert
Landform: Swamp - Depression: Makutopora
Site: Flat to almost flat, slope 1%
Microrelief: Gilgai relief
Elevation: 3520'
Climate: Bsh (Köppen)
Parent material: alluvium
Land use/Vegetation: Grassland, short grasses
Moisture condition: Moist throughout
Groundwater: Not observed in the profile
Drainage class: Poorly drained. Run-off; Slow, Internal: Slow
Rock outcrops/Surface stones: -
Erosion/Deposition: -
Others: Small polygonal cracks

Brief Profile Description:

Deep; poorly drained dark grey, slightly calcareous, extremely sodic and moderately saline cracking clay.

Individual horizon description:

0-9 cm — Grey to dark grey (2.5Y 4.5/4) moist; very fine clay; very weak coarse subangular blocks; dry very hard; moist firm, wet sticky and plastic; many very fine tubular pores; common fine roots; pH 6.3; clear smooth boundary.

9-90 cm — Dark grey (2.5Y4/0) moist; very fine clay; very weak coarse subangular blocks; dry very hard; firm moist, wet sticky and plastic; many very fine tubular pores; common fine and medium and few coarse roots; slightly calcareous; pH 9.0.

SOIL ANALYTICAL DATA

Mapping unit: S
Date of sampling: 13/3/1979
Soil unit: V

Profile No.: 143/3/2
Surveyor(s): Magoggo

Sample No.	Depth cm	pH H_2O	pH $CaCl_2$	Particle size distribution: Sand	Silt 50-20m	Silt 20-2m	Clay
11.8214	0-9(a)	6.3	5.8	20.8	4.4	8.8	66.0
15	80 cm(b)	8.2	7.8	18.8	1.0	4.2	76.0
16	50 cm(c)	9.0	8.3	20.8	6.4	3.8	75.0

O.C. %	N %	C/N	Exchangeable cation meq/100g soil: Na	K	Ca	Mg	H	Sum bases	CEC soil (NH_4OAc)
0.49	0.050	10	3.7	0.2	42.4	22.9	-	69.20	56.00
0.29	0.040	7	33.5	1.8	28.0	18.8	-	81.10	-
0.49	0.050	10	20.2	1.9	28.8	15.2	-	66.10	-

Texture class	Silt/ clay	Sum bases clay meq/100g ( )	CEC meq/100g clay	ESP	P ppm
C	0.20	105	85	7	Trace
C	0.07	107	-	-	1
C	0.06	88	-	-	1