Climate and soils of the South Kinangop Plateau of Kenya.
Their limitations on land use

Promotor: Dr.ir. J. Bennema, oud-hoogleraar in de tropische bodemkunde aan de Landbouwhogeschool te Wageningen.

N.N. NYANDAT

CLIMATE AND SOILS OF THE SOUTH KINANGOP PLATEAU OF KENYA

Their limitations on land use

Proefschrift
ter verkrijging van de graad van
doctor in de landbouwwetenschappen,
op gezag van de rector magnificus,
dr. C.C. Oosterlee,
hoogleraar in de veeteeltwetenschappen,
in het openbaar te verdedigen
op woensdag 11 april 1984
des namiddags te vier uur in de aula
van de Landbouwhogeschool te Wageningen.

Climate and soils of the South Kinangop Plateau of Kenya
Their limitation on land use.

To my parents.
For Pamela, Pritt, Beatrice,
Paul, Job, Eric and Linda.

CONTENTS

ACKNOWLEDGEMENT

ABSTRACT

SUMMARY

PART 1 -	INTRODUCTION	1
1.	Introduction	1
	1.1 General introduction	1
	1.2 Features (location, population, infrastructure, marketing, extension services) of the area	5
	1.3 Background data and objectives of the present study	11
	1.4 The methods used for acquiring the data	13
PART 2 -	ACQUIRED DATA AND THEIR IMPLICATION	16
2.	The land use before resettlement and the present pattern of land use	16
	2.1 Arable agriculture	16
	2.2 Livestock production	23
	2.3 Tree production	27
3.	Farm types and crops	28
4.	The value of the present small-farm settlement	31
5.	The climate of the area and its constraints on land use	34
	5.1 The temperature and forst regime	34
	5.1.1 Temperature type and variability	34
	5.1.2 Influence of temperature with regard to crops	38
	5.2 Water availability	38
	5.2.1 Rainfall distribution	38
	5.2.2 Rainfall probability	41
	5.2.3 Evaporation and evapotranspiration patterns	41
	5.2.4 Cumulative water balance and the length of the growing period	44
	5.2.5 Influence of water availability with regard to crops	46
	5.3 The land use pattern as influenced by temperature and water availability	46
6.	The soils of the area and their constraints on land use	51
	6.1 Introduction (Geology, Physiography, Surface Hydrology)	53
	6.2 The classification and correlation of the soils; and a description of some of the soil units	57
	6.3 Problems of the soil and how they influence land use	70
PART 3 -	POSSIBILITIES FOR LAND USE	74
7.	The Land Utilization types identified for the area and their land requirements	74
	7.1 Land Utilization types	74
	Small scale rainfed arable farming for non-cereal annual crops at low level management	76
	Small scale rainfed arable farming for non-cereal annual crops at intermediate level of management	76
	Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management	77
	Small scale rainfed arable farming for fruit trees at intermediate level of management	78

continued

	Small scale grazing for cattle and sheep at intermediate level of management	79
	Tree production for firewood and building poles	80
	Fish pond for fish production	81
	7.2 The Land Requirements of the Land Utilization Types	81
8.	The kind of Land Qualities identified for the area, their grades and how they fit the requirements of the land utilization types	84
9.	The Possibility for improvement of the land and the limits of the grades of land qualities set for the suitability classes for the different land utilization types	88
10.	The Current land utilization types	93
11.	A preliminary assessment of the posssibility of improving the drainage of the imperfectly and poorly drained soils and the potential land suitability	95
PART 4 -	RESULTS, CONCLUSIONS AND NECESSARY FOLLOW-UP	100
12.	Results and Conclusions	100
13.	Necessary Follow-up	106
REFERENCES		108

STATEMENTS

1. Survival of man depends on responsible and rational use of the finite soil resource of the earth.
2. Soil and climate are the base of development and without a good knowledge of them man's survival is placed at jeopardy.
3. The development of agriculture should not only be without degradation of the track of land under consideration but should also not have a negative impact on the wider environment.
4. A poor farmer can become rich on good soil and a rich farmer can make poor soil productive, but a poor farmer on poor soil has little chance of succeeding.
5. Drainage is the most critical factor limiting the use and productivity of the soils of the study area. The first need is to improve the general drainage system of the region.
6. Land suitability classification should always be for a specified land use since the land suitability depends on the use to which the land is to be put.
7. Soil structure degradation by use of inappropriate implements and the degradation of soil fertility by erosion of top soil are the most serious soil problems in the developing countries.
8. Loss of soil through secondary salinization under poorly managed irrigation outweights advantage from irrigated agriculture in the world today.
9. The lack of use of soil information at farm level for soil management and conservation has partly been due to non-problem solving soil research approach and partly due to improper presentation of the soil information by the soil scientists.
10. It is high time less emphasis was placed on soil fertility maintenance with fertilizer in a low capital investment farming which is common in the developing countries and more emphasis placed on organic residue and biological nitrogen as alternative sources for fertility maintenance.
11. Soil scientists should now pay equal attention to the soil problems for pasture production in animal production just as they do for crop production.
12. Field soil training should be compulsary for all agricultural research scientists and extension workers.

13. Agricultural extension workers destined to work in the tropics, whether derived from international, bilateral or local sources should be conversant in the subject matter of soil conservation.

14. The contribution of research by international institutions can only be effective in the developing countries through collaborative research with the national soil research institutions.

15. Self reliance is the surest way of development.

16. Technical aid without concommitant training of the nationals is an incomplete aid.

17. Although the methodology proposed in the framework of land evaluation for the land suitability classification is elaborate, it is an important step forward.

    FAO, 1976. A Framework for land evaluation. FAO Soils Bulletin No. 32, p. 9-10, Rome.

18. Emphasis on the development of non food crops in the developing countries where food shortage is critical should be discouraged.

19. Crop breeding has until now placed emphasis on disease resistance and yield response to added fertilizer. It is high time the breeding was also done for the soil conditions.

20. Sex education should be an essential part of a school curriculum in Kenya so that the school youth can be assisted to behave responsibly.

21. The teaching of agriculture at school level is necessary for the motivation of the school youth in the developing countries to develop interest in working in the rural area.

N.N. NYANDAT

Doctorate thesis: Climate and soils of the South Kinangop Plateau of Kenya: their limitations on land use

ANNEXES:

1. Land occupied between 1964 and 1975 by various crops during the long rain seasons in seven Kinangop Settlement Schemes
2. Livestock numbers during 1967 to 1975 and the stocking rates in seven Kinangop Settlement Schemes
3. Profile description and analytical data of some representative profiles
4. Proposals for grading of land qualities (partly after Van de Weg and Braun, 1977)

5A-G. The current land suitability classification

6. Scientific names of the crops mentioned in the report

FIGURES

1a. Location of the study area in relation to the country
1b. The study area
2. Settlement schemes of the study area
3. Main crops of the settlement schemes during 1975
4. Climate stations of the study area
5. Sites of observation of the soils in the field
6. The geology of the study area
7. The surface hydrology and contours of the study area
7A. Semi-detailed soil map of South Kinangop Settlement Schemes
8a-c. Characteristic schematic profiles of the soils

PLATES

1. The landscape: Aberdare Mountains in background and overgrazed pasture in foreground
2. The field meteorological station set for the drainage investigation
3. Example of crop mix: cabbages and potatoes grown in some farms
4. Type of cattle and sheep kept by farmers
5. Better managed grass pasture; compare with overgrazed grass pasture in plate 1
6. Mount Longonot, the source of recent volcanic ash sprinkling at Kinangop, in the background

TABLES

1. Production and Marketing of some agricultural produce from the Kinangop area during 1975 and 1976 after resettlement and in 1961 before the resettlement
2. Land occupied by the major crops in the Kinangop area in 1960
3a-g. Land occupied between 1964 and 1975 by various crops during the long rain season in seven Kinangop Settlement Schemes (found in Annex 1)
4. Present yields and the yields before the resettlement, of some crops in the Kinangop area
5. Sensitivity to frost, temperature, altitude and rainfall requirement for the crops found in the Kinangop area and others that could be considered for the area

6. Some soil requirement of the crops found in the Kinangop area and others that could be considered for the area
7. Number of livestock before the land resettlement
8a-g. Livestock numbers during 1967 to 1975 and the stocking rates in seven Kinangop Settlement Schemes (found in Annex 2)
9. The proportion of green and dried out grass during different months of the year
10. Nutritive value of the green and dried out grass during different months of the year
11. Temperature (°C) at three sites of the study area
12. Absolute minimum temperature (°C) during 1975 to 1979
13. Comparison of absolute minimum temperature (°C) at high lying and low lying grounds
14. Monthly mean rainfall and calculated annual potential evaporation data (mm) for the areas in and around the study area
15. Rainfall probability at Ndiara metereological site (representing Tulaga, Njabini and Bamboo Settlement Schemes) and Karati meteorological site (representing Karati Settlement Scheme)
16. Monthly potential evaporation (mm) at South Kinangop and Kimakia according to Woodhead (1968)
17. Monthly potential evaporation as percentage of year potential evaporation; calculated from Table 16
18. Estimated monthly and annual potential evaporation (mm) for the area in and around the study area
19. The monthly maximum crop evapotranspiration and rainfall (mm) at three representative meteorological stations
20. Ranges of the available soil moisture storage capacity
21a. Cumulative water balance from March to February at Ndiara Meteorological Station representing Tulaga, Njabini and Bamboo Settlement Schemes
21b. Cumulative water balance from March to February at Carnell Meteorological Stations representing Muruaki, Githioro and South Kinangop Settlement Schemes
21c. Cumulative water balance from April to March at karati Meteorological Station representing Karati Settlement Scheme
22. The classification and correlation of the soils
23. The major characteristics of the soils and the area of soils

per scheme

24. The grades of the land qualities of the soils units

25a-g. Limits of the grades of land qualities set for the suitability classes for the different land utilization types

26. Current land suitability for various rainfed land uses

27. Crop establishment and yields as well as monthly rainfall during the drainage test period 1976 to 1979 inclusive

28. Depth to water table under various drainage treatment

29. The rate of drying of the land surface under various drainage treatment determined by penetrometer

30a. Comparison of the effectiveness of the various drainage treatment and the distance from open ditch drain

30b. Comparison of the yields from the middle and the sides of camberbed

ABSTRACT

In the Kinangop Plateau of Kenya where small holder farmers have been settled, varied climate and soils occur and the level of land use and management is not as high as may be expected. The climate and soils were therefore studied with a view to identify the constraints they present to land use and management and how the constraints may be rectified. Low temperatures and frequent frosts are the main climate constraints while imperfect drainage, low fertility and shallow effective rooting depth are some of the soil constraints. A comprehensive project which incorporates sub-programmes on the improvement of soil drainage and fertility, the improvement of collection, storage, transportation and marketing of produce, the improvement of the economics of farm enterprises and advisory services, and the improvement of on-farm roads has been proposed.

ACKNOWLEDGEMENT

The work on this thesis arises from the initiative of my promotor, E. Prof.Dr. J. Bennema, who is the E. Professor in Tropical Soil Science at the State Agricultural University in Wageningen, The Netherlands. I am indebted to him for initiating this investigation, the guidance he provided to me throughout the investigation, and the useful advice he gave during the compilation of the report. I am also indebted to Prof.Dr. W.H. Van der Molen, Prof.Dr. M. Flach and Prof.Dr. J.F. Bierhuizen who are respectively Professors in Agrohydrology, Tropical Agriculture and Horticulture at the same University, for their useful suggestions and assistance.

Grateful thanks also go to the many people whom without their assistance it would have been impossible to accomplish the task of completing the investigation and reporting. I am particularly grateful to the staff of the Kenya Soil Survey, the National Agricultural Laboratories and the Department of Settlement in Nairobi and Kinangop for the invaluable assistance during both the field and laboratory investigations. Special mention needs to be made Messrs. J.R. Rachilo and Mureithi Waweru of the Kenya Soil Survey whose assistance during the field work was tremendous. Special mention also needs to be made of Mr. D.M. Olulo and his staff who were responsible for the well prepared diagrams and pictures found in this report. Mrs. O.N. Waswa formerly of the National Agricultural laboratories tirelessly worked to type the many drafts which had to be produced throughout the investigation and this assistance is very much acknowledged. Without the assistance of Ir. R.F. Van de Weg, Ing. W. Boxem and Miss Bea Verhaar of Wageningen Agricultural University's Department of Soil Science and Geology with the organization of the printing of the thesis in The Netherlands and its presentation, the successful defence of this thesis would have not been made easy. I am indebted to them. The Senior Chief of Kinangop, Mr. Mugo, provided his land for the field drainage experiments and I am indeed grateful to him. Also the suggestions given by Dr. J.W. Kijne formerly of the Department of Agricultural Engineering at the University of Nairobi during the drainage experiments undoubtely helped me to acquire useful data. I very much appreciate his help.

Finally, I owe much to my wife, Pamela, who accepted to relieve me of many of the family engagements so that I could find adequate time for this thesis. For her, our childeren and my parents, this publication is dedicated.

SUMMARY

An area of approximately 32,500 ha in the Kinangop Plateau of Kenya where 2881 families have been settled in seven Settlement Schemes (South Kinangop, Bamboo, Njabini, Githioro, Karati, Muruaki and Tulaga) was investigated with a view to find out the constraints of climate and soils on the land use of the area and how the constraints may be rectified.

Section 4 of the report gives the results of the analysis of climatic regimes and the soils. The mean monthly temperature lies between 10°C and 16°C with a mean annual temperature between 11°C and 15°C. These rather low mean temperatures are not conductive to the growing of warmth requiring crops. The crops that could be considered for the area are indicated in Table 5. They include pyrethrum, potato, cabbage, cauliflower, kale, carrot, onion, leek, peas, sunflower, wheat, barley, beet, oats, mangold, apple, plum, pear and peaches. But because of the frequent occurrence of night frost which is detailed in Section 4.1.1, the crops like potato and sunflower which are very sensitive to frost can only be grown during the frost-free period. This frost-free period was found to extend only from the middle of March to middle of June. The presently available maize varieties which are late maturing and which are at present being grown by the farmers can therefore only be grown with considerable risk of frost damage.

The rainfall amount and reliability is adequate. Only its storage by the soil makes the difference as has been shown in Tables 21a to 21c. The higher the capacity of the soil to store the rainwater the higher the moisture sufficiency to meet the evapotranspiration requirement of the plant. In order to obtain at least three months of continuous moisture sufficiency for crops in the area, it has been found that the soil moisture storage capacity must be at last 90 mm within 100 cm depth of soil.

In Section 5, the thirty-four soil units identified at a scale of 1:50,000 are presented. The soils key out into seventeen units according to the FAO/UNESCO legend and into twenty-six soil families according to the United States Soil Taxonomy. These soils are characteristically fine textured and are deep. Some are well drained while others are imperfectly to poorly drained. The imperfectly drained and poorly drained soils which constitute 22,450 ha of the 32,500 ha of the study area have a subsoil claypan which greatly limits the effective rooting depth. All soils have low fertility and pH in general. The water holding capacity of the well drained soils is high but that of the imperfectly drained and poorly drained soils is low because of

the shallow effective soil depth of these latter soils.

The present and past land use back to 1960 has been reviewed in Sections 2 and 3 and possible land utilization types as well as their land requirements identified. Also investigated are the land qualities. The latter have then been matched against the requirements of the land utilization types in order to identify the constraints and their possible remedies.

Seven land utilization types which have been identified for the study area are presented in Section 6.2. They include:

A. Small scale rainfed arable farming for non cereal annual crops at low level of management
B. Small scale rainfed arable farming for non cereal annual crops at intermediate level of management
C. Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management
D. Small scale rainfed arable farming for fruit trees at intermediate level of management
E. Small scale grazing for cattle and sheep at intermediate level of management
F. Tree production for firewood and building poles
G. Fish pond for fish production.

The land qualities fullfil to a smaller or greater extent the requirements of the land utilization type and are expressed in similar terms. Identified are the relevant land qualities for each of the land utilization types. These land qualities are shown in Section 7 of the report. They relate to:

1. Availability of water (moisture)
2. Availability of drinking water
3. Availability of nutrients
4. Resistance of erosion
5. Possibility of use of mechanical implements
6. Presence or hazard of water logging (availability of oxygen)
7. Availability of foodhold
8. Presence or hazard alkalinity/sodicity/alkalinization
9. Hinderance by vegetation
10. Risk of overgrazing
11. Risk of periodically occuring pests and diseases
12. Presence of windfall hazard

13. Presence of forest fire hazard
14. Availability of conditions for pond construction.

The land qualities have been quantified and graded for the assessment of land suitability classes according to the scheme presented in Annex 5 while the grades of the relevant land qualities computed for each of the soil units of the study area are given in Table 24. These grades of the land qualities of the soil units have been matched against the land requirements of each of the land utilization types in order to assess the current land suitability and also to identify the major land constraints. The current land suitability for each of the land use alternatives is presented in Table 26. The well drained soils (comprising some 10,050 ha) are in general marginally drained soils (comprising about 22,450 ha) are unsuitable for arable agriculture. The imperfectly drained soils are however largely marginally suitable for tree production and grazing but moderately to highly suitable for construction of fish pond.

A major land constraint related to the imperfect drainage which affects 22,450 ha of the study area of 32,500 ha. The Settlement Schemes mostly affected by the imperfect drainage are Muruaki, Githioro, Karati and Tulaga (see Fig. 2). It is worst in Githioro and Karati Settlement Schemes because of the undissected and rather flat topography found in these schemes. Other minor constraints relate to shallow effective rooting depth mostly in the soils with claypan and the low phosphorus as well as nitrogen and pH.

A preliminary four-year field drainage experiment was conducted from 1976 to 1979 to compare the effectiveness of mainly ditch drain, ditch drain plus ripping, and camberbed. The results of this experiment are presented in Section 10 of the report. The results indicated that the camberced is fairly effective for drainage and can be easily adopted in small scale farming under a well laid out overall network of surface drainage.

With regard to soil fertility this may considerably be improved when fertilizers, manures and lime are used for crop production. The areas affected by shallow effective rooting depth may however best be used for grazing, tree production and fish pond construction. A number of Eucalyptus, Cupresses and Pinus species indicated in Section 2.3 were found to perform well on these soils with shallow effective depth.

It may be necessary to mount a comprehensive land development project for the study area. The project would incorporate a number of sub-programmes on the following:

1. Improvement of the surface drainage and water storage
2. Investigation of appropriate husbandry techniques for crops and livestock as well as preparation of advisory materials
3. Conducting a detailed farm survey to identify the major socio/economic constraints of the development of the farms and analysis of the economic viability of the different farm enterprises
4. Programme to improve the collection, storage, transportation and marketing facilties for the produce
5. Programme to rehabilitate and maintain the on-farm roads to all-weather standard.

The formulation of such a comprehensive project and the investigations to follow will no doubt be greatly facilitated by the base data provided from the present study.

Samenvatting

In een gebied ter grootte van 32.500 ha is een onderzoek uitgevoerd met het oogmerk om de beperkingen van het landgebruik, van het klimaat en de bodems nader te bepalen en tevens is onderzocht hoe deze beperkingen kunnen worden bijgesteld. Het gebied ligt in Kenia op het Kinangop plateau, waar, verdeeld over zeven vestigingsgebieden,(South Kinangop, Bamboo, Njabini, Githioro, Karati, Muruaki en Tulaga) zich 2.881 boerengezinnen hebben gevestigd.
In hoofdstuk 4 worden de resultaten van de klimaatsanalyses en het bodemonderzoek gegeven. De gemiddelde jaarlijkse temperatuur ligt tussen 11°C en 15°C terwijl de gemiddelde maandelijkse temperatuur tussen 10°C en 16°C ligt. Voor de groei van gewassen die veel warmte vereisen zijn deze lage temperaturen niet bevorderlijk. De voor dit gebied in aanmerking komende gewassen (zie tabel 5) zijn pyrethrum, aardappelen, kool, bloemkool, bladkool, wortelen, uien, prei, erwten, zonnebloemen, tarwe, gerst, bieten, haver, voederbieten, appelen, pruimen, peren en perzikken. Aangezien nachtvorst frequent voorkomt in het gebied, kunnen nachtvorst-gevoelige gewassen zoals aardappelen en zonnebloemen, alleen verbouwd worden gedurende de vorstvrije periode. Deze periode strekt zich uit van medio maart tot medio juni. Dat houdt in dat de huidige verbouwde laatrijpende mais variëteiten door de boeren geteeld worden met een aanzienlijk gevaar voor vorstschade.

De regenval en de betrouwbaarheid van de regenval is over het algemeen voldoende. Er zijn echter grote verschillen in vochtbergend vermogen, zoals uit de tabellen 21a tot en met 21c duidelijk wordt. Naarmate het vochthoudend vermogen van de bodem hoger ligt, wordt meer voldaan aan de evapotranspiratie behoefte van de plant. Er werd vastgesteld dat om zeker te zijn van een driemaandelijkse groeiperiode tenminste 90 mm beschikbaar vocht binnen een bewortelbare bodem van 1 m aanwezig moet zijn.

Op een schaal van 1:50.000 worden 34 bodemeenheden onderscheiden en deze zijn beschreven in hoofdstuk 5. De bodems zijn geclassificeerd in 17 eenheden volgens het FAO/UNESCO systeem en in 26 bodemfamilies volgens

het USDA Soil Taxonomy classificatiesysteem. De bodems zijn in het algemeen diep en zwaar. Sommige bodems zijn van nature goed ontwaterd, terwijl andere onvoldoende tot slecht ontwaterd zijn. De onvoldoende en slecht ontwaterde

bodems beslaan een oppervlakte van 22.450 ha en bij deze bodems is er een dichte kleilaag (*clay pan*) aanwezig die in hoge mate de effectieve bewortelingsdiepte beperkt. Alle bodems hebben een lage bodemvruchtbaarheid en een lage pH. Vanwege de geringe effectieve bewortelingsdiepte hebben de onvoldoende en slecht ontwaterde bodems een gering vochthoudend vermogen terwijl dit groot is bij de bodems met een goede ontwatering.
Het huidige en vroegere (rond 1960) landgebruik is beschreven in de hoofdstukken 2 en 3 en de mogelijke vormen van landgebruik (landgebruikstypen) met de daaraan gerelateerde landgebruiksbehoeften zijn geidentificeerd. Ook de landhoedanigheden (*land qualities*) zijn onderzocht. Deze zijn getoetst aan de behoeften van de landgebruikstypen ten einde de beperkingen vast te stellen met de mogelijke verbeteringen.

Zeven landgebruiktstypen zijn in het gebied te onderscheiden; zij zijn weergegeven in hoofdstuk 6.2. Deze zijn:
1) Kleinschalige regen-afhankelijke akkerbouw van jaarlijkse niet-graan gewassen met een laag bedrijfvoeringsniveau.
2) Kleinschalige regen-afhankelijke akkerbouw van jaarlijkse niet-graan gewassen met een matig (*intermediate*) bedrijfsvoeringsniveau.
3) Matig grootschalige regen-afhankelijke akkerbouw van graangewassen met een matig bedrijfsvoeringsniveau.
4) Kleinschalige regen-afhankelijke fruitbomenteelt met een matig bedrijfsvoeringsniveau.
5) Kleinschalige veehouderij (koeien en schapen) met een matig bedrijfsvoeringsniveau.
6) Houtproductie voor brandhout en bouwhout.
7) Vijvers voor visteelt

De landhoedanigheden voldoen in meerdere of mindere mate aan de landgebruiksbehoefte van het landgebruikstype en zijn dan ook in vergelijkbare termen gesteld. De relevante landhoedanigheden voor elk landgebruikstype zijn aangegeven in hoofdstuk 7.
Deze zijn gerelateerd aan:
1) Beschikbaarheid van vocht voor het gewas
2) Beschikbaarheid van drinkwater
3) Beschikbaarheid van voedingsstoffen voor de plant
4) Erosiegevoeligheid

5) Mogelijkheden tot gebruik van landbouwwerktuigen
6) Verankeringsmogelijkheid voor de plant (*foothold*)
7) Risico's van verzouting
8) Beperkingen t.g.v. de natuurlijke vegetatie
9) Risico van overbeweiding
10) Risico van ziekten en plagen
11) Gevaar van windschade
12) Risico's van bosbranden
13) Mogelijkheden tot visvijver constructie

De landhoedanigheden zijn gekwantificeerd en in klassen ingedeeld ter bepaling van de geschiktheid volgens een schema weergegeven in appendix 5. De gradaties van de landhoedanigheden voor elk van de voorkomende bodemeenheden zijn gegeven in tabel 24. De gradaties van de landhoedanigheden van de bodemeenheden zijn vergeleken met de landgebruiksbehoeften van elk landgebruikstype om op die manier de actuele landgeschiktheid vast te stellen en bovendien de voornaamste landbeperkingen te identificeren. De actuele landgeschiktheid voor elk landgebruiksalternatief is in tabel 26 weergegeven. De goed ontwaterde gronden (10.050 ha) zijn in het algemeen marginaal tot matig geschikt voor akkerbouw, terwijl de onvoldoende ontwaterde gronden (22.450 ha) ongeschikt zijn. De onvoldoende ontwaterde gronden zijn marginaal voor houtproductie en beweiding maar matig tot goed geschikt voor de constructie van visvijvers.
De belangrijkste landbeperking zijn de onvoldoende ontwaterde bodems die 22.450 ha van het totale onderzochte gebied beslaan. Vooral de vestingsgebieden Muruaki, Githioro, Karati en Tulaga (zie fig. 2) hebben drainage problemen. Voor Githioro en Karati geldt dit in het bijzonder omdat die gebieden tamelijk vlak zijn en niet versneden. De wat minder belangrijke beperkingen zijn: de geringe effectieve bewortelingsdiepte, wat het duidelijkst zichtbaar is in de bodem met een dikke kleilaag (*clay pan*); het lage fosfaatgehalte; het lage stikstofgehalte en de lage pH.

Een vierjarig drainage veldonderzoek is uitgevoerd van 1976 t/m 1979 om de effectiviteit te vergelijken van slootdrainage, slootdrainage met diepwoelen, akkers op ruggen met greppels (*camberbeds*).

Hoofdstuk 10 geeft de resultaten van dit veldexperiment weer. Geconstateerd werd dat akkers met greppels redelijk drainage- verbeterend werkt en dat het gemakkelijk geintroduceerd kan worden in kleinschalige akkerbouw althans indien er een goed netwerk van waterlopen aanwezig zou zijn.

Met gebruikmaking van kunstmest, stalmest en bekalking kan de bodemvruchtbaarheid aanzienlijk worden verbeterd. De gebieden met geringe effectieve bewortelingsdiepte kunnen het beste gebruikt worden voor beweiding, houtproductie en het aanleggen van visvijvers. In hoofdstuk 2.3 worden een aantal Eucalyptus, Cupressus en Pinus soorten genoemd die het goed doen op deze ondiepe gronden.

Voor het studiegebied zou het noodzakelijk zijn een alomvattend landontwikkelingsproject te starten. Zo'n project zou de navolgende deelprojecten moeten omvatten:

1) Verbetering van de oppervlakkige drainage en het vocht bergend vermogen.
2) Onderzoek naar de meest geschikte teelttechnieken en veehouderij methodieken, terwijl tevens voorlichtings materiaal zou moeten worden opgesteld.
3) Gedetailleerde bedrijfsstudies om de belangrijkste socio-economische beperkingen van de bedrijfsontwikkeling te onderkennen, met een kosten en baten analyse van de verschillende bedrijven.
4) Een programma om oogstmethoden, opslag, transport en afzet van de landbouwproducten te verbeteren.
5) Een programma tot herstel en onderhoud van de bedrijfswegen voor permanent gebruik (*all weather*).

De basis gegevens uit onderhavig onderzoek zullen ongetwijfeld van nut zijn bij het opstellen van zo'n integraal project en het daarmee samenhangend onderzoek.

****

PART 1

INTRODUCTION

1. INTRODUCTION

1.1 GENERAL

The area being considered in the present study is the southern part of the Kinangop Plateau of Kenya and is known as the South Kinangop Plateau. It is part of the area formely called the "white highland" and now called the "Kenya highland". It is one among those areas which has experienced land resettlement just before and following the attainment of political independence in Kenya. Prior to independence the area was subject to the 1939 Kenya Ordinance in council which barred the indingeous Kenyan from owing land in the area. However, in 1980 the Kenya Ordinance in Council was promulgated and from 1961 onwards all Kenyan races could own and farm in the Kinangop Plateau. Before the promulgation of the Ordinance the main line of agricultural development in the area was dairy and sheep farming with a few patches of cultivated pyrethrum, wheat and fruit trees. With the promulgation of the restriction, there were bound to be changes in not only the pattern of farming but also in its characteristics. To relieve the serious land pressure which had been built up over the years, the Kinangop area became one of the settlement schemes which were intended to facilitate an orderly transfer of land to indingeous african ownership with little or no drop in productivity. A significant result of this process was a complete re-orientation of the farming systems not only in respect to the land use but also the introduction of peasant farming into the area for the first time. Abrams (1979) reports that by 1975 some 769,493 ha had been given to peasant settlers throughout the country with some 84,414 ha being resettled in the Kinangop area alone.

The settlement planners were concious of the need to maintain if not raise production in the course of transformation. For this reason, the number of the peasant families which could be settled on a particular piece of land in Kinangop had to be carefully considered so that the plots were of a size that could be operated on economic lines to yield annual net income of at least Kenya shillings 500 to 5,000 over and above the subsistence requirements of a family and the amount required to meet annual loan repayment, depending on the type of settlement (Abrams, loc cit). In the case of the Kinangop Plateau, there are 15 conventional settlement schemes and 2 cooperative farms with a total of about 6,545 plot holders settled. The average plot size ranges from 5.54 ha in the high density schemes to 17.53 ha in the low density schemes.

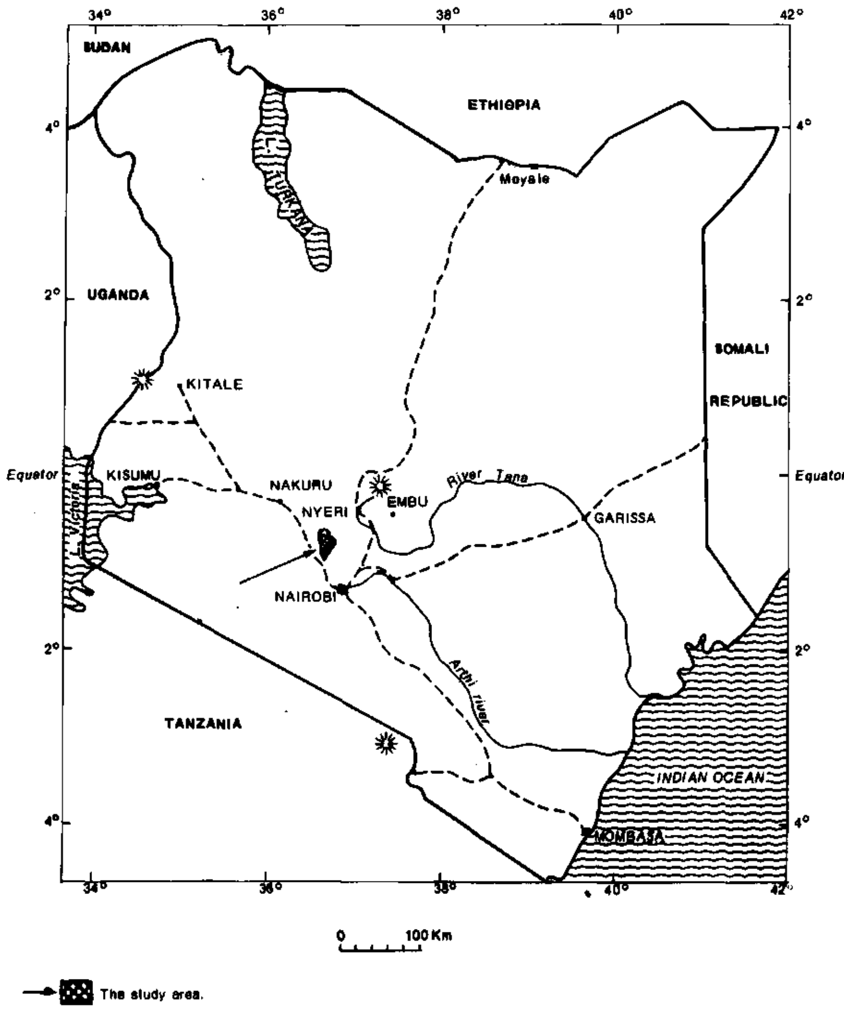
The Settlement Department provided a detailed subdivision plan drawn on scale of 1:2,500 and giving plots that were designed to yield the annual net income of Kenya shillings 500 to 5,000 based on 1963 prices (Kenya shilling 7.0 = U.S. dollar 1.0). Careful consideration was supposed to have been given to drainage, soil types, water availability and access roads to each plot. The plot boundaries followed contour drains. The land was categorised as fertile, fair and poor and designated Class I, Class II and Class III respectively. Class I land was considered to have a Kenya Shilling 480 per hectare profitability potential and Class II land a Kenya Shilling 240. The land which was only suitable for permanent grazing or building site was classified as Class III land. Even if the haste with which the settling had to be carried out is recognised, it is to be appreciated that categorising land in terms of its soil fertility alone can not be without serious deficiences. The size of the plots has in many cases not been well adapted to the production potentials of the particular land.

Land purchase loans amounting to 10% of purchase price were given at 6% annual interest and repayement over 30 years in sixty half yearly equal instalments. In addition, a development loan repayable over 10 years by way of twenty half yearly equal instalments was given. The lending of money to the new farmers was a comparativelty easy process. However, the recovery of the loan has not been as easy. Abrams (loc cit) states that as at the end of December 1975, the Kenya pounds 8.313 million had been recovered out of the billed Kenya pounds 17.129 million and only 1,414 plot holders out of 32,294 had been able to keep 100% repayement rate. The inability of the majority of plot holders to keep up the loan repayement is not without pertinent reasons some of which may be the land resource constraints. With the coming of peasant farmers to the settlement schemes, especially the Kinangop Plateau settlement schemes, the whole farming outlook has been forced to change, with new problems also being created.

The new outlook in farming in the South Kinangop Plateau is essentially peasant and so are problems which have been created. New crops which used not to be grown in the area under large scale farming have emerged. In the same way a new pattern of livestock farming has emerged. Settlement has unwittingly produced a diversification and intensification of the farming without a base to do so.

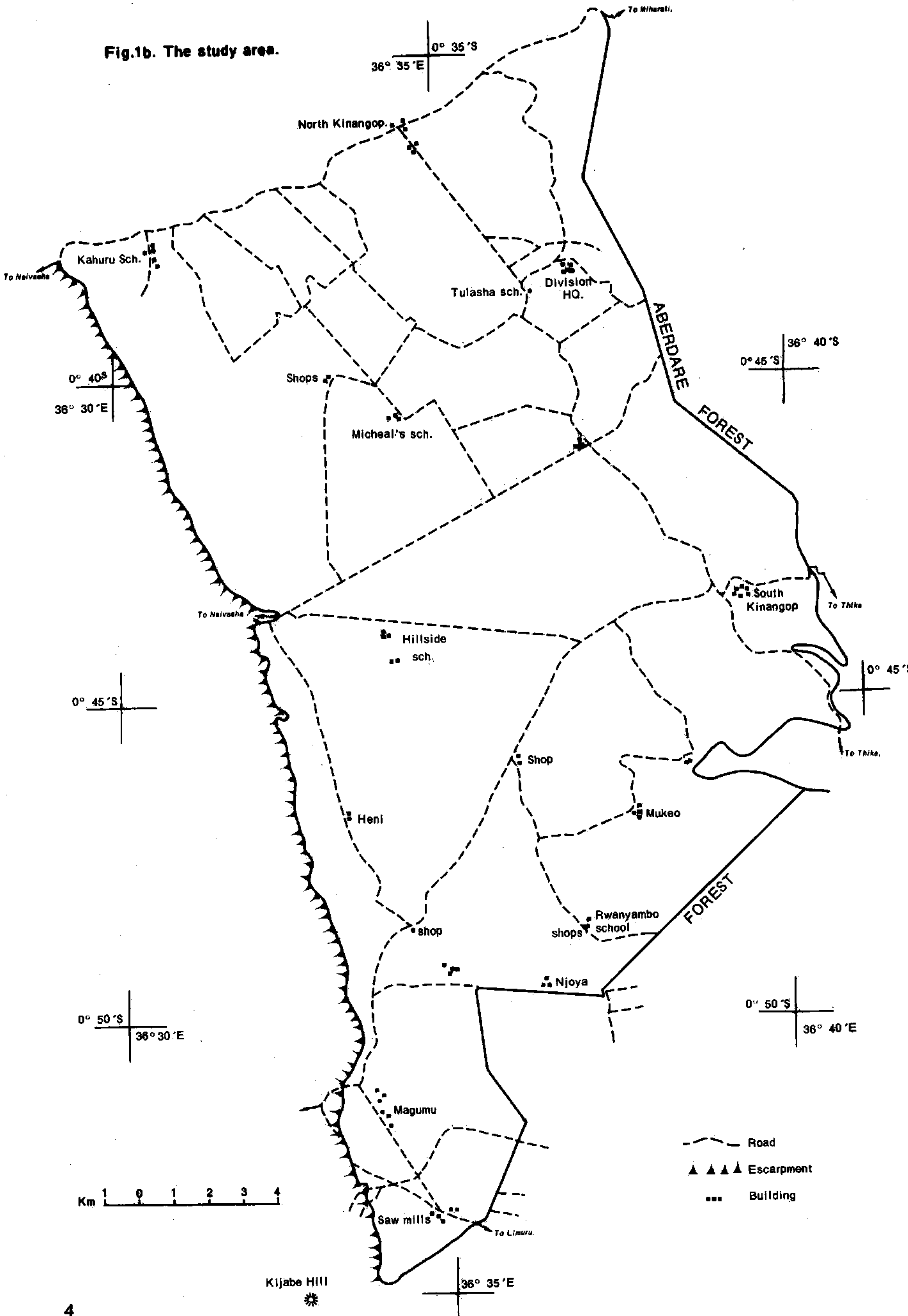
Fig. 1a: Location of the study area in Kenya.

Fig. 1a. Location of the study area in Kenya



There are two questions which require urgent attention. The first one is how to scientifically manage the land to bring the benefits of farming to the settlers. The second is how best to educate them to approach farming in the area as scientifically as the previous large scale farmers did. With the adoption of scientific farming, the need for planned land development and management becomes obvious. For such planned land development and management to be successful it must be partly based on a clear appreciation of the constraints of the land resource and how to overcome them. The present land use study in the South Kinangop Plateau is to contribute to this basic requirement. It is the first step towards planned land development and management. Its purpose is to identify the physical constraints to land use, examine the possibilities to counteract the constraints, and assess projects and research needs.

Fig.1b. The study area.



The study is also aimed at demonstrating how the methodology of the framework for land evaluation (FAO, 1976) can be used as a first basis for determining the form of improvement of the land use of an area with settlement schemes having traditional or improved traditional farming. Moreover, only a few examples are available in Kenya where the land evaluation have been carried out according to the framework and so far examples do no exist for comparable areas.

The study is based on a pilot area of some 32,500 ha strechting from the Southern part of the Kinangop Plateau to the North Kinangop township (see Figs. 1a and 1b) and having 2,892 settler families in seven settlement schemes (Fig. 2). The selected area has a diversity of soil and crops grown. Also the change in rainfall pattern is markedly clear to enable assessment of its influence on the land use pattern. It represents conditions which range from the worst to the best and therefore represents the entire area of settlement in the Kinangop Plateau. The area was also chosen because it is one which is close to the city of Nairobi and this makes it possible to find a market for the produce. Furthermore the information on socio-economic background of the area was available.

1.2 FEATURES OF THE AREA

1.2.1 Location

The area of study is situated in Nyandarua District of Central Province in Kenya. Figs. 1a and 1b show its setting in relation to the country. It lies 55 km North West of Nairobi and is situated on latitudes 0°34'S to 0°54'S and longitudes 36°31'E to 36°41'E. The altitude ranges from 2,460 m to 2,740 m and it consists of a series of platforms with the first three highest plains occurring approximately at 2,700 m, 2,620 m and 2,560 m. From the south west, the plateau rises to the north east to end in the Aberdares mountain with a top at 3,906 m (see Plate 1).

The scarp of the Aberdares forms the north eastern limit of the study area whereas the Naivasha - North Kinangop road form the north western limit. The Rift Valley escarpment forms the southern and western boundary whereas the eastern boundary is at the forest reserve.

The area studied covers seven settlement schemes namely South Kinangop, Bamboo which is officially part of the South Kinangop Scheme, Karati, Njabini, Githioro, Muruaki and Tulaga (see Fig. 2).


Plate 1: The landscape: Aberdare mountains in background and overgrazed pasture in foreground.

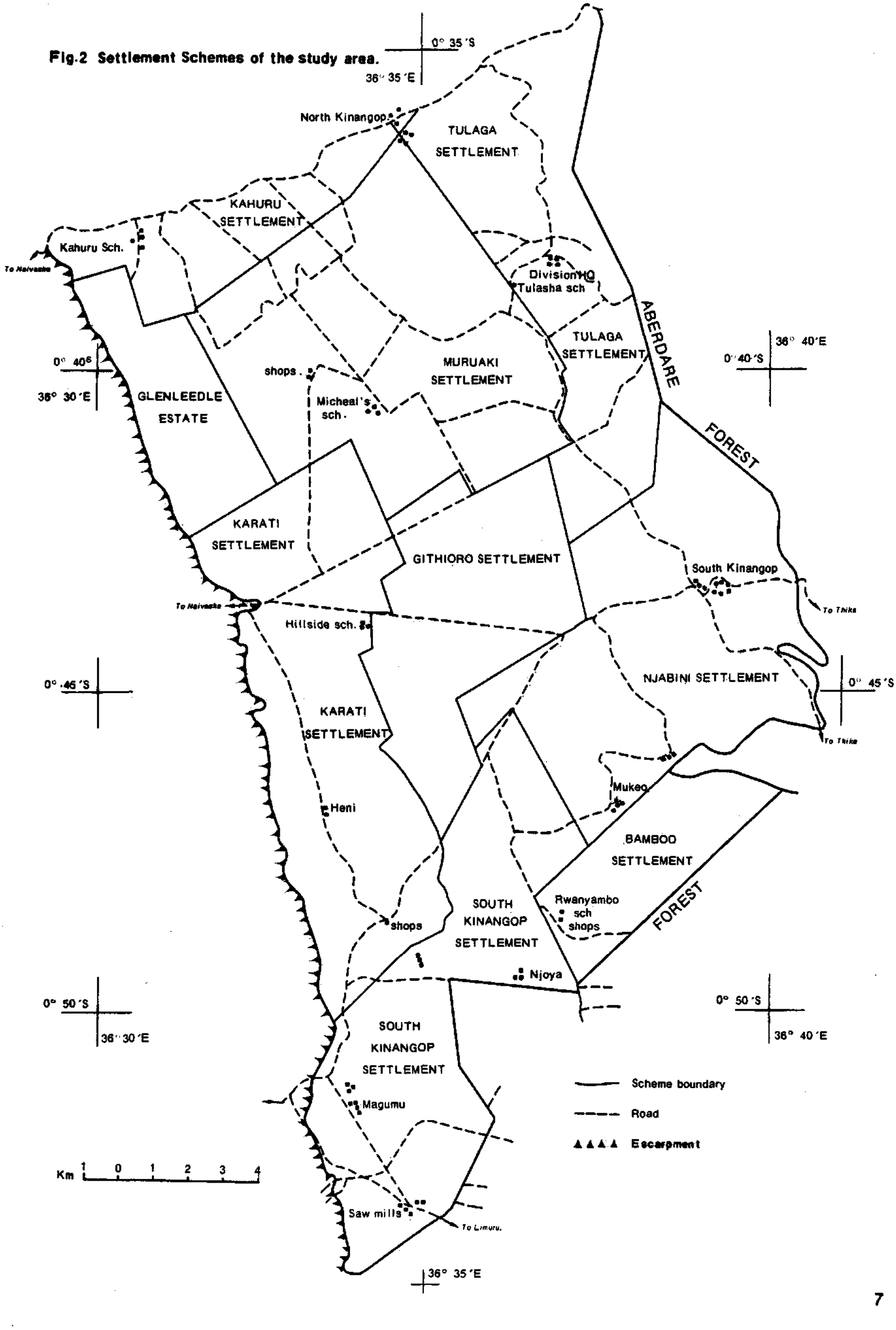
1.2.2 Population

No precise figure can be given about the population but some 2,892 persons own land in the area under study. Furthermore there are persons employed from outside as government agricultural, settlement, administration, forestry, police and health workers. Besides, there are cooperative workers and business people at many trading centres that exist in the area. The population including that of the farming families consist of people of diverse ethnic groups and agricultural background. They need more technical guidance and assistance for agricultural production.

1.2.3 Infrastructure

At the inception of the settlement in the area in the early sixties, a network of major roads, access roads and settlement administration centres were established. Although the external road communication of the area with Nairobi, Thika, Nyahururu${}$u and Naivasha (see Fig. 1) is still good, some of the roads within the study area are now in very bad shape. Those roads classified as settlement access roads and which do not fall under the Ministry

Fig.2 Settlement Schemes of the study area.



of Transport and Communication's classified roads are the worst affected. Recognizing the harm that poor road communication in the area may bring to the agricultural production, the Ministry of Transport and Communication of the Kenya Government has examined the required rehabilitation of roads which they estimate will cost about Kenya £3,400 per km as per 1977 prices (DANIDA, 1977). The annual maintenance cost thereafter is estimated at Kenya £240 per km. It is possible that the road rehabilitation programme could favourably attract external funding under the Kenya Goverment's Rural Access Road Programme. It should however, be emphasized that the maintenance of the roads is as important as the rehabilitation. For this reasons there should be a definite commitment to the annual maintenance of the roads by the government. With passable roads throughout the year it can be expected that the amount of produce transported from the farmers will substantially increased to enhance the agricultural productivity by the farmers.

Two health centers and two large market centres exist at North Kinangop and Njabini townships. There also exist small market center which are fairly well distributed in the area. Similarly, many schools are available and are well distributed throughout the area.

1.2.4 Marketing

The main agricultural production that prevails in the area is dairy production. This is supplemented with the production of mainly wool, potatoes, cabbages, pyrethrum, maize, barley, wheat, green peas and leeks. Table 1 gives the agricultural production and marketing of some of the produce in 1975 and 1976 after resettlement and in 1961 before the resettlement.

The main outlets for carrots and green peas are respectively the dehydration factory of the Pan African Foods Ltd. in Naivasha and the Kabazi Canners Factory at Kabazi in Nakuru. The Pan African Foods Ltd. enter into delivery constracts with the farmers through the Farmers Cooperative Union. The company provides seeds and chemicals on credit, organizes transport for collection of the produce from the farmers and sees that the farmers harvest their produce according to a plan that fits with the needs for an even supply to the processing plant. The contracts stipulate a certain minimum production and in order to encourage the farmers to honour the contract, bonuses are paid when the minimum production under contract is exceeded.

Table 1: Production and Marketing of some agricultural produce from the Kinangop area during 1975 and 1976 after resettlement. (Source: Annual Report for 1975 and 1976 of the Kinangop complex, Department of Settlement, Kenya).

Produce	1975		1976	
	Metric tons	K£	Metric tons	K£
Milk	nd	nd	16,086	721,150
Wheat	nd	nd	nd	nd
Barley	nd	nd	nd	nd
Potatoes	3,000	33,100	nd	nd
Carrots	3,000	33,350	nd	nd
Pyrethrum	nd	nd	522	125,050
Cabbages	478	4,800	nd	nd
Green peas	268	6,850	nd	nd
Wool	nd	nd	55	25,900
Vegetables	nd	78,100	nd	nd

nd = no data.

Note: Milk, pyrethrum and wool figures cover only the first 11 months of the year. Figures for carrots and cabbages are sales to the Pan African Foods Factory while green peas are sales to the Kabazi Canners Factory. A certain amount of cabbages, carrots and green peas is definitely sold to private traders and no data can be given.

The production and marketing of some agricultural produce from the Kinangop area in 1961 before the resettlement. (Source: Annual Report of Department of Agriculture, South Kinangop, 1961).

Produce	*Production	Total value (K£)
Milk	nd	nd
Wheat	15,539 metric tons	323,000
Barley	2,692 " "	49,482
Potatoes	3,600 " "	36,000
Carrots	nd	nd
Pyrethrum	2,677.3 metric tons	589,000
Cabbages	nd	nd
Green peas (pulse drops)	18.2 " "	4,000
Vegetables	318.2 " "	7,000
Wool	nd	nd

* Note: Converted to the metric units from the original imperial units.
1 bag wheat = 90.7 kg : 1 bag barley = 81.6 kg
1 bag potatoes = 90 kg : 1 kg = 2.2 lbs.
1 Kenya pound = 20 Kenya shillings.

Other outlets for vegetables consists of private traders who collect vegetables directly from the farmers for sales in urban centres, mainly Nairobi wholesale and retail markets. Potatoes, leeks and cabbages are mainly bought by private traders from the farmers. According to the information from the Agricultural Economics Department of the University of Nairobi quoted by the German Agricultural Team (1976), the total daily consumption of vegetables in Nairobi is as follows: Cabbage, 9,500 metric tons; carrots, 3,200 metric tons; green peas, 1,500 metric tons; potatoes, 35,000 metric tons. About 40 to 60 percent of the produce sold in Nairobi pass through the whole-sale market. There is no fixed price system between the private traders and the farmers. They strike a balance at each delivery. The prices may be extremely low during the peak production season but could also be very high during the off season.

For the other produce namely milk, pyrethrum, wheat, barley, maize and wool, secured market outlets exist. The milk, pyrethrum and wool are respectively sold to the Kenya Cooperative Creameries, the Pyrethrum Marketing board and the Kenya Farmers Association through collection centres organized by the Farmers Cooperative Union. Maize, wheat and barley, like the rest of the produce, are respectively sold to the National Cereal and produce Board (for maize and wheat) and Kenya Breweries (for barley) through individual arrangement by the farmers.

The marketing for the bulk of vegetables produced in the area needs to be improved. In the original conception of the settlement programme it was expected that cooperative societies would solve many marketing problems. The cooperatives were not only expected to deal with matter like mechanization but also intended to be the pillar of increased productivity. They would provide the best method for farming the land economically, make large marketing possible and thus benefit the individual peasant farmer both at the production and marketing levels. One of the administrative conditions imposed on the settlers has therefore been the insistence that the head of the family becomes a member of a marketing cooperative society from the day that they sign the necessary letter of allotment. All the suppositions assumed that the cooperative society would be well run and function perfectly. As it is, the majority of the cooperative societies have not functioned well. The success of cooperative however depends on social considerations such as the willingness of the people to work together. But the lack of the right person at the leadership and management of the farmers cooperative societies has given rise to improper functioning of the cooperative societies. This is one of the aspects that need to be streamlined to achieve effective and beneficial marketing system for the farmers. The Kinangop Cooperative Union must be operated efficiently and be adequately mobile in terms of vehicles for transporting produce. The union also needs to work closely with the Horticultural Cooperative Union for the purpose of the marketing of vegetables.

There are also other facilities like the grading, packing, collection and storage centres for the horticultural crops which need to be improved in order to secure good average prices in the fresh vegetable markets. This matter it is understood is receiving the due attention it deserves.

1.2.5 Extension services

The extension services in the area under the staff of the Ministry of Agriculture, the Department of Settlement and the Ministry of Cooperative Development. The efforts of these ministries are supplemented with that of Pan African Foods Ltd. who provide extension service to the farmers for the production of vegetables particularly carrots. In 1976 some 33 agricultural staff and 14 cooperative staff were operating in the Kinangop area (Department of Settlement, Kinangop Complex Annual Report, 1976). Furthermore, the Njabini Farmers Training Centre which is located in the study area also provides some extension work. Although the number of extension staff may appear small in relation to the number of farmers to be assisted (above 10,000 plot holders) perhaps what is more essential is a streamlined extension approach to enable the farmers to be easily reached. As already stated under the general information, there is urgent need to bring the benefits of farming to the settlers and to educate them to approach farming in a scientific way. For this reason, it is desirable that methods of extension such as demonstration, field days, tours, cinemas and courses be itensified. Moreover the coordination of timely supply of inputs, improved agricultural husbandry and marketing, needs to be given greater emphasis.

1.3 BACKGROUND DATA AND OBJECTIVES OF THE PRESENT STUDY

The study area which is a rural settlement is agriculturally important for the production of food crops, pyrethrum, milk and wool. In spite of its agricultural importance only general soil investigations of the area have been carried out.

The area constains a range of soils including Planosols which become waterlogged during the rainy season. Gethin-Jones and Scot (1958) published a soil map on scale 1:3,000,000 which being too small, places the area under one soil namely "dark brown clays with light textured top soils". Moreover the soil they so identified lacks proper characterization in terms of laboratory data and field description. Undoubtedly, an area as large as the Kinangop Plateau (about 100,000 ha), can not possibly have only one kind of soil. This deficiency was recognised by the German Agricultural Team (loc cit) during their pre-feasibility study of the development of the Kinangop Plateau. Among the recommendation arising from the study was one which called for a soil map on scale 1:100,000 and which would indicate the proportion of different soils together with their limitations to crop production. Following this recommendation and in order to gain a preliminary impression about the soils, Rachilo (1978) carried out a generalised appraisal (scale 1:100,000) of the soils of an area covering about 108,430 ha and including the area of the present study. For the present study area, the report indicates seven soil units described as follows:

- well drained, deep to very deep, reddish brown, friable, clay to gravelly clay (ando-ferric ACRISOLS)
- well drained, very deep, dark reddish brown to very dark greyish brown, friable clay (mollic ANDOSOLS)
- imperfectly drained to poorly drained, deep very dark greyish brown, mottled, friable to firm, clay, abruptly underlying 45-55 cm of silty clay loam to clay loam, with many iron-manganese concretions at transition (dystric PLANOSOLS)
- imperfectly drained to poorly drained, deep, very dark grey to greyish brown, mottled, firm clay (eutric GLEYSOL)
- poorly drained, deep, very dark greyish brown to very dark grey, mottled, very firm clay, abruptly underlying 30-45 cm of silty clay loam to clay loam, with common iron-manganese concretions at transition (dystric PLANODOLS)
- complex of well drained, shallow to moderately deep, dark brown to very dark brown, friable, clay loam to clay.

It reveals that the soils vary in depth from moderately deep to very deep and similarly the drainage range from good through imperfect to poor.

Recognizing the marked variation revealed by the preliminary investigation of Rachilo (loc cit) even at the small scale of mapping, it was considered appropriate to study the area in a little more detail at semi-detailed level (scale 1:50,000) in order to provide a base for determining the need for more detailed soil investigation and assessment of the constraints of the land resource to the agricultural production in the Kinangop Plateau. Since soils and climate may be inseparable with regard to the assessment of agricultural production potential, the study also includes the examination of the rainfall and temperature of the area. The objectives of the study were therefore the following:

1. To examine the present land use
2. To analyse the rainfall and temperature regime of the area
3. To map the soils at semi-detailed level, scale 1:50,000
4. To define the relevant land utilization types and their requirements
5. To establish grades of the relevant land qualities and to determine how they fit the requirements of the land utilization types
6. To establish on the basis of the identified constraining land qualities the present (current) land suitability and to suggest how the constraints may be removed partly or completely by minor improvements of the land or adaptation of the land utilization type
7. To examine the possibility of improving the soil drainage and to determine the potential land suitability
8. To suggest any further investigations and projects necessary for the improvement of agricultural production in the area.

1.4 THE METHODS USED FOR ACQUIRING THE DATA

The study primarily concerns the examination of the present pattern of land use, the climatic trends and the nature of soils. The interaction of these variables are then investigated with a view to arrive at the present land suitability without any major improvement. Attempt is also made to investigate the possibility for improving the drainage of the imperfectly drained and poorly drained soils so as to assess the possibility of improving the land use. The following is a brief outline of the methods that have been applied for the acquisition of the data.

The data on present land use with regard to crops and livestock were acquired by studying the annual reports of the South Kinangop Divisional Agricultural Office for the period 1964 to 1975. This was supplemented with published data such as that of Odingo (1971) and also ground observation. Also possible crops for introduction such as rice were investigated. The pattern of land use with regard to trees was however acquired by observing and collecting the trees growing in the area. Some of the trees were sent to the Kenya Herbarium for identification. The performance, dominance of the tree species, and the purpose of growing the trees were noted at specific sites where soils profiles had been studied.

The climatic data were obtained from the published reports of the Kenya Meterological Department (1970, 1974 and 1975) and Jaetzold (1976). For the purpose of assessing the state of the night frost in the area and also for the purpose of the experiment on the improvement of drainage, a meterological recording station (see Plate 2) was established in 1975.

The station involved the records of only temperature, rainfall and A-Pan evaporation. It was operated until the end of 1980.

The soils were studied at semi-detailed scale of 1:50,000. Aerial photographs were first studied and tentative soil boundaries marked on the basis of topography and pattern on the photographs. Auger observations were then made to identify the different soils. This was followed by a comprehensive description and sampling of the representative profiles. The results of soil analysis together with further augering where necessary were used to fix the boundaries between the soils. The interpretation of the soils was made in order to determine their present and potential suitability for agricultural and forestry development. The possibility for improving the drainage of the poorly drained soils was investigated by conducting a preliminary drainage experiment to test ripping, ditch drain and camberbed. The details on the layout of this experiment are found in Part 3, section 10.

Plate 2: The field meteorological station set for the drainage investigation.

PART 2

ACQUIRED DATA AND THEIR IMPLICATION

2. THE LAND USE BEFORE RESETTLEMENT AND THE PRESENT PATTERN OF LAND USE

2.1 ARABLE AGRICULTURE

The prevailing topography in most of the study area is very gently to gently undulating. This type of topography lends itself to mechanized farming for small grain cereal. It is for this reason as well as climate among others, it is found that before the area was broken up for small holders settlement, the mechanized farming for small grain cereal was the main type of farming practised. Because of the rainfall which is distributed throughout the year in the area and appropriate temperature, not only two crops of wheat were possible to be grown in a year but also the wheat could be grown together with other crops such as barley, oats and pyrethrum (see Annex 6 for the scientific names of the crops). According to Odingo (loc cit) the following was the land occupied by the major crops in the Kinangop in 1960 before the small-farm resettlement.

Table 2: Land occupied by the major crops in the Kinangop area in 1960 (According to Odingo, 1971).

Crop	Area (ha)	As percentage of cultivated land	Remarks
Wheat	840	10-19	mostly in North Kinangop
Barley	560	5-9	
Oats	400	more than 5	
Pyrethrum	extensive	20-25	on higher lying parts
Linseed	400	no data	
Grass leys	480	20	

Pyrethrum was apparently an important crop for the mixed farming. It was extensively grown on the higher lying part of the Kinangop Plateau and occupied about 20 to 25 percent of the cultivated land in the whole area. Its importance might have arisen from the fact that it is a relatively easy crop to produce which might have proved easy to adopt as a sideline to dairy farming since it is economical in terms of the land size required. The small grain cereals were rotated with pyrethrum. No maize was grown in the area and grass ley farming was quite successful.

Fig 3 Main crops of the settlement schemes during 1975.

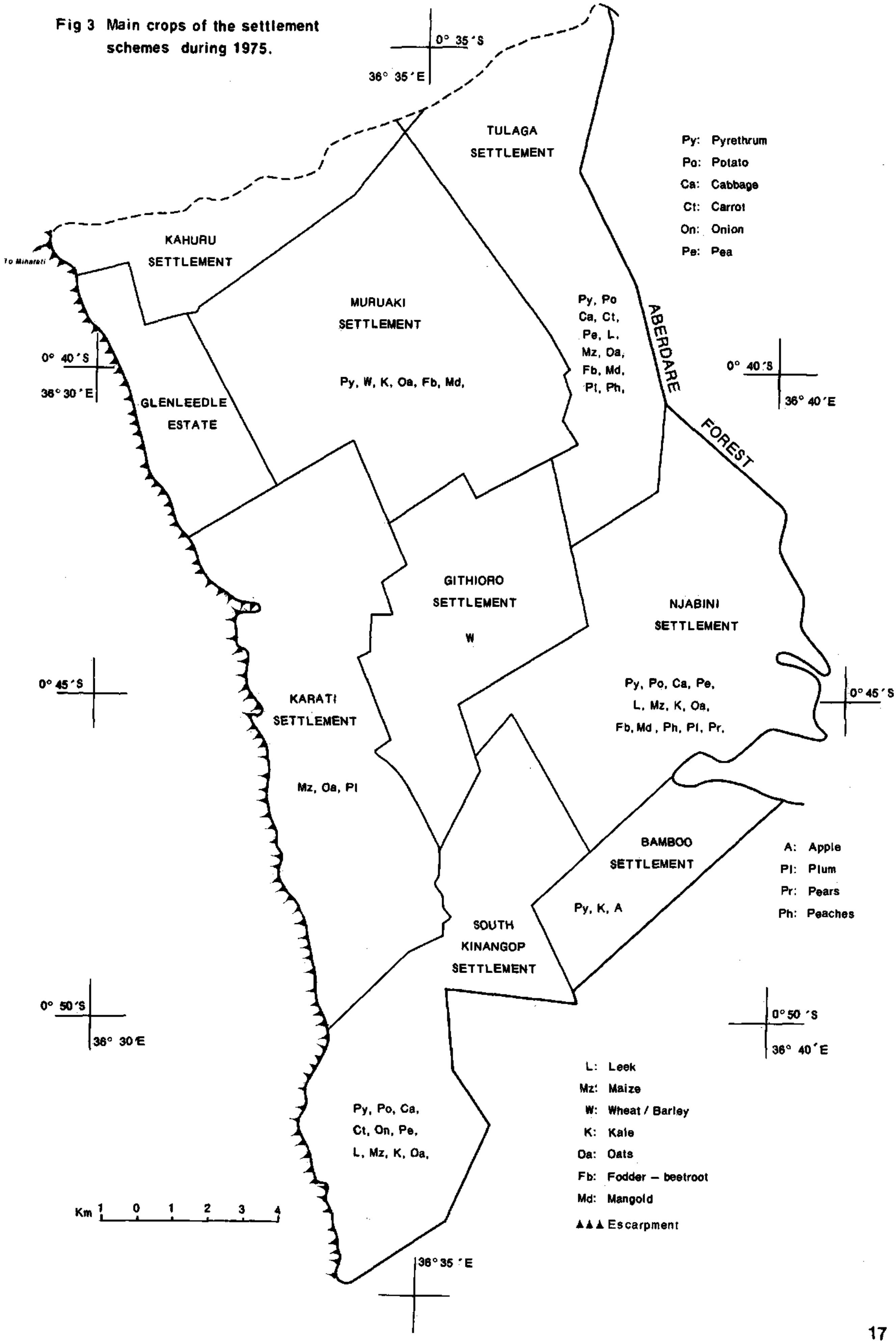


Plate 3: Example of cropmix: cabbages and potatoes grown in some farms.

As already stated, from 1961 the land ownership in Kinangop Plateau was open to all Kenyans and the area consequently placed to small holder settlement scheme. The area attracted settlement partly because it was a mixed farming area and partly because it was assumed that the system of farming being followed in these areas could coveniently be adopted or modified to suit the requirements of small holder farming. However, profound changes in both the nature and pattern of farming followed the land resettlement in the Kinangop area. Table 3a to 3g in Annex 1 provide approximate indication of the land occupied between 1964 and 1975 by various crops in the Kinangop settlement schemes covered by the present study while Fig. 3 shows the major crops found in the schemes. The data refer to the long rain cultivation (March to June) when most of the land is generally cultivated in the Kinangop area. Since intercropping is characteristic of the farming in the area, this may lead to underestimate or overestimate of the area under some crops. The crops likely to be affected in this respect are potato, peas, cabbages, kale and leek which sometimes occur in mix as seen in Plate 3.

The growing of crops is substantial in all the schemes covered by this study except in the Githioro scheme. The latter area also happens to contain predominantly the typical Planosols of the area. Pyrethrum is grown throughout the area but the main production areas seem to be the South Kinangop, Njabini, Muruaki, Tulaga and Bamboo schemes. Potatoes are also grown throughout the area but the main growing areas found in Njabini, Tulaga and South Kinangop schemes. The main schemes for cabbages are Njabini, South Kinangop and Tulaga whereas carrots are produced mainly from Tulaga and South Kinangop.

South Kinangop is the main onion producing areas whereas peas are mainly produced in the South Kinangop, Njabini and Tulaga schemes. The main areas for leeks are found in Njabini, South Kinangop and Tulaga. Maize growing is concentrated in South Kinangop, Njabini, Karati and Tulaga. The areas for wheat are found in Muruaki and Githioro, whereas the production of kale is concentrated in Njabini, South Kinangop, Muruaki and Bamboo schemes. The schemes where oats is mainly produced are Tulaga, South Kinangop, Muruaki, Njabini and Karati. Beet is produced from Muruaki, Tulaga and Njabini whereas mangold is produced mainly in the Muruaki, Njabini and Tulaga schemes.

The development of the crops within the schemes since 1964 to 1975 follow certain trends which cannot be fully explained in the present study. For the South Kinangop Scheme, pyrethrum, potatoes, peas and maize were the major crops in 1964. They are still the major crops to date but also have cabbages, carrots, onions and oats are present. Following the drop in the cultivated land in Kinangop scheme during 1965 to 1969 mainly due to reduced growing of potatoes, peas and maize, there was a general increase in the cultivated land from 1970 with a substantial increase in the growing of pyrethrum. Small areas of wheat were tried in 1969 and 1970 but later abandoned.

For the Bamboo Scheme, pyrethrum, potatoes, maize and peas were the main crops in 1964. This situation changed in 1975 to give rise to pyrethrum, potatoes, cabbages, carrots and kale as the main crops. Drastic drop in the growing of most crops especially potatoes, cabbages, peas, maize and kale occurred in the Bamboo scheme after 1971. Pyrethrum however still remains the major crop. There was substantial growing of the beet in 1970.

The Karati Scheme had mainly pyrethrum, potatoes, peas and maize in 1964. By 1975 other crops were also grown included cabbages, carrots, wheat, kale, oats, beet and mangold. The main crops grown lately are however pyrethrum, cabbages, potatoes, peas, maize and oats. The period 1968 to 1970 was the major period for wheat growing whereas the growing of potatoes substantially decreased in 1974 and 1975.

In the Njabini Scheme, the main crops grown in 1964 were pyrethrum, potatoes, peas and maize. These crops are still very prominent in the area. Other crops that figure prominently are cabbages, carrots, leeks, kale, oats and beet. The growing of wheat occurred during 1968 and 1970 but has since been abandoned. The peak production of pyrethrum and potatoes was in 1970, with 1,700 ha being under the former and 1,000 ha being under the latter.

Githioro Scheme had virtually no cultivated crops from 1964 till 1969 ·

when only small areas were under pyrethrum, potatoes, carrots and beet. In 1971, cabbages and peas were introduced in this scheme whereas wheat and barley were introduced in 1973. By 1975 the main crops were pyrethrum, potatoes, cabbages, peas, leeks, wheat, oats and mangold. The total area which was under cultivation was however very small compared to that of other schemes. This is because of the dominance of the imperfectly drained soils (Planosols) which lead to difficulties in drainage.

The Muruaki Scheme had pyrethrum, potatoes, peas and maize as the main crops grown in 1964. These crops except maize were still being grown in 1975. In addition, cabbage, carrots, leeks, wheat, kale, oats, fodder beet and mangold are prominent in the area. Wheat was introduced in this scheme in 1966 and the area under this crop reached the highest peak in 1970 with 1,270 ha planted. The growing of wheat has however gone down considerably since 1972. There was a large area under potatoes in 1973 but the area under this crop went down by 1975.

For Tulaga Scheme the crops grown in 1964 were pyrethrum, potatoes, peas and maize. These crops continued to be grown and by 1975 there were also cabbages, carrots, leeks, wheat, kale, oats, beet and mangold. Wheat was particularly widely grown in 1968 and 1970 but its production declined considerably since 1970. The major crops by 1975 were pyrethrum, potatoes, cabbages, carrots, peas, maize and oats.

From the above, the diversity of the crops in the area is evident. The fluctuation of the area under various crops from year to year is also evident. This fluctuation seems to be caused by the desire of the farmers to secure successful harvests. The main factors which seem to influence the crop production in the area are the soil and the weather. In years when the rainfall is heavy the area of the imperfectly drained soils (Planosols) become waterlogged and the crops including even wheat which may do well on the planosols under moderate rainfall are destroyed. Similarly periods of insufficient rainfall may occur and the drought destroys crops. Another unpredictable weather phenomenon which may effect crop production is the occurrence of night frost. So in a particular year, the weather may be favourable and a bumper crop may be obtained. This encourages the farmers to increase the acreage of such crops the following year. But the weather in the following year may then become unfavourable so that crops fail. This discourages the farmers so that the following year they abandon the cultivation of the affected crops. The areas under cultivation for various

Table 4: Present yield per hectare of some of the crops in the Kinangop area (Source: DANIDA, 1977).

Crop	yield per ha	Potential yield/ha
Pyrethrum	200 kg	400 kg
Cabbages	4 metric tons	22 tons
Potatoes	11 metric tons	30 tons
Peas	1.5 metric tons	3.5 tons
Carrots	10 metric tons	15 tons
Leeks	2 metric tons	12 tons
Beet	4 metric tons	12 tons
Cauliflower	11 metric tons	22 tons

Yields of some crops from the Kinangop area in 1961 before the resettlement. (Source: Annual Report of Department of Agriculture, South Kinangop, 1961 and Odingo, loc cit).

Produce	Yield per ha
Wheat	1.02 metric tons
Barley	1.43 " "
Potatoes	11.30 " "
Vegetables	5.70 " "
Pyrethrum	567 kilograms

Note: Converted to metric units from the original imperial units: 1 Acre = 0.4 ha.

crops may therefore go up one year only to drop again the following year.

Pyrethrum is fairly suitable for small holder farming in the settlement scheme. It is a cash crop which fetches high income under relatively small acreage of say 1.0 to 2.0 ha besides providing easy area of employment for the families of the settlers. The crop has remained an important one in the Kinangop area inspite of the various fluctuations. Indeed small holder pyrethrum production has been so successful that at present all the pyrethrum in Kenya is produced by small scale farmers.

Maize has popularly been adopted throughout the schemes. But the growing of this late maturing crop is not without risk of being destroyed by frost at any month of the year. In addition to maize and pyrethrum, the many crops that are now being grown in the schemes (see Tables 3a - g in Annex 1) can easily be adapted to suitable growing conditions so that the farmers can derive better returns.

With the diversity of crops introduced by trial and error, there has been unavoidable drop in crop husbandry with the resultant drop in yields. Table 4 gives rough indication of the present yields of some of the crops. Given that crop varieties have been considerably improved, the present yields are rather low compared to those before the resettlement. Crop rotations or proper intercropping has disappeared and many of the farmers do not use fertilizers although they may be aware of their value. As an aid to rehabilitating the crop production, Tables 5 and 6 below categories the diversity of crops now being grown or that could be tried in the area according to their sensitivity to frost, temperature requirement, altitude requirement, rainfall requirement and soil requirement. This categorisation is based on information obtained from such publications as Bailey (1958), Brown (1963), Acland (1971), Purseglove (1974, 1975), Janick (1974), Usher (1974) and FAO (1978). Rice crop is included for consideration because of the occurrance of soils (Planosols) which characteristically have impended drainage. Its development is however subject to breeding appropriate cool tolerant rice varieties.

From Tables 5 and 6, the variability in the crops with regard to sensitivity to frost, temperature, altitude, rainfall and soil can be seen.

Table 5: Sensitivity to frost, temperature, altitude and rainfall requirement of the crops found in the Kinangop area and others that could be considered for the area (nd = no data).

Crop	Effect of frost	Temperature optimum	°C Range	Altitude m	** Rainfall mm
Pyrethrum	slight	15-20	5-30	2000-2900	over 1500
Potato	severe	15-20	5-30	1800-2900	over 900
Cabbage	slight	15-20	5-30	above 900	over 900
Cauliflower	slight	15-20	5-30	nd	nd
Kale	slight	15-20	5-30	nd	nd
Carrot	slight	nd	nd	nd	nd
Onion	slight	nd	nd	0-2300	900-1100
Leek	slight	nd	nd	nd	nd
Beet	slight	15-20	5-30	nd	nd
Peas	slight	15-20	5-30	2100-2700	over 1000
Maize	severe	25-30	10-45	upto 2400	nd
Wheat	slight	15-20	5-30	1800-2900	nd
Barley	slight	15-20	5-30	1800-2900	nd
Oats	slight	15-20	5-30	1800-2900	nd
Mangold	slight	nd	nd	nd	nd
Apples	slight	nd	nd	1800-2700	over 1000
Plums	slight	nd	nd	1800-2700	over 900
Pears	slight	nd	nd	2100-2700	over 1000
Peaches	slight	nd	nd	1800-2400	over 900
Rice*	slight	25-30	10-35	less 1500	-
Sunflower	severe	15-20	5-30	upto 2600	over 700

* Included because of the occurrence of soils (Planosols) which characteristically have impeded drainge. Its development is however subject to breeding appropriate cool tolerant rice varieties.

** Assuming a standard soil for the rainfall requirement.

Table 6: Some soil requirement of the crops found in the Kinangop area and other that could be considered for the area. (nd = no data).

Crop	Soil depth (cm) optimum	Soil drainage Class Range	optimum	range	pH 1:2.5 water optimum	range
Pyrethrum	nd	nd	nd	nd	nd	nd
Potato	more than 75	50-75	W-SE	MW-E	5.0-5.4	5.2-8.5
Cabbage	nd	nd	nd	nd	5.7-7.0	nd
Cauliflower		nd	nd	nd	nd	ndnd
Kale	nd	nd	nd	nd	5.3-7.0	nd
Carrot	nd	nd	nd	nd	5.7-7.0	nd
Onion	nd	nd	nd	nd	6.0-6.6	nd
Leek	nd	nd	nd	nd	nd	nd
Beet	nd	nd	MW-W	nd	5.5-7.0	nd
Peas	nd	nd	MW-W	nd	6.0-7.0	nd
Maize	more than 50	10-50	MW-W	I-SE	5.5-7.0	5.2-8.5
Wheat	more than 50	10-50	MW-W	I-SE	5.5-7.0	5.2-8.5
Barley	nd	nd	MW-W	nd	5.5-7.0	nd
Oats	nd	nd	MW-W	nd	5.5-7.0	nd
Mangold	nd	nd	nd	nd	nd	nd
Apples	nd	nd	nd	nd	5.5-7.0	nd
Plums	nd	nd	nd	nd	nd	nd
Pears	nd	nd	nd	nd	nd	nd
Peaches	nd	nd	nd	nd	nd	nd
Rice	more than 50	25-50	I-MW	VP-W	5.5-7.5	5.2-8.2
Sunflower	more than 75	50-75	MW-W	nd	nd	nd

VP = very poorly drained
P = poorly drain
I = imperfectly drained
MW = moderately well drained
W = well drained
SE = somewhat excessively drained
E = excessively drained

In paragraphs 4 and 5, the climate and soils of the area will be examined with a view to assessing their effect on the crops of the area.

2.2 LIVESTOCK PRODUCTION

Before the break up of land in the Kinangop area for settlement in 1961, cattle and woo-sheep production figured prominently. Livestock farming contributed greatly to the successful mixed farming with dairy cattle playing a very important role. Wool-sheep were introduced so as to raise the carrying capacity of the land. According to Odingo (loc cit), the following Table 7 shows the trend of livestock farming in 1960 before the time of land resettlement.

Table 7: Number of livestock before the land resettlement (according to Odingo, loc cit, p. 153-171).

	Number of	As percentage of total number of cattle
Dairy cattle	4,300	more than 80%
Sheep	23,000	no data
Beef cattle	no data	less than 20%

Odingo reports that the grass ley farming was fairly successful in the Kinangop area and the area of planted grass leys per 100 dairy cattle was about 8.1 to 15.8 ha, i.e. 6.3 to 12.3 livestock units (LU) per hectare.

Mixed farming including cattle and sheep continued to be given prominence in the Kinangop area even after the land resettlement (see Plate 4). This mix farming was considered essential in order to provide the farmer with diversified enterprises to safeguard him economically. The settlement plan was therefore designed to include two or more dairy cows to give the settlement farmer the opportunity to earn a regular income. Table 8a to 8g in Annex 2 show the livestock number during 1967 to 1975 and also the calculated stocking rate. The implication of the stocking rates can be assessed by considering the state of grass for grazing as in 1975. Planted grass leys which enabled a high stocking rate of 6.3 and 1.3 LUs per hectare in 1960 no longer exist. They have given way to natural pasture whose composition and quality is described below.

The dominant grasses of grazing lands which are mainly on Planosols are: *Eragrostic atrovirens, Digitaria scalarum, Alchemilla gracilipes, Setaria aurea, Ficine filiformis* and *Thesium sp.B.* Other grasses which are common are: *Eragrostic schweinfurthii, Helichrysum cymosum, Trifolium semipilosum var semipiluan, Crepis carbonaria, Medicago sp., Monopsis stellaroides var schimperiana, Lobelia ancepts* and *Pennisetum clandestinum.* The grasses occur in various proportions of dried out and green depending on the time of the year. Table 9 shows the proportion of green and driedout grass as determined during 1975 and 1976 while Table 10 shows the nutritive value of both the green and dried out grass.

The nutritive value of the grass measured by % crude protein is only medium. Moreover it tends to go down when the grass becomes dried out. Thus the value of grass would be at best during August when there is greater proportion of green grass and at worst during February and March when there is greater proportion of dried out grass. The nutritive value of grass was lowest

Plate 4: Type of cattle and sheep kept by farmers.

The stocking rates have since 1967 to 1975 varied in the schemes as follows:

Scheme	Range of stocking rate (LU/ha) during 1967 to 1975		
Githioro	0.10	-	0.34
Muruaki	0.34	-	0.92
Karati	0.48	-	0.91
Tulaga	0.49	-	1.20
South Kinangop	0.29	-	1.40
Njabini	0.36	-	2.04

Compared with the stocking rate, before the land resettlement, of 0.50-0.83 LU/ha, i.e. 1.2-2 ha/LU (Odingo, loc cit, p. 153).

during December. This is probably due to the effect of frost which was severe in December.

Against the above nutritive value of the pasture it could be said that the stocking rates during 1975 was found in Tables 8a to 8g (Annex 2) are somewhat too high in most of the schemes. Indeed as can be seen by comparing Plate 1 which shows grazed land and Plate 5 which shows ungrazed pasture within an enclosure, there is evidence of overgrazing. Unless the stocking rate is kept low and the natural pasture supplemented with fodders or concentrates, the yield of milk is likely to be only moderate. The milk production at present is fair at about 1,200 to 1,500 kg per cow per year (DANIDA, loc cit). The annual milk yield per cow before the resettlement, according to Odingo (loc cit, p. 162) was 1096.6 litres (1,129 kg). But the full genetic potential of the grade cows (Ayrshires and Friesians) which are being kept is certainly not being realised at the present level of milk yield.

The possibility of producing some of the fodders like beet, oats, kale and mangold to improve the livestock feeding will be examined in this report in relation to the climate and soils suitability.

Table 9: The proportion of green and dried out grass during different months of the year.

Month	% Green grass	% Dried out grass
January	50	50
February	20	80
March	20	80
May	50	50
July	50	50
August	75	25
September	50	50
October	50	50
November	50	50
December	55	45

Table 10: Nutritive value of the green and dried out grass at various times of the year.

Month		% Crude Oil	% Crude Protein	% Crude Fibre	Proportion Green/Dried out grass
February	Dried out grass	1.40	5.94	28.12	20/80
	Green grass	1.50	6.69	25.60	
	Mean	1.45	6.32	26.86	
May	Dried out grass	1.48	5.88	27.79	50/50
	Green grass	1.56	6.30	25.34	
	Mean	1.52	6.09	26.57	
August	Dried out grass	1.41	5.13	28.70	75/25
	Green grass	1.50	7.50	30.02	
	Mean	1.46	6.32	29.36	
October	Dried out grass	1.49	5.07	28.85	50/50
	Green grass	1.53	6.63	29.81	
	Mean	1.51	5.85	29.33	
December	Dried out grass	1.53	3.26	29.02	55/45
	Green grass	1.61	5.38	30.21	
	Mean	1.57	4.32	29.62	

Plate 5: Better managed grass pasture; compare with overgrazed pasture in Plate 1.

2.3 TREE PRODUCTION

The whole area of study is almost devoid of natural trees which have been cleared to provide land for cultivation and grazing. In those areas where trees are available, the trees are mostly exotics planted for various purposes. The main purpose for planting the trees appear to be for wind-break, building timber and firewood. There is however no evidence anywhere in the schemes that trees planting is carried out for a commercial purpose.

A survey of the exotic trees that are planted in the area was carried out. *Cupressus lusitanica* and *Eucaplyptus saligna* are most common on the well drained and moderately well drained soil units UPrl to UPbl8p and are all doing well. Also found on some well drained soils are *Eucalyptus globulus, Eucalyptus paniculata* and *Pinus* which are doing quite well. Commonly found on imperfectly drained soil units UPap to BPp are *Cupressus lusitanica, Eucalyptus saligna* and *Eucalyptus globulus*. They are all doing well on these soils, except soil unit BPp. Also found on some of the imperfectly drained soils are *Cupressus microcarpa, Cupressus benthimii, Eucalyptus maculata* and *Pinus halapensis*. They are all doing well. There therefore exist suitable tree species for both the well drained and imperfectly drained land to provide for building timber and firewood. Tree production can therefore be one of the best form of land use for the imperfectly drained soils.

3. FARM TYPES AND CROPS

The existence of a diversity of crops grown in the Kinangop area gives rise to variation in the farm types. Although the farming in the area is directed towards advanced farming, it is to be noted that traditional way of farming which involves intercropping is very much evident with regard to some crops.

The farms in the Kinangop are small holdings. The average size range from about 6.40 ha in South Kinangop schemes to about 15.02 ha in Muruaki scheme as follows: (Source: Department of Settlement, Annual Report for 1976).

Scheme	Average plot size (ha)
Muruaki	15.02
Karati	14.33
Tulaga	9.14
Njabini	6.68
South Kinangop and Bamboo	6.40

The farming is complex since the farmer operates a very much diversified agricultural enteprise. It is however, largely on small scale for both subsistence and commercial purpose. The later involves the sale of surplus milk and the production of wool, pyrethrum, wheat and barley. In order to promote agricultural development the government adopts a variety of policy measures intended to modify agricultural production. The changes express themselves at the farm level in the adaption of the pattern of farming that are followed. Generally the official measures are aimed at assisting or accelerating increased production. They are undoubtedly vital factors influencing the development and evaluation of farming patterns.

Because of the continually changing institutional, economic, social and cultural situations, the farmers of Kinangop try to farm more itensively to make more productive use of land. The development path that each farm type and crops tends to follow when the farming is itensified depends to a high degree on the nature of the above situations. The emerging farm types are however designed in a manner that they consist of a combination of inputs in numbers, sequences and timing to satisfy specific objectives of the farmer under a specified environmental setting. Crops production, dairy farming and sheep rearing for wool and meat are all practised.

The farm types found in the study area may be categorised as indicated below. The main ones are the Annual field crops. Tree crops, livestock, livestock-Timber and Livestock-Annual field crop. The following is a brief outline of the nature of each farm type.

Annual field crop: This farm type is characterised by annual crops grown either single or in mixtures. A marked feature of the mixtures is the variety of their forms. The cropping pattern utilized on a given farm determines the nature or make up of the farm type. The variations and changes in cropping pattern have arisen from the land reform and the development of semi-commercial production of food crops. The cropping patterns which are very much evident in the area full under Mixed intercropping, Relay inter-cropping, Row inter-cropping and Sole (single) cropping. Features of these cropping patterns are briefly mentioned below.

Mixed inter-cropping: This is the growing of two or more crops stimultaneously intermingled on the same land with no distinct row arrangement. This together with Row inter-cropping and Relay inter-cropping are appropriate where the land is scarce but labour is ample since they increase yield, save moisture, reduce risk and save fertilizer and power. In the Kinangop area the mixed inter-cropping involves mainly cabbage (Kale) - potato (see Plate 3), cabbage (Kale) - leek and potato-peas.

Row inter-cropping: The row inter-cropping is where two or more different crops are grown together in distinct row arrangement. An example of this cropping pattern in the Kinangop area is found in some plots under maize and peas.

Relay inter-cropping: This is the growing of two or more crops in overlapping sequence. Usually the seeding or transplanting of the succeeding crop is done before the harvest of the preceding crop. It is a common farming practice in Kenya in areas with extended rainy seasons or where several rainy seasons overlap. It is exemplified in the study area by some plots under cabbage and peas.

Sole (single) cropping: The sole or single cropping is where one crop variety or species is grown alone in pure stands. It is a wide spread practice in the Kinangop area for the growing of the commercial crops as well as semi-commercial food crops which include pyrethrum, wheat, barley, maize, cabbage and potatoes.

Recently there has been considerable interest in the study of inter-cropping in Kenya since it is now appreciated that in a small holder farming, the farmer not only requires varied food supply but also requires to obtain them in a continuous fresh supply as there are no storage faciliteit and the storage losses are high. Moreover it is now recognised that by having inter-cropping the farmer of small holding is able to cater for his needed food and also reduces the risks. The extend of inter-cropping involved in the production of various crops grown in the Kinangop area has not been determined. This in itself could form an exercise requiring considerable time for field work. It is however evident that, while crops in mixtures are apparently established haphazardly, a close examination of planting patterns, indicates that the pattern of planting usually involves location and spacing of plants insuch a way that prevents the overlapping of their canopies.

Tree crop: This farm type involves fruit trees and occur in the area as fruit orchards. The main trees found are apples, plums, pears and peaches. The orchards however appear to have been inherited from European settlers and their husbandry has now been left to deteriorate. When the fruit trees are found they are now inter-cultured with either annual crops for food or grass for grazing. The evidence from a small number of orchards that are well cared for shows that with care better yields and more money can be gained.

Livestock: This farm type concerns the production of milk, wool and meat. The farmers rely almost entirely on the natural grass regeneration. There is no intensive use of pasture either through the development of ley pasture or proper management of the natural grass. The grazing is however supplemented by small areas given to fodder oats and beets. The low animal husbandry gives rise to low yields. Consequently regulated ley systems remain more or less uneconomic since under the low yields the farmer does not receive a sufficient return to justify any appreciable expenditure on the establishment and improvement of leys. The farmers however must appropriately adapt their stock to the fodder produced by the natural grass.

Livestock-Annual field crop: This farm type combines livestock and annual field crops. The parts of the farm not under crops are grazed by livestock to produce milk, wool and meat. The nature of the Livestock-Annual field crop farm type is a combination of those of the livestock and Annual field crop farm types as already described above.

Livestock-Timber: The livestock-timber farm type is found mainly on the imperfectly drained soils (Planosols) where trees especially Eucalyptus species are planted for timber and firewood. Whatever grass there is in between the trees is usually grazed by cattle and sheep.

4. THE VALUE OF THE PRESENT SMALL FARM SETTLEMENT

The area under discussion underwent a major subdivision after 1960 to accomodate small-holding farms. With this small holder settlement, came into being a significant diversification of the crops being grown as will be seen from Table 3 in Annex 1. Although the yields of some produce might have gone down with this change from large farms to small farms, the overall value of current small-farm settlement may be viewed against some of the Kenya Government policy objectives namely:

- employement creation
- income earning and distribution
- food sufficiency.

Employement creation: The urban and rural labour forces continue to increase. Many of these new demands for employement have to be absorbed into the primary and processing activities within agriculture. With the sub-division of the study area from 30 large farms into 2892 small farms, self-employement was created for a large number of people and their families apart from retention of some of the salaried farm labourers.

Income earning and distribution: Not only there is a wide disparity between average incomes in rural and in urban but also the distribution is highly unequal. Equity and growth of incomes will initially depend on the development of rural agriculture. The Kenya government at present aims to raise the rural per capita income to Kenya Shillings 3,000 per year.

In 1975 and 1976 the sales of produce from the study area was as follows in Kenya pounds (one Kenya pound equals about US dollar 3.0 at the time):

	Sale in Kenya pounds	
Produce	1975	1976
Milk	nd	721,150
Potatoes	33,100	nd
Carrots	33,350	nd
Pyrethrum	nd	125,050
Cabbages	4,800	nd
Green peas	6,850	nd
Wool	nd	25,900
Vegetables	78,100	nd

Source: Annual Report for 1975 and 1976 of the Kinangop Complex, Department of Settlement, Kenya.

Note: nd = no data.

This income went into the hands of the 2892 settlers and their families as compared to only 130 previous settlers. There can be no doubt of the extent to which the sub-division of the large farms has helped to bring many rural people in the area into the income earning bracket.

Food sufficiency: The importance of food production in Kenya can be seen from the table below which shows the distribution of daily calorie consumption in Kenya as in 1975.

Income Class	% of total population	Daily calorie consumption per person	Daily calorie deficit per person
Rural			
1	39	1578	642
2	32	2077	143
3	19	2545	-
4	5	2867	-
5	2	2788	-
6	4	3036	-
Total	100	2069	151
Urban			
1	42	1787	343
2	25	2117	13
3	33	2453	-
Total	100	2086	44

Source: M.M. Shah, 1978. Calorie Demand Projections Incorporating Urbanization and Income Distribution. Food and Agricultural Programme, International Institute for Applied Systems Analysis.

A moderately active rural worker requires 2,200 calories per day while urban light activity requires 2,130 calories per day. It is evident from the table that Kenyan rural areas has a deficit of 151 calories on average with a range from 143 to 642 calories while the urban areas have a deficit of 44 on average with a range of 13 to 343 calories.

That the inadequate supply of food is an endouring problem is obvious from the occurrence of hunger and malnutrition. Increased food production and distribution may seem to be the abivous answer to meeting the problem of hunger and malnutrition. The extent to which food production in the study area has been diversified since the small holder settlement, can be seen by comparing the produce before the sub-division of of farms (Tables 3 and 8 in Annex 1). The variety of food produced from the area has markedly increased with a surplus for sale as already shown above. In 1975 and 1976 the food production in metric tons was as shown below:

Produce	Food production in metric tons	
	1975	1976
Milk	nd	16,086
Potatoes	3,000	nd
Carrots	3,000	nd
Cabbages	478	nd
Green peas	268	nd

Source: Annual Report for 1975 and 1976 of the Kinangop Complex, Department of Settlement, Keynya.
nd = no data.

Although the yields per hectare are at present low as shown in Table 4, overall, the small holder settlement has greatly helped to save many families from hunger and malnutrition which are some of the serious problems of developing countries. There is however a potential for increased agricultural production in the study area which when realised should lead to even increased benefit and better standard of living for the farmers.

5. THE CLIMATE OF THE AREA AND ITS CONSTRAINTS OF LAND USE

Climate is an important factor influencing land use. The climatic variables that exert profound influence on the trend of agricultural development of an area and its productivity include rainfall, evaporation and temperature. The study area falls within a rain-shadow of the Aberdare Mountains (see Plate 1). Therefore the rains may be variable in the area. Another feature connected with the climate is the occurrance of frost. This arises from the cold air which is generated on the moorlands of the Aberdare Mountains during clear nights and which flows down to the study area. Also observed are the rather low mean temperatures and minimum temperatures which may exclude the possibility of the growing of certain crops. The following sections give the details about the climate.

5.1 THE TEMPERATURE AND FROST REGIME

5.1.1 Temperature type and variability

Little data on temperature exist for the area. Where they exist, it is only for short period. The available data on temperature however provide fair indication on the type and variability of the temperature of the study area. Table 11 gives the temperature of three sites in the area. The South Kinangop Forest Station which has nine years of data lies in the eastern edge of the study area (see Fig. 4). The Kinangop Mtarakwa Farm which has seven years of data lies within the study area and South West of the South Kinangop Forest Station. In the south of Kinangop Forest Station lies Sasumua Dam which has fifteen years of data.

The mean monthly temperature lies between 10°C and 16°C with the mean annual temperature between 11°C and 15°C. The monthly absolute maximum temperature does not exceed 26°C with the hottest months being January, February and March while the coldest months being July and Augyst. The monthly mean minimum temperature lies between 2.7°C and 9.4°C with an absolute minimum temperature of as low as minus 2.2°C. The Meteorological station which the author set up in the study area in 1975 (see Plate 2) to monitor especially the incidence of frost revealed the situation indicated in Table 12 with regard to the absolute minimum temperature on the ground and above the ground at 1.5 meters.

It is evident that the absolute minimum temperature above the ground is about 1°C higher than near the ground. Moreover, as shown in Table 13 which

Fig.4. Climatic stations of the study area.

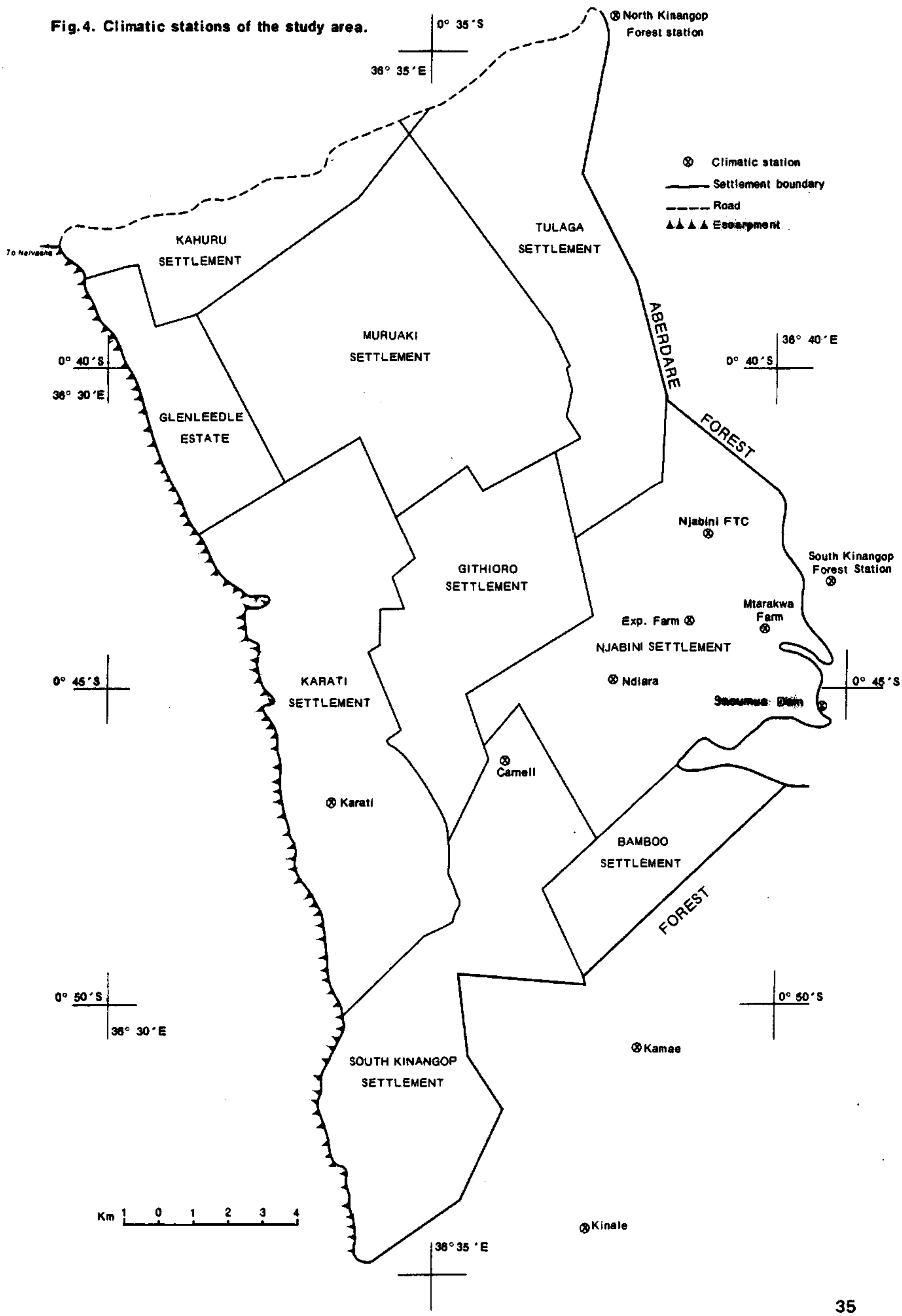


Table 11: Temperature (°C) at three sites in the study area.

Stat.No. and Place		Month												
		J	F	M	A	M	J	J	A	S	O	N	D	Year
90.36 S. Kinangop	Mean Max.	19.4	20.1	19.8	18.2	17.5	16.6	15.5	15.9	16.8	17.4	17.5	18.3	17.7
For.Sta.	Mean Min.	3.6	3.7	5.6	7.8	6.9	5.2	5.1	4.8	4.6	6.2	6.8	4.7	5.4
(9 years data)	Absolute Max.	25.6	24.0	25.5	24.0	22.8	20.6	20.2	20.0	20.6	20.6	20.6	23.2	25.6
	Absolute Min.	1.4	1.1	0.8	2.4	0.8	-1.1	-2.2	-0.6	-1.4	-1.1	-0.4	0.0	-2.2
	Mean	11.5	11.9	12.7	13.0	12.2	10.9	10.3	10.4	10.7	11.8	12.2	11.5	11.6
188 Sasumua Dam	Mean Max.	23.7	24.8	23.8	21.5	20.2	19.4	17.9	18.6	20.9	22.1	21.6	22.9	21.4
(15 years data)	Mean Min.	6.4	6.4	8.0	9.7	9.4	7.5	7.1	7.4	7.1	8.4	8.6	7.4	7.8
	Absolute Max.	31.1	32.2	30.6	28.3	31.7	30.0	29.4	31.1	28.9	28.9	28.9	29.4	32.8
	Absolute Min.	0.0	0.0	1.1	3.9	2.8	1.1	0.0	0.6	1.0	2.2	1.1	1.0	0.0
	Mean	15.1	15.6	15.9	15.6	14.8	13.5	13.0	14.0	15.3	15.3	15.1	15.1	14.6
036 Kinangop														
Mtarakwa Farm	Mean Max.	21.6	21.9	21.6	19.4	16.9	16.7	16.6	16.4	19.2	19.3	18.9	19.3	19.0
(7 years data)	Mean Min.	2.7	5.1	5.7	7.6	7.6	6.0	5.9	5.8	4.8	6.4	6.5	5.2	5.8
	Absolute Max.	25.0	25.0	25.6	22.5	20.8	18.9	21.1	20.0	22.2	23.3	22.8	23.9	25.6
	Absolute Min.	-0.6	-1.1	-0.6	1.1	1.7	2.2	0.6	-1.7	-1.7	-1.1	-1.1	-0.6	-1.7
	Mean	12.2	13.5	13.7	13.5	12.3	11.4	11.3	11.1	12.0	12.9	12.7	12.3	12.4

Source: East African Meteorological Department (1970).

Table 12: Absolute minimum temperature (°C) recorded by the authors during 1975 to 1979; ground measurement is at 1.5 metres (nd = no data).

Month	1975		1976		1977		1978		1979	
	Above ground	ground	Above ground	ground	Above ground	ground	Above ground	ground	Above ground	ground
Jan.	nd	nd	-3	nd	1	nd	-2	-3	0	0
Feb.	nd	nd	0	nd	1	nd	-2	-2	4	3
Mar.	nd	nd	-1	nd	1	nd	5	4	-2	-2
Apr.	nd	nd	2	nd	7	nd	7	6	4	3
May	3	nd	2	nd	6	nd	2	1	5	4
Jun.	2	nd	-1	nd	0	nd	0	0	4	3
Jul.	0	nd	0	nd	1	1	0	0	nd	nd
Aug.	1	nd	-2	nd	1	0	5	3	nd	nd
Sep.	1	nd	0	nd	1	-1	nd	nd	4	3
Oct.	1	nd	-1	nd	1	1	4	3	1	0
Nov.	2	nd	2	nd	5	5	nd	nd	-3	-4
Dec.	-2	nd	-1	nd	1	0	5	4	-1	-2

Table 13: Comparison of absolute minimum temperature (°C) at high lying and low lying grounds.

DATE	MEASURED AT GROUND LEVEL		MEASURED 1.5 M ABOVE GROUND	
	HIGH LYING ELEVATION	LOW LYING ELEVATION	HIGH LYING ELEVATION	LOW LYING ELEVATION
4 Dec. 1977	-1	0	0	1
7 Jan. 1978	-3	-2	-2	-2
3 Feb. 1978	-3	-1	no data	no data
2 Mar. 1979	-2	-1	-1	-1
20 Oct. 1979	0	0	1	2

compares the absolute minimum temperature at two elevations, the absolute minimum temperature appears, at the site studied, to be lower at high lying ground than at low lying ground.

Frost was observed to occur whenever the temperature dropped to -10°C and below. They were observed on the following dates since May, 1975.

Severe frost	Mild frost
January 1976, 1978	March 1976
February 1878	June 1976
March 1979	August 1979
July 1979	September 1976, 1977
August 1976	October 1976
December 1975, 1979	December 1976

Frost may therefore be expected to occur in the study area during most months of the year except during April and May. Mild frost occurred at 0°C to -1°C but a severe one occurred when the temperature dropped below -1°C. Frost damage may be expected to be more severe at the ground level and at the high lying ground. It also happens that the high lying grounds in the study area are the area with better drained soils which can easily be farmed. The constraint of the temperature will be further examined in section 5.1.2 below. However the type and range of temperature appear uniform throughout the area. The study area may therefore be considered to have only one type of temperature whose mean annual is from 11°C to 15°C with the risk of frost in most of the months except April and May.

5.1.2 Influence of temperature with regard to crops

The mean monthly temperature ranges between 10°C and 16°C with the mean annual temperature between 11°C 15°C. The main problem associated with temperature is the occurrence of night frost in most of the months except April and May. Therefore the growing of certain crops which are very sensitive to frost especially maize, sunflower and potatoe may be risky if extended beyond March to June. Maize which requires at least ten months to maturity can not easily be adapted for the area. The rather low mean temperatures are also not conductive to the growing of the warmth-requiring crops such as beans, sorghum, sweet potatoes, bananas, pawpaw, cassava and coffee. Crops that could be considered for the area are given in Table 5 above and include pyrethrum, potato, cabbage, cauliflower, kale, carrot, onion, leek, peas, sunflower, wheat, barley, beet, oats, mangold, apples, plums, pears and peaches.

5.2 WATER AVAILABILITY

5.2.1 Rainfall distribution

Table 14 gives the rainfall at some of the sites in and around the study area. The rainfall as can be deduced from Fig. 4 increases from North to South on some longitude while it decreases from East to west. Sasumua Dam area which lies in the extreme east of the study area receives 920 mm. Rains occur throughout the year but a few months of the year may be considered as wet months. If a monthly rainfall of 50 mm to 100 mm is taken as indicative of moist season while over 100 mm rainfall is taken as indicative of a wet season then the following is the position with regard to the rainfall stations mentioned in Table 14.

Table 14: Monthly mean rainfall and calculated annual potential evaporation data (mm) for the area in and around the study area.

Sta.No. and Place 90.36	Altitude (metres)	No. of years rainfall	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Eo (calcu-ted)
164 South Kinangop For. Sta.	2588	20	68	72	153	268	222	84	62	67	62	127	147	78	1410	1495
188 Sasumua Dam	2474	22	77	78	152	313	266	81	57	69	63	126	174	93	1549	1536
152 Njabini F.T. Centre	2588	21	65	57	114	218	176	74	62	68	63	102	118	73	1190	1495
012 Kinangop Expt. Sta.	2561	11	43	65	110	183	204	72	41	56	49	83	122	73	1101	1505
250 Kamae For. Sta.	2591	13	75	75	129	308	244	63	42	51	72	105	206	95	1465	1494
025 N. Kinangop For. Sta.	2629	53	43	51	90	171	162	108	73	92	103	95	94	58	1140	1481
042 Ndiara	2546	26	52	56	110	226	200	68	40	58	49	85	113	73	1130	1510
191 Kerita-Kinale	2591	25	67	72	118	290	230	62	39	42	38	91	157	90	1296	1496
031 Carnell	2439	31	61	67	115	203	169	60	35	58	54	75	101	81	1079	1549
183 Karati Scheme	2618	16	64	59	80	156	125	47	36	47	51	68	105	84	922	1485

Source: East African Meteorological Department (1974) for rainfall.

Annual potential evaporation, Eo calculated from the following formula: Eo (mm) = 2422-0.358h where h is altitude in metres (Woodhead, 1968).

Station	Wet seasons (months with more than 100 mm rainfall)	
N. Kinangop For. Sta.	April-June	September
S. Kinangop For. Sta.	March-May	October-November
Sasumua Dam	March-May	October-November
Kamae For. Sta.	March-May	October-November
Njabini F.T. Centre	March-May	October-November
Njabini F.T. Centre	March-May	November
Kerita-Kinale	March-May	November
Kinangop Expt. Sta.	March-May	November
Ndiara	March-May	November
Karati Scheme	April-May	November

The wet seasons for Tulaga, Muruaki, Githioro, Njabini, Bamboo and South Kinangop schemes therefore occur during March to May and in November while they occur during April to May and in November for Karati Scheme. There are in general two wet periods within the study area. A dry period occurs in Karati Scheme during June to August whereas it occurs during July in the rest of the schemes. For the purpose of further analysis of rainfall, the representativeness of the rainfall is treated as shown below:

Representative rainfall site	Settlement Schemes represented
Ndiara	Tulaga, Njabini, Bamboo
Carnell	Muruaki, Githioro, South Kinangop
Karati	Karati

Table 15: Rainfall Probability at Ndiara meteorological site (representing Tulaga, Njabini and Bamboo Settlement Schemes) and Karati meteorological site (representing Karati Settlement Scheme).

Sta. number 90.36...	Name	Observation period for rains	Average annual rainfall for the observation period mm	Estimated long period average rainfall mm	Expected minimum rainfall in mm: 4 out of 5 years	Expected minimum rainfall in mm: 2 out of 3 years
042	Ndiara	1931-1960	1140	1140	940	1090
183	Karati Scheme	1957-1974	905	900	740	800

Source: Jaetzold, 1976: Climatic situation of the Kinangop area. Internal Publication of the Department of Settlement, Ministry of Lands and Settlement, Nairobi.

5.2.2 Rainfall probability

The rainfall occurs throughout the year as revealed in Table 14. The rainfall probability can therefore be assessed on annual basis. Jaetzold (loc cit) has computed the probabilities as indicated in Table 15.

For the Ndiara site which represent Tulaga, Njabini and Bamboo settlement schemes the probability of receiving a minimum of 940 mm in a year is 4 out of 5 years whereas the probability of receiving a minimum of 1090 mm in a year is 2 out of 3 years. Even for the rather dry Karati area which represent the Karati Scheme, the rainfall reliability is high. In 4 out of 5 years a minimum of 740 mm of rainfall could be received in a year whereas a minimum of 800 mm could be received in 2 out of 3 years.

The high rainfall reliability in the study area favours intensified agricultural production and should lead to good crop yields every year.

5.2.3 Evaporation and evapotranspiration pattern.

Information on evaporation and evapotranspiration for the study area is meagre since to acquire this information needs a completely equiped meteorological station to obtain among other, the data on radiation, wind speed, humidity and daily sunshine. Woodhead (1968) has however, using the Penman (1956) formula, computed potential evaporation for the South Kinangop Forest Station which lies just outside the eastern edge of the study area and also for Kimakia which lies some 16.5 km east of the study area. Table 16 provides his computed Penman potential evaporation for the two sites while Table 17 gives the monthly potential evaporation as percentage of the year potential evaporation.

Woodhead (Ibid) has also provided a formula for estimating annual Penman potential evaporation from the altitude of a site as follows: Annual potential evaporation, $Eo = 2422-0.358h$ where h is altitude in metres. This formula was arrived at by carrying out a correlation between potential evaporation and altitude at different areas of Kenya. The above formula has been employed to estimate the annual potential evaporation of the meteorological stations in and around the study area while the monthly mean percentages of Table 17 have been used to calculate the monthly potential evaporation from the estimated monthly annual potential evaporation. Table 18 provides the estimated monthly and annual potential evaporation. The potential evaporation is lowest during the month of July while it is highest during the month of March. It is also fairly high during the months of January, February and October.

Table 16: Monthly Penman potential evaporation (mm) at South Kinangop Forest Station and Kimakia according to Woodhead (1968).

MONTH	PENMAN POTENTIAL EVAPORATION (Eo)	
	South Kinangop Forest Station	Kimakia
January	116	150
February	113	149
March	129	160
April	110	132
May	99	116
June	88	105
July	81	89
August	86	99
September	100	122
October	119	143
November	105	131
December	105	133
Year	1251	1529

Table 17: Monthly potential evaporation as percentage of year potential evaporation; calculated from Table 16.

MONTH	% S. Kinangop	% Kimakia	% Mean
January	9.3	9.8	9.5
February	9.0	9.7	9.4
March	10.3	10.5	10.4
April	8.8	8.6	8.7
May	7.9	7.6	7.7
June	7.0	6.9	6.9
July	6.5	5.8	6.2
August	6.9	6.5	6.7
September	8.0	8.0	8.0
October	9.5	9.4	9.4
November	8.4	8.6	8.5
December	8.4	8.7	8.6

Work by Dagg (1965) has shown that the average ratio of maximum crop evapotranspiration (ETm) to potential evaporation (Eo) is 72.3 percent over a growing period of 180 days. According to FAO (1979, p. 25) the crop coefficient, kc for most crops averaged over growing period is 0.7 to 0.95 (average 0.825). It is therefore apparent that maximum crop evapotranspiration (ETm) averaged over the growing season for most crop is approximately 2/3 of the potential evaporation (Eo) since ETm = kcE and ETo = 0.8Eo. This ratio of 2/3 is also the one used by the Kenya Soil Survey (see Van de Weg and Mbuvi, 1975, p. 11) and has therefore been adopted for the present study as to keep the result in line with the investigations by the Kenya Soil Survey elsewhere in the country. Table 19 gives the monthly maximum crop evapotranspiration

Table 18: Estimated monthly and annual Penman potential evaporation (mm) for the area in and around the study area.

Sta.No. and Place 90.36....	Altitude (metres)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
164 S. Kinangop For.Sta.	2588	142	140	155	130	115	103	93	100	120	141	127	129	1495
188 Kinangop Sasumua Dam	2474	146	144	160	134	118	106	95	103	123	144	130	132	1535
152 Njabini F.T. Centre	2588	142	140	155	130	115	103	93	100	120	141	127	129	1495
012 Kinangop Expt. Sta.	2561	143	142	157	131	116	104	93	101	120	142	128	129	1506
250 Kamae For. Sta.	2591	142	141	156	130	115	103	93	100	120	140	127	129	1496
025 N. Kinangop For. Sta.	2629	141	139	154	129	114	102	92	99	119	139	126	127	1481
042 Ndiara	2546	144	142	157	131	116	104	94	101	121	142	128	130	1510
191 Kerita-Kinale	2591	142	140	155	130	115	103	93	100	120	140	127	129	1494
031 Carnell	2439	147	146	161	135	119	107	96	104	124	146	132	133	1550
183 Karati Scheme	2618	141	140	154	129	114	102	92	100	119	140	126	128	1485

Note: Annual Penman potential evaporation; Eo estimated from the formula of Woodhead (1968):

Eo (mm) = 2422 - 0.358h where h is altitude in metres.

Monthly potential evaporation estimated from the estimated annual potential evaporation, using the percentages in column four of Table 17.

Table 19: The monthly maximum crop evapotranspiration and rainfall (mm) at three representative meteorological stations.

STATION	Ndiara Station		Carnell Station		Karati Station	
MONTH	Rainfall	Maximum evapotranspiration (ETm)	Rainfall	Maximum evapotranspiration (ETm)	Rainfall	Maximum evapotranspiration (ETm)
Jan.	52	96	61	98	64	94
Feb.	56	95	67	98	59	94
Mar.	110	105	115	108	80	103
Apr.	226	88	203	90	156	86
May	200	78	169	80	125	76
Jun.	68	70	60	72	47	68
Jul.	40	63	35	64	36	62
Aug.	58	68	58	70	47	67
Sep.	49	81	54	83	51	80
Oct.	85	95	75	98	68	94
Nov.	113	86	101	88	105	84
Dec.	73	87	81	89	84	86

Note: Maximum crop evapotranspiration (ETm) computed as two/third (2/3) Penman potential evaporation (Eo).

(2/3 Eo) computed for Ndiara, Carnell and Karati meteorological stations which are representative for the seven settlement schemes covered by this investigation.

5.2.4 Cumulative Water Balance and the Length of the Growing Period.

The presence of clay pan or solid rock layer in a soil can limit the soil's moisture storage capacity and the cumulative water balance. Tests on the imperfectly drained soils (Planosols) of the study area show that the soil moisture storage of these imperfectly drained soils with clay pan lies between 40 mm and 80 mm. This greatly contrast with that of the better drained soils which are free of the clay pan and where the tests reveal that the soil moisture storage down to 100 cm depth varies between 50 mm and 240 mm depth, where the soil depth allows, the following (see Table 20) were the ranges of the moisture storage.

Table 20: Ranges of the available soil moisture storage capacity.

Moisture storage	Number of representative soils
40-50 mm	5
50-75 mm	4
75-100 mm	7
100-125 mm	6
125-150 mm	2
150-200 mm	2
200-250 mm	1

Therefore for the purpose of assessing the cumulative water balance, the levels of available soil moisture storage capacity adopted for this report are 200, 150, 125, 100, 75, 50 and 25 mm. Table 21a - c provide the data on cumulative water balance for a whole year using the monthly rainfall and maximum crop evapotranspiration shown in Table 19.

The Growing Period

This is regarded as the period when water availability and temperature permit crop growth. Except for the occurrence of night frost which is a risk to some crops, the temperatures in Kinangop as shown in Table 11 above are ideal for most crops throughout the year. For this reason, only moisture availability will be considered for the purpose of assessing the growing period.

In order to enable a quantitative assessment of the growing period, a simple water balance model which compares the stored soil moisture with the monthly maximum crop evapotranspiration (ETm) is used in this report. The precision of this assessment would no doubt be improved by using rainfall and evapotranspiration periods shorter than one month (say 10 days intervals) but the published climatic data available to the author do not easily allow for such a refinement.

If optimum growth of crop is to be attained then a continuous moisture supply is required throughout the growing season. The balance between available soil moisture and the maximum crop evapotranspiration (ETm) should accordinly be continously positive throughout the growing season. As is evident from Tables 21a - c, this situation is dependent on the available soil moisture storage capacity. Where the soil is capable of storing more available moisture there is a longer period of moisture sufficiency. For the Ndiara area which represent Tulaga, Njabini and Bamboo Settlement Schemes, the period of continuous moisture sufficiency ranges from 3 months for a 100 mm available soil moisture storage capacity to 11 months for a 200 mm available soil moisture storage. Similarly for the Carnell area which represents Muruaki, Githioro and South Kinangop Settlement Schemes the period of continuous moisture sufficiency ranges from 3 months for a 200 mm available moisture storage capacity. The period of continuous moisture sufficiency is shorter for the Karati area which represents Karati Settlement Scheme. The period ranges from 3 months for 100 mm available soil moisture storage capacity to 6 months for a 200 mm available soil moisture storage capacity.

Calculations for available soil moisture storage between 75 mm and 100 mm indicate that soils with less than 90 mm available moisture storage capacity either have the period of continuous moisture suffucuency less than three months or are suffering a moisture deficiency throughout.

5.2.5 Influence of water availability with regard to crops

The Western part of the study area may be considered semi-humid while the central and eastern parts are sub-humid. In the eastern side and the middle of the area, there are two main peak of rainfall, one in April and the other in November, and there is substantial rain in the rest of the months except July. The moist and humid periods may therefore be considered to occur throughout the year. For the western part of the study area, the two rainy seasons are more clearly divided. There are two peaks in April and November but the months of June, July and August receive less than 50 mm and may be considered dry.

Important for crops are the differences in the water balance computed on the basis of simple model that compares the soil moisture with monthly maximum crop evapotranspiration. A positive balance between the two factors is necessary for optimum growth of the crop. But as can be seen in Tables 21a to 21c the situation is substantially influenced by the capacity of the soil to store the water during the humid and moist periods to be available to the crop. The higher the soil moisture storage capacity, the fewer the months with moisture deficit in the study area. Taking available soil moisture storage of 90 mm as average it is evident that there are only three months of continuous moisture sufficiency in the study area. As can be seen from Table 23 in section 6.3 a number of soils of the study area have available moisture storage capacity less than 90 mm. Such soils will therefore has less than 3 months of continuous moisture sufficiency and are less favourable for crop growing.

5.3 THE LAND USE PATTERN AS INFLUENCED BY TEMPERATURE AND WATER AVAILABILITY

The rather cool temperature and the three types of rainfall in the study area have influence on the land use pattern. The eastern part of the area which comprises Tulaga, Njabini and Bamboo Settlement Schemes have moist and humid rainfall regimes throughout the year and could be a little too wet for crops sensitive to excess moisture e.g. oats. The long moist and humid periods are however favourable to many crops and support good pasture throughout the year. The good pasture is benefitial to the livestock for milk and wool

Table 21a: Cumulative water balance (mm) from March to February at Ndiara Meteorological Station representing Tulaga, Njabini and Bamboo Settlement Scheme (assuming no runoff).

		Available Soil Moisture Storage Capacity of:														
		200 mm		150 mm		125 mm		100 mm		75 mm		50 mm		25 mm		
Month	Rainfall (mm)	Max. evapotranspiration (mm) - (ETm)	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance
Mar.	110	105	110	+ 5	110	+ 5	110	+ 5	100	- 5	75	- 30	50	- 55	25	- 80
Apr.	226	88	200	+112	150	+ 62	125	+ 37	100	+ 12	75	- 13	50	- 38	25	- 63
May	200	78	200	+122	150	+ 72	125	+ 47	100	+ 22	75	- 3	50	- 28	25	- 53
Jun.	68	70	190	+120	140	+ 70	115	+ 45	90	+ 20	68	- 2	50	- 20	25	- 45
Jul.	40	63	160	+ 97	110	+ 47	90	+ 27	60	- 3	40	- 23	40	- 23	25	- 38
Aug.	58	68	155	+ 87	105	+ 37	85	+ 17	58	- 10	58	- 10	50	- 18	25	- 43
Sep.	49	81	136	+ 55	86	+ 5	66	- 15	49	- 32	49	- 31	49	- 32	25	- 56
Oct.	85	95	140	+ 45	90	- 5	85	- 10	85	- 10	75	- 10	50	- 45	25	- 70
Nov.	113	86	158	+ 72	113	+ 27	113	+ 27	100	+ 14	75	- 11	50	- 36	25	- 61
Dec.	73	87	145	+ 58	100	+ 13	100	+ 13	87	0	73	- 14	50	- 37	25	- 62
Jan.	52	96	110	+ 14	65	- 31	65	- 31	52	- 44	52	- 44	50	- 46	25	- 71
Feb.	56	95	70	- 25	56	- 39	56	- 39	56	- 39	56	- 39	50	- 45	25	- 70
Months of continuous moisture Sufficiency			11		7	6		3	nil		nil	nil				
Continuous moisture Deficit months			1		1	2		4	12		12	12				

Table 21b: Cumulative water balance (mm) from March to February at Carnell Meteorological Station representing Muruaki, Githioro and South Kinangop Settlement Schemes (assuming no runoff).

			Available Soil Moisture Storage Capacity of:													
			200 mm		150 mm		125 mm		100 mm		75 mm		50 mm		25 mm	
Month	Rainfall (mm)	Max. evapo-transpiration (mm) - (ETm)	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance
Mar.	115	108	115	+ 7	115	+ 7	115	+ 7	100	- 8	75	- 33	50	- 58	25	- 83
Apr.	203	90	200	+110	150	+ 60	125	+ 35	100	+ 10	75	- 15	50	- 40	25	- 65
May	169	80	200	+120	150	+ 70	125	+ 45	100	+ 20	75	- 5	50	- 30	25	- 55
Jun.	60	72	180	-108	130	+ 58	105	+ 33	80	+ 8	60	- 12	50	- 22	25	- 47
Jul.	35	64	143	+ 79	93	+ 29	68	+ 4	43	- 21	35	- 29	35	- 29	25	- 39
Aug.	58	70	137	+ 67	87	+ 17	62	- 8	58	- 12	50	- 12	50	- 20	25	- 45
Sep.	54	83	121	+ 38	71	- 12	54	- 29	54	- 29	54	- 29	50	- 33	25	- 58
Oct.	75	98	113	+ 15	75	- 23	75	- 23	75	- 23	75	- 23	50	- 48	25	- 73
Nov.	101	88	116	+ 28	101	+ 13	101	+ 13	100	+ 12	75	- 13	50	- 38	25	- 63
Dec.	81	89	109	+ 20	94	+ 5	94	+ 5	93	+ 4	75	- 14	50	- 39	25	- 64
Jan.	61	98	81	- 17	66	- 32	66	- 32	61	- 37	61	- 37	50	- 48	25	- 73
Feb.	67	98	67	- 31	67	- 31	67	- 31	67	- 31	67	- 31	50	- 48	25	- 73
Months of countinuous Moisture Sufficiency Continuous Moisture deficit month						10	6	5	3	nil	nil	nil				

Table 21c: Cumulative water balance (mm) from April to March at Karati Meteorological Station representing Karati Settlement Scheme.

			Available Soil Moisture Storage Capacity of:													
			200 mm		150 mm		125 mm		100 mm		75 mm		50 mm		25 mm	
Month	Rainfall (mm)	Max. evapo-transpiration (mm) - (ETm)	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance	Moisture held	Moisture balance
Apr.	156	86	156	+ 70	150	+ 64	125	+ 39	100	+ 14	75	- 11	50	- 36	25	- 61
May	125	76	195	+119	150	+ 74	125	+ 49	100	+ 24	75	- 1	50	- 26	25	- 51
Jun.	47	68	166	+ 98	121	+ 53	96	+ 28	71	+ 3	47	- 21	47	- 21	25	- 43
Jul.	36	62	134	+ 72	89	+ 27	64	+ 2	39	- 23	36	- 26	36	- 26	25	- 37
Aug.	47	67	119	+ 52	74	+ 7	49	- 18	47	- 20	47	- 20	47	- 20	25	- 42
Sep.	51	80	103	+ 23	58	- 22	51	- 29	51	- 29	51	- 29	50	- 30	25	- 80
Oct.	68	94	91	- 3	68	- 26	68	- 23	68	- 23	68	- 23	50	- 44	25	- 69
Nov.	105	84	105	+ 21	105	+ 21	105	+ 21	100	+ 16	75	- 9	50	- 34	25	- 59
Dec.	84	86	105	+ 19	105	+ 19	105	+ 19	100	+ 14	75	- 11	50	- 36	25	- 61
Jan.	64	94	83	- 11	83	- 11	83	- 11	78	- 16	64	- 30	50	- 44	25	- 69
Feb.	59	94	59	- 35	59	- 35	59	- 35	59	- 35	59	- 35	50	- 44	25	- 69
Mar.	80	103	80	- 23	80	- 23	80	- 23	80	- 23	75	- 28	50	- 53		- 78
Months of Continuous moisture sufficiency							6	5	4	3	nil	nil	nil			
Continuous moisture deficit months							1	2	3	4	12	12	12			

production. The cold nights highly favour pyrethrum because they assist to increase flowering and pyrethrin content.

The middle part of the area which is comprised of Muruaki, Githioro and South Kinangop Settlement Schemes also has a rather cool and subhumid climate. The humid periods are not as strong as in the eastern parts but there occur long moist and humid periods. Like in the eastern part, the climate is favourable for a large range of crops which include pyrethrum, potato, wheat, barley, oats, cabbage, cauliflower, peas, carrots and fruit trees. The risk of frost is still great and a crop like maize cannot safely be produced. Even potato should be grown during March to June. This zone still supports good pasture for both milk and wool production.

The western part of the study area comprises of the Karati Settlement Scheme. It is characterised by short humid periods and a definite rather dry period. The humid seasons occur only in April, May and November with dry periods from June to September. The short humid period and the intervening dry period is not favourable to crops like wheat, barley, potato, cabbago and peas which require ample period for vegetable setting. Although the cold nights are favourable for pyrethrum production, the rainfall is rather low for this crop. Since there is no extreme drying up during the dry period there is fair pasture throughout the year to support milk and wool production. This pasture can also be supplemented with the production of fodder crops like oats, beet and mangold which are ideal for this zone.

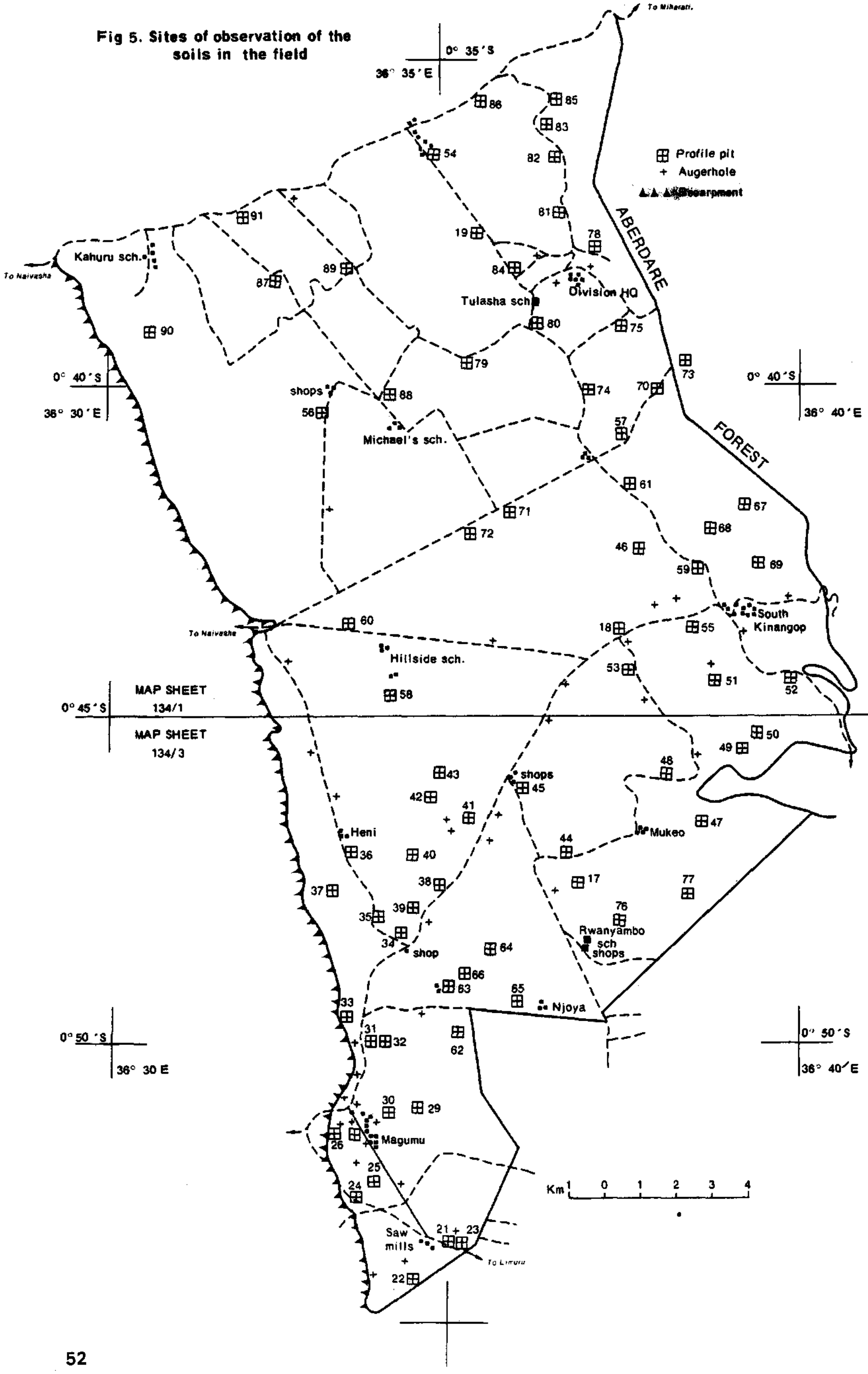
6. THE SOILS OF THE AREA AND THEIR CONSTRAINTS ON LAND USE

Kikuyu Red Loam and Black Cotton Soil are common names which have been used respectively to identify the well drained red soils and the imperfectly drained dark coloured soils which occur in the area. Like most common names, they lack precision, but are more readily understood by a large audience than scientific names. The names are frequently used locally to convey respectively an image of a deep and well drained red soil which is ideal for coffee and or tea growing and an imperfectly drained dark soil which is ideal for cotton, sugarcane and rice growing.

Soils on young landscape or recently deposited pyroclastics and river sediments as occur in the area may be rich in plant nutrients and support a vigorous plant and animal community provided that water, sunlight and temperature are not limiting. But the soil nutrient supply is not limitless and with time, soluble nutrients are removed in crops and some find their way to ground and river waters. What remains on the landscape may be a soil that is stripped of its capacity to retain and supply the nutrients essential for plant growth. Formulation of sound soil management practices therefore depends on the understanding of the causes and effect relationship between the crop response and soil manipulation. A poor farmer can become rich on fertile soil and a rich farmer can make infertile soil productive, but a poor farmer on fertile soil has little chance of succeeding. Sound principles are needed to assist farmers to reduce the risk of failure when they are advised to implement farming practices which are unfamilair to them. For this reason the most exacting principles are needed to forecast with great accuracy the likely response when a soil is subjected to a particular use. The first step for accomplishing this objective is to carry out a field study to determine the characteristics of the soils so that the information could be used to predict the behaviour of the soils, identify their best use and estimate their productivity.

The following sections provide information on the characteristics of the soils of the study area and also an assessment of how the soils may influence the land use. The previous soil investigations in the area and the methodology for present soil study is already indicated in Section 1.4 of this report. Fig. 5 shows the sites where the soils were examined in the field in order to confirm the various soils previously delineated from aerial photographs.

Fig 5. Sites of observation of the soils in the field



6.1 THE GEOLOGY, PHYSIOGRAPHY AND HYDROLOGY OF THE AREA

Geology.

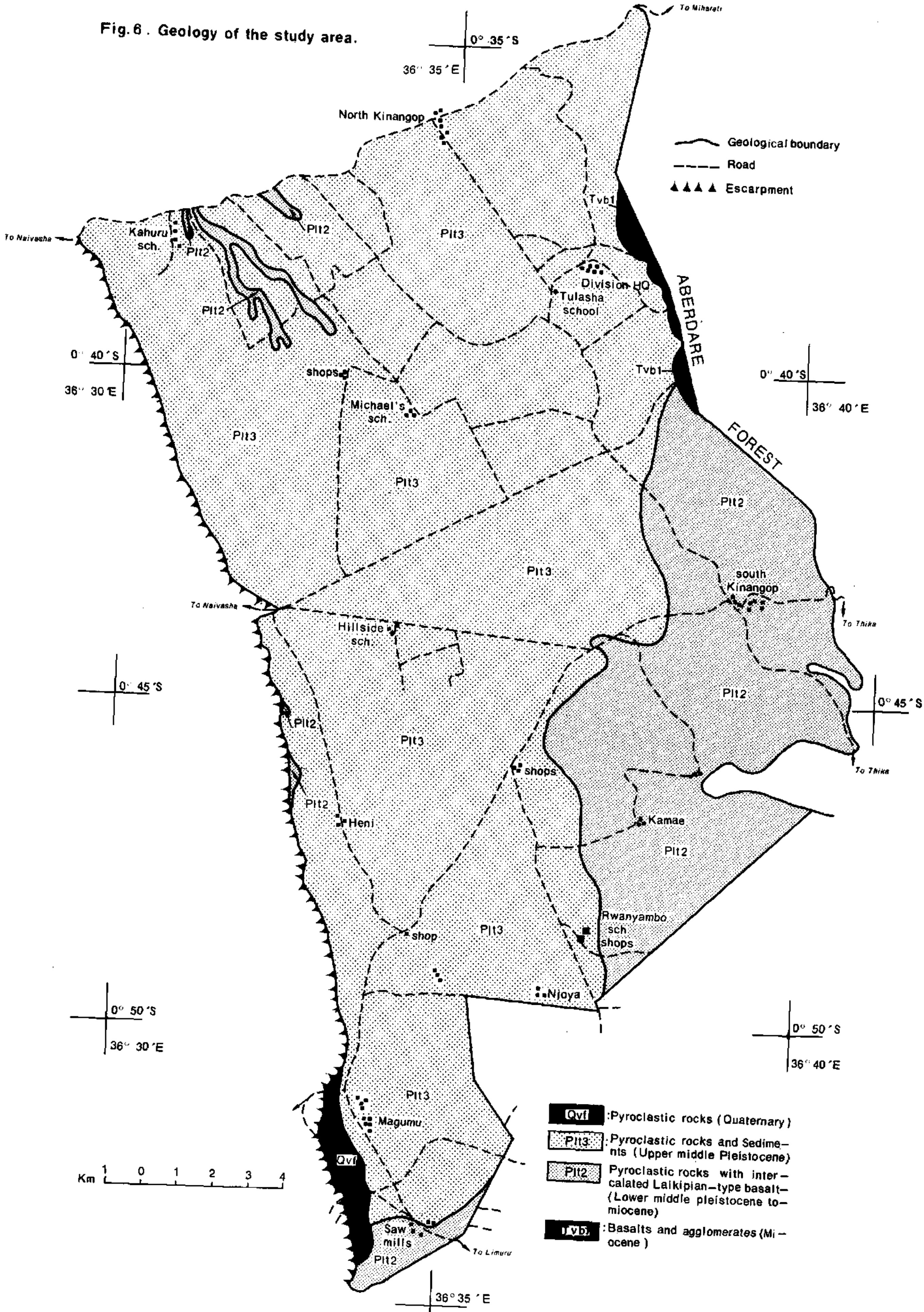
The geology of the area is reported by Thomson (1964). Fig. 6 shows the occurring geology. The rocks are of volcanic origin. They consist of pyroclastic rocks and basalt. Soft and coloured trachytic pumice tuffs which frequently form thick deposits are the most common pyroclastic rocks in the area. Thomson (loc cit, p. 26) reports that the powdery light grey pumiceous ash found over much of the study area was deposited possibly during the Holocene period and may be equivalent in age with the pumice eruptions derived from the nearby Mt. Longonot (see Plate 6) which lies some 15 km south west of the study area. The weathering of the rocks has resulted in the various soils found in the area.

Physiography

The geomorphological phenomena which comprise of volcanicity and other tectonic activities together with climate have produced extensive areas of plateau and scarps as well as raised ground within and the vicinity of the

Plate 6: Mount Longonot, the source of recent volcanic ash sprinkling at Kinangop, in the background.

Fig. 6 . Geology of the study area.



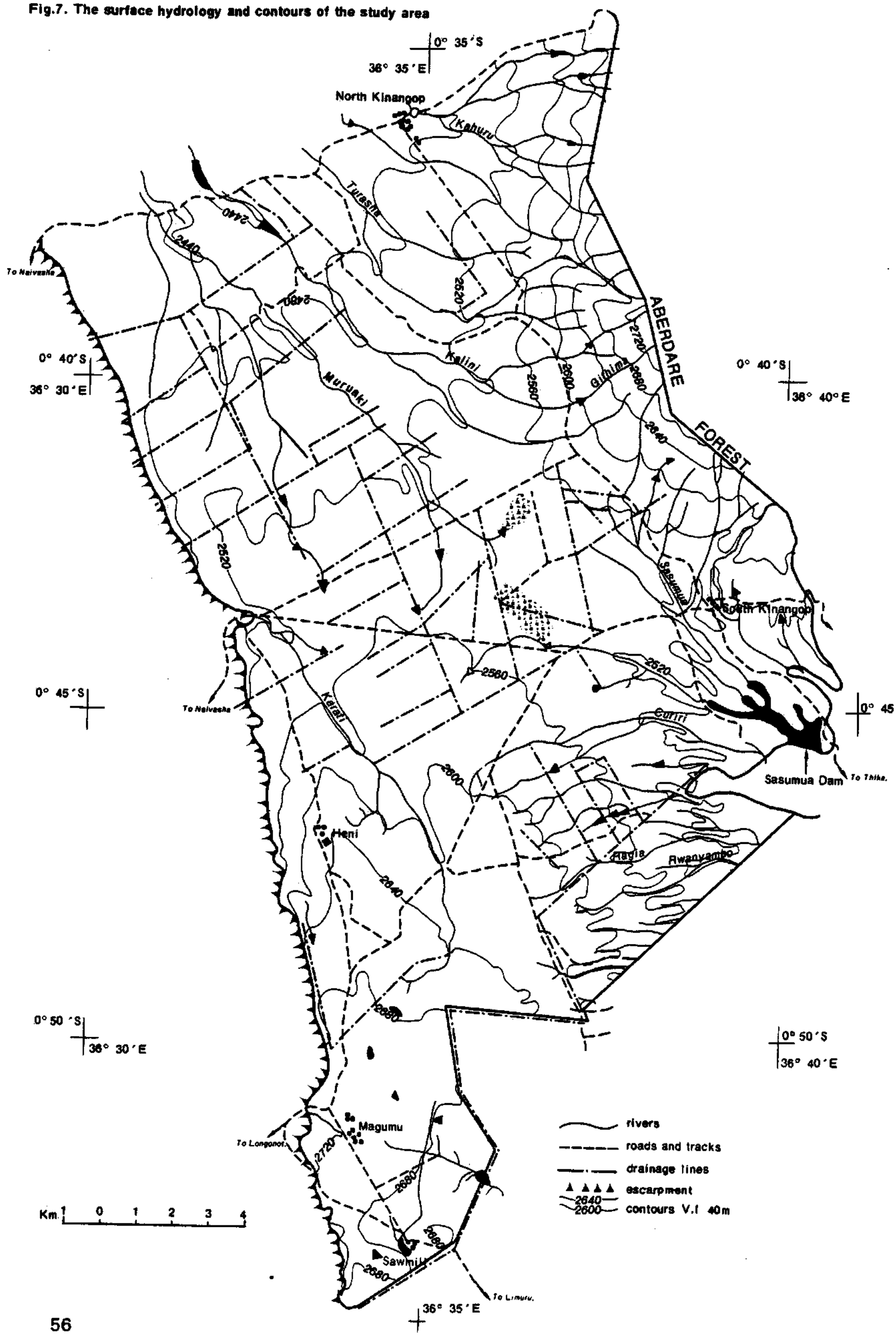
study area. Kijabe Hill which is of basaltic origin lies 2 km south of the study area whose southern and western boundaries coincide with the Rift Valley escarpment. Although the general physiography of the study area may be referred to as a plateau, it is a step which forms a plain or platform on the side of the Rift Valley (Thomson and Dodson, 1963, p. 11; Thomson 1964, p. 7). Also Shackleton (1954, p. 7) considers it as a marginal strip of a plain of accumulation which formely extended from the foot of the Aberdares (shown in Plate 1) across the Rift Valley, and possibly also across the northern end of the Aberdares.

Within the study area, the plain falls from south to north by a series of three platforms whose elevations lie approximately at 2700 m, 2620 m and 2560 m above sea-level. The plain also rises to the north-east to end in the scarps of the Aberdares mountain with a top at 3906 m. The first two steps in the south have undissected topography with occasionally raised ground (inselbergs) which carry better drained soils. The last step in the north of the study area is deeply dissected by widely spaced streams. The widely spaced dissection gives rise to fairly wide and flat interfluves with rather short but steep sides. Similar topography prevails in the extreme eastern and north eastern parts of the area.

Surface Hydrography

Fig.7 shows the surface hydrography and contour of the area. The north western part is deeply dissected by the Muruaki, Kitiri, Turasha and other rivers which are the tributaries of Malewa which ultimately discharges into Lake Naivasha laying 11 km west of the study area. The southern and south-eastern part is also the catchment area for tributaries to the Athi and Tana rivers which discharge into Indian Ocean (Fig. 1a). In the central part of the area natural drainage ways whose valleys are generally flat. A number of dams have been built to store water along some of the rivers. The Sasumua dam which lies in the east of the area is among these dams and is the main source of water for the city of Nairobi which is situated 50 km southeast of the study area. On the imperfectly drained lands are found cutlines and ditches which have been installed to drain the lands into the natural drainage lines. Some of these cutlines and ditches which were constructed at the inception of the settlement in 1963 are no longer effective and definitely need to be rehabilitated.

Fig.7. The surface hydrology and contours of the study area



6.2 THE CLASSIFICATION AND CORRELATION OF THE SOILS AND DESCRIPTION OF SOME OF THE SOIL UNITS

Fig. 7A (soil map) shows the soils of the area. The general pattern of the soils is related to the topography. On low lying areas are found mainly Planosols which have imperfect to poor drainage. These soils have a clay pan subsoil with a bleached and light topsoil. On high lying ground are found better drained soils consisting of Andosols, Phaeozems and Cambisols. Table 22 gives the thirthy four soil which have been delineated together with their correlation to both FAO/UNESCO/legend (1974) at Sub-Group level and United States Soil Survey Staff's Soil Taxonomy (1975) at Family level.

Fig. 7A: Semi-detailed soil map of the Kinangop area (original 1:50,000 soil map can be obtained from the Kenya Soil Survey, Nairobi).

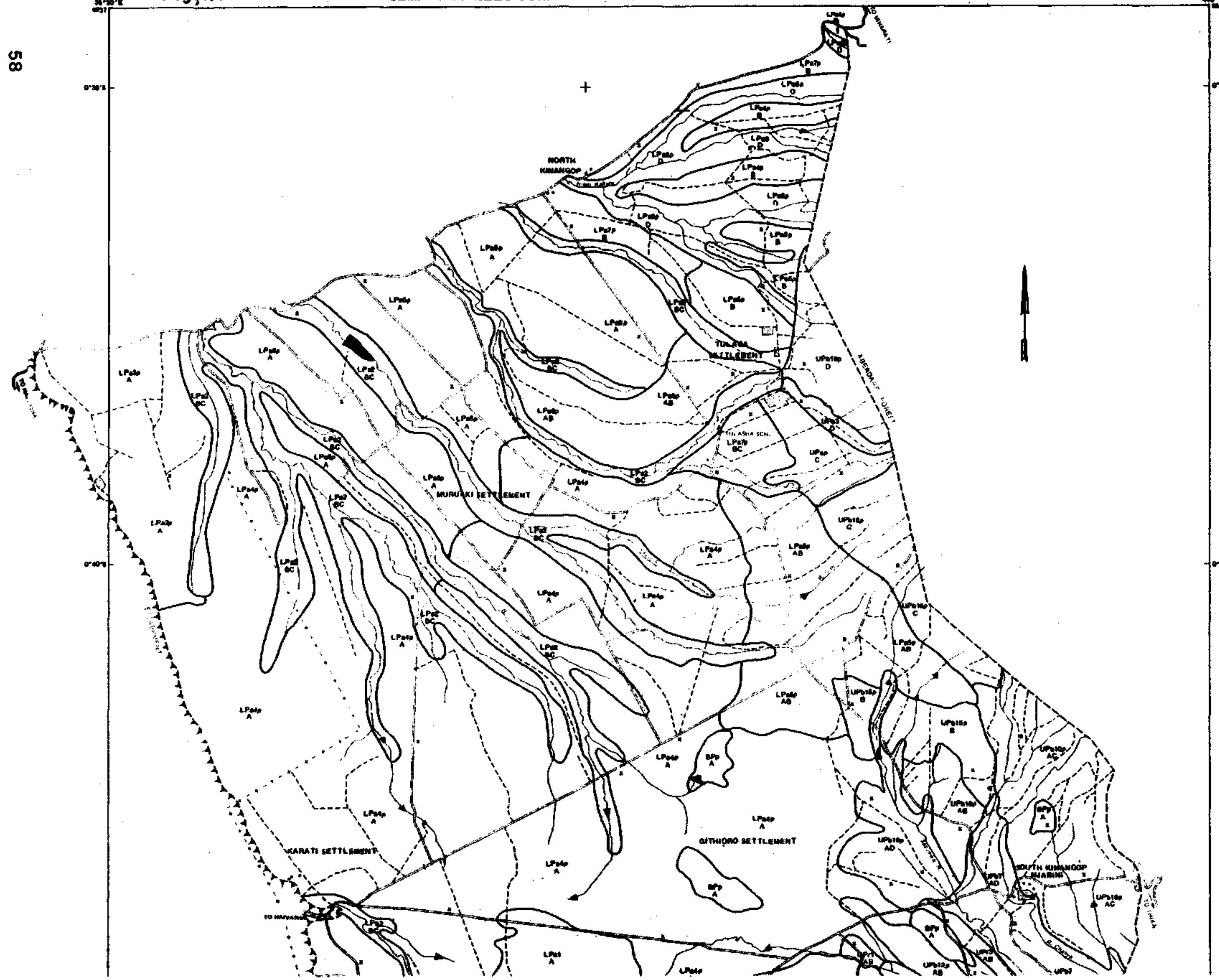
1. For the description of the soil unit represented by the symbol in the numerator, see Table 22.
2. The letters A, B, C, D en E in the denominator of the soil unit symbol represent the slope classes.
3. Key to slope classes:

Slope	Slope class Symbol	Name of the macrorelief
0- 2	A	flat to very gently undulating
2- 5	B	gently undulating
5- 8	C	undulating
8-16	D	rolling
16-30	E	hilly

3. Key to depth classes:

Thickness soil in cm	Symbol	Name
0- 50		shallow
50- 80	P	moderately deep
80-120	P	deep
more than 120		very deep

Fig. 7A SEMI - DETAILED SOIL MAP OF SOUTH KINANGOP SETTLEMENT SCHEMES



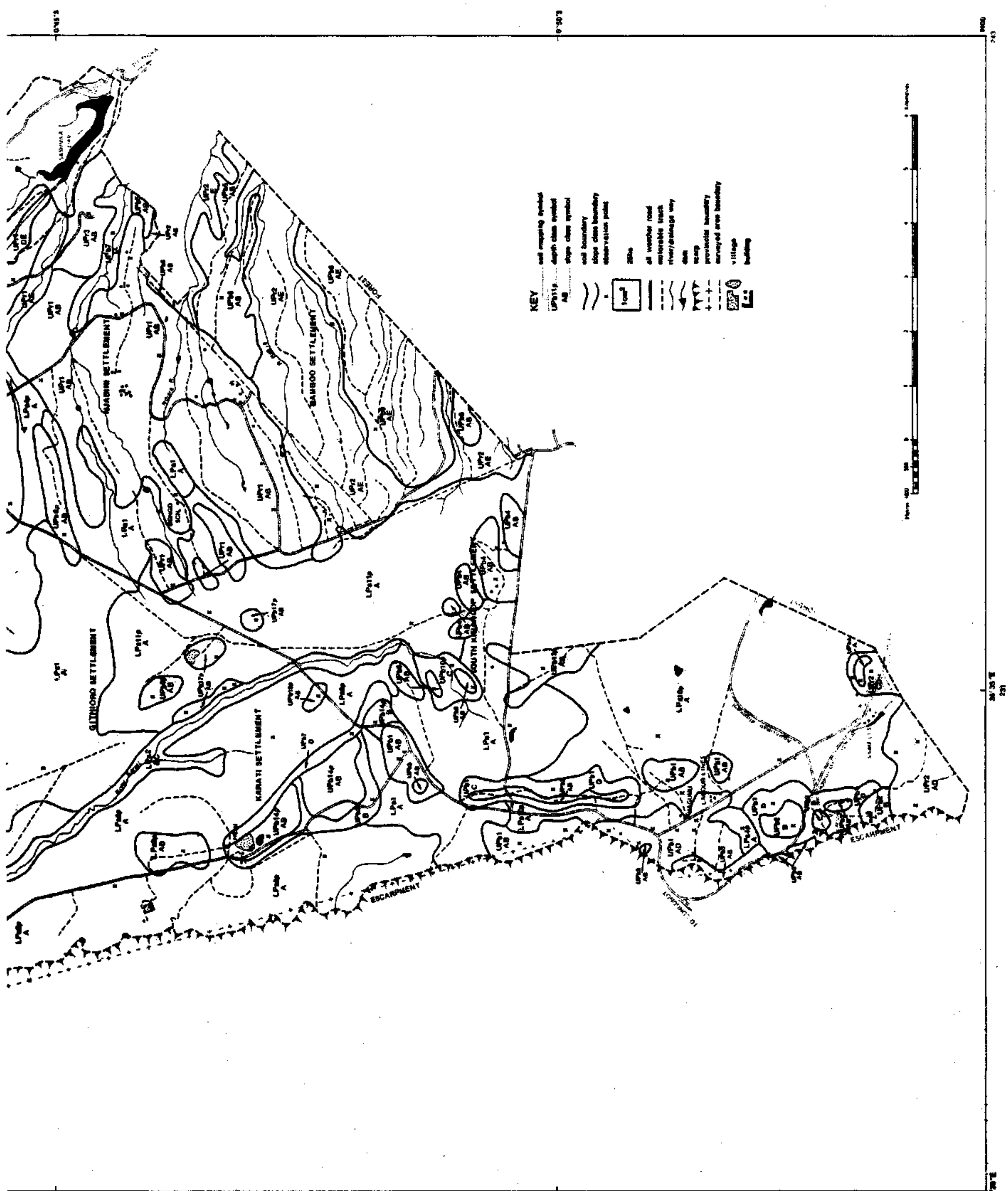

KEY
GITHIORO SETTLEMENT
KARATI SETTLEMENT
BAMBOO SETTLEMENT
FOREST
ESCARPMENT

Table 22: The classification and correlation of the soils: The FAO/UNESCO classification terms indicated in brackets are those which have been introduced by the Kenya Soil Survey as reported by Siderius and Van der Pouw (1980). Where the clay mineralogy is not mentioned it is amorphous.

Map unit	Description	FAO/UNESCO	SOIL TAXONOMY
UPr1	Well drained, very deep, reddish brown to dark reddish brown, friable clay loam, underlying loam with many iron-manganese concretions	haplic PHAEOZEM	udic HAPLUSTOLL, fine loamy, isothermic
UPr2	Well drained, very deep, reddish brown to dark reddish brown, friable clay, underlying black, silt loam	luvic PHAEOZEM	udic ARGIUSTOLL, fine clayey, isothermic
UPr3	Well drained, very deep, dark reddish brown, friable clay, with few iron-manganese concretions	(ando)-luvic PHAEOZEM	udic ARGIUSTOLL, very fine clayey isothermic
UPb1	Well drained, very deep, reddish brown to very dark brown, friable clay loam, underlying dark brown to very dark brown, loam	haplic PHAEOZEM	cumulic HAPLUSTOLL, fine loamy isothermic
UPb2	Well drained, very deep, dark brown, to very dark brown, friable clay loam, underlying black, silt loam	(cumulo)-luvic PHAEOZEM	pachic ARGIUSTOLL, fine clayey, isothermic
UPb3	Well drained, very deep, reddish brown to dark reddish brown, friable clay loam, underlying dark brown to very dark brown, clay loam	(cumulo)-haplic PHAEOZEM	cumulic HAPLUSTOLL, fine clayey, isothermic
UPb4	Well drained, very deep, reddish brown to very dark brown, friable to firm clay, underlying very dark grey to black, loam	(ando)-luvic PHAEOZEM	pachic ARGIUSTOLL, fine clayey isothermic
UPb5	Well drained, very deep, dark reddish brown, friable clay, underlying very dark grey to black clay	(luvo)-mollic ANDOSOL	ultic HAPLUSTALF, fine clayey, isothermic
UPb6	Well drained, very deep, dark reddish brown, friable clay, underlying very dark grey to black, clay	(luvo)-mollic ANDOSOL	ultic HAPLUSTALF, fine clayey, isothermic

Map unit	Description	FAO/UNESCO	SOIL TAXONOMY
UPb7	Well drained, very deep, reddish brown to dark reddish brown, friable clay	(ando)-humic CAMBISOL	andic ustic HUMITROPEPT, fine clayey, isothermic
UPb8p	Well drained, deep, reddish brown to dark reddish brown, friable loam, underlying very dark greyish brown to greyish brown, silt loam, with many iron-manganese concretions	eutric CAMBISOL sodic phase	ustric HUMISTROPEPT, fine loamy, isothermic
UPb9p	Well drained, deep reddish brown to dark reddish brown, very friable clay loam, underlying dark brown to very very dark, silt loam, with common iron-manganese concretions	luvic PHAEOZEM	udic ARGIUSTOLL, fine loamy isothermic
UPb10p	Well drained, deep reddish brown to dark reddish brown friable clay loam, underlying reddish brown to very dark brown, clay loam, with few to common iron-manganese concretions	dystric CAMBISOL	ustic HUMITROPEPT, fine loamy isothermic
UPb11p	Well drained, deep, dark brown to very dark brown, friable clay loam, underlying black, loam	haplic PHAEOZEM sodic phase	udic HAPLUSTOLL, fine loamy, isothermic
UPb12p	Well drained, deep, reddish brown to dark reddish brown, friable clay, underlying loam, with many iron-manganese concretions	dystric CAMBISOL	ustic HUMITROPEPT, fine loamy, isothermic
UPb13p	Well drained, deep, dark brown to very dark brown, friable to firm clay, underlying reddish brown to dark reddish brown, silty clay loam, with with many manganese concretions	eutric CAMBISOL sodic phase	typic USTROPEPT, fine clayey, isothermic
UPb14p	Well drained, deep, dark brown to very dark brown, friable to firm clay, underlying very dark greyish brown to greyish brown, clay loam	luvic PHAEOZEM sodic phase	pachic ARGIUSTOLL, fine clayey, isothermic

Map unit	Description	FAO/UNESCO	SOIL TAXONOMY
UPbl5p	Moderately well drained, deep, dark brown to very dark brown, friable to firm, sodic, clay, loam, underlying reddish brown to dark reddish brown, loam, with common to many iron-manganese concretions	dystric CAMBISOL sodic phase	utric HUMITROPEPT, fine loamy isothermic
UPbl6p	Moderately well drained, deep, reddish brown to dark reddish brown, friable clay, underlying clay loam, with few iron-manganese concretions	luvic PHAEOZEM sodic phase	pachic ARGIUSTOLL, fine clayey, isothermic
UPbl7p	Well drained, moderately deep, reddish brown to dark reddish brown, friable loam, underlying dark brown to very dark brown, loam, with many iron-manganese concretions	eutric CAMBISOL	typic USTROPEPT, fine loamy, isothermic
UPbl8p	Moderately well drained, moderately deep, dark brown to very dark brown, friable clay, underlying clay loam, with few iron-managese concretions	dystric CAMBISOL	ustic DYSTROPEPT, clayey-skeletal, over fine loamy, isothermic
UPap	Imperfectly drained, deep, very dark greyish brown to greyish brown, mottled firm clay, underlying more than 40 cm of clay, with many iron-manganese concretions	eutric CAMBISOL sodic phase	typic USTROPEPT, fine clayey, mixed montmorillonitic/illitic, isothermic
LPa1	Imperfectly drained, very deep, dark brown to very dark brown, mottled, very firm sodic clay, abruptly underlying less than 40 cm of very dark greyish brown to greyish brown loam	solodic PLANOSOL	albic NATRAQUALF, fine clayey, montmorillonitic, isothermic
LPa2	Imperfectly drained, very deep, very dark greyish brown to greyish brown, mottled, friable clay, abruptly underlying more than 40 cm of dark brown to very dark brown, silt loam	solodic PLANOSOL	abruptic TROPAQUALF, fine clayey, montmorillonitic isothermic

Map unit	Description	FAO/UNESCO	SOIL TAXONOMY
LPa3p	Imperfectly drained, deep, black, mottled, firm clay, abruptly less than 40 cm of very dark greyish brown to greyish brown, loam, with common iron-manganese concretions at transition	solodic PLANOSOL	abruptic TROPAQUALF, fine clayey, montmorillonitic isothermic
LPa4p	Imperfectly drained, deep, dark brown to very dark brown, mottled, firm clay abruptly underlying 30-50 cm of very dark greyish brown to greyish brown, loam, with many iron-manganese concretions at transition	solodic PLANOSOL	aeric TROPAQUALF, very fine clayey, (montmorillonitic/ illitic) isothermic
LPa5p	Imperfectly drained, deep, dark brown to very dark brown, mottled, firm clay, abruptly underlying 20-40 cm of very dark greyish brown to greyish brown, silt loam with common iron-manganese concretions at transition	solodic PLANOSOL	abruptic TROPAQUALF, fine clayey, mixed (montmorillonitic) isothermic
LPa6p	Imperfectly drained, deep, dark brown to very dark brown, mottled, firm clay abruptly underlying more than 40 cm of very dark greyish brown to greyish brown, silt loam, with many iron-manganese concretions at transition	solodic PLANOSOL	aeric TROPAQUALF, fine clayey, isothermic
LPa7p	Imperfectly drained, deep, dark brown to very dark brown, mottled, firm clay, abruptly underlying 20-40 cm of very dark greyish brown to greyish brown, silt loam, with many iron-manganese concretions at transition	eutric PLANOSOL	abruptic TROPAQUALF, very fine clayey, mixed, (montmorillonitic/illicit/ kaolitic) isothermic
LPa8p	Imperfectly drained to poorly drained, deep, black, mottled, friable to firm, sodic clay abruptly underlying 30-40 cm of very dark greyish brown to greyish brown, silt loam, with few iron-manganese concretion at transition	solodic PLANOSOL	typic NATRAQUALF, fine, clayey, mixed (montmorillonitic/ illitic/kaolonitic) isothermic

Map unit	Description	FAO/UNESCO	SOIL TAXONOMY
LPa9p	Imperfectly drained to poorly drained, deep, dark brown to very dark brown, mottled, firm clay, abruptly underlying less than 40 cm of very dark grey to grey, silty clay loam, with few iron-manganese concretions at transition	eutric PLANOSOL sodic phase	abruptic TROPAQUALF, very fine clayey, isothermic
LPa10p	Imperfectly drained to poorly drained, deep, black, mottled, firm sodic clay, abruptly underlying 30-40 cm of very dark greyish brown to greyish brown, clay loam	solodic PLANOSOL	typic NATRQUALF, fine clayey, isothermic
LPa11p	Poorly drained, deep, black, mottled firm clay, abruptly underlying less than 40 cm of very dark greyish brown, silt loam	solodic PLANOSOL	abruptic TROPAQUALF, fine clayey, mixed (montmorillonitic/illitic/kaolinitic), isothermic
BPp	Imperfectly drained to poorly drained, moderately deep, dark brown to very dark brown, mottled, friable to firm clay, underlying very dark grey to grey clay loam	humic GLEYSOL	aeric TROPAQUEPT, fine clayey, isothermic

Eleven soil mapping units fall under Phaeozem (Mollisol); eleven units are Planosols (Alfisol); nine units are Cambisol (Inceptisol); two units are Andosol (Ultisol or Alfisol) and one unit is Gleysol (Inceptisol).

Not alle the soil mapping units identified are described in this report. Only a few soil units representative of soils with significantly different properties are presented. The rest of the soils are described in a supplementary report which can be found at the Kenya Soil Survey in Nairobi. The following sections provide a description of the soils together with their characteristic schematic profiles.

PHAEOZEMS (Mollisols)

Eleven soil units have been identified as Phaeozems. These soils are generally deep to very deep and are well drained. One unit (UPb16p) is however only moderately well drained. The textures of the topsoil are loam, silt loam, clay loam or clay while the textures of the subsoil are clay loam or clay. The pH of the topsoil varies from 4.9 to 6.7 (average 5.7) and can be considered moderately acid. The soil fertility assessed in terms of available phosphorus is variable but commonly low. The available phosphorus varies between 2 ppm and 193 ppm (average 50 ppm). These soils have a favourable ability to store moisture. The moisture storage capacity for 100 cm depth varies from 54.5 mm to 133.4 mm (average 99.0 mm).

The description and analytical data of three of these Phaeozems is given in Annex 3. Fig. 8 shows the characteristic schematic profiles of the Phaeozems.

CAMBISOLS (Inceptisols)

Nine soil units have been identified as Cambisols. They are generally deep and well drained. One soil unit (UPap) however has imperfect drainage while two soil units (UPb15p and UPb18p) are only moderately well drained. Also one soil unit (UPb7) is very deep while two others (UPb17p and UPb18p) are only moderately deep. The textures of the topsoil are loam, silt loam, silty clay loam, clay loam or clay while textures of the subsoil are loam, clay loam or clay. The pH of the topsoil varies from 4.4 to 6.4 (average 5.2) and can be considered moderately acid. The soil fertility is generally low with available phosphorus varying between 4 ppm and 182 ppm (average 45 ppm). The soils however have a very favourable capacity for storing moisture. The moisture storage capacity down to 100 cm varies from 92.7 mm to 234.5 mm (average 142.4 mm).

The description and analytical data of three of the Cambisols is given in

Fig. 8 a. Characteristic schematic profiles of the Phaeozems (Mollisols) (L: Loam; SiL: Silty loam; SiCL: silty clay loam; SCL: sandy clay loam; CL: clay loam; C: clay)

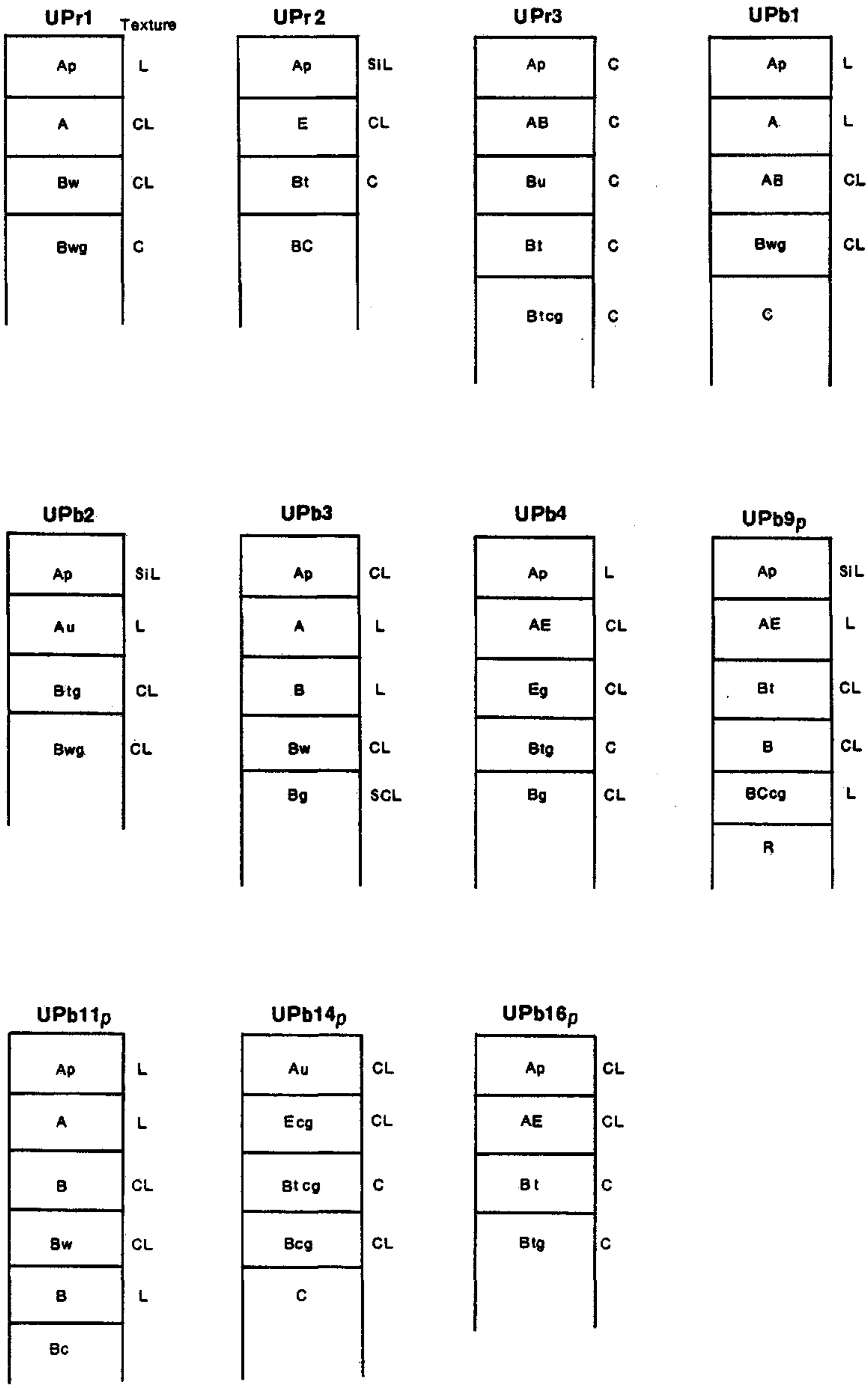


Fig. 8b. Characteristic schematic profiles of the Cambisols (Inceptisols) and Andosols (Ultisols and Alfisols)

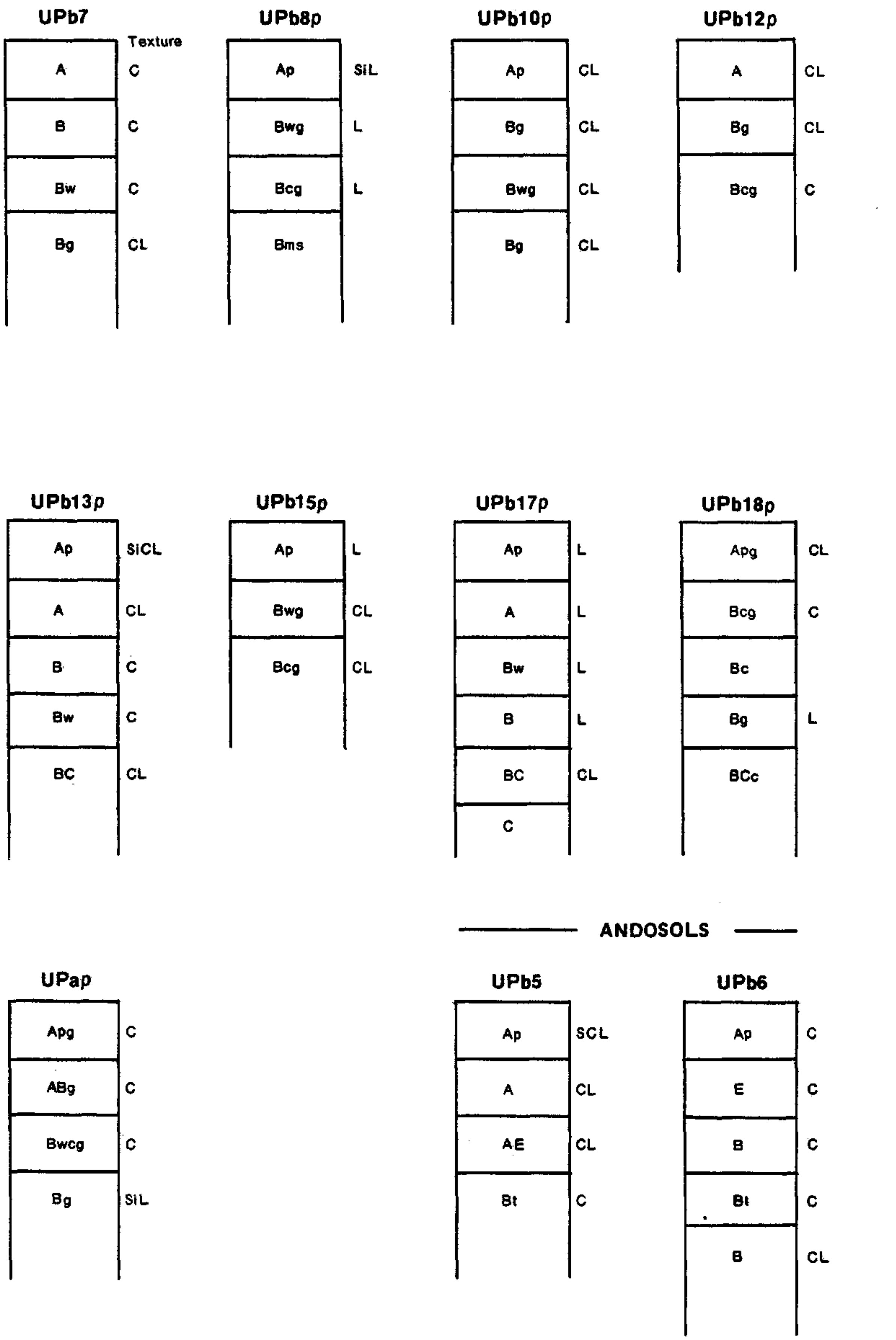
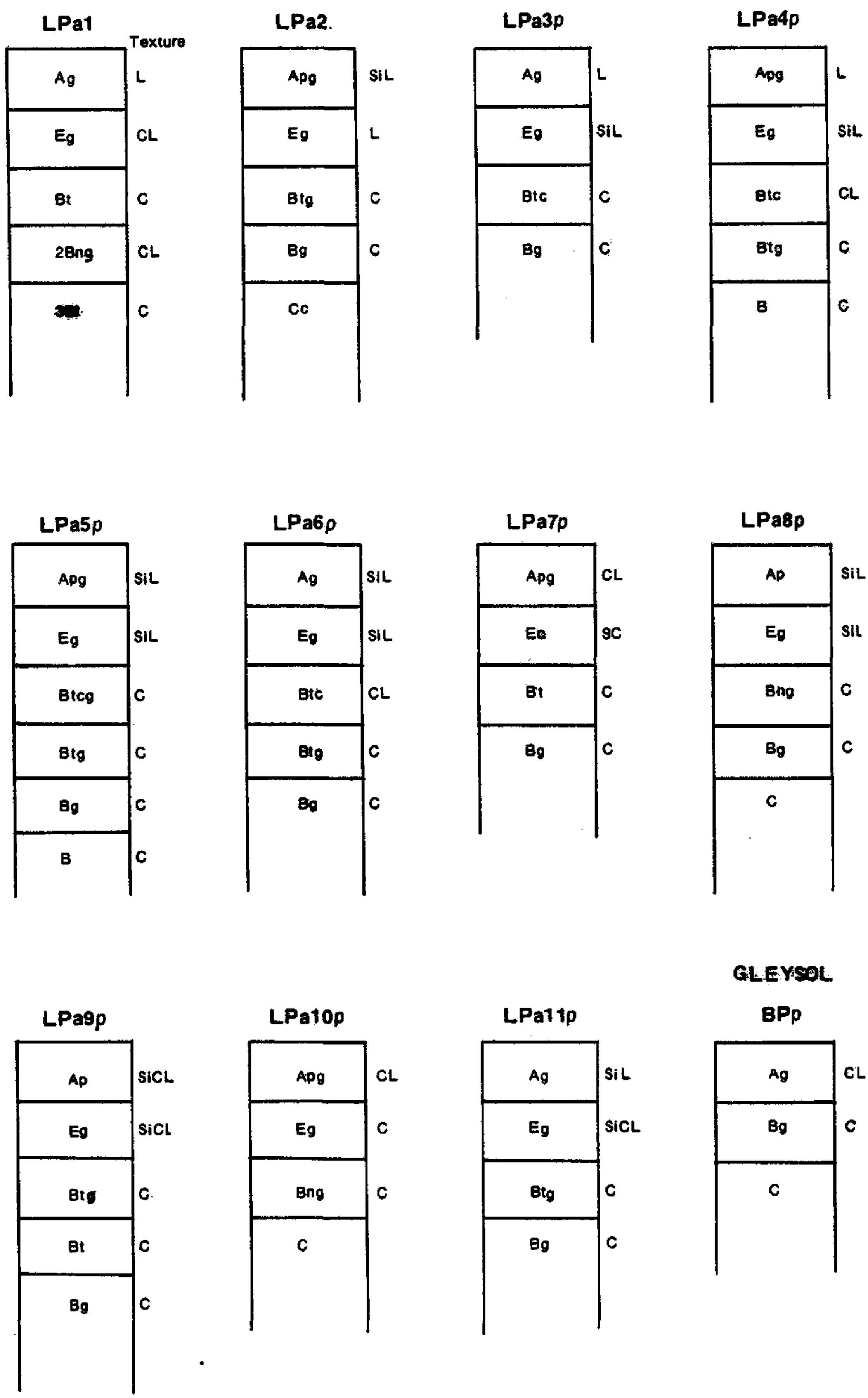


Fig.8c. Characteristic schematic profiles of the Planosols (Alfisols) and Gleysol (Inceptisol)



Annex 3. Fig. 8 indicates the characteristic schematic profiles of the Cambisols.

ANDOSOLS (Ultisol or Alfisol).

These are comprised of two soil units. They are very deep soils which are well drained. The textures of the topsoils are sandy clay loam or clay while the textures of the subsoil are clay. The soils have a pH of the topsoil which varies from 4.7 to 5.6 (average 5.2) and this may be graded as moderately acid. The phosphorus status of the soil is variable and ranges between 12 ppm and 130 ppm (average 71 ppm). These soils have a good water storage capacity which varies from 90.5 mm to 112 mm (average 101.3 mm).

The description and analytical data of the Andosols is given in Annex 3. Fig. 8 shows the characteristic schematic profiles of the Andosols.

PLANOSOLS (Alfisols).

Eleven soil units have been identified as Planosols. The soils are mostly deep but two of them (units LPa1 and LPa2) are very deep. All the soils have imperfect to poor drainage which arises from the existence of a subsoil clay pan with a very low permeability. The textures of the topsoil which generally contain mainly amorphous clay minerals are loam, silt loam, silty clay loam or clay loam while the textures of the subsoil which mainly contain montmorillonite clay mineral are clay. The pH of the topsoil varies from 4.6 to 5.8 (average 5.3) and can be rated as moderately acid. The fertility of these soils especially available phosphorus and nitrogen is very low. The available phosphorus is about 11 ppm (range 2 ppm to 78 ppm). These soils have only a moderate moisture storage capacity which varies from 40.8 mm to 75.6 mm for 100 cm storage depth (average 53.3 mm).

The description and analytical data of three of these Planosols is given in Annex 3. Fig. 8 shows the characteristic schematic profiles of the Planosols.

GLEYSOL (Inceptisol).

One soil unit falls under this group. It is a moderately deep and imperfectly to poorly drained soil. The topsoil texture is clay loam which overlies a clay subsoil. The pH of the topsoil is 5.2 and the phosphorus status is very low being 6 ppm.

The description and analytical data of this soil is given in Annex 3 while Fig. 8 indicates the characteristic schematic profile.

6.3 PROBLEMS OF THE SOILS AND HOW THEY INFLUENCE LAND USE

Plants have specific requirements for optimal production. The integrated effect of climate and soil condition at a site determine the production from a given crop or plant cultivated under a specified level of management. Although the effect of climate by way of temperature and moisture supply is overriding in determining crop production, the effect of soil and land management are as important. Basic land requirements of plants may be summarised as below:

1. temperature regime as concerns the annual or seasonal and/or daily temperature level and fluctuations
2. the soil moisture regime as related to the possibility to release moisture
3. the soils aeration as related to the capacity to supply oxygen to the rootzone
4. the effective soil depth that is available for root development and foothold of the crop
5. the natural soil fertility regime with regard to its ability to retain, store and release plant nutrients and absence of harmful conditions such as high salinity and sodicity as well as too low pH
6. the soil tilth as required for germination and early growth
7. absence of soil degradation to enable sustained yields.

In the study area, the high lying areas contain soils that are friable and porous. The infiltration and permeability for both water and air are good and the soils are well drained. They are also deep to very deep for foothold and have a high capacity to store and release moisture. In the low lying areas the soils have a subsoil claypan giving rise to low infiltration and permeability. The soils in these low lying areas are consequently imperfectly to poorly drained. In some areas the soils have very high content of sodium (alkali) and this worsens the drainage condition. In spite of their deep profiles, the effective depth of these soils is restricted by the occurrence of claypan. Their capacity to store and release moisture is therefore rather low. They also have a poor state of aeration.

Most soils as assessed by the method of Mehlich et al (1962) are moderately acid and have low fertility especially with regard to phosphorus. The available phosphorus is generally below 20 ppm. Total analysis for phosphorus has been carried out on topsoil to derive some measure of the potential supply source for this element. Total phosphorus levels range from 28 ppm to 120 ppm (average 68 ppm) for better drained soils and 16 ppm to 110

Table 23: The major characteristics of the soils and the area of soils per scheme (moisture between pF 2.0 and 4.2; ref. FAO, 1979).

Soil unit	Drainage	Depth	Moisture holding capacity (mm) to 100 cm;	150 cm	Other special features	Area (ha) in the scheme: South Kinangop	Bamboo	Karati	Njabini	Githioro	Muruaki	Tulaga	Special management problem
UPr1	good	v.deep	103.7	137.2	Iron-Mn concretions	551	10	nil	1323	nil	nil	nil	low pH, low phosphorus
UPr2	"	"	120.4	137.2	-	536	767	nil	22	nil	nil	nil	-
UPr3	"	"	146.8	202.8	-	nil	nil	nil	205	nil	nil	nil	low phosphorus
UPb1	"	"	187.0	238.8	-	683	nil	211	nil	nil	nil	nil	low phosphorus
UPb2	"	"	140.1	186.6	-	96	nil	nil	nil	nil	nil	nil	-
UPb3	"	"	206.5	285.0	-	125	nil	109	nil	nil	nil	84	-
UPb4	"	"	156.8	207.3	-	228	nil	nil	nil	nil	nil	nil	low phosphorus
UPb5	"	"	202.3	248.3	-	nil	259	nil	11	nil	nil	nil	low pH; low phosphorus
UPb6	"	"	143.6	206.1	-	15	474	42	nil	nil	nil	nil	-
UPb7	"	"	247.7	385.7	-	nil	nil	79	789	nil	nil	nil	low pH; very low fertility
UPb8p	"	deep	118.8	130.9	iron-Mn concretions	nil	nil	265	nil	nil	nil	nil	low pH; very low fertility
UPb9p	"	"	120.4	139.7	"	nil	nil	nil	nil	400	nil	nil	-
UPb10p	"	"	148.0	210.5	-	66	nil	12	1145	nil	nil	49	low pH; very low fertility
UPb11p	"	"	139.0	191.5	-	132	nil	nil	nil	nil	nil	nil	low phosphorus
UPb12p	"	"	145.7	206.2	iron-Mn concretions	nil	nil	nil	200	nil	nil	nil	low pH; very low fertility
UPb13p	"	"	207.9	252.3	"	nil	nil	18	nil	nil	nil	nil	-
UPb14p	"	"	111.6	119.3	-	nil	nil	218	nil	nil	nil	nil	-
UPb15p	mod. good	"	266.6	391.6	Iron-Mn concretions	nil	nil	nil	135	nil	nil	161	low pH; very low fertility
UPb16p	"	"	138.8	199.3	-	nil	nil	nil	92	nil	nil	323	low phosphorus
UPb17p	good	mod. deep	149.8	149.8	Iron-Mn concretions	15	nil	nil	nil	57	nil	nil	Low pH; very low fertility
UPb18p	mod. good	"	151.6	151.6	-	nil	nil	nil	205	nil	nil	305	low pH; very low fertility
UPap	Imperfect	deep	138.9	199.4	-	nil	nil	nil	nil	nil	nil	239	heavy clay subsoil; low permeability
LPa1	Imperfect	very deep	104.6	104.6	sodic; clay	455	nil	640	335	739	nil	nil	low nitrogen and phosphorus heavy and alkal subsoil; low permeability
LPa2	Imperfect	very deep	83.3	83.3	claypan	30	nil	272	nil	69	1814	221	very low fertility; heavy clay subsoil; low permeability
LPa3p	"	deep	89.5	89.5	"	nil	nil	nil	nil	nil	nil	nil	low nitrogen and phosphorus; heavy clay subsoil; low permeability
LPa4p	"	"	90.8	90.8	"	44	nil	2131	427	1904	2612	478	low nitrogen and phosphorus heavy clay subsoil; low permeability.
LPa5p	"	"	142.5	142.5	"	nil	nil	nil	nil	68	718	1117	low nitrogen and phosphorus heavy clay subsoil; low permeability
LPa6p	"	"	91.4	91.4	"	nil	nil	nil	nil	nil	925	992	very low fertility; heavy clay subsoil; low permeability
LPa7p	"	"	64.5	64.5	"	nil	nil	nil	nil	nil	24	472	low nitrogen and phosphorus heavy clay subsoil; low permeability
LPa8p	"	"	86.7	86.7	sodic; claypan	nil	nil	1473	nil	nil	nil	nil	low pH; low fertility; heavy clay subsoil; low permeability
LPa9p	Imperfect to poor	"	110.2	110.2	claypan	nil	nil	79	nil	nil	536	nil	very low fertility; low low permeability
LPa10p	"	"	57.4	57.4	sodic; claypan	2100	nil	37	nil	nil	nil	nil	very low fertility; heavy and alkali subsoil; low permeability
LPa11p	poor	"	92.3	92.3	claypan	867	nil	nil	nil	404	nil	nil	low phosphorus; heavy clay subsoil
BPp	Imperfect to poor	"	66.9	66.9	-	nil	nil	nil	70	159	nil	nil	low phosphorus; flooded

ppm (average 66 ppm) for imperfectly drained soils. This may be considered a moderate supply level. It should however be borne in mind that during the release of this phosphorous, fixation process may be operative in the soil in which case the total phosphorous figure is of less significance.

It was observed that when the imperfectly drained soils are cultivated with mouldboard or disc plough, the soil is turned into large lumps of hard soil. To prepare a seedbed from these soils requires at least two ploughing and three harrowings. The process is even more elaborate for a finer seedbed necessary for wheat or barley growing. The cost of land preparation on the imperfectly drained soils is consequently high and is an important drawback in the use of these soils for arable agriculture. Also because especially the subsoils of these imperfectly drained soils predominantly contain montmorillonite clay mineral, the soils become very sticky and plastic when wet and may stay so for a long time. They can therefore not be reasily cultivated when wet and also driving over them during the rainy season is difficult.

Table 23 shows the soils characteristics with regard to the drainage, depth, moisture holding capacity, fertility and workability. It also show the hectarages of the various soil units in the different settlemtn schemes. Soil drainage is the most outstanding limiting factor in the area. About 31% of the area of the seven schemes (32,500 ha) covered by this study consist of well drained and moderately well drained soils while about 69% of the area comprises imperfectly drained to poorly drained soils.
The percentage distribution of the better drained and imperfectly drained soils between the schemes is as follows:

Scheme	South Kinangop	Bamboo	Karati	Njabini	Githioro	Muruaki	Tulaga	Total
% well drained soils	7.5	4.7	2.1	13.5	0.3	0	2.8	30.9
% imperfectly drained soils	10.8	0	14.2	2.6	10.3	20.4	10.8	69.1

Muruaki and Githioro Settlement Schemes consist exclusively of imperfectly drained soils while Karati and Tulaga Schemes are dominated by the imperfectly drained soils. Bamboo Scheme is exclusively of well drained soils while Njabini Scheme is dominantly by well drained soils and the well drained soils are in almost equal proportion in the South Kinangop Scheme. The effect of imperfect soil drainage is therefore expected to be felt more in Muruaki, Githioro, Karati and Tulaga Settlement Schemes. However the very dissected topography in the Muruaki and Tulaga Scheme (see Fig. 7) no doubt helps in the lateral removal of excess water. for this reason, Githioro and Karati Schemes are the worst affected with regard to poor drainage.

PART 3

POSSIBILITIES FOR LAND USE

7. THE LAND UTILIZATION TYPES IDENTIFIED FOR THE AREA AND THEIR LAND REQUIREMENTS

In the previous sections 2 and 3 the crops, livestock and trees that are adapted to the study area have been discussed. Furthermore the nature of the climate and the soils of the area are presented in sections 5 and 6. The information in the above mentioned sections indicates the diversity of the crops and soils which however occur under a climatically favourable situation not withstanding the occurrence of night frosts which as already mentioned can be contained by adapting suitable crops. The following sections attempt to examine the possibilities that the prevailing physical nature of the area offer for improved land use.

7.1 LAND UTILIZATION TYPES

The determination of physically possible forms of land use in an area is necessary if the agricultural production of the area is to be improved. The methodology for such a determination has been developed by various workers (Beek and Bennema, 1972; Brinkman and Smyth (eds.), 1973; FAO, 1972-1975) culminating in the publication by FAO (1976) of the "Framework for Land Evaluation". The concept of Land Utilization Type (LUT) as introduced by Beek and Bennema (loc cit) and elaborated by Beek (1978) has been adopted by FAO (1976) in the framework for land evaluation. According to this concept, the LUT is considered to be the subject of land evaluation whereas the Land Unit (LU) is the object of land evaluation. LUT and LU then constitute a Land Use System (LUS).

A Land Utilization Type can be either a known common practice to the land user or a new practice that can be managed within the land user's know-how and economic capability. It can therefore only adequately be defined using essential distinguishing factors which have marked influence on the performance of the land. These factors are produce, capital intensity, labour intensity, farm power, level of technical know how, farm size, land tenure, farm incomes and institutional infrastructure (roads, markets, price structures, etc). A land utilization type also requires the specification of the management level. The management refers to the practices connected with the improvement of the land qualities.

Based on the observation of the farming practices in the study area, the following land utilization types are relevant to the area:

A. Small scale rainfed arable farming for non cereal annual crops at low level of management.
B. Small scale rainfed arable farming for non cereal annual crops at intermediate level of management.
C. Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management.
D. Small scale rainfed arable farming for fruit trees at intermediate level of management.
E. Small scale grazing for cattle and sheep at intermediate level of management.
F. Tree production for firewood and building poles.
G. Fish pond for fish production.

In considering the crops for the land utilization typs, maize is omitted because of the risk of frost mentioned in section 5.3 and the lack of a suitable variety which can mature within the period March to June which is the safe period with regard to frost. Similarly, because of the lack of a suitable cool tolerant rice variety for the cool temperature of the area this crop is omitted although some of the soils may be ideal for rice. Sixteen rice varieties supposed to be cool tolerant were tested but found unsuitable for the cool temperature of Kinangop. Eight varieties named Jyanak, Fujisaka 5, Ai-nan-tsao 1, Kn-lh-361-1-8-6-9-1, Kn-lh-361-1-8-6, IR1846-300-1-1, IR 3941-1 and China 1039 were obtained from the International Rice Research Institute in Philippine whereas the other eight varieties known as Kayayuki, Hokusetsa, Kachi Honami, Oirase, Ishikari, Sorachi, Tatsumi-mochi and Yoneshiro were obtained from Japan's Third Laboratory of Rice, Hokkaido National Agricultural Experimental Station. Potato is included as a crop for the area provided it is grown during mid March to mid June which is free from frost. The characteristics of the above land utilization types are discussed below:

A. Small scale rainfed arable farming for non cereal annual crops at low level of management.

This land use alternative is characterised in the study area by the practice of mixed cropping. The cropping pattern is essentially of a mixed nature as already discussed elsewhere in this text. The crops grown are pyrethrum, potato, cabbage, cauliflower, kale, carrot, onion, leek, beet, peas, mangold and sunflower. The mixed cropping mostly involve potato, cabbage, kale and leek. Yields are low but the farmer is able to assure continued supply of his food. Fertilizer use under this land utilization is difficult to justify as there are no experimental data to aid the determination of the amounts to apply and how to apply them. Because of the low yields this land use alternative mainly cater for the food needed by the family. The little surplus crop especially with regard to cabbage and potato may however be sold.

The capital intensity is low. The investment is confined mainly to the purchase of seeds. Land cultivation is by hoe but is also sometimes by hired tractor which is owned by the cooperative society. The present land tenure system in the area which consists of settlement schemes does not act as an impediment to the development of this land utilization type. The head of the family is the registered plot holder and owner of the land title deed.

The farm sizes vary between the schemes as already indicated elsewhere in the text. Also the actual area put under crop at a particular time varies considerably depending on the family food needs and desired cash income. The farm power is mostly made up of manpower. Much of the work is carried out by women. The technical know-how is low. Moreover little improvement on the farming system has been carried out by agricultural research.

B. Small scale rainfed arable farming for non cereal annual crops at intermediate level of management.

This involves that level of farming where certain inputs (fertilizers, insecticides, herbicides, mechanization, etc.) are used on modest scale at lower levels than those recommended from research trials. In order to raise the presently low level of management the farming in the area to a higher level of intermediate management, an appropriate development strategy has to be worked out.

Similar crops are grown as in the low level management. The technology for the majority of crops consists of the use of improved seeds but the use of fertilizers and pesticides is in practice limited. The latter are practised mainly for the production of carrots which is supported by a commercial firm. Hired tractor is commonly used for land preparation. The greater investment goes to the purchase of improved seed and tractor ploughing. However investment for moderate fertiliser use is necessary under this intermediate level of management. As already stated elsewhere in the text the yields achieved at present are rather low and can substantially be increased with modest fertilizer application, timely planting, better weeding, and adequate pest and disease control. The improved agricultural husbandry should be based on sound farm planning.

Apart from manpower, tractor power is essential especially for the land preparation on the rather difficult imperfectly drained soils (Planosols). The lack of technical know-how at the farm level is definitely a constraint and greater agricultural extension effort needs to be placed on educating the farmers on improved agricultural husbandry and its impact on yields. With improved crop husbandry methods, the farm incomes could be increased without basically changing the farming system. The adoption of improved methods will also no doubt be an essential first step towards the development of a high level of farm management in the study area.

The farm size is not different from that operated under the low level management since the area is comprised of settlement schemes with demarcated plots. The actually cultivated areas are however somewhat larger than those under the low level management.

A significant problem that can have profound effect on this land use alternative is the lack of good farm road system and profitable markets for the surplus food crops. Availability of profitable markets is hampered by high transport costs and the lack of well organised marketing system except for produce such as pyrethrum, wool, milk and carrots which have organized marketing systems within the area. The farmers can put in a lot of effort when they are provided with appropriate marketing system for their produce.

C. Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management.

This land use alternative concerns the growing of wheat, barley and oats where the full range of agricultural production inputs are used as recommended from agricultural research. Since the technology for wheat growing in Kenya is at present fully mechanized using combine planters and harvestes etc., it is not economic to use these machinery on small plots of wheat. It is for this reason of the lack of small scale technology for wheat/barley/oat growing, that the areas where this land use alternative can be practised is restricted to the schemes with larger farm sizes. This land use is therefore mainly practised in the extensively flat and slightly sloping areas which carry the imperfectly drained soils (Planosols) and where the holdings are slightly larger to compensate for the poor soils. It is a common practice for the farmers to rent the land to outsiders who have the capital for full mechanization of the production of wheat, barley and oats. Success in the production of these crops is however not always attained as a lot of effort is required to produce from the imperfectly drained soils the fine seedbed necessary for the crops. Moreover, unless camberbeds are used the drainage conditions are such that in years of unusually heavy rainfall the fields are waterlogged and crops totally fail.

The production of wheat has been encouraged through loans from the Kenya Agricultural Finance Corporation whereas the growing of barley is supported by the Kenya Breweries. Because of the generally poor land preparation and the adverse effect of drainge, yields are low. The profitability of the wheat, barley and oats enterprise is therefore not assured. Moreover, the Department of Settlement (1976, p7 and p9) has reported that the wheat and barley have taken up the grazing and pyrethrum land and subsequently reduced the dairy and pyrethrum production. Investments involve the purchase of improved seeds, fertilizers, pesticides, land preparation and mechanical harvesting. The labour requirement is however low since the operations are largely mechanized. The full use of tractor is made and the manpower required is only for a few operators of the machinery.

The level of technical know-how for production is high although it is not up to full use by the present farmers. Prior to the small-holder settlement, the study area was prominent in large scale wheat farming which employed research proved advance technology on the sloping lands of the imperfectly drained soils.

D. Small scale rainfed farming for fruit trees at intermediate level of management.

This land utilization type is at present mostly practised in the form of orchards. The fruit trees involved are mainly plums, apples and pears, but also are peaces. Yields are low since the husbandry is poor. Because of the low yields, this land utilization type mainly cater for the fruit needed by the family. There is however scope for intensifying the production of the above fruits which are not only very much required for the domestic market but also for the export market.

The capital intensity is low. The investment goes mainly to the purchase of planting material. Land preparation is by hoe but ploughing is also sometimes done by hired tractor owned by the cooperative society. The farm size is similar to that under the non-cereal land utilization types. Also the actual area put under crop depends on the family needs. The farm power is mostly made up of manpower. The lack of technical know-how at the farm level is a constraint and greater effort is required to assist the farmer to improve the husbandry of the growing of fruit-trees. With improved crop husbandry methods, the farm incomes could be increased. Profitable markets are difficult to secure because of high transport cost to such markets and also lack of organized marketing. This constraint can greatly be improved through efforts of the Kenya Horticultural Development Authority.

E. Small scale grazing for cattle and sheep at intermediate level of management.

This land use alternative is practiced in the study area for milk, meat and wool production. The herd and flock consist almost exclusively of grade cattle (Aryshire and Friesian) and sheep. The stocking rate varies from 0.34 Livestock Unit (LU) per hectare to 2.04 LU/ha. Because of the low level of pasture management, profitability of the livestock enterprise is not as high as expected. Since the carrying capacity of the prevailing natural pasture is low, there is already some degree of overstocking and this could even worsen the rather low profitability. The stocking rate needs to be regulated and the production of fodder and improved ley grass encouraged.

The farm size in the areas of better drained soils is small and the grazing is often supplemented with fodders such as kale, mangold, beet and oats. The farm size is however large in the areas with imperfectly drained soils where the livestock husbandry is wholly dependent on grazing the natural pasture. The production of oats as a fodder is tried in these areas but the yields are usually low because of imperfect drainage of the land. The technology consists of the use of grade cattle and sheep which are highly susceptible to diseases and must be protected at all cost. The capital requirement therefore concerns the acquisition of grade animals, the chemicals for maintenance of the animal health and artificial insemination.

The technical know-how is high and the extension service for animal health and articificial insemination is well organized. The labour requirement of confined to manpower for milking, shearing and spraying of the animals. Almost exclusively, this is handled by the family labour. The marketing of milk and wool is through organized cooperatives with well laid collection centres. This well organized marketing for milk and wool is a great incentive to the farmers.

F. Tree production for firewood and building poles.

This land utilization type concerns silviculture for the provision of firewood and building poles. For many farmers of the area, trees have traditionally provided and continues to provide some of the basic needs for life namely fuel for cooking and building materials. The shortage of firewood alone presents an energy crisis as profound as and probably more intractable than that connected with oil. If local crisis are to be avoided and the environmental role of trees preserved, ways must be found to satisfy the local trees requirements particularly for firewood and building. These needs may be met by encouraging the development of woodlots as part of the farming system. The extent of the woodlot will obviously depend on the demand and availability of land that can be spared for this purpose. Only land with little potential for arable agriculture could in principle be set aside for the purpose of tree plantation. The area under trees is present very small. The major tree species found on the imperfectly to poorly drained soils are *Eucalyptus saligna, Eucalyptus globulus, Eucalyptus maculata, Cupressus lusitanica, Cupressus microcarpa, Cupressus benthimii and Pinus halapensis.* There are possibilities for other species as well.

Attention should be paid to the above tree species which have been planted especially on the imperfectly drained soils (Planosols) by the farmers. In considering the possibility for tree exploitation it should be realised that apart from their timber potental they also have other functions such as the provision of shelter belt. It was observed that crops in fields surrounded by trees are normally protected from severe damage by frost and strong winds which are common in the Kinangop area. Firewood and building pole plantations on the imperfectly drained areas of Planosols could be viable enterprises since the need for fuelwood and poles appear high.

G. Fish pounds for fish production.

There exist a number of dams in the area (see Fig. 7) and it is possible to construct others. With support from the Fisheries Department, some of the dams could be developed for fish farming especially to increase the value of land in the imperfectly drained areas with claypan soils.

Fish culture has assumed progressively greater importance in Kenya. Once the ponds are constructed there are two approaches to the management that may be adopted. One is extensive fish farming while the other is intensive fish farming. In the former, the fish are placed in large body of water and are allowed to grow until harvesting without additives in the form of food or fertilizers. In intensive fish culture, the fish are given additional fertilizer and food to improve growth rates. Fish farming has two culturing systems namely mono-culture and poly-culture. Mono-culture is the culture of a single species of fish and usually involves only the males of that species to prevent unwanted breeding in the production ponds. The fish most commonly used for mono-culture are Tilapia which are indigenous to Africa. The other system which is poly-culture entails a situation where several species of fish with complementary feeding habits are used. One poly-culture practised in Africa involves Tilapia and Clarias.

An alternative to fish culture by itself is an integrated system of fish farm closely associated with other domestic livestock such as chicken. The livestock are housed in such a way that their droppings can easily be washed into fish ponds thereby increasing the productivity of the ponds. A yields of fish of 2 tonnes/ha/year from a fish pond is not excessive. Normally however, for a village fish farmer a figure of 1 tonne/ha/year would be considered a good yield.

The construction cost of fish ponds are probably a little more than those for gravity fed irrigation ditches. However the cost is justified considering the improved nutritional status of the farmer as a result of having a high quality protein supply on his doorstep.

7.2 THE KIND OF LAND REQUIREMENTS OF THE LAND UTILIZATION TYPES

In section 7.1 the Land Utilization types have been identified and their key attributes described. With this background it is possible to identify the specific land requirements of each land utilization type. Land requirements relate to those land factors which have direct influence on the feasilibity and performance of the type of land under consideration. If the land use envisaged is for instance grazing on natural grassland then the requirement of good grassland as well as drinking water becomes significant.

The land requirements may be categorised according to Beek and Bennema (loc cit) as follows: requirements of plant growth; requirements of animal growth; requirements of natural product extraction and requirements of management practices in plant and animal production or extraction. The land requirements for each of the land utilization type of the study area is as indicated below:

A. Small scale rainfed arable farming for non cereal annual crops at low level of management:
   - Water requirement
   - Nutrient requirement
   - Lack of risk of erosion
   - Requirement of use for agricultural implements
   - Oxygen requirement
   - Lack of risk of alkalinity/sodicity/alkalization
   - Lack of risk of periodically occurring pests and diseases.

B. Small scale rainfed arable farming for non cereal annual crops at intermediate level of management:
   - Land requirements are similar to the above mentioned.

C. Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management:
   - Land requirements are similar to the above mentioned.

D. Small scale rainfed arable farming for fruit trees at intermediate level of management:
   - Water requirement
   - Nutrient requirement
   - Lack of risk of erosion
   - Requirement for use of agricultural implements.
   - Oxygen requirement
   - Lack of risk of alkanity/sodicity/alkalization
   - Requirement of foothold
   - Lack of risk of periodically occurring pests and diseases.

E. Small scale grazing for cattle and sheep at intermediate level of management:
   - Water requirement
   - Nutrient requirement

- Lack of risk of erosion
- Oxygen requirement
- Lack of hinderance by vegetation
- Lack of risk of overgrazing
- Requirement of drinking water
- Lack of risk of alkalinity/sodicity/alkalinization
- Lack of risk of periodically occurring pests and diseases.

F. Tree production for firewood and building poles:
   - Water requirement
   - Nutrient requirement
   - Lack of risk of erosion
   - Oxygen requirement
   - Lack of risk of alkalinity/sodicity/alkalinization
   - Requirement of foothold
   - Lack of forest fire hazard
   - Lack of windfall hazard
   - Lack of risk of periodically occuring pests and diseases.

G. Fish pond for fish production:
   - Requirement of pond construction
   - Lack of risk of erosion
   - Water requirement.

The relationship of the land requirements with the land qualities will be treated in section 8 as to identify the constraints to the land utilization types.

8. THE KIND OF THE LAND QUALITIES IDENTIFIED FOR THE AREA, THEIR GRADES AND HOW THEY FIT THE REQUIREMENTS OF THE LAND UTILIZATION TYPES.

Many land or soil characteristics are unlikely to influence land suitability independently unless they are extreme. The majority of the land and soil characteristics must therefore be considered jointly with or in relation to other characteristics to allow for interaction between them. Proposals have been made by Beek and Bennema (loc cit), FAO (1976) and Beek (loc cit) to group single characteristics into a combination called a "land quality". It is defined in FAO (1976) as "a complex attribute of land which acts in a distinct manner in its influence on the suitability of and for a specific kind of use". The expression of each land quality is determined by a set of interacting land characteristics which may be single or compound and which have different weights in different environments depending on the values of all characteristics in the set.

Beek and Bennema (loc cit) have provided a list of examples of land qualities. The following land qualities correspond to the land requirements of the land utilization types of the study area:

A. Small scale rainfed arable farming for non cereal annual crops at low level of management:
   - Availability of water
   - Availability of nutrients
   - Resistance to erosion
   - Possibility to use mechanical implements
   - Presence/hazard of water logging (availability of oxygen)
   - Presence/hazard of alkalinity/sodicity/alkalinization
   - Risk of periodically occurring pests and diseases.

B. Smalle scale rainfed arable farming for non cereal annual crops at intermediate level of management:
   - Land qualities are similar to the above mentioned.

C. Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management:
   - Land qualities are similar to the above mentioned.

D. Medium scale rainfed arable, farming for fruit trees at intermediate level of management:
   - Availability of water
   - Availability of nutrients

- Resistance to erosion
- Possibility to use mechanical implements
- Presence/hazard of waterlogging (availability of oxygen)
- Availability of foothold
- Presence/hazard of alkalinity/sodicity/alkalinization
- Risk of periodically occurring pests and diseases.

E. Small scale grazing for cattle and sheep at intermediate level of management:
- Availability of water
- Availability of nutrients
- Resistance to erosion
- Presence/hazard of waterlogging (availability of oxygen)
- Hinderance by vegetation
- Risk of overgrazing
- Availability of drinking water
- Presence/hazard of alkalinity/sodicity/alkalinization
- Risk of periodically occurring pests and diseases.

F. Tree production for firewood and building poles:
- Availability of water
- Availability of nutrients
- Resistance to erosion
- Presence/hazard of waterlogging (availability of oxygen)
- Availability of foothold
- Presence/hazard of alkalinity/sodicity/alkalinization
- Presence of windfall hazard
- Presence of forest fire hazard
- Risk of periodically occurring pests and diseases.

G. Fish pond for fish production:
- Resistance to erosion
- Availability of water
- Availability of conditions for pond construction.

A land quality can be quantified and graded for assessment of land suitability classes. There is no international system for grading of the land qualities but various methods of grading have been proposed by various workers including van de Weg and Braun (1977) and Debele (1980). Van de Weg and Braun (loc cit) have proposed a system for the rating of land qualities for regional land evaluation in Kenya while Debele (loc cit) in a paper presented at the meeting of the Eastern Africa Soil Correlation and Land Evaluation Sub-Committee presented a methodology for the rating of the land qualities and determining the land suitability classes based on the weighting of the land characteristics and land qualities. The problem with methods based on the weighting of indices such as Debele's method is that the weight or idex of one land characteristic or land quality can not be treated independently of the others and yet often it is the one land characteristic or land quality which presents the strongest constraint which is the determining one for a land suitability class. Moreover, the weights must of necessity be different for different situations and their use cannot therefore appropriately allow for extrapolation.

The methodology of van de Weg and Braun (loc cit) on the other hand treats the land characteristics and land qualities independently and thus allows the individual effect to be assessed. It is for this reason that the latter methodology is considered to be more appropriate for the present study and is therefore employed with appropriate modifications, in computing the grades of the land qualities. The use of this method is particularly facilitated because the laboratory and field soils data essential for its application have been determined for the area in the course of the present study. The grading of the land qualities according to van de Weg and Braun (loc cit) is found in Annex 4 while the grades of the relevant land qualities computed for the soil units of the area are found in Table 24. A significant modification made with regard to the ratings of van de Weg and Braun concerns the moisture availability. The grades of available moisture carrying capacity have in this study been related to the periods of moisture sufficiency since it is the latter, rather than the available moisture carrying capacity, which influences plant growth. Moreover the available moisture has been considered between pF 2.0 and 4.2 as recommended by FAO (1979, p26)

Table 24: The grades of the land qualities of the soil units; see Annex 4 for the definition of the grades.

Soil Unit		UPr1	UPr2	UP3	UPb1	UPb2	UPb3	UPb4	UPb5	UPb6	UPb7	UPb8p	UPb9p	UPb10p	UPb11p	UPb12p	UPb13p	UPb14p	UPb15p	UPb16p	UPb17p	UPb18p	UPap	LPa1	LPa2	LPa3p	LPa4p	LPa5p	LPa6p	LPa7p	LPa8p	LPa9p	LPa10p	LPa11p	BPp
Availability of moisture	100 cm	3	3	2	2	2	1	2	1	2	1	3	3	2	2	2	1	3	1	2	2	2	2	3	4	4	3	2	3	4	4	3	4	3	4
	150 cm	2	2	1	1	2	1	1	1	1	1	2	2	1	2	1	1	3	1	2	2	2	2	3	4	4	3	2	3	4	4	3	4	3	4
Availability of nutrients		3	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	4	4	4	5	5	5	3	4	4	3	3
Hazard of alkalinity/sodicity/alkalinization		1	1	1	1	1	1	3	1	1	1	2	1	1	3	1	1	2	1	2	1	1	1	2	2	2	2	2	2	2	2	1	3	2	1
Resistance to erosion		3	4	3	4	3	4	3	3	3	4	3	3	3	1	3	4	4	4	4	4	4	4	3	5	3	4	4	4	5	3	4	3	3	3
Possibility of use of implements	Hand	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
	Oxen	1	2	1	2	1	2	1	2	1	2	1	1	1	1	2	2	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
	Tractor	1	3	1	2	1	2	1	2	1	3	1	1	1	1	2	2	1	1	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1
Hazard of water-logging		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	2	3	3	3	3	3	3	3	3	4	4	4	4	4
Availability of foothold		1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3
Hinderance by vegetation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Risk of overgrazing		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
Availability of drinking water		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hazard of forest fire		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hazard of windfall		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Risk of pests & diseases		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Availability of conditions for pond construction		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	4	3	3	3	3	3	3	3	3	2	3	2	3	3

9. THE IMPROVEMENT POSSIBILITY OF THE LAND AND THE LIMITS OF THE GRADES OF LAND QUALITIES SET FOR THE SUITABILITY CLASSES FOR THE DIFFERENT LAND UTILIZATION TYPES

Before a land suitability classification is carried out, the possibilities of improvement of the land have to be established and the minimum grades of the land qualities that should be allowed for each land suitability class set for each land utilization type as assumed level of management (i.e. input). The technical improvement possibilities include the following among others: improvement of fertility status by using fertilizers; improvement of water availability by irrigation; improvement of the soil aeration by drainage; the control of soil erosion with soil conservation practices; the control of floods with embankment. The technical improvement can be assessed in terms of the capital inputs involved of the effectiveness of the measures. They may be designated by letters O, A, B, C, D and E which respectively represent no improvement, low input improvement, medium input improvement, high input improvement, very high initial improvement plus normal recurrent cost, and very high initial input improvement plus high recurrent cost. At low input improvement, only special crop management and simple soil management may be required while at medium input improvement, intensive soil management is involved and the farmer needs well organized advisory service. Measures requiring high input are usually beyond on-farm development and implies regional planning and development. These input measures which may concern large scale land and water engineering operations such as reclamation, land grading, drainage system, terracing, etc. may require service of a contractor. Where the improvement of the land involved high input the classification of the land is regarded as a potential suitability at medium and low input the classification is treated as current suitability.

The suitability of the land then depends on the degree to which its land qualities satisfy the requirements of the land utilization types at assumed level of input (management). If the yields from a number of sites on different types of land are available, this may provide a better clue for the suitability class. But information on the relationship between land qualities and yields are scarce. For the study area and indeed for the whole of Kenya, this information is lacking. Furthermore, examples of conversion tables are scarce in literature. Tables 25a to 25g give the limits of the grades of the land qualities which the author has set for the suitability classes for the different land utilization types applicable in the study area and at assumed low and medium levels of input (management). The limits for moisture availability especially take into account the fact that the rainfall in the study area is well distributed throughout the year. Thus the moisture is frequently replenished even though that the available moisture may be small.

Table 25a: Limits of the grades of land qualities set for the suitability classes for the land utilization type A: Small scale rainfed arable farming for non cereal annual crops at low level of management (i.e. at low input requirement).

Suitability Class	Land Quality: Availability of moisture	Availability of nutrients	Resistance to erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1 Highly suitable	1	1	2	2	3	2	3	n.a.	n.a.	n.a.	n.a.	n.a.	2	n.a.
1.2 Moderately suitable	2	2	3	3	3	2	4	n.a.	n.a.	n.a.	n.a.	n.a.	3	n.a.
1.3 Marginally suitable	3	3	4	3	3	3	4	n.a.	n.a.	n.a.	n.a.	n.a.	4	n.a.
3 Unsuitable	4	4	5	4	4	4	5	n.a.	n.a.	n.a.	n.a.	n.a.	5	n.a.

Note: n.a. = not applicable

Table 25b: Limits of the grades of land qualities set for the suitability classes for the land utilization type B: Small scale rainfed arable farming for non cereal annual crops at intermediate level of management (i.e. at medium input requirement)

Suitability Class / Land Quality	Availability of moisture	Availability of nutrients	Resistance of erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1 Highly suitable	1	2	2	2	2	2	3	n.a.	n.a.	n.a.	n.a.	n.a.	2	n.a.
1.2 Moderately suitable	2	3	3	3	2	2	4	n.a.	n.a.	n.a.	n.a.	n.a.	3	n.a.
1.3 Marginally suitable	3	3	4	3	3	3	4	n.a.	n.a.	n.a.	n.a.	n.a.	4	n.a.
3 Unsuitable	4	4	5	4	4	4	5	n.a.	n.a.	n.a.	n.a.	n.a.	5	n.a.

Table 25c: Limits of the grades of land qualities set for the suitability classes for the land utilization type C: Medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management (i.e. at medium input requirement).

Suitability Class / Land Quality	Availability of moisture	Availability of nutrients	Resistance of erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1 Highly suitable	1	2	2	2	2	2	3	n.a.	n.a.	n.a.	n.a.	n.a.	2	n.a.
1.2 Moderately suitable	2	3	3	3	2	2	4	n.a.	n.a.	n.a.	n.a.	n.a.	3	n.a.
1.3 Marginally suitable	3	4	4	3	3	3	4	n.a.	n.a.	n.a.	n.a.	n.a.	4	n.a.
3 Unsuitable	4	5	5	4	4	4	5	n.a.	n.a.	n.a.	n.a.	n.a.	5	n.a.

Note: n.a. = not applicable

Table 25d: Limits of the grades of land qualities set for the suitability classes for the land utilization type D: Small scale rainfed arable farming for fruit trees at intermediate level of management (i.e. at medium input requirement).

Suitability Class / Land Quality	Availability of moisture	Availability of nutrients	Resistance to erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1 Highly suitable	1	3	2	2	n.a.	2	1	n.a.	n.a.	n.a.	n.a.	n.a.	2	n.a.
1.2 Moderately suitable	2	4	3	3	n.a.	2	2	n.a.	n.a.	n.a.	n.a.	n.a.	3	n.a.
1.3 Marginally suitable	3	5	4	3	n.a.	3	3	n.a.	n.a.	n.a.	n.a.	n.a.	4	n.a.
3 Unsuitable	4	5	5	4	n.a.	4	4	n.a.	n.a.	n.a.	n.a.	n.a.	5	n.a.

Table 25e: Limits of the grades of land qualities set for the suitability classes for the land utilization type E: Small scale grazing for cattle and sheep at intermediate level of management (i.e. at medium input requirement).

Suitability Class / Land Quality	Availability of moisture	Availability of nutrients	Resistance to erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1 Highly suitable	1	3	3	3	3	2	n.a.	2	2	2	n.a.	n.a.	2	n.a.
1.2 Moderately suitable	2	4	4	3	3	3	n.a.	3	3	3	n.a.	n.a.	3	n.a.
1.3 Marginally suitable	3	5	5	4	4	4	n.a.	4	4	4	n.a.	n.a.	4	n.a.
3 Unsuitable	4	5	5	5	5	5	n.a.	5	5	5	n.a.	n.a.	5	n.a.

Note: n.a. = not applicable.

Table 25f: Limits of the grades of land qualities set for the suitability classes for land utilization type F: Tree production for firewood and building poles (i.e. at medium input requirement).

Suitability Class	Land Quality	Availability of moisture	Availability of nutrients	Resistance to erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1	Highly suitable	2	3	3	3	n.a.	2	2	n.a.	n.a.	n.a.	2	2	2	n.a.
1.2	Moderately suitable	3	4	4	3	n.a.	3	2	n.a.	n.a.	n.a.	3	3	3	n.a.
1.3	Marginally suitable	4	5	5	4	n.a.	4	3	n.a.	n.a.	n.a.	4	4	4	n.a.
3	Unsuitable	4	5	5	5	n.a.	5	4	n.a.	n.a.	n.a.	5	5	4	n.a.

Table 25g: Limits of the grades of land qualities set for the suitability classes for the land utilization type G: Fish ponds for fish production (i.e. at medium input requirement).

Suitability Class	Land Quality	Availability of moisture	Availability of nutrients	Resistance to erosion	Hazard of alkalinity/ sodicity/alkalinization	Possibility of use of implements	Hazard of waterlogging	Availability of foothold	Hinderance by vegetation	Risk of overgrazing	Availability of drinking water	Hazard of forest fire	Hazard of windfall	Risk of pests and diseases	Availability of conditions for pond construction
1.1	Highly suitable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2
1.2	Moderately suitable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3
1.3	Marginally suitable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4
3	Unsuitable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5

Note: n.a. = not applicable

10. THE CURRENT LAND SUITABILITY

The current land suitability classes based on low and medium land improvement have been established for a particular land utilization type by considering the minimum land quality requirements which have been set in Tables 25a to 25g. By comparing the land qualities of the land mapping units with the limits that have been set for each land utilization type, the classes are set. It is the most limiting land quality of the land mapping unit that has been regarded to determine the land suitability class, taking into consideration personal judgement as well. Only one limiting land quality has been considered at a time since the present level of investigation which is at scale 1:50,000 is less detailed and therefore does not justify subdivision into many suitability classes. For more detailed investigation two or more limiting land qualities could be used simultaneously to separate the suitability classes. With regard to annual crops utilization types, the moisture availability as a land quality has been considered only down to 100 cm depth of soil while it is considered down to 150 cm depth of soil for tree crops and other trees. Furthermore, for the arable farming which is to be practiced at low level of management, only the possibility of the use of hand implements is taken into consideration. Table 26 gives the current land suitability for the different land utilization types applicable in the study area.

Table 26: Current Land Suitability for rainfed land use
1.1 - Highly suitable; 1.2 - Moderately suitable; 1.3 - Marginally suitable; 3 - Unsuitable. For the distribution of the area of soil units between the settlement schemes, see Table 23.

Soil Unit	Area (ha)	A: Small scale non cereal annual crops at low input management	B: Small scale non cereal annual crops at medium input management	C: Medium scale wheat/barley/oats at medium input management	D: Small scale fruit trees at medium input management	E: Small scale grazing for cattle and sheep at medium imput management	F: Tree production for firewood and building poles	G: Fish ponds for production
UPr1	1884	1.3	1.3	1.3	1.2	1.2	1.1	3
UPr2	1325	1.3	1.3	1.3	1.3	1.2	1.2	3
UPr3	205	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb1	894	1.3	1.3	1.3	1.3	1.2	1.2	3
UPb2	96	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb3	318	1.3	1.3	1.3	1.3	1.2	1.2	3
UPb4	228	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb5	270	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb6	531	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb7	868	1.3	1.3	1.3	1.3	1.2	1.2	3
UPb8p	265	1.3	1.3	1.3	1.2	1.2	1.1	3
UPb9p	400	1.3	1.3	1.3	1.2	1.2	1.1	3
UPb10p	1272	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb11p	132	1.3	1.2	1.2	1.2	1.2	1.1	3
UPb12p	200	1.3	1.2	1.2	1.2	1.1	1.1	3
UPb13p	18	1.3	1.3	1.3	1.3	1.2	1.2	3
UPb14p	218	1.3	1.3	1.3	1.3	1.3	1.2	3
UPb15p	296	1.3	1.3	1.3	1.3	1.2	1.2	1.3
UPb16p	415	1.3	1.3	1.3	1.3	1.2	1.2	1.3
UPb17p	72	1.3	1.3	1.3	1.3	1.2	1.3	3
UPb18p	510	1.3	1.3	1.3	1.3	1.2	1.3	1.3
UPap	239	1.3	1.3	1.3	1.3	1.2	1.3	1.2
LPa1	2169	1.3	1.3	1.3	1.3	1.3	1.3	1.2
LPa2	2406	3	3	3	3	3	3	1.2
LPa3		3	3	3	3	3	1.3	1.2
LPa4p	7596	3	3	1.3	1.3	1.3	1.3	1.2
LPa5p	1903	3	3	3	1.3	1.3	1.3	1.2
LPa6p	1917	3	3	3	1.3	1.3	1.3	1.2
LPa7p	496	3	3	3	3	3	1.3	1.2
LPa8p	1473	3	3	3	3	3	1.3	1.1
LPa9p	615	3	3	3	3	1.3	1.3	1.2
LPa10p	2137	3	3	3	3	3	3	1.1
LPa11p	1271	3	3	3	3	1.2	1.3	1.2
BPp	229	3	3	3	3	3	1.3	1.2

11. A PRELIMINARY ASSESSMENT OF THE POSSIBILITY OF IMPROVING THE DRAINAGE OF THE IMPERFECTLY AND POORLY DRAINED SOILS AND THE POTENTIAL LAND SUITABILITY

The major land constraint affecting substantial part of the study area is imperfect soil drainage. Out of the 32,500 ha studied 22,450 ha are affected in this respect. A preliminary assessment of the possibility of improving the drainage of the imperfectly and poorly drained soils was therefore made by carrying out an observational drainage experiment which run from 1976 to 1979. The experiment was a straight block design comparing the following drainage treatments: open ditch drain; ripping plus open ditch drain; camberbed plus open ditch drain; camberbed; ridged camberbed; ridged flat and untreated (control). The experiment was on solodic Planosol (Abtruptic Tropaqualf, fine clayey, mixed- montorillonitic/illitic/kaolinitic, isothermic) on slight slope. The ditch drained, ripped and control plots measured 30 m length and 20 m width while the camberbeds measured 20 m length and 10 m width. The ripping was 60 cm apart and 60 cm deep. The hybrid maize variety 613C and peas (Greenfeast variety) were the test plants with sampling done in triplicates from sub-plots measuring 25 sq.m. Table 27 provides the results on percentage crop establishment and yields as well as the monthly rainfall during the period. The rain in 1978 was exceptionally wet. After planting on 4th April there was never a reasonably dry period as it rained daily upto 16th April with a daily rainfall ranging from 1.3 mm to 50.0 mm (average 12.7 mm). The germination and establishment of both maize and peas were therefore extremely poor and the growing of the crop was abandoned during the year.

Ripping plus open ditch drain is the most effective in terms of yield followed by open ditch drain alone, camberbed plus open ditch drain and camberbed alone. The ridging appears to worsen the condition of drainage. The different drainage systems have different influence on the quickness with which the land surface is dried and the depth to which the water table is lowered. As can be seen from Table 28, camberbed keeps the water table deepest followed by ripping plus open ditch drain.

Furthermore, as can be seen from Table 29, the land surface dries fastest under camberbed followed by ripping plus ditch drain. The ripping considerably improves the effect of the open ditch drain (see Tables 27 and 30).

Table 27: Crop establishment and yields as well as monthly rainfall during the drainage test period 1976 to 1979 inclusive.

Drainage Treatment	% CROP ESTABLISHMENT										
	1976	1977		1978		1979	1976		1977		1979
	Maize	Maize	Peas	Maize	Peas	Peas	Maize Dry matter yield (kg)	Maize Dry yield (kg)	Maize Grain yield (kg)	Peas Grain yield (kg)	Peas Dry matter yield (kg)*
Ripping plus open ditch drain	92	97	68	0.21	0.03	26	53.57	51.56	9.12	12.86	0.61
Open ditch drain	79	99	64	0.03	0.05	19	42.33	38.07	7.30	7.63	0.18
Camberbed plus open ditch drain	89	94	62	0.26	0.07	11	22.14	29.81	5.96	9.05	0.37
Camberbed	77	91	68	0.23	0.02	6	15.74	36.04	4.01	6.75	0.17
Ridged camberbed	nd	97	70	0.19	0.02	9	nd	33.11	3.67	4.09	0.04
Ridge flat	nd	85	51	0	0	nd	nd	28.23	4.07	1.41	nd
Untreated	62	87	56	0	0	8	9.94	27.50	4.37	2.14	0.02

Note: Ripping (60 cm wide, 60 cm deep) done in February 1976.
Sampled plot size = 25 sq.m.; * Aerial part including pods and grains
nd = no data.

Table 27 continued

RAINFALL (mm) DURING GROWING SEASONS

	1976	1977	1978	1979
January	19.4	181.7	116.2	163.0
February	54.3	82.4	151.2	235.1
March	97.9	89.0	481.0	133.0
April	164.4	495.6	343.4	269.9
May	103.9	195.2	148.8	362.2
June	132.6	86.3	80.5	143.5
July	71.5	76.2	39.6	62.0
August	46.8	121.2	88.3	52.0
September	86.8	37.8	111.7	60.0
October	26.0	183.8	175.5	30.5
November	131.1	278.4	96.8	74.0
December	95.8	223.0	302.2	33.0
Planting date	8/4/76	5/4/77	4/4/78	22/3/79

Table 28: Depth to water table under various drainage treatment

Drainage treatment	Depth (cm) to water table on	
	6/5/78	12/5/78
Camberbed	38.3	61.0
Camberbed plus open ditch drain	34.5	55.0
Ripping plus open ditch drain	21.5	41.7
Open ditch drain	5.5	32.5
Untreated (control)	5.0	29.0

Visual observation on crop growth showed that the effectiveness of the open ditch drain alone extends to about 13 m (also see Table 30). Moreover the open ditch, on the soil with a subsoil clay pan (Planosol), was obserbed to the subject to continual collapse and widening. These two factors mean that the ditch drain can only conveniently be applied to improve the drainage in the study area if installed in the form of tile drains which empty into major water courses and also they have to be closely spaced for effectiveness. This entails very high initial cost which is beyond individual on-farm operation and requires an overal regional plan. The same remarks may be made with regard to the ripping which requires the use of crawler tractor and which for effectiveness must be accompanied by a kind of ditch drain although the spacing of the latter would be much wider.

The camberbed although not as effective as the ripping plus ditch drain appears to be easily adaptable to individual on-farm application. The camberbeds as were constructed of 10 m width for the experiment can easily be made with a tractor disc plough. The water from the dead furrows however needs to be emptied into the drainage system already existing in the study area (see Fig. 7) but which has fallen into dis-service. A major programme of rehabilitation of this regional network of drains to be used in conjunction with camberbeds is required.

One problem that was observed with the camberbed was the variation in yield within the bed. The middle part of the bed had a much better crop yield than the sides (see Table 30). This may be attributed to the fact that the water table and soil depth are respectively deeper and thicker in the middle of the camberbed than at the sides thus providing a more favourable condition for crop growth. The substantial improvement of yield when camberbed is used over that of undrained land together with its simplicity of manipulation at individual farm level however, merits its being considered as a potential

Table 29: The rate of drying of the land surface under various drainage treatment determined by penetrometer (readings in pounds per square inch)

DAY	DITCH DRAIN	DRAINAGE TREATMENT DITCH DRAIN + RIPPING	DITCH DRAIN + CAMBERBED	CAMBERBED		RIDGED CAMBERBED	UNTREATED CONTROL	RAINFALL (mm)
1	-	-	-	-	-	-	27.0	
2	1.0	1.0	1.0	1.0	1.0	0.75	0	
3	0.75	1.0	1.0	1.25	1.0	0.75	30.0	
4	1.0	1.0	1.0	1.25	1.25	1.25	25.0	
5	1.0	1.0	1.0	1.25	1.25	1.0	0	
6	0.75	1.25	1.25	1.25	1.25	1.0	0	
7	1.0	1.25	1.0	1.25	1.25	1.0	0	
8	0.75	1.0	2.0	1.50	1.50	1.0	0	
9	1.25	1.25	1.75	2.25	2.0	1.0	0	
10	1.0	1.0	2.0	2.25	1.50	0.75	14.0	
11	1.0	1.0	1.0	1.25	1.25	1.0	0	
12	1.0	1.25	1.50	1.50	1.50	1.25	0	
13	1.25	1.5	2.0	1.75	1.75	1.0	0	
14	1.0	1.75	1.75	2.0	1.50	1.0	0	
15	1.25	1.75	2.0	1.75	1.50	1.25	8.0	
16	1.50	1.50	1.50	2.50	1.50	1.50	0	
17	1.75	1.50	1.75	2.0	1.50	1.50	0	
18	1.50	1.50	1.50	2.50	1.50	1.50	0	
19	1.75	1.75	2.50	2.0	1.75	1.75	0	
20	1.50	1.75	2.50	2.50	2.0	1.50	3.0	
21	1.50	2.50	2.0	2.50	1.75	1.0	0	
22	2.50	2.50	2.0	2.0	2.5	1.50	0	

Note: Field visual observation indicated that the surface was fairly dry when the penetrometer readings were 1.5 and above. If the figure 1.5 is regarded as indicative of a transition between wet and dry then it can be seen that it took 7 days for the surface soil of the ditch drain plus camberbed plot, camberbed plot and ridged camberbed plot to dry; it took 12 days for the ditch drain plus ripping plot to dry; and it took 15 days for both the ditch drained and control plots to dry. Camberbed therefore seems the most effective in drying the surface soil whereas ripping improves the effect of the open ditch drain.

Table 30a: Comparison of the effectiveness of the various drainage treatments and the distance from the open ditch drain; the yields from 1977 experiments are grams of peas from sub-plots of 25 sq.m.

Distance from ditch drain	Ditch drain	Ripping plus ditch drain	Camberbed plus ditch drain	Camberbed	Untreated control
10 m	7625	12,861	9,048	6749	2138
20 m	5926	11,074		Ridged Camberbed	Ridged control
30 m	5223	10,793		4088	1410

(b)Comparison of the yields (grams of peas) from the middle and the sides of camberbed. Yields are from sub-plots of 25 sq.m.

	Camberbed plus ditch drain	Camberbed	Ridged camberbed
Side	6412	6138	3339
Middle	12771	8317	5671
Side	7960	5792	3253

means of improving the drainage in the study area.

It is expected that when the camberbed are used the current suitability of the imperfectly drained soils units UPap to BPp for arable farming (especially for wheat, barley and oats) in the area can be upgraded by a least one class.

PART 4

RESULTS, CONCLUSIONS AND NECESSARY FOLLOW-UP

12. RESULTS AND CONCLUSION

A number of constraints to the land use in the study area have been identified. These constraints include low temperature, poor drainage and low fertility of soils, lack of good marketing for most of the horticultural crops, and poor on-farm roads. The constraints are briefly discussed below and some of the means to alleviate them are suggested.

12.1 CONSTRAINT OF CLIMATE

The climatic variables that were found to exert profound influence on the crop, grass and tree development in the study area are temperature and water availability.

Temperature and Frost

The mean monthly temperatures in the study area lie between 10°C and 16°C with a monthly maximum which does not exceed 26°C and a monthly minimum between 2.7°C and 9.4°C. Another feature connected with the temperature is the occurrence of night frost in most of the months a a result of the cold air which flows down the study area. The apparently rather cool temperatures and the incidence of frost no doubt present substantial constraint to the crops and trees that can be adopted for the Kinangop area. Since it is not physically possible to alter the field temperature regime by any technological manipulation the only choice open is to select and breed cool tolerant crops. However, as seen from Table 5 and section 2.3 a wide range of crop varieties and plant species which are adaptable to the temperature of the study area are already available and can be expanded to include others. These adaptable crops unfortunately exclude the rice which would have otherwise been ideal for the imperfectly drained soils which are widespread in the study area had a suitable cool tolerant rice variety been available. Furthermore the growing of crops like potato, sunflower and maize which are very sensitive to frost will need to be precisely timed during the frost-free period. This frost-free period was found to occur only from late March to early June. It is for the reason of this rather short frost-free period that it will be difficult to grow the currently available late maturing maize varieties without the risk of frost damage.

One other effect of frost that is likely to be experienced is on the quality of grass for grazing by livestock. As revealed by the data in Table 10 the percentage crude protein which is a measure of the nutritive value of grass is rather low during December when the frost is severest and frequent. The quantity of milk production and the liveweight of the animals may be expected to go down during December to February. This calls for supplementary feeding of the livestock especially the dairy cattle if the milk production is to be maintained at a high level. It will not be possible to produce any fodder crops during the period of December to February since it is also a dry period. Therefore the use of concentrates as a supplementary feed would appear to be the only choice in the absence of hay and sileage. The economics and logistics of the availability of concentrates, hay of sileages will dictate which ones can be adapted as a supplementary cattle feed.

Water Availability

Under rainfed agriculture and forestry, examination of the interaction between rainfall, soil water storage and evapotranspiration is necessary in the assessment of water availability to plant. In the absence of irrigation, there should be ample source of water in the form of rainfall and the soil must store enough of it to meet the evapotranspiration requirement of the plant. During the plant growing period there should ideally not be a period of moisture deficit to satisfy the evapotranspiration demand. The length of the period when evapotranspiration is fully met would determine the length of the growing period.

The study area falls into three rainfall and evapotranspiration regimes as presented in Table 19. The length of the period when the rainfall fully satisfies the evapotranspiration demand then depends on the soil moisture storage capacity as shown in Table 21a to 21c. The higher the soil moisture storage capacity the more the evapotranspiration is catered for when enough supply of rainfall is available. The length of the growing period according to the results of this investigation is expected to be longest for the eastern part of the study area and shorter for the western part. Thus depending on the water holding capacity of the soil, the same soil will have a different water availability potential and therefore a different length of the period it is capable of supplying adequate water to the plant. For the study area, it was generally found that a soil with less than 90 mm water storage capacity will have the length of the period of moisture sufficiency (i.e. the growing period) less than three months. A period less than three months would be too short a growing period for most crops and can be considered unfavourable for arable agriculture.

The results of the matching of the moisture availability and the length of the growing period computed for the study area is found in sections of Annex 4. Against this categorization, the moisture availability status of the soils of the study area, examined to a depth of 100 cm and 150 cm, where soil depth allowed, was graded as shown in Table 24. The availability of moisture in the study area markedly varies. It ranges from very high to moderate for the well drained soils but ranges from high to low for the imperfectly drained soils. A large proportion of the latter soils have low availability of moisture largely because of their shallow depth arising from the presence of the clay pan at shallow depth. Although the availability of moisture can be improved through supplementary irrigation, this will need careful study before its feasibility can be ascertained. It should also be pointed out that the majority of the soils that have low availability of moisture happen to be the soils which are at present unsuitable for arable agriculture (see Table 26).

12.2 CONSTRAINT OF SOILS

This semi-detailed soil investigation at scale of 1:50,000 reveals thirty four soil units over an area of 32,500 ha (see Table 22). These soils falls into seventeen units according to the FAO/UNESCO (1974) legend and twenty-six units according to the United States Soil Survey Staff (1975) soil families. The major problems with these soils relate to the drainage, shallow depth due to presence of clay pan at shallow depth and low soil fertility and pH as presented in Table 23.

Thirteen soil units fall under the category of imperfect drainage to poor drainage due to an impermeable subsoil clay pan. These soils constitute a substantial proportion of the study area since they occupy some 22,450 ha of the studied area of 32,500 ha of seven settlement schemes. The schemes which are mostly affected by the imperfect to poor drainage are Muruaki, Githioro, Karati and Tulaga. It is worst in Githioro and Karati because of the undissected and rather flat topography which occurs in these latter schemes. In section 10 of this report the possibility of improving the drainage of the imperfectly drained and poorly drained soils have been examined on a preliminary basis. It is possible under the conditions of the study area to effect the improvement of the drainage through a well planned system of camberbeds. This will however, require an overall drainage plan whereby the camberbeds can empty into well laid shallow fields drain which can in turn drain into natural drainage channels. During the demarcation of settlement plots in the study area some of the drains were laid down but these have now become unserviceable and need to be rehabilitated.

With regard to the shallow depths, it is found that this is due to the presence of a compact and impermeable subsoil layer which may occur from 40 cm but generally occurs within 75 cm. The preliminary experiment reported in section 11 reveals that the compact layer can be broken by ripping but this requires the use of crawler tractor which may not be easily available. These soils with a clay pan may best be utilized for grazing or tree production for building poles and firewood or pond construction for fish production. Section 2.3 shows some of the trees species which were found to be performing well and which among others can be developed on these soils with a clay pan.

The low soil fertility is widespread and this involved mainly phosphorus, nitrogen and the pH (see Table 23 and annex 3). The soil nutrient status must be improved if satisfactory crop yields are to be obtained. Data from agronomic experiments are meagre for the area and more agronomic trials will have to be carried out in order that judicious and beneficial fertilizer recommendation can be made.

In section 7.1 the seven land use alternatives identified for the study area are presented. Table 26 further gives the present physical suitability of the soil units for each of the seven land utilization types. It is evident that the physical soil suitability varies with the kind of use to which the land is to be put. This no doubt re-emphasizes one of the main principles of land evaluation which stipulated that the assessment of land suitability only makes sense when related to a specified land use. No doubt the same tract of land may have the same suitability for various land utilization types. The use to which the land is put then will depend on the contemporary socio-economic conditions. Such a socio-economic analysis of the land suitability is outside the scope of the present investigation although could easily be undertaken as a follow-up project to the present study.

The physical suitability of land can potentially be improved when a major operation is carried out to improve the land. In the study area such a major operation will involve the improvement of drainage of the imperfectly drained and poorly drained soils. When the drainage of these soils is improved it is expected that suitability for the reported uses other than that for pond construction can be upgraded by at least one class. The area requiring drainage constitutes a very large proportion of the area of the seven schemes covered by the study. It would therefore seem to merit the formulation of a drainage project if the farmers occupying these imperfectly and poorly drained soils are to be assisted to improve the productivity of their land and the farm income.

12.3 CONSTRAINT OF THE MARKET FOR THE PRODUCE

As explained in section 1.2.4, there is no proper arrangement for the marketing of most of the horticultural crops but organized marketing exists for milk, wool, carrots, green peas, wheat, barley, maize and pyrethrum. The milk, pyrethrum and wool are respectively sold to the Kenya Co-operative Creameries, the Pyrethrum Board and the Kenya Farmers Association through collection centres organized by the Farmers Co-operative Union. Maize and wheat are sold to be National Cereals and Produce Board through individual farmers arrangement while barley is similarly sold to be Kenya Breweries. The Pan African Foods Ltd. buys carrots and green peas through the Farmers Co-operative Union. For these, the company provides organized transporation from the farms.

For the rest of the crops which are mainly horticultural crops the marketing arrangement is quite unsatisfactory. Many farmers have neither the means to transport the crops nor the storage facilities. They therefore strive to sell their surplus produce as soon as they obtain it. This is done through the middlemen who are usually in a stronger bargaining position and therefore tend to control the prices. The operation of the Kinangop Farmers Co-operative Union therefore needs to be strengthened to incorporate the marketing of a wide range of produce especially the horticultural crops. In this endavour, assistance to the farmers by the Ministry of Co-operative Development and Horticultural Development Authority is very much required. Such assistance will involve the streamlining of the operation of the Kinangop Co-operative Societies to instil greater efficiency and effectiveness as well as the improvement of collection, storage and transporation facilities. Feasibility for exporting crops to potential markets outside Kenya could also be explored by the Horticultural Development Authority and the Kenya External Trade Authority to provide a larger market outlet for the horticultural crops.

12.4 CONSTRAINT OF ON-FARM ROADS

Information on the on-farm road situation is provided in section 1.2.3. Some of the roads in the study area are now in very bad shape. The poor roads are those classified as settlement access roads and are therefore those which do not fall under the Ministry of Transport's classified roads. These settlement access roads are however very important since they provide the main accessiblity for the farmers and without being accessible during all seasons the farmers operations would greatly be handicaped. A programme for the rehabilitation on on-farm roads to all weather standard needs to be mounted as a priority and adequate arrangements made for their maintenace thereafter. This exercise may be carried out as part of a comphensive programme to revitilize the agricultural production of Kinangop area.

12.5 CONSTRAINT OF IMPERFECT DRAINAGE

The present investigation at semi-detailed scale of 1:50,000 reveals that imperfect drainage affects a large part of the study area. Imperfect drainage affects soil units UPap to BPp (see the soil map - Fig. 7A). Some 22,450 ha are involved out of the 32,500 ha covered in this study. The less dissected and rather flat parts of the study area (see Fig. 7) are the worst affected by imperfect drainage. This large area of imperfectly drained land is usually virtually waterlogged during the six months of rainy season and it not even ideal for grazing during this period. Moreover the area of imperfectly drained soils carries nutritionally rather poor grass as shown in section 2.2.

Preliminary drainage experiments which is reported in section 11 of this report indicates that it is possible to effect substantial improvement of the drainage of the imperfectly drained soils by use of camberbeds. Such drainage improvement will however require an overall drainage plan which lies beyond the efforts of individual formers. At the time of the demarcation of the settlement plots, ditch drains were laid to take care of flooding but these also now require rehabilitation.

In order to effect drainage improvement more detailed physical investigations that will be necessary are the following:

- detailed soil survey on scale 1:10,000
- study of the surface hydrology.

Contour maps on scale 1:50,000 (vertical interval 20 meter) and scale 1:10,000 (vertical interval 10 ft i.e. 3 meter) already exist at the Survey of Kenya but could also be improved for the rather flat part of the study area.

When the drainage of the 22,450 ha of imperfectly drained soils is improved, it sould be possible to grown on these soils at least fodder crops like fodder-beet, oats, kale and mangold for the livestock to improve the presently rather low milk yields of 1,200 to 1,500 kg. per cow per year.

13. NECESSARY FOLLOW-UP

13.1 Poor drainage is extensively encounterd in the study area and is the main problem affecting land use. Arising out of the preliminary test on drainage reported here, possibilities for improving the drainage through camberbeds appear to exist but the improvements has to be approached on a regional basis. A comprehensive field programme for the improvement of the surface drainage and storage of the water is needed.

13.2 Due to the present low yields of the many farm products, benefits can be attained from improved husbandry techniques. Soil fertility needs to be maintained and increased. This cannot be done to appreciable level without an increasing use of fertilizers. Husbandry investigations are also required for intensive land use. It is especially essential to investigate appropriate cultuvation and husbandry techniques for crops and livestock and to prepare advisory materials for use by the field extension workers. The economics and feasibility of the use of concentrates, hay and sileages as a supplementary feed for especially the dairy cattle during the dry season needs to be studied.

13.3 Advisory service to farmers needs to be intensified so that the farmers can be better equiped on the technical and economic know-how of farming. For this purpose it will be necessary to design a problem oriented extension work aimed at specified development objectives and targets for the area. As a prerequisite to this it will be essential to carry out a detailed farm survey to identify the major socio/economic constraints of the development of the farms and analyse the economic viability of the different farm enterprises.

13.4 The marketing arrangement for the majority of the horticultural crops is poor. Many farmers have not got either the means to transport the crops or facilities for storage. There will be need to institute a programme to strenghten the operations of the Kinangop Co-operative Societies by improving the collection, storage and transportation facilities for the produce. A feasibility study on the possibility to establish expanded markerts for horticultural crops outside Kenya may also be carried out with advantage. Furthermore, investigation to improve on-farm storage of horticultural produce like potatoes, even if only to improve the storage of produce for domestic consumption, is required.

13.5 The on-farm roads are in poor condition. This greatly hampers accessibility and theregore the effectiveness of the farming in the study area. There is need for a project to rehabilitate the on-farm roads to all-weather standard and also to make suitable arrangement for their maintenance thereafter.

13.6 The results of the present study show that the study area has a large potential for both livestock and crop production. But for this to be attained there is need to undertake among others, the measures outlined above. It is possible to mount for the area a comprehensive agricultural development project which incorporates sub-programmes on all of above mentioned problems. The formulation of such a comprehensive project will no-doubt be greatly facilitated by the information from the present study.

REFERENCES

Abrahams, P.D., 1979. Kenya's land re-settlement story, 1st Ed., Challenge publishers and Distributors, Nairobi.

Acland, J.D., 1971. East African Crops. Longman, London 252 pp.

Bailey, L.H., 1958. Manual of cultivated plants. The MacMillan Company, New York.

Beek, K.J., 1978. Land evaluation for Agricultural Development. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands, 333 pp.

Beek, K.J. and Bennema, J., 1972. Land evaluation for Agricultural Land Use Planning. An Ecological methodology. Agricultural University, Wageningen, The Netherlands, 70 pp.

Braun, H.M.H.. Calculated data on Eo and Average Annual Temperature for all Met. Stations in Kenya. Also Monthly rainfall means and calculated r/Eo. Kenya Soil Survey, Nairobi, Kenya.

Brinkman, R. and Smyth, A.J. (ed.), 1973. Land Evaluation for Rural Purposes. Summary of an expert consultation, The Netherlands, 6-12 October 1972. Publication 17, International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands, 119 pp.

Brown, L.H., 1963. A National Cash Crops Policy for Kenya. Government Printer, Nairobi, Kenya.

Dagg, M., 1965. A rational approach to the selection of crops for area of marginal rainfall in East Africa. E. Afr. For. J.30, 296 pp.

DANIDA, 1977. Horticultural Development, Kinangop Plateau, Kenya. Danish International Development Agency Appraisal Mission Report. Department of Settlement, Nairobi, Kenya.

Debele, B., 1980. The Physical Criteria and their rating proposed for land evaluation in the highland regions of Ethiopia. Paper presented at the meeting of the Easter African Sub-Committee for Soil Correlation and Land Evaluation, Arusha, Tanzania 29 Oct.-4 Nov. 1980, FAO, Rome.

Department of Agriculture, South Kinangop 1981 Annual Report, Nairobi, Kenya.

Department of Settlement, 1976, Annual Report, Nairobi, Kenya.

Department of Settlement, Kinangop Complex, 1976. Annual Report, Nairobi, Kenya.

Duckham, A.N. and Masefield, G.B., 1970. Farming system of the world. Chatto and Windus, London, 542 pp.

East African Meterological Department, 1970. Temperature data for stations in East Africa, Part 1, Kenya. E.A. Community, Nairobi, Kenya.

East African Meterological Department, 1974. Summary of rainfall in Kenya for the year 1972. E.A. Community, Nairobi, Kenya.

East African Meterological Department, 1975. Climatological statistics for East Africa, Part 1, Kenya. E.A. Community, Nairobi, Kenya.

Economic and Statistical Division, 1961. Agricultural Census 1961. Government Printers, Nairobi. Kenya.

FAO, 1972. Background document. Expert consultation on Land Evaluation for Rural Purpose. AGL: LERP 72/1, oct. 1972, FAO, Rome, 110 pp.

FAO, 1973. A Framework for land evaluation. Draft edition, AGL/MISC/73/14, FAO, Rome, 65 pp.

FAO, 1974. Approaches to land evaluation. Soils Bulletin 22, FAO, Rome, 120 pp.

FAO, 1975. Report on the ad-hoc Expert Consultation on Land Evaluation, Rome Italy, 6 - 8 Jan. 1975. World Soil Resources Report 45, FAO, Rome, 152 pp.

FAO, 1976. A framework for land evaluation. Soils Bulletin 32, FAO, Rome, 72 pp.

FAO, (Doorenbos, J. and Pruitt, W.D.), 1977. Crop Water requirements. Irrigation and Drainage Paper No. 24 (revised) Rome.

FAO, 1978. Reports of Agro-Ecological Zones Project, World Soil Resources Report No. 48, Rome.

FAO, (Doorenbos, J. and Kassam, A.H.) 1979. Yield response to water. Irrigation and Drainage Paper No. 33. Rome.

Soil Survey Guidelines for Soil description, FAO, Rome.

FAO/UNESCO, 1974. Soil Map of the world, vol. 1 legend. UNESCOm Paris.

Gethin-Jones, G.H. and Scott, E.M., 1958. The Soils of Kenya. The Kenya Atlas, Goverment printer, Nairobi, Kenya.

Jaetzold, R., 1976. Climatic situation of the Kinangop Area. Internal publication of the Department of Settlement, Ministry of Lands and Settlement, Nairobi, Kenya.

Janick, J., Schery, R.W., Woods, F.W. and Rattan, V.W., 1974. Plant Science: An Introduction to World Crops. 2nd Ed. H.W. Freeman and company, San Francisco.

MsCulloch, J.S.G., 1965. Tables for the rapid computation of the Penman estimate of evaporation. E. Afr. Agric. for J. Vol. XXX, No. 3, p. 266.

Odingo, R.S.. The Kenya Highlands - Land Use and Agricultural development. E.A. Publishing House, Nairobi, Kenya.

Okigbo, B.N., 1978. Cropping Systems and related research in Africa. Occasional Publications Series - OT 1. Association for the Advancement of Agricultural Science in Africa, Addis Abada, Ethopia. 81 pp.

Penman, H.L., 1956. Evaporation - An Introductory Survey. Neth. J. Agri. Sci. 4.

Purseglove, J.W., 1974. Tropical Crops: Dicotyledons 3rd Edition. Longman, London, 719 pp.

Purseglove, J.W., 1975. Tropical Crops: Monocotyledons 2nd Edition. Longman, London, 607 pp.

Rachilo, J.R., 1978. Soil Conditions in the Kinangop area - A Preliminary investigation. Site Evaluation Report No. 34, Kenya Soil Survey, Nairobi, Kenya.

Ruthenberg, H., 1976 (2nd ed.). Farming systems in the tropics, Oxford Clarendon Press, 366 pp.

Shackleton, R.M., 1975. Geology of the Nyeri Area. Report No. 12, Government Printer, Nairobi, Kenya.

Shah, M.M., 1978. Calorie Demand Projections Incorporating Urbanization and Income Distribution. Food and Agricultural Programme, International Institute for Applied Systems Analysis.

Siderius, W. and Van der Pouw, B.J.A., 1980. The application of the FAO/ UNESCO terminology of the soil map of the world legend for soil classification in Kenya. Miscellaneous Soil Paper M15, Kenya Soil Survey, Nairobi, Kenya.

Soil Survey Staff, 1951. Soil Survey Manual United States Dept. of Agriculture handbook No. 18. Government Printer, U.S.A..

Soil Survey Staff, 1975. Soil Taxonomy. A basic System of Soil Classification for making and interpreting Soil surveys. Agric. Handbook No. 436. Soil Conservation Service. United States Dept. of Agric.

South Kinangop Divisional Agricultural Office, 1964-1975. Annual Reports, Kinangop, Kenya.

Thompson, A.O., 1964. Geology of the Kijabe Area. Report No. 67 Government Printer, Nairobi, Kenya.

Thompson, A.O. and Dodson, R.G., 1963. Geology of the Naivasha Area. Report No. 55 Government Printer, Nairobi, Kenya.

Usher, G., 1974. A dictionary of plants used by man. Constable, London.

Van de Weg, R.F. and Braun, H.M.H., 1977. Proposals for rating of Land Qualities. KSS Internal Communication No. 7, Kenya Soil Survey memiographed report, Nairobi, Kenya.

Van de Weg, R.F. and Mbuvi, J.P., 1975. Soils of the Kindaruma area Reconnaissance Soil Survey Report no. R1. Government Printer, Nairobi, Kenya.

Woodhead, T., 1968. Studies of Potential Evaporation in Kenya. EAAFRO, Nairobi, Kenya.

ANNEX 1. Land occupied between 1964 and 1975 by various crops during the long rain season in seven Kinangop Settlement Schemes

Table 3a. Area (hectares) under various crops in South Kinangop Scheme (6033ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	418.0	342.5	0.0	0.0	0.0	166.0	0.0	434.0	0.1	0.0	0.0	0.0	0.0	4.6	0.0	1,365.2
1965	392.4	272.8	0.0	0.0	0.0	26.8	0.0	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	730.0
1966	489.6	59.2	56.7	0.0	0.0	30.0	0.0	42.0	0.0	0.0	0.0	14.4	0.0	0.0	0.0	691.9
1967	526.3	95.9	55.0	0.0	0.0	35.1	0.0	32.1	0.0	0.0	0.0	16.0	0.0	0.0	0.0	760.4
1968	530.4	51.6	142.1	0.0	0.0	19.5	0.0	4.3	0.0	0.0	0.0	21.5	0.0	0.0	0.0	769.4
1969	529.2	40.8	10.1	6.4	0.0	10.0	0.0	16.4	6.8	2.0	11.0	0.6	0.0	0.0	1.0	624.3
1970	2009.0	270.0	280.0	57.0	19.0	96.0	250.0	156.0	12.5	25.0	21.0	8.0	11.0	0.0	20.0	3,234.5
1971	1381.0	229.0	96.0	71.0	36.0	127.0	87.5	129.0	0.0	10.0	29.0	1.0	20.0	0.0	0.0	2,216.5
1972	1404.0	48.0	85.0	47.0	21.0	27.0	0.5	28.0	0.0	11.0	38.0	4.0	5.0	0.0	0.0	1,718.5
1973	1404.0	368.0	693.0	366.0	149.0	252.0	14.0	246.0	0.0	32.0	254.0	24.0	10.0	0.0	0.0	3,812.0
1974	1123.0	388.0	439.0	707.0	179.0	313.0	8.5	246.0	0.0	75.0	361.0	42.0	26.0	0.0	0.0	3,907.5
1975	1123.0	309.0	319.0	268.0	179.0	179.0	61.0	150.0	0.0	88.0	181.0	32.0	18.0	0.0	0.0	2,907.0

Table 3b. Area (hectares) under various crops in Bamboo Scheme (1510ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	132.0	191.5	0.0	0.0	0.0	26.9	0.0	50.7	4.6	0.0	0.0	0.0	0.0	0.8	0.0	406.5
1965	222.4	114.8	0.0	0.0	0.0	27.6	0.0	28.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	393.8
1966	267.2	128.8	272.0	0.0	0.0	41.6	0.0	52.0	0.0	0.0	0.8	9.0	0.0	0.0	0.0	771.4
1967	419.2	221.9	416.4	0.0	0.0	121.8	0.0	102.0	0.8	0.0	0.8	175.6	0.0	0.0	0.0	1,458.5
1968	380.0	253.6	390.8	0.0	0.0	164.8	0.0	102.0	0.0	0.0	0.0	173.4	0.0	0.0	0.0	1,464.6
1969	560.0	288.0	28.0	84.0	0.0	84.0	0.0	0.0	74.0	12.0	3.2	20.0	16.0	0.0	0.8	1,170.0
1970	764.0	500.0	475.0	150.0	5.8	212.0	30.0	220.0	0.0	185.0	9.0	247.0	14.0	0.0	43.0	-
1971	694.0	500.0	490.0	86.0	2.5	109.0	60.0	100.0	0.0	189.0	8.0	18.0	14.0	0.0	30.0	-
1972	570.0	100.0	89.0	28.0	20.0	86.0	5.0	48.0	0.0	58.0	10.0	5.0	5.0	0.0	0.0	1,024.0
1973	460.6	365.0	69.0	19.0	0.5	28.0	30.0	19.0	0.0	59.0	20.0	5.0	5.0	0.0	0.0	1,080.1
1974	370.0	32.0	36.0	8.0	1.0	10.0	30.0	12.0	0.0	30.0	12.0	2.0	4.0	0.0	0.0	547.0
1975	383.0	34.0	45.0	23.0	1.0	15.0	4.0	14.0	0.0	39.0	15.0	14.0	6.0	0.0	0.0	583.0

Table 3c. Area (hectares) under various crops in Karati Scheme (5863ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	160.0	74.4	0.0	0.0	0.0	31.6	0.0	44.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	310.8
1965	188.8	139.2	0.0	0.0	0.0	42.0	0.0	37.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	407.6
1966	360.0	100.0	27.6	0.0	0.0	40.0	0.0	36.0	0.0	0.0	0.0	14.6	0.0	0.0	0.0	578.2
1967	620.00	100.0	155.6	0.0	0.0	104.0	0.0	44.0	0.0	0.0	0.0	16.8	0.0	0.0	0.0	1,040.4
1968	632.0	140.0	64.0	0.0	0.0	153.6	0.0	36.0	124.4	0.0	0.0	33.2	0.0	0.0	0.0	1,183.2
1969	302.0	112.0	40.0	16.0	0.0	72.0	0.0	0.0	116.4	20.0	0.8	20.0	0.0	0.0	0.2	699.4
1970	306.3	180.0	80.0	8.0	1.0	160.0	1.0	95.0	291.0	50.0	8.0	4.0	2.5	0.0	0.0	1,186.8
1971	700.0	600.0	500.0	270.0	0.0	140.0	17.5	97.0	0.0	125.0	100.0	0.0	37.0	0.0	2.0	2,588.5
1972	365.0	100.0	65.0	2.0	23.0	40.0	16.0	70.0	54.0	40.0	70.0	2.0	10.0	0.0	0.0	857.0
1973	378.0	370.0	75.0	1.5	0.0	35.0	0.0	90.0	20.0	25.0	55.0	5.0	13.0	0.0	0.0	1,067.5
1974	410.0	65.0	55.0	3.0	0.0	25.0	0.3	85.0	30.0	12.0	40.0	8.0	12.0	0.0	0.0	745.3
1975	360.0	55.0	65.0	2.0	0.0	45.0	0.0	127.0	20.0	12.0	80.0	4.0	6.0	0.0	0.0	776.0

Table 3d. Area (hectares) under various crops in Njabini Scheme (5301ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	236.8	136.0	0.0	0.0	0.0	47.5	0.0	61.5	2.8	0.0	2.8	0.0	0.0	2.8	0.0	490.2
1965	389.2	157.2	0.0	0.0	0.0	88.0	0.0	44.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	679.2
1966	441.6	157.2	40.0	0.0	0.0	90.8	0.0	51.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	781.2
1967	514.0	200.0	39.8	0.0	0.0	105.6	0.0	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	898.2
1968	556.4	123.6	87.0	0.0	0.0	53.2	0.0	0.0	74.0	0.0	0.0	36.6	0.0	0.0	0.0	930.8
1969	560.0	288.0	28.0	84.0	0.0	84.0	0.0	0.0	74.0	12.0	3.2	20.0	16.0	0.0	0.8	1,170.0
1970	1700.0	1000.0	250.0	250.0	0.0	220.0	17.5	60.0	56.0	40.0	8.0	25.0	35.0	0.0	90.0	3,751.5
1971	700.0	600.0	500.0	270.0	0.0	140.0	17.5	97.0	0.0	125.0	100.0	0.0	37.0	0.0	2.0	2,588.5
1972	955.0	640.0	320.0	36.0	0.0	150.0	0.0	90.0	0.0	75.0	180.0	32.0	32.0	0.0	0.0	2,510.0
1973	955.0	320.0	145.0	65.0	16.0	130.0	0.0	95.0	0.0	75.0	130.0	42.0	64.5	0.0	0.0	2,037.5
1974	955.0	814.0	395.0	170.0	0.25	250.0	150.0	250.0	0.0	210.0	460.0	60.0	166.0	0.0	0.0	3,880.3
1975	791.0	546.0	721.0	66.5	1.0	131.0	53.5	122.0	0.0	51.0	95.0	51.0	19.0	0.0	0.0	2,648.0

Table 3e. Area (hectares) under various crops in Githioro Scheme (3641ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1969	9.2	20.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	3.0	0.0	0.0	0.0	54.0
1970	16.5	1.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	1.0	19.5	1.0	0.0	0.0	0.0	42.0
1971	59.0	20.0	15.0	0.0	0.0	5.0	0.0	3.0	0.0	0.3	18.5	0.0	1.0	0.0	0.0	121.8
1972	72.0	65.0	20.0	0.0	0.0	16.0	0.0	0.0	0.0	2.0	12.0	0.0	2.0	0.0	0.0	189.0
1973	72.0	66.0	9.0	3.0	0.0	5.0	0.0	2.5	0.0 *100.0	0.0	16.0	0.0	0.0	0.0	0.0	273.5
1974	65.0	12.5	20.0	0.3	0.0	4.0	7.0	2.5	150.0	5.0	7.0	0.3	4.5	0.0	0.0	278.1
1975	65.0	10.0	8.0	0.3	0.0	5.0	7.0	2.5	150.0	0.0	2.5	0.0	4.5	0.0	0.0	245.8

* Barley

Table 3f. Area (hectares) under various crops in Muruaki Scheme (6832ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	74.0	336.4	0.0	0.0	0.0	269.2	0.0	178.4	0.0	0.0	0.0	0.0	0.0	3.6	0.0	861.6
1965	192.8	144.0	0.0	0.0	0.0	104.0	0.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	520.8
1966	406.0	220.0	15.2	0.0	0.0	50.0	0.0	82.0	20.0	0.0	0.0	10.4	0.0	0.0	0.0	803.6
1967	628.8	140.0	30.4	0.0	0.0	64.0	0.0	46.0	12.3	0.0	0.0	32.6	0.0	0.0	0.0	954.1
1968	718.4	301.6	8.0	0.0	0.0	98.0	0.0	0.0	174.0	0.0	0.0	18.8	0.0	0.0	0.0	1,318.8
1969	306.0	48.0	4.0	8.0	0.0	16.0	0.0	0.0	259.0	8.0	3.0	12.0	0.0	0.0	0.0	664.0
1970	1048.0	200.0	220.0	15.0	1.5	70.0	25.0	15.0	1270.0	85.0	54.0	42.0	30.0	0.0	30.0	3,105.5
1971	529.0	150.0	120.0	25.0	0.0	22.0	25.0	0.0	121.0	108.0	18.0	42.0	30.0	0.0	0.0	1,190.0
1972	612.0	100.0	50.0	15.0	65.0	41.0	15.0	105.0	976.0	109.0	50.0	32.0	41.0	0.0	0.0	2,211.0
1973	632.0	632.0	20.0	65.0	0.0	35.0	15.0	0.0	56.0	22.0	33.0	6.0	11.0	0.0	0.0	2,037.0
1974	625.0	80.0	40.0	45.0	0.0	40.0	20.0	40.0	79.0	55.0	63.0	27.0	30.0	0.0	0.0	1,144.0
1975	625.0	75.0	60.0	45.0	7.0	40.0	20.0	0.0	173.0	80.0	130.0	75.0	75.0	0.0	0.0	1,405.0

Table 3g. Area (hectares) under various crops in Tulaga Scheme (4733ha) during long rains of 1964 to 1975

Year	Pyreth-rum	Potato	Cabba-ge	Carrot	Onion	Peas	Leek	Maize	Wheat	Kale	Oat	Fodder Beetroot	Man-gold	Bean	Cauli-flower	Total
1964	119.8	130.4	0.0	0.0	0.0	108.8	0.0	62.5	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1,503.5
1965	255.4	144.4	0.0	0.0	0.0	75.6	0.0	105.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	581.0
1966	391.2	216.0	15.6	0.0	0.0	132.0	0.0	152.0	0.0	0.0	0.0	13.0	0.0	0.0	0.0	919.8
1967	514.0	232.0	34.0	0.0	0.0	48.0	0.0	31.2	0.0	0.0	0.0	21.6	0.0	0.0	0.0	880.8
1968	514.0	212.8	49.9	0.0	0.0	114.4	0.0	56.0	178.0	0.0	0.0	33.2	0.0	0.0	0.0	1,158.3
1969	484.8	223.2	6.4	14.0	0.0	22.0	0.0	0.0	139.2	4.4	9.2	8.0	0.0	0.0	1.0	912.2
1970	490.0	520.0	52.0	48.0	2.0	59.0	0.0	250.0	140.8	14.0	25.0	6.5	5.0	0.0	1.5	1,613.8
1971	490.0	590.0	170.0	48.0	7.0	90.0	1.0	169.0	46.0	14.0	27.0	2.0	39.0	0.0	0.0	1,693.0
1972	427.0	410.0	200.0	45.0	4.0	90.0	17.0	12.0	60.0	16.0	30.0	8.0	55.0	0.0	0.0	1,374.0
1973	645.0	599.0	38.0	62.0	3.0	40.0	30.0	30.0	40.0	24.0	200.0	30.0	55.0	0.0	0.0	1,796.0
1974	525.0	220.0	150.0	370.0	2.0	60.0	30.0	40.0	16.0	30.0	300.0	11.0	40.0	0.0	0.0	1,794.0
1975	560.0	450.0	300.0	500.0	1.0	175.0	30.0	100.0	30.0	45.0	240.0	56.0	40.0	0.0	0.0	2,527.0

ANNEX 2. Livestock numbers during 1967 to 1975 and the stocking rates in seven Kinangop Settlement Schemes

Table 8a. S. Kinangop Scheme; Area 6033ha

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	648	244	451	-	98	1218	240	254	425	251			
	LU	648	122	451	-	24.5	174	34.29	36.29	60.71	8.96	1559.75	5272.6	0.30
1968	No	715	231	217	-	245	1667	361	288	501	182			
	LU	715	115.5	217	-	61.25	238.14	51.57	41.14	71.57	6.50	1517.67	5263.6	0.29
1969	No	933	302	251	-	223	2060	463	343	553	449			
	LU	933	151	251	-	55.75	294.29	66.14	49.0	79.0	16.04	1895.22	5408.7	0.35
1970	No	1081	428	427	245	328	1448	366	359	525	228			
	LU	1081	214	427	245	82	206.86	52.29	51.29	75.0	8.14	2442.58	2798.5	0.87
1971	No	1348	422	598	-	354	1705	487	188	424	147			
	LU	1348	211	598	-	88.5	243.86	69.57	26.86	60.57	5.25	2651.61	3816.5	0.69
1972	No	1621	349	451	-	239	1851	518	233	292	162			
	LU	1621	174.5	451	-	59.75	264.43	74.0	33.29	41.71	5.79	2725.47	4314.5	0.63
1973	No	1844	278	340	-	251	1881	503	232	237	236			
	LU	1844	139	340	-	62.75	268.71	71.86	33.14	33.86	8.43	2801.75	2221.0	1.26
1974	No	2006	221	307	-	389	1843	832	234	214	177			
	LU	2006	110.5	307	-	97.25	263.29	118.86	33.43	30.57	6.32	2973.22	2125.5	1.40
1975	No	2268	208	327	-	-	1877	694	239	204	240			
	LU	2268	104	327	-	-	268.14	99.14	34.14	29.14	8.57	3138.13	3126.0	1.00

1 Livestock Unit (LU) = 1 cow or 1 steer or 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs
Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth

Table 8b. Bamboo Scheme; Area 1510ha

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	460	206	201	-	68	2050	355	180	425	166			
	LU	460	103	201	-	17	292.86	50.71	25.71	60.71	5.93	1216.92	51.5	23.63
1968	No	695	426	488	-	38	2544	332	448	230	166			
	LU	695	213	488	-	9.5	363.43	47.43	64.0	32.86	5.93	1919.15	45.4	42.27
1969	No	760	442	370	-	120	2700	160	385	280	207			
	LU	760	221	370	-	30	385.71	22.86	55.0	40.0	7.39	1891.96	340.0	5.56
1970	No	800	464	390	-	73	2695	436	566	408	93			
	LU	800	232	390	-	18.25	385.0	62.29	80.86	58.29	3.32	2030.01	-	-
1971	No	800	464	385	-	80	2695	430	-	408	190			
	LU	800	232	385	-	20	385.0	61.43	-	58.29	6.79	1948.51	-	-
1972	No	809	459	346	-	300	2770	520	630	659	290			
	LU	809	229.5	346	-	75	395.71	74.29	90.0	94.14	10.36	2124.0	486.0	4.37
1973	No	876	490	360	-	252	3100	605	770	706	1000			
	LU	876	245	360	-	63	442.86	86.43	110.0	100.86	35.71	2319.86	429.9	5.40
1974	No	990	489	320	-	338	3197	730	880	804	360			
	LU	990	244.5	320	-	84.5	456.71	104.29	125.71	114.86	12.86	2453.43	963.0	2.55
1975	No	1154	491	417	-	91	3267	760	855	861	125			
	LU	1154	245.5	417	-	22.75	466.71	108.57	122.14	123.0	17.86	2677.53	927.0	2.89

1 Livestock Unit (LU) = 1 cow or 1 steer or 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs

Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth.

Table 8c. Karati Scheme; Area 5863 ha

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	895	113	329	-	198	4862	190	712	2411	670			
	LU	895	56.5	329	-	49.5	694.57	27.14	101.71	344.43	23.93	2521.78	4822.6	0.52
1968	No	910	197	350	-	355	3890	460	565	540	869			
	LU	910	98.5	350	-	88.75	555.71	65.71	80.71	77.14	31.04	2257.56	4679.8	0.48
1969	No	728	361	717	-	384	3865	705	814	829	1056			
	LU	728	180.5	717	-	96.0	552.14	100.71	116.29	118.43	37.71	2646.78	5155..6	0.51
1970	No	972	351	896	-	548	4272	759	1933	668	2106			
	LU	972	175.5	896	-	137.0	610.29	108.43	276.14	95.43	75.21	3346.0	4676.2	0.72
1971	No	871	530	843	-	555	3288	650	554	1300	1161			
	LU	871	265	843	-	138.75	469.71	92.86	79.14	185.71	41.46	2986.63	3274.5	0.91
1972	No	960	540	840	-	595	3295	750	755	415	950			
	LU	960	270	840	-	148.75	470.71	107.14	107.86	59.29	33.93	2997.68	5006.0	0.60
1973	No	675	590	870	1	650	3585	565	990	560	1045			
	LU	675	295	870	1	162.5	512.14	80.71	141.43	80.0	37.32	2855.10	4795.5	0.60
1974	No	1267	675	1320	-	634	3573	596	1015	2107	1017			
	LU	1267	337.5	1320	-	158.5	510.43	85.14	145.0	301.0	36.32	4160.89	5117.7	0.81
1975	No	1325	672	1100	-	580	3495	610	725	2050	615			
	LU	1325	336	1100	-	145.0	499.29	87.14	103.57	292.86	21.96	3910.82	5087.0	0.77

1 Livestock Unit (LU) = 1 cow or 1 steer or 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs

Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth

Table 8d. Njabini Scheme; Area 5301ha

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	938	384	-	-	598	1145	116	215	406	684			
	LU	938	192	-	-	149.5	163.57	16.57	30.71	58.0	24.43	1572.78	4402.8	0.36
1968	No	1062	743	100	-	43	1379	108	310	364	146			
	LU	1062	371.5	100	-	10.75	197.0	15.43	44.29	52.0	5.21	1859.18	4370.2	0.43
1969	No	960	708	172	-	90	1185	198	780	1130	280			
	LU	960	354	172	-	22.5	169.29	28.29	111.43	161.43	10.0	1988.94	4131.0	0.48
1970	No	2256	438	135	-	148	2520	270	360	362	460			
	LU	2256	219	135	-	37.0	360.0	38.57	51.43	51.71	16.43	3165.14	1549.5	2.04
1971	No	1180	556	325	6	387	2197	340	399	357	415			
	LU	1180	278	325	6	96.75	313.86	48.57	57.0	51.0	14.82	2371.0	2712.5	0.87
1972	No	1056	370	380	1	482	1790	285	371	399	260			
	LU	1056	185	380	1	120.5	255.71	40.71	53.0	57.0	9.29	2158.21	2791.0	0.77
1973	No	1049	362	361	-	229	1818	231	428	375	429			
	LU	1049	181	361	-	57.25	259.71	33.0	61.14	53.57	15.32	2070.99	3263.5	0.63
1974	No	1042	362	355	-	247	1820	214	428	375	469			
	LU	1042	181	355	-	61.75	260.0	30.57	61.14	53.57	16.75	2061.78	1420.7	1.45
1975	No	1095	321	279	-	346	1067	124	440	436	685			
	LU	1095	160.5	279	-	86.5	152.43	17.71	62.86	62.29	24.46	1940.75	2653.0	0.73

1 Livestock Unit (LU) = 1 cow or 1 steer or 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs

Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth

Table 8e. Githioro Scheme; Area 3641 ha

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	LU	-	-	-	-	-	-	-	-	-	-	-	3440.0	-
1968	No	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd		
	LU	-	-	-	-	-	-	-	-	-	-	-	3440.0	-
1969	No	107	172	30	-	29	463	33	199	157	238			
	LU	107	86	30	-	7.25	66.14	4.71	28.43	22.43	8.50	360.46	3587.0	0.10
1970	No	269	43	21	-	40	551	43	21	129	355			
	LU	269	21.5	21	-	10.0	78.71	6.14	3.0	18.43	12.68	440.46	3599.0	0.12
1971	No	285	98	75	-	93	960	30	263	237	227			
	LU	285	49	75	-	23.25	137.14	4.29	38.45	33.86	8.11	654.1	3519.2	0.19
1972	No	320	88	100	-	61	1004	38	180	294	214			
	LU	320	44	100	-	15.25	143.43	5.43	25.71	42.0	7.64	703.46	3452.0	0.20
1973	No	431	301	168	-	124	979	40	190	320	450			
	LU	431	150.5	168	-	31	139.86	5.71	27.14	45.71	16.07	1014.99	3367.5	0.30
1974	No	443	282	224	-	150	1260	44	225	329	625			
	LU	443	141	224	-	37.5	180.0	6.29	32.14	47.0	22.32	1133.25	3362.9	0.34
1975	No	215	51	65	-	21	1127	88	248	483	272			
	LU	215	25.5	65	-	5.25	161.0	12.57	35.43	69.0	9.71	598.46	3395.2	0.18

1 Livestock Unit (LU) = - cow or 1 steer or 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs

Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth

Table 8f. Muruaki Scheme; Area 6832ha

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	2500	1500	300	-	1200	7000	850	560	2000	2150			
	LU	2500	750	300	-	300	1000	121.43	80.0	285.71	76.79	5413.93	5877.9	0.92
1968	No	769	637	32	-	404	3991	430	450	1218	29			
	LU	769	318.5	32	-	101	570.14	61.43	64.29	174.0	1.04	2091.40	5513.2	0.38
1969	No	810	380	15	-	580	4205	599	452	1212	321			
	LU	810	190	15	-	145	600.71	85.57	64.57	173.14	11.46	2095.45	6168.0	0.34
1970	No	1269	825	852	1	239	2864	143	700	1045	272			
	LU	1269	412.5	852	1	59.75	409.14	20.43	100	149.29	9.71	3282.82	3726.5	0.88
1971	No	1439	725	842	1	499	3340	143	720	699	582			
	LU	1439	362.5	842	1	124.75	477.14	20.43	102.86	99.86	20.79	3490.33	5642.0	0.62
1972	No	1460	750	857	1	870	3497	165	910	860	732			
	LU	1460	375	857	1	217.5	499.57	23.57	130.0	122.86	26.14	3712.64	4621.0	0.80
1973	No	1169	945	820	1	1197	3812	247	349	864	1628			
	LU	1169	472.5	820	1	299.25	544.57	35.29	49.86	123.43	58.14	3573.04	4795.0	0.75
1974	No	1185	948	811	1	1254	3816	276	1361	1505	1650			
	LU	1185	474	811	1	313.5	545.14	39.43	194.43	215.0	58.93	3837.43	5688.0	0.67
1975	No	1185	984	811	1	1254	3816	276	1361	1505	1780			
	LU	1185	492	811	1	313.5	545.14	39.43	194.43	215.0	63.57	3860.07	5427.0	0.71

1 Livestock Unit (LU) = 1 cow or 1 steer or 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs

Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth

Table 8g. Tulaga Scheme; Area 4731

Yearly stocking rate at the period when the highest number of dairy cows were available

Year		D/Cow	Heifer	Steer	Bull	Calf	Ewe	Ram	Wether	Hogett	Lamb	Total L/Unit	(ha) Area of pasture	LU per ha
1967	No	660	530	200	-	650	2500	345	225	750	1200			
	LU	660	265	200	-	162.5	357.14	49.29	32.14	107.14	42.86	1876.07	3850.2	0.49
1968	No	728	530	217	-	605	2535	334	249	849	1220			
	LU	728	265	217	-	151.25	362.14	47.71	35.57	121.29	43.57	1971.53	3572.7	0.55
1969	No	729	521	212	-	615	2400	285	239	848	1228			
	LU	729	260.5	212	-	153.75	342.86	40.71	34.14	121.14	43.86	1937.96	3818.8	0.51
1970	No	702	445	120	-	500	2090	176	150	120	830			
	LU	702	222.5	120	-	125.0	298.57	25.14	21.43	17.14	29.64	1561.42	3117.2	0.50
1971	No	780	241	150	-	520	2260	130	126	212	920			
	LU	780	120.5	150	-	130.0	322.86	18.57	18.00	30.29	32.86	1603.08	3038.0	0.53
1972	No	897	349	152	1	320	2500	160	246	324	980			
	LU	897	174.5	152	1	80.0	357.14	22.86	35.14	46.29	35.00	1800.93	3357.0	0.54
1973	No	941	374	750	1	340	3190	219	350	433	1120			
	LU	941	187	750	1	85.0	455.71	31.29	50.00	61.86	40.00	2602.86	2935.0	0.89
1974	No	980	447	340	-	390	3400	200	379	489	1256			
	LU	980	223.5	340	-	97.5	485.71	28.57	54.14	69.86	44.86	2324.14	2937.0	0.79
1975	No	975	905	430	-	380	3530	215	315	505	1350			
	LU	975	452.5	430	-	95.0	504.29	30.71	45.00	72.14	48.21	2652.85	2204.0	1.20

1 Livestock Unit (LU) = 1 cow or 1 steer of 1 bull or 2 heifers or 4 calves or 7 sheep or 28 lambs

Wether is castrated male sheep; Hogett is mature female sheep which has not yet given birth

ANNEX 3: Profile description and analytical data of some representative profiles

Unit UPrl, Profile no. 48

Soil classification: haplic Phaeozem; udic Haplustoll, fine loamy, isothermic
Ecological zone: Sub-humid
Observation: 134/3-48; Nyandarua District; E37.2, N15.2; 2767m; 4/4/78
Geological formation: pyroclastic rocks with inter-calated Laikipia type basalt
Local petrography: Tuff
Physiography: Uplands
Relief-macro: Flat to undulating, 100-250m long; convex uniform slopes
Relief-meso, micro: Nil
Vegetation: planted Cupressus lusitanica and Eucalyptus globulus with predominantly grass cover; potatoes and cabbages growing
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 1%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

Ap 0-29 cm: dark reddish brown (Ped-7.5YR 4/4 dry, 5YR 3/2 moist; crushed-10YR 5/2 dry, 10YR 3/2 moist); loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common to many medium pores, few coarse pores, many very fine roots, common to many fine roots; many insect activities and krotovinas; clear and smooth transition to: (sample no. 134/3-48a)

A 29-60 cm: dark reddish brown (Ped-10YR 3/3 dry, 5YR 2.5/2 moist; crushed-10YR 4/2 dry, 7.5YR 3/2 moist); clay loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; some shiny coating, probably due to insect activities; many very fine, fine and medium pores, few coarse pores; common very fine roots; many insect activities and krotovinas; clear and smooth transition to: (sample no. 134/3-48b)

Bw 60-106 cm: dark reddish brown (5YR 3/3 dry, 2.5YR 3/4 moist); clay loam; moderate medium and coarse sub-angular blocky peds falling apart to moderate very fine and fine angular blocky structure; friable when moist, sticky and plastic when wet; many very fine, fine and medium pores; common coarse pores; common soft and hard manganese and iron concretions (5%, 2-5 mm in size); very few very fine roots; many insect activities and krotovinas; gradual and smooth transition to: (sample no. 134/3-48c)

Bwg 106-128 cm+: dark reddish brown (7.5YR 5/6 dry, 2.5YR 3/4 moist); common fine to medium distinct yellowish red (5YR 5/8) mottles, probably due to initial stages of manganese concretions formation; clay; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few coarse pores; many soft and hard manganese and iron concretions (10%, 2-10 mm in size); some weathering rock gravels; very few very fine roots; many insect activities and krotovinas: (sample no. 134/3-48d)

Laboratory no. ..../78	4779	4780	4781	4782
Horizon	Ap	A	Bw	Bwg
Depth (cm)	0-29	29-60	60-106	106-108
pH-H_2O (1:2.5 v/v)	4.9	5.5	5.7	5.9
pH-KCl "	5.3	5.7	5.9	5.5
EC (mmho/cm) "	0.70	0.08	0.12	0.11
C (%)	3.6	1.7	0.8	0.5
N (%)	0.34	-	-	-
C/N	11	-	-	-
CEC (me/100g), pH 8.2	32.0	27.0	21.6	18.8
CEC " , pH 7.0	31.0	27.0	19.4	16.4
Exch. Ca (me/100g)	11.5	12.9	9.3	6.7
" Mg "	2.7	3.1	4.4	4.0
" K "	0.5	0.5	1.0	3.0
" Na "	0.9	0.7	0.9	0.6
Sum of cations	15.6	17.2	15.6	14.3
Base sat. %, pH 8.2	49	64	72	76
Base sat. %, pH 7.0	50	64	80	89
ESP at pH 8.2	3	3	4	3
Texture, lim. pretreatment				
Sand % 2.0-0.05 mm	30	28	24	32
Silt % 0.05-0.002 mm	46	40	42	38
Clay % 0.002-0 mm	24	32	34	30
Texture class	L	CL	CL	CL
Texture USDA:				
Sand % 2.0-1.0 mm	1	1	3	-
" " 1.0-0.50 mm	2	2	3	-
" " 0.50-0.25 mm	4	5	5	-
" " 0.25-0.10 mm	5	6	6	-
" " 0.10-0.05 mm	2	3	3	-
Total sand %	14	17	20	-
Silt %	67	57	38	-
Clay %	19	26	42	-
Bulk density (g/cc)	0.98	1.11	1.22	-
Moisture % w/v at:				
pF 0	60.0	52.4	52.0	-
pF 2.0	42.4	40.8	41.0	-
pF 2.3	38.6	37.3	38.5	-
pF 2.7	35.3	35.7	35.7	-
pF 3.7	28.4	34.3	34.3	-
pF 4.2	25.5	31.8	34.3	-

Fertility aspects: (0-30 cm) Lab. no. 4753/78	Available nutrients	Total nutrients
Ca (me/100g)	10.4	-
Mg "	1.8	5.5
K "	0.5	3
P (ppm)	22	28
Mn (me/100g)	1.2	-
Exch. acidity (me/100g)	6.4	-
pH-H_2O (1:1 v/v)	5.0	-
C %	3.3	-
N %	0.36	-
CEC-clay (me/100g)	55	-
CEC-carbon (me/100g)	500	-

Clay mineralogy: Dominantly amorphous; traces of illite and kaolinite

Unit UPr3, *Profile no. 50*

Soil classification: ando-luvic Phaeozem; udic Argiustoll, very fine clayey, isothermic
Ecological zone: Sub-humid
Observation: 134/3-50; Nyandarua District: E 39.7, N16.5; 2758m; 5/4/78
Geological formation: pyroclastic rocks with intercalated Laikipian type basalt
Local petrography: tuff
Physiography: Uplands
Relief-macro: flat to rolling, 200-300m long, convex, uniform slopes
Relief-meso, micro: some meso-relief due to ploughing
Vegetation/land use: planted Cupressus lusitanica with predominantly grass cover/pasture for livestock

Erosion: Nil
Surface stoniness: Nil
Slope gradient: 0%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: well drained

Profile description

Ap 0-29 cm — dark reddish brown (Ped-7.5YR 4/4 dry, 5YR 3/3 moist; crushed - 7.5YR 4/4 dry, 7.5YR 3/2 moist); clay; moderate fine and medium sub-angular blocky structure tending to be crumby; friable when moist; sticky and plastic when wet; many very fine pores; common to many fine pores; very few hard manganese and iron concretions, probably brought up by ploughing, some artefacts (piece of charcoal); many very fine and fine roots; few to common medium roots; insect and earthworms activities and krotovinas; clear and smooth transition to: (sample no. 134/3-50a)

AB 29-43 cm — dusky red (Ped-5YR 3/3 dry; 2.5YR 3/2 moist; crushed - 7.5YR 5/4 dry, 7.5YR 3/2 moist; clay; moderate very fine, fine medium and coarse sub-angular blocky structure; friable when moist, sticky and plastic when wet, many very fine and fine pores, common to medium pores, few coarse pores, very few hard manganese and iron concretions; many ver fine roots, common fine roots; insects and earthworms activities and krotovinas; gradual and smooth transition to: (sample no. 134/3-50b)

Bu1 43-58 cm — dusky red (5YR 34/4 dry, 2.5YR 3/2 moist); clay; moderate fine, medium and coarse sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common to many pores, few coarse pores; many very fine roots, common fine roots; insects and earthworms activities and krotovinas; few sanidine minerals; gradual and smooth transition to: (sample no. 134/3-50c)

Bu2 58-83 cm — dark reddish brown (5YR 4/4 dry, 2, 5YR 3/4 moist); clay; weak to moderate, very fine, fine, medium and coarse sub-angular blocky structure; friable when moist, sticky and plastic when wet; some clay coating, may be due to insect activities; many very fine, fine and medium pores; few coarse pores; very few hard manganese and iron concretions (1%, 2-5 mm in size); few to common, very fine and fine roots; insects and earthworms activities and krotovinas; few sanidine minerals; gradual and smooth transition to: (sample no. 134/3-50d)

Bt 83-98 cm — dark reddish brown (5YR 4/4 dry, 2.5YR 3/4 moist); clay; strong very fine, fine, medium and coarse angular blocky structure; friable when moist, sticky and plastic when wet; few weak clay cutans; many very fine and fine pores; common medium pores; few coarse pores; some subrounded gravels; few very fine roots, very few fine roots; insects and earthworms activities and krotovinas; few sanidine minerals; clear and smooth transition to: (sample no. 134/3-50e)

Btg 98-119 cm — dark reddish brown (5YR 4/4 dry, 2.5YR 3/4 moist); many fine to coarse distinct red (2.5YR 4/6) mottles; silt loam; moderate to strong very fine, fine and medium angular blocky structure; very friable when moist, sticky and plastic when wet; common moderately thick clay cutans; many very fine and fine pores, few to common medium pores; many soft and hard manganese and iron concretions (10%, 2-10 mm in size); the hard one diminishing with depth; very few very fine roots; insect and earthworms activities, and krotovinas few sanidine minerals: (sample no. 134/3-50f)

Lab. no. ....../78	4789	4790	4791	4792	4793	4794
Horizon	Ap	AB	Bu1	Bu2	Bt	Btg
Depth (cm)	0-29	29-43	43-58	58-83	83-98	98-119
pH-H_2O (1:2.5 v/v)	5.9	4.8	5.0	5.2	5.3	5.8
pH-KCl	5.9	5.1	5.0	5.2	5.6	5.8
EC (mmho/cm) "	0.04	0.11	0.06	0.10	0.07	0.06
C (%)	3.0	2.2	1.9	1.2	1.0	0.6
N (%)	0.35	-	-	-	-	-
C/N	9	-	-	-	-	-
CEC (me/100g), pH 8.2	33.0	28.0	27.0	23.2	20.0	17.2
CEC (me/100g), pH 7.2	30.0	27.0	27.0	21.0	19.0	15.4
Exch, Ca (me/100g)	14.7	6.7	7.5	7.9	6.3	4.3
Exch, Mg "	4.1	1.9	2.0	2.0	1.6	2.0
Exch, K "	3.0	2.4	1.5	0.3	0.2	0.1
Exch, Na "	0.4	0.4	0.5	0.4	0.3	0.3
Sum of cations	22.2	11.4	11.5	10.6	8.4	6.7
Base sat. %, pH 8.2	67	41	43	46	42	39
Base sat. %, pH 7.0	74	42	43	50	44	44
ESP at pH 8.2	1	1	2	2	2	2
Texture, lim. pretreatment:						
Sand % 2.0-0.05 mm	28	28	20	28	24	16
Silt % 0.05-0.002 mm	32	32	32	22	33	50
Clay % 0.002-0 mm	40	40	48	50	43	34
Texture class	CL/C	CL/C	C	C	C	SiCL
Texture USDA:						
Sand % 2.0-1.0 mm	Tr	1	Tr	2	1	1
" " 1.0-0.50 mm	2	1	1	1	2	2
" " 0.50-0.25 mm	5	3	4	2	6	2
" " 0.25-0.10 mm	10	5	6	7	6	4
" " 0.10-0.05 mm	8	1	3	5	5	2
Total sand %	25	11	14	17	20	11
Silt %	55	33	25	31	31	51
Clay %	20	56	61	52	49	38
Bulk density (g/cc)	0.83	0.91	0.96	-	-	-
Moisture % w/v at:						
pF 0	56.8	56.8	54.6	-	-	-
pF 2.0	48.3	38.4	37.5	-	-	-
pF 2.3	42.1	34.3	33.9	-	-	-
pF 2.7	38.3	31.4	31.5	-	-	-
pF 3.7	27.5	30.3	29.4	-	-	-
pF 4.2	25.1	27.2	26.3	-	-	-

Fertility aspects: (0-30 cm) Lab. no. 4755/78	Available nutrients	Total nutrients
Ca (me/100g)	7.2	-
Mg (me/100g)	2.4	11
K (me/100g)	1.4	7
P (ppm)	8	100
Mn (me/100g)	1.2	-
Exch, acidity (me/100g)	0.3	-
pH-H_2O (1:v/v)	5.2	-
C %	3.0	-
N %	0.31	-
CEC-clay (me/100g)	30	-
CEC-carbon (me/100g)	700	-

Clay mineralogy: Dominantly amorphous; traces of illite and kaolinite

Unit UPb3, Profile no. 26

Soil classification: cumulo-haplic Phaeozem; cumulic Haplustoll, fine clayey, isothermic
Ecological zone: Semi-humid
Observation: 134-3.26; Nyandarua District; E27.7 NO5.3; 2950m; 21/2/78
Geological formation: Pyroclastic rocks
Local petrography: Volcanic ashes
Physiography: Uplands
Relief-macro: Undulating, 200 m long, convex regular slope
Relief-meso, micro: mole mounds, 0.5 m in diameter and 0.3-0.4 m high
Vegetation/land use: Planted Cupressus lusitanica and Eucalyptus saligna for windbreak, cultivated area under maize and cabbages
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 1%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

Ap 0-22 cm — very dark brown (Ped-10YR 4/3 dry, 10YR 2/2 moist; crushed-10YR 5/2 dry, 10YR 3/1 moist); clay loam; moderate very fine and fine sub-angular blocky structure; friable when moist and sticky and plastic when wet; common very fine pores, few fine pores; many very fine and fine roots; common medium roots; krotovinas and insect activities; some sanidine minerals; gradual and smooth transition to: (sample no. 134/3-26a)

A 22-54 cm — black (Ped-10YR 3/2 dry, 5YR 2.5/1 moist; crushed-10YR 5/2 dry, 10YR 3/1 moist); loam; moderate to strong very fine, fine and medium sub-angular blocky structure; friable when moist; sticky and plastic when wet; many very fine and fine pores; common medium pores, many very fine and fine pores, common medium pores; many very fine and medium roots, few coarse roots; krotovinas and insect activities; some sanidine minerals; gradual and smooth transition to: (sample no. 134/3-26b)

B 54-71 cm — dark reddish brown (10YR 4/3 dry, 5YR 3/2 moist); loam; moderate to strong fine and medium sub-angular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine pores; common medium pores, few coarse pores; common very fine roots, few to common fine roots, common medium roots; krotovinas and insect activities; some sanidine minerals; gradual and smooth transition to: (sample no. 134/3-26c)

Bw1 71-91 cm — dark reddish brown (5YR 3/2 dry, 5YR 3/3 moist); clay loam; moderate to strong fine and medium sub-angular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine pores; common to many medium pores; few coarse pores; some quartz-like gravels probably sanidine minerals; common very fine roots, few fine roots, many medium roots; krotovinas and insect activities; some sanidine minerals; clear and smooth transition to: (sample no. 134/3-26d)

Bw2 91-132 cm — dark reddish brown (7.5YR 4/4 dry, 5YR 3/2 moist); few fine black mottling probably initial stages of manganese concretions formation; clay loam; strong fine medium and coarse angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few coarse pores; some quartz-like gravels and weathering pumice; very few very fine and fine roots; some sanidine minerals; clear and smooth transition to: (sample no. 134/3-26e)

Bg 132-150 cm — dark reddish brown (5YR 3/2 moist); many medium black mottling; sandy clay loam; strong medium and coarse angular blocky peds falling apart to very fine and fine sub-angular blocky structure; friable when moist, sticky and slightly plastic when wet; common very fine, fine and medium pores, few coarse pores, some quartz-like gravels (probably sanidine minerals); very few fine and medium roots; some sanidine minerals: (sample no. 134/3-26f)

Laboratory no. ..../78	2856	2857	2858	2859	2860	2861
Horizon	Ap	A	B	Bw1	Bw2	Bg
Depth (cm)	0-22	22-54	54-71	71-91	91-132	132-160
pH-H_2O (1:2.5 v/v)	6.2	6.2	6.6	6.8	6.9	7.2
pH-KCl	5.1	5.1	5.2	5.3	5.4	5.7
EC (mmho/cm)	0.15	0.35	0.10	0.15	0.14	0.15
C (%)	3.3	2.8	1.5	1.1	0.7	0.6
N (%)	0.40	-	-	-	-	-
C/N	8	-	-	-	-	-
CEC (me/100g), pH 8.2	29.0	22.6	20.4	21.6	22.1	14.4
CEC (me/100g), pH 7.0	28.0	21.6	20.7	20.4	21.0	13.8
Exch. Ca (me/100g)	15.0	15.0	13.0	10.0	10.0	9.2
" Mg "	3.0	3.0	2.6	2.4	3.2	3.0
" K "	2.9	1.9	1.1	1.6	2.6	2.6
" Na "	0.4	0.6	0.6	0.4	0.7	0.7
Sum of cations	21.3	20.5	17.3	14.4	16.5	15.5
Base sat. %, pH 8.2	73	91	85	67	75	100+
" " %, pH 7.0	76	95	86	71	79	100+
ESP at pH 8.2	1	3	3	2	3	5
Texture, lim. pretreatment						
Sand % 2.0-0.05 mm	34	38	36	38	44	54
Silt % 0.05-0.002 mm	43	46	42	34	24	20
Clay % 0.002-0 mm	23	16	22	28	32	26
Texture class	CL	L	L	CL	CL	SCL
Texture USDA:						
Sand % 2.0-1.0 mm	2	1	1	4	4	-
" " 1.0-0.50 mm	3	2	2	5	7	-
" " 0.50-0.25 mm	6	1	6	9	11	-
" " 0.25-0.10 mm	9	14	9	10	12	-
" " 0.10-0.05 mm	6	6	6	5	4	-
Total sand %	26	24	24	33	38	-
Silt %	51	47	50	38	30	-
Clay %	23	29	26	29	32	-
Bulk density (g/cc)	0.88	0.97	1.05	-	-	-
Moisture % w/v at:						
pF 0	62.5	59.5	54.9	-	-	-
pF 2.0	49.3	44.2	39.8	-	-	-
pF 2.3	39.6	36.9	33.2	-	-	-
pF 2.7	32.1	32.8	29.8	-	-	-
pF 3.7	23.8	24.1	24.7	-	-	-
pF 4.2	21.0	21.7	24.1	-	-	-

Fertility aspects: (0-30 cm) Lab. no 2949/78	Available nutrients	Total nutrients
Ca (me/100g)	12.0	-
Mg "	2.0	7
K "	1.8	4
P (ppm)	28	45
Mn (me/100g)	-	-
Exch. acidity (me/100g)	-	-
pH-H_2O (1:1 v/v)	5.6	-
C %	3.7	-
N %	0.38	-
CEC clay (me/100g)	55	-
CEC carbon	500	-

Clay mineralogy: Entirely amorphous

Unit UPb5, Profile no. 47

Soil classification: humic Andosol, ustic Tropohumult, fine clayey, isothermic
Ecological zone: Sub-humid
Observation: 134/3-47; Nyandarua District; E38.3, N14.0; 2767m; 4/4/78
Geological formation: Pyroclastic rocks with intercalated Laikipian type basalt
Local petrography: Tuff
Physiography: Uplands
Relief-macro: Flat to undulating, 100-200 m; convex uniform slopes
Relief-meso, micro: Nil
Vegetation/land use: Planted Cupressus lusitanica with predominantly grass cover; part under cultivation

Erosion: Nil
Surface stoniness: Nil
Slope gradient: 0%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

Ap 0-21 cm — dark reddish brown (Ped-10YR 3/4 dry, 5YR 2.5/2 moist; crushed-10YR 4/2 dry, 10YR 2/1 moist); sandy clay loam; strong very fine granular structure; friable when moist, non sticky and slightly plastic when wet; many very fine and fine roots, few to common roots (most of them dead); insect activities and krotovinas; gradual and smooth transition to: (sample no 134/3-47a)

A 21-40 cm — dark reddish brown (Ped-10YR 2/2 dry, 5YR 2.5/2 moist; crushed-10YR 4/2 dry, 10YR 2/1 moist); clay loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, slightly sticky and plastic when wet; many very fine and fine pores, common medium pores; common very fine roots, few to common fine roots; insect activities (excrements) and krotovinas; some sanidine minerals; gradual and smooth transition to: (sample no. 134/3-47b)

AE 40-60 cm — dark reddish brown (10YR 3/3 dry, 5YR 3/2 moist); clay loam; moderate medium and coarse angular blocky peds falling apart to moderate very fine and fine sub-angular blocky structures; friable when moist, sticky and plastic when wet; few weak clay cutans (probably agricutans - looks like clay coating due to insect activities); many very fine and fine pores, common medium pores; very fine and fine roots; insect activities and krotovinas; some sanidine minerals; clear and smooth transition to: (sample no. 134/3-47c)

Bt1 60-90 cm — dark reddish brown (7.5YR 4/4dry, 5YR 3/3 moist); clay loam; moderate medium and coarse angular blocky peds falling apart to moderate very fine and fine sub-angular blocky structure; friable when moist, sticky and plastic when wet; common weak clay cutans; many very fine and fine pores; common medium pores; few rock (tuff) gravels; few very fine and fine roots; insects and krotovinas; sanidine minerals; gradual and smooth transition to: (sample no. 134/3-47d)

Bt2 90-112 cm — dark reddish brown (5YR 3/3 dry, 2.5YR 3/4 moist); clay; strong very fine, medium and coarse angular blocky structure; friable when moist, sticky and plastic when wet; many moderately thick clay cutans; many very fine pores, common fine pores; very few very fine and fine roots; insect activities; many sanidine mineral quartz-like; gradual and smooth transition to: (sample no. 134/3-47e)

Bt3 112-129 cm — dark reddish brown (7.5YR 4/4 dry, 5YR 3/4 moist); clay; moderate fine and medium angular blocky peds falling apart to moderate very fine sub-angular blocky structure; friable when moist, sticky and plastic when wet; few weak clay cutans; many very fine and fine pores, common medium pores; rounded and sub-rounded rock gravels (tuff); very few very fine and fine roots; insect activities; many sanidine minerals quartz-like; clear and smooth transition to: (sample no. 134/3-47f)

Bt4 129-180 cm — dark reddish brown (2.5YR 3/4 moist); clay; strong very fine, fine medium and coarse angular blocky structure; friable when moist, sticky and plastic when wet; many thick clay cutans; common very fine and fine pores, few medium pores; some insect activities; many sanidine minerals: (sample no. 134/3-47g)

Laboratory no. ..../78	4767	4768	4769	4770	4771	4772
Horizon	Ap	A	AE	Bt1	Bt2	Bt3
Depth (cm)	0-21	21-40	40-60	60-90	90-112	112-129
pH-H_2O (1:2.5 v/v)	4.8	4.7	4.6	4.8	4.5	4.9
pH-KCl	5.1	4.9	5.2	5.4	5.6	5.9
EC (mmho/cm)	0.09	0.08	0.05	0.04	0.07	0.4
C (%)	5.5	4.5	3.6	2.7	1.5	0.7
N (%)	0.55	-	-	-	-	-
C/N	10	-	-	-	-	-
CEC (me/100g), pH 8.2	44.0	39.0	32.0	26.0	19.5	15.5
CEC (me/100g), pH 7.0	42.0	36.0	30.0	27.0	18.4	14.0
Exch. Ca (me/100g)	11.1	8.3	7.9	4.3	4.3	4.2
" Mg "	1.8	3.2	2.3	1.2	2.1	2.1
" K "	0.9	0.6	0.7	0.4	1.0	1.3
" Na "	0.3	0.3	0.6	0.2	0.6	1.3
Sum of cations	14.1	12.4	11.5	6.1	8.0	8.9
Base sat. %, pH 8.2	32	32	36	23	41	57
" " %, pH 7.0	34	34	38	23	43	64
ESP at pH 8.2	1	1	2	1	3	8
Texture, lim. pretreatment						
Sand % 2.0-0.05 mm	48	28	38	30	36	40
Silt % 0.05-0.002 mm	26	38	38	34	24	20
Clay % 0.002-0 mm	26	34	32	36	40	40
Texture class	SCL	CL	CL	CL	CL/C	CL/C
Texture USDA:						
Sand % 2.0-1.0 mm	-	5	2	3	1	3
" " 1.0-0.50 mm	-	8	2	4	2	5
" " 0.50-0.25 mm	-	10	10	6	8	2
" " 0.25-0.10 mm	-	11	5	10	18	Trace
" " 0.10-0.05 mm	-	3	3	4	7	4
Total sand %	-	37	22	27	36	14
Silt %	-	3	40	34	32	33
Clay %	-	60	38	39	32	53
Texture class	-	C	CL	CL	CL	C
Bulk density (g/cc)	0.67	-	0.68	0.95	-	-
Moisture % w/v at:						
pF 0	70.0	-	69.0	62.9	-	-
pF 2.0	55.6	-	52.4	53.0	-	-
pF 2.3	39.9	-	41.5	48.3	-	-
pF 2.7	33.2	-	37.9	44.1	-	-
pF 3.7	22.2	-	29.3	43.7	-	-
pF 4.2	21.2	-	28.5	43.8	-	-

Fertility aspects (0-30 cm) Lab. no. 475/78	Available nutrients	Total nutrients
Ca (me/100g)	5.4	-
Mg "	2.0	10.5
K "	0.7	4
P (ppm)	12	120
Mn (me/100g)	1.4	-
Exch. acidity (me/100g)	1.7	-
pH-H_2O (1:1 v/v)	4.7	-
C %	5.3	-
N %	0.53	-
CEC-clay (me/100g)	22	-
CEC-carbon (me/100g)	700	-

Clay mineralogy: Dominantly amorphous; traces of kaolinite and illite

Unit UPb6, Profile no. 76
Soil classification: luvo-mollic Andosol; ultic Haplustalf, fine clayey, isothermic
Ecological zone: Sub-humid
Observation: 134/3-76; Nyandarua District E35.8, N11.2; 2850 m; 20/5/78
Geological formation: Pyroclastic rocks with intercalated Laikipian type basalt
Local petrography: Volcanic ash
Physiography: Uplands
Relief-macro: very gently undulating to rolling, 200-300 m long, convex regular slopes
Relief-meso, micro: Nil
Vegetation/land use: Planted Cupressus lusitanica and Eucalyptus paniculata with Kikuyu grass; predominantly under maize and pyrethrum cultivation

Erosion: Nil
Surface stoniness: Nil
Slope gradient: 2%; top
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

Ap	0-25 cm	black (Ped-10YR 3/2 dry, 10YR 2.5/1 moist; crushed-10YR 5/2 dry, 10YR 2/1 moist); clay; moderate fine and medium sub-angular blocky *peds falling* apart to moderate very fine crumby structure; loose when dry, friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine roots, common medium roots, very *few coarse roots*; some insect nests; sanidine minerals; clear and smooth transition to: (sample no. 134/3-76a)
E	25-45 cm	black (Ped-7.5YR 4/4 dry, 10YR 2/1 moist, crushed-10YR 4/3 dry, 10YR 2/2 moist); clay; moderate very fine, fine *and* medium sub-angular blocky structure; slightly hard when dry; friable when moist, slightly sticky and plastic when wet; common fine and medium roots; sanidine minerals; clear and smooth transition to: (sample no. 134/3-76b)
B	45-64 cm	dark brown (10YR 3/1 dry, 7.5YR 3/2 moist); clay; moderate very fine, fine medium and coarse sub-angular blocky structure; friable when moist; slightly sticky and plastic when wet; many very fine pores, common to many fine pores few medium pores, very few coarse pores; common very fine and fine roots; some insect nests; sanidine minerals; gradual and smooth transition to: (sample no. 134/3-76c)
Bt	64-93 cm	dark reddish brown (10YR 3/2 dry, 5YR 3/2 moist); clay; moderate to strong very fine, fine medium and coarse angular blocky structure; friable when moist, sticky and plastic when wet; few thin clay cutans; many very fine and fine pores; common medium roots; insect activities; some *sanidine* minerals gradual and smooth transition to: (sample no. 134/3-76d)
B	93-123 cm	dark reddish brown (5YR 3/3 dry, 5YR 3/3 moist); clay loam; moderate to strong medium and coarse angular blocky *peds falling apart to* moderate and strong very fine and fine sub-angular blocky structure; friable when moist; sticky and plastic when wet; few thin clay cutans; common very fine, fine *and medium pores, few* coarse pores; very few very fine and fine roots; some insect activities; sanidine minerals: (sample no. 134/3-76e)

Laboratory no. ..../78	6103	6104	6105	6106	6107
Horizon	Ap	E	B	Bt	B
Depth (cm)	0-25	25-45	45-64	64-93	93-123
pH-H_2O (1:2.5 v/v)	6.6	6.8	6.2	6.6	6.8
pH-KCl "	5.9	6.0	5.4	5.6	6.0
EC (mmho/cm) "	0.15	0.03	0.07	0.05	0.09
C (%)	4.6	3.0	4.5	3.8	1.4
N (%)	0.67	-	-	-	-
C/N	7.0	-	-	-	-
CEC (me/100g), pH 8.2	34.0	35.0	44.0	41.0	19.0
CEC " , pH 7.0	30.0	28.0	35.0	30.0	14.0
Exch. Ca (me/100g)	16.7	11.3	11.8	10.5	8.9
" Mg "	4.7	2.9	3.0	2.3	2.2
" K "	3.3	1.9	2.0	1.8	3.0
" Na "	1.1	1.4	1.2	1.0	1.0
Sum of cations	25.8	17.5	18.0	15.6	15.1
Base sat. % pH 8.2	76	50	41	38	79
" " %, pH 7.0	86	63	51	52	100+
ESP at pH 8.2	3	4	3	2	5
Texture, lim. pretreatment					
Sand % 2.0-0.05 mm	26	27	26	30	24
Silt % 0.05-0.002 mm	24	27	22	14	46
Clay % 0.002-0 mm	50	46	52	56	30
Texture class	C	C	C	C	CL
Texture USDA:					
Sand % 2.0-1.0 mm	2	Tr	-	Tr	3
" " 1.0-0.5 mm	2	1	-	1	3
" " 0.50-0.25 mm	3	3	-	2	5
" " 0.25-0.10 mm	-	5	-	5	5
" " 0.10-0.05 mm	-	3	-	4	3
Total sand %	-	13	-	12	19
Silt %	-	65	-	68	29
Clay %	-	22	-	20	52
Bulk density (g/cc)	0.60	0.66	0.67	-	-
Moisture % w/v at:					
pF 0	70.2	66.7	65.2	-	-
pF 2.0	51.6	42.6	47.5	-	-
pF 2.3	45.2	38.1	42.4	-	-
pF 2.7	41.3	35.3	39.0	-	-
pF 3.7	32.3	32.2	36.2	-	-
pF 4.2	30.0	32.2	35.0	-	-

Fertility aspects: (0-30 cm) Lab. no. 5966/78	Available nutrients	Total nutrients
Ca (me/100g)	12.8	-
Mg "	3.6	-
K "	1.6	-
P (ppm)	130	-
Mn (me/100g)	0.9	-
Exch. acidity (1:1 v/v)	-	-
pH-H_2O (1:1 v/v)	5.6	-
C %	5.1	-
N %	0.63	-
CEC-clay (me/100g)	40	-
CEC-carbon (me/100g)	500	-

Clay mineralogy: Entirely amorphous

Unit UPb7, Profile no. 52

Soil classification: *ando-humic Cambisol, andic ustic Humitropept, fine clayey, isothermic*
Ecological zone: Sub-humid
Observation: 134/1-52; Nyandarua District; E40.7, N18.1; 2750 m; 6/4/78
Geological formation: Pyroclastic rocks with intercalated Laikipian type basalt
Local petrography: Tuff
Physiography: Uplands
Relief-macro: Flat to rolling; 300 m long, convex uniform slopes
Relief-meso, micro: Nil
Vegetation/land use: Cupressus lusitanica, Eucalyptus saligna and Acacia mollisna with predominantly grass pasture for livestock
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 0%
Salinity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

A	0-24 cm	dark reddish brown (Ped-5YR 4/3 dry, 5YR 3/3 moist; crushed-10YR 4/3 dry, 7.5YR 4/4 moist); clay; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores; common medium pores; many very fine and fine roots, few medium roots; some insect activities; gradual and smooth transition to: (sample no 134/1-52a)
B	24-46 cm	dark reddish brown (Ped-5YR 3/4 dry, 5YR 3/3 moist; crushed-7.5YR 5/4 dry, 5YR 4/2 moist); clay; moderate medium and coarse angular blocky peds falling apart to moderate very fine and fine sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores; very few soft manganese concretions (1%, 2-5 mm in size); common very fine and fine roots, few medium roots; some insect activities; some sanidine minerals; clear and smooth transition to: (sample no. 134/1-52b)
Bw	46-80 cm	dark reddish brown (5YR 4/6 dry, 5YR 3/4 moist); clay; moderate to strong very fine, fine, medium and coarse angular blocky structure; friable when moist, sticky and plastic when moist; many very fine and fine pores, common to many medium pores, few coarse pores; few soft manganese concretions (1%, 2-5 mm in size); few very fine and fine roots; some insect activities; some sanidine minerals - some quartz-like; clear and smooth transition to: (sample no. 134/1-52c)
Bg	80-120 cm+	dark red (5YR 5/6 dry, 2.5YR 3/6 moist); common, fine to coarse distinct black (2.5YR N2.5) mottles, probably initial stages of manganese concretion formation common fine to medium distinct dusky red (10YR 3/6) mottles; clay loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few coarse pores; few to common manganese concretions (5%, 2-20 mm in size); few very fine roots, very few fine roots; many insect activities; some sanidine minerals: (sample no. 134/1-52d)

Laboratory no. ..../78	4799	4800	4801	4802
Horizon	A	B	Bw	Bg
Depth (cm)	0-24	24-46	46-80	80-120
pH-H_2O (1:2.5 v/v)	4.6	4.4	5.0	4.9
pH-KCl	4.9	4.7	5.1	5.9
EC (mmho/cm)	0.09	0.06	0.04	0.03
C (%)	3.1	2.3	1.0	0.7
N (%)	0.33	-	-	-
C/N	9	-	-	-
CEC (me/100g), pH 8.2	26.0	21.3	18.0	14.5
CEC (me/100g), pH 7.0	24.0	21.4	17.0	13.4
Exch. Ca (me/100g)	1.1	2.3	2.7	3.3
Exch. Mg (me/100g)	0.8	1.0	1.8	2.1
Exch. K (me/100g)	1.9	0.5	0.3	0.2
Exch. Na (me/100g)	0.3	0.6	0.5	0.6
Sum of cations	4.1	4.4	5.3	6.2
Base sat. %, pH 8.2	16	21	29	43
Base sat. %, pH 7.0	17	21	31	46
ESP at pH 8.2	1	3	3	4
Texture lim. pretreatment				
Sand % 2.0-0.05 mm	24	20	26	20
Silt % 0.05-0.002 mm	32	32	24	32
Clay % 0.002-0 mm	44	48	50	48
Texture class	C	C	C	C
Texture USDA:				
Sand % 2.0-1.0 mm	1	5	4	1
" " 1.0-0.50 mm	3	5	4	2
" " 0.50-0.25 mm	5	9	5	4
" " 0.25-0.10 mm	2	8	6	6
" " 0.10-0.05 mm	6	7	3	4
Total sand %	17	34	22	16
Silt %	30	33	21	27
Clay %	53	33	57	57
Texture class	C	CL	-	-
Bulk density (g/cc)	0.87	1.02	1.12	-
Moisture % w/v at:				
pF 0	65.5	57.9	56.6	-
pF 2.0	52.4	48.9	46.5	-
pF 2.3	46.3	41.8	42.8	-
pF 2.7	43.0	38.6	40.2	-
pF 3.7	38.0	31.2	21.3	-
pF 4.2	28.6	30.0	18.9	-

Fertility aspects: (0-30 cm) Lab. no. 4757/78	Available nutrients	Total nutrients
Ca (me/100g)	0.2	-
Mg (me/100g)	1.0	6.5
K (me/100g)	0.8	3.5
P (ppm)	6	43
Mn (me/100g)	0.9	
Exch. acidity (me/100g)	1.7	
pH-H_2O (1:1 v/v)	4.6	
C %	3.7	
N %	0.35	
CEC clay (me/100g)	23	
CEC carbon (me/100g)	500	

Clay mineralogy: Dominantly amorphous; traces of kaolinite and illite

Unit UPblOp, Profile no. 67

Soil classification: dystric Cambisol; ustic Humitropept, fine loamy; isothermic
Ecological zone: Sub-humid
Observation: 134/1-67; Nyandarua District; E39.4, N22.8; 2833m; 17/5/78
Geological formation: Pyroclastic rocks with intercalated Laikipian type basalt
Local petrography: Tuff
Physiography: Uplands
Relief-macro: Flat to gently undulating; 300-400m, straight, regular slopes
Relief-micro: Cowfoetoes
Vegetation/land use: Planted Cupressus lusitanica and Eucalyptus saligna; grazing area
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 3%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

Ap 0-18 cm — dark reddish brown (Ped-7.5YR 4/4 dry, 5YR 3/4 moist; crushed-10YR 5/4 dry, 10YR 4/3 moist); clay loam; moderate very fine, fine and medium sub-angular blocky structure friable when moist, slightly plastic when wet; many very fine pores, common fine pores, few medium pores, many very fine and fine roots; some insect activities; sanidine minerals; clear and smooth transition to: (sample no. 134/1-67a)

Bg 18-36 cm — reddish brown (Ped-5YR 4/4 dry, 5YR 4/4 moist; crushed-10YR 5/6 dry, 10YR 4/3 moist); few to common fine faint dark reddish brown (5YR 3/3) mottles; clay loam; moderate fine, medium and coarse sub-angular blocky structure; friable when moist, slightly sticky and slightly plastic when wet; many very fine pores, common to many fine pores; few to common medium pores; common very fine and fine roots; insect activities; some sanidine minerals; clear and smooth transition to: (sample no. 134/1-67b)

Bwg 36-68 cm — dark reddish brown (10YR 5/6 dry, 5YR 3/3 moist); few to common fine faint dark reddish brown (5YR 3/2) mottles; clay loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine pores, few medium pores; few to common soft and hard iron and manganese concretions (5%, 3-10 mm in size); few to common very fine roots, few fine roots; insect activities some sanidine minerals; clear and smooth transition to: (sample no. 134/1-67c)

Bg1 68-86 cm — reddish brown (10YR 4/6 dry, 5YR 4/4 moist); few to common faint, dark reddish brown (5YR 3/2) mottles; clay loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine pores, common fine pores, few and medium pores; few to common soft and hard iron and manganese concretions; very few very fine roots; some insect activities; sanidine minerals; clear and smooth transition to: (sample no. 134/1-67d)

Bg2 86-106 cm+ — dark reddish brown (10YR 4/6 dry, 5YR 3/4 moist); few to common fine faint dark reddish brown (5YR 3/2) and black mottling, the latter probably due to initial stages of manganese concretions formation; clay loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine pores, common fine pores; few medium and coarse pores; common soft and hard iron and manganese concretions; very few very fine roots; some sanidine minerals; (sample no. 134/1-67e)

Laboratory no. ..../78	6144	6145	6146	6147	6148
Horizon	Ap	Bg	Bwg	Bg1	Bg2
Depth (cm)	0-18	18-36	36-68	68-86	86-108
pH-H_2O (1:2.5 v/v)	5.2	5.4	6.0	6.4	6.6
pH-KCl "	4.8	4.8	5.4	5.6	5.6
EC (mmho/cm) "	0.05	0.03	0.02	0.03	0.01
C (%)	4.1	2.8	1.3	1.0	0.8
N (%)	0.36	-	-	-	-
C/N	11	-	-	-	-
CEC (me/100g), pH 8.2	18.5	15.0	12.8	13.8	10.7
CEC (me/100g), pH 7.0	12.5	11.1	10.5	11.1	9.8
Exch. Ca (me/100g)	1.5	1.3	2.5	3.1	3.1
Exch. Mg "	1.0	0.6	1.0	0.6	1.0
Exch. K "	0.5	0.3	0.2	0.3	0.3
Exch. Na "	0.7	0.6	0.7	0.7	0.8
Sum of cations	3.2	2.8	4.4	4.7	5.2
Base sat. %, pH 8.2	20	19	34	34	49
Base sat. %, pH 7.0	30	25	42	42	53
ESP at pH 8.2	4	4	6	5	8
Texture lim. pretreatment					
Sand % 2.0-0.05 mm	34	30	36	38	34
Silt % 0.05-0.002 mm	38	40	26	24	32
Clay % 0.002-0 mm	28	30	38	38	34
Texture class	CL	CL	CL	CL	CL
Sand " 2.0-1.0 mm	Tr	Tr	17	10	-
" " 1.0-0.50 mm	Tr	2	6	9	-
" " 0.50-0.25 mm	1	8	12	7	-
" " 0.25-0.10 mm	3	8	6	9	-
" " 0.10-0.05 mm	3	4	3	5	-
Total sand %	7	22	44	40	-
Silt %	54	26	22	25	-
Clay %	39	52	34	35	-
Bulk density (g/cc)	0.88	1.15	1.32	-	-
Moisture % w/v at:					
pF 0	62.8	54.8	57.3	-	-
pF 2.0	50.6	46.2	42.5	-	-
pF 2.3	46.6	41.9	39.6	-	-
pF 2.7	43.4	38.2	36.2	-	-
pF 3.7	34.2	33.1	35.1	-	-
pF 4.2	28.6	30.4	30.0	-	-

Fertility aspects: (0-30 cm) Lab. No. 5978/78	Available nutrients	Total nutrients
Ca (me/100g)	0.2	-
Mg "	0.2	5.8
K "	0.3	2.3
P (ppm)	14	73
Mn (me/100g)	0.7	-
Exch. acidity (me/100g)	1.2	-
pH-H_2O (1:1 v/v)	4.9	-
C %	4.5	-
N %	0.39	-
CEC-clay (me/100g)	23	-
CEC-carbon (me/100g)	300	-

Clay mineralogy: Dominantly amorphous; traces of kaolinite and illite

Unit UPbl3p, Profile no. 38

Soil classification: eutric Cambisol, sodic phase; typic Ustropept, fine clayey, isothermic
Ecological zone: Semi-humid
Observation: 134/3-38; Nyandarua District; E30.8, N12.3; 2866 m; 8/3/78
Geological formation: Pyroclastic rocks and sediments
Local petrography: Tuff
Physiography: Uplands
Relief-macro: flat to gently undulating; 100-200 m, convex and regular slope
Relief-meso, micro: Nil
Vegetation/land use: Planted Cupressus lusitanica, Eucalyptus saligna and Pinus patula; maize and potatoes grown
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 1%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Well drained

Profile description

Ap 0-17 cm — very dark brown (Ped-10YR 5/3 dry, 10YR 3/2 moist; crushed-10YR 6/2 dry, 10YR 3/2 moist); silty clay loam; weak fine and medium sub-angular blocky structure falling apart to moderate very fine crumbs; friable when moist, slightly sticky and plastic and wet; many very fine and fine pores, common medium pores; some rounded insect excrements - look like clay nodules; many very fine and fine roots, very few medium roots; many insect activities; gradual and smooth transition to: (sample no. 134/3-38a)

A 17-33 cm — very dark brown (Ped-10YR 5/3 dry, 10YR 2/2 moist; crushed-10YR 6/2 dry, 10YR 3/2 moist); clay loam; weak fine and medium sub-angular blocky peds falling apart to moderate crumby structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few coarse pores; rounded insect excrements - look like clay nodules; common very fine roots, many fine roots; many insect activities; gradual and smooth transition to: (sample no. 134/3-38b)

B 33-50 cm — dark reddish brown (10YR 4/3 dry, 5YR 3/2 moist; clay; moderate fine and medium sub-angular blocky peds falling apart to moderate very fine crumby structure; very friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few coarse pores; few to common hard manganese and iron concretions (5%, 2-5 mm in size); some clay nodules; very few very fine roots; many insect activities; clear and smooth transition to: (sample no. 134/3-38c)

Bw 50-74 cm — dark reddish brown (Ped-7.5YR 5/4 dry, 5YR 3/2 moist; crushed-10YR 6/4 dry, 7.5YR 4/4 moist); black mottling probably due to initial stages of manganese concretions formation; clay; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; very fine and fine pores; very few very fine and fine roots; many insect activities; sanidine minerals; clear and smooth transition to: (sample no. 134/3-38d)

Bc 74-115 cm — reddish brown (7.5YR 5/6 dry, 5YR 4/4 moist), black and brown mottling which may be due to initial stages of manganese and iron concretion formation; clay loam; strong very fine and fine angular blocky structure; friable to firm when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores; few coarse pores; many hard manganese and iron concretions (15%, 2-10 mm in size); sanidine minerals: (sample no. 134/3-38e)

BC > 115 cm — Soil mixed with weathering parent material

Laboratory no. .../78	3869	3870	3871	3872	3873
Horizon	Ap	A	B	Bw	Bc
Depth (cm)	0-17	17-33	33-50	50-74	74-115
$pH-H_2O$ (1:2.5 v/v)	6.4	6.8	7.0	7.0	7.4
pH-KCl	5.5	5.8	5.9	6.0	6.1
EC (mmho/cm)	0.16	0.14	0.11	0.10	0.09
C (%)	3.6	3.4	1.2	0.6	0.1
N (%)	0.35	-	-	-	-
C/N	9	-	-	-	-
CEC (me/100g), pH 8.2	30.0	33.0	26.0	19.5	15.2
CEC (me/100g), pH 7.0	28.0	32.0	25.0	19.0	14.7
Exch. Ca (me/100g)	18.1	22.0	18.0	14.4	11.3
Exch. Mg "	4.6	4.1	4.6	4.4	4.1
Exch. K "	2.8	2.7	1.8	1.6	1.6
Exch. Na "	0.7	0.7	1.5	1.5	1.2
Sum of cations	26.2	29.5	25.9	21.9	18.2
Base sat. %, pH 8.2	86	89	100+	100+	100+
Base sat. %, pH 7.0	94	92	100+	100+	100+
ESP at pH 8.2	2	2	6	8	8
Texture lim. pretreatment					
Sand % 2.0-0.05 mm	20	24	28	26	40
Silt % 0.05-0.002 mm	48	38	32	32	28
Clay % 0.002-0 mm	32	38	40	42	32
Texture class	S/CL	CL	CL/C	C	CL
Texture USDA:					
Sand % 2.0-1.0 mm	1	1	1	3	9
" " 1.0-0.50 mm	3	2	3	5	10
" " 0.50-0.25 mm	4	2	5	7	10
" " 0.25-0.10 mm	5	4	8	7	8
" " 0.10-0.05 mm	3	5	5	3	4
Total sand %	16	14	22	25	41
Silt %	44	55	46	41	37
Clay %	40	31	32	34	22
Bulk density (g/cc)	0.85	1.31	1.43	-	1.28
Moisture % w/v at:					
pF 0	62.6	47.7	42.8	-	49.9
pF 2.0	52.5	41.5	37.8	-	43.2
pF 2.3	51.2	40.2	36.5	-	41.4
pF 2.7	48.8	38.2	34.6	-	38.8
pF 3.7	-	-	-	-	-
pF 4.2	27.5	30.8	20.4		13.6

Fertility aspects (0-30 cm) Lab. no. 3919/78	Available nutrients	Total nutrients
Ca (me/100g)	17.2	-
Mg "	3.7	7.5
K "	1.9	6.5
P (ppm)	185	-
$pH-H_2O$ (1:1 v/v)	6.4	-
C %	3.7	-
N %	0.42	-
CEC-clay (me/100g)	43	-
CEC-carbon (me/100g)	500	-

Clay mineralogy: Entirely amorhpous

Unit LPal, Profile no. 58

Soil classification: solodic Planosol; albic Natraqualf, fine clayey, montmorillonitic, isothermic
Ecological zone: Semi-humid
Observation: 134/1-58; Nyandarua District; E29.4, N17.5; 2800 m; 14/4/78
Geological formation: Pyroclastic rocks and sediments
Local petrography: Tuff
Physiography: Plain
Relief-macro: Flat to very gently undulating; 500 m long
Relief-meso, micro: cowfoetoes
Vegetation/land use: Grassland for livestock grazing; also planted Eucalyptus saligna, Cupressus lusitanica and Pinus halephenis

Erosion: Nil
Surface stoniness: Nil
Slope gradient: 0%
Salinity/sodicity: Alkali
Surface sealing: Nil
Drainage class: Imperfectly drained

Profile description

Ag 0-20 cm	dark greyish brown (Ped-10YR 6/2 dry, 10YR 4/2 moist; crushed-10YR 7/1 dry, 10YR 4/2 moist), common fine to medium distinct reddish brown (5YR 4/4) mottles; loam; moderate very fine, fine and medium sub-angular blocky structure; friable when moist, sticky and plastic when wet; common to many very fine pores, common fine pores; many very fine roots, common to many fine roots; clear and smooth transition to: (sample no 134/1-58a)
Eg 20-36 cm	greyish brown (Ped-10YR 6/2 dry, 10YR 5/2 moist; crushed-10YR 7/1 dry, 10YR 4/2 moist), common fine to medium distinct strong brown (7.5YR 5/6) mottles; clay loam; moderate very fine, fine and medium angular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few hard manganese and iron concretions (2%, 2-5 mm in size); common very fine roots; fine roots; abrupt and smooth transition to: (sample no. 134/1-58b)
Bt 36-62 cm	dark brown (10YR 4/2 dry, 7.5YR 3/2 moist); clay; strong very fine, fine and medium angular blocky structure; very firm when moist, sticky and plastic when wet; few weak clay cutans; many very fine and fine pores, common medium pores; few subrounded gravels; common very fine roots; sanidine minerals; slow hydraulic conductivity; abrupt and smooth transition to (sample no. 134/1-58c)
2Bng 62-86 cm	dark greyish brown (10YR 6/2 dry, 10YR 4/2 moist), many fine to medium distinct reddish brown (5YR 4/4) mottles, many fine to medium distinct black (7.5YR N.2) mottles; clay loam; strong medium and coarse prismatic peds falling apart to strong very fine and fine angular blocky structure; firm when moist, sticky and plastic when wet; many very fine and fine pores, common medium pores, few coarse pores; very slow hydraulic conductivity; abrupt and smooth transition to: (sample no. 134/1-58d)
3Bt1 86-110 cm	very dark grey (10YR 3/3 dry, 10YR 3/1 moist); clay; strong very fine, fine and medium angular blocky structure; very friable when moist, sticky and plastic when wet; few thin slickensides; many very fine and fine pores, common medium pores; some sub-rounded gravels; dead roots; sanidine minerals: (sample no. 134/1-58e)
3Bt2 110-160 cm	augered and continues like above

Laboratory no. .../78	4828	4829	4830	4831	4832
Horizon	Ag	Eg	Bt	2Bng	3Bt1
Depth (cm)	0-20	20-36	36-62	62-86	86-110
$pH-H_2O$ (1:2.5 v/v)	5.7	6.0	7.3	7.4	7.4
pH-KCl	4.2	4.2	4.8	5.0	5.2
EC (mmho/cm)	0.08	0.09	0.10	0.26	0.15
C (%)	2.1	1.2	1.4	0.6	0.4
N (%)	0.21	-	-	-	-
C/N	10	-	-	-	-
CEC (me/100g), pH 8.2	17.5	17.0	32.0	12.6	27.0
CEC " , pH 7.0	16.0	14.0	28.0	12.0	24.0
Exch. Ca (me/100g)	5.6	6.7	23.4	10.1	21.3
" Mg "	1.5	1.8	6.3	2.6	6.0
" K "	0.8	0.4	1.4	1.5	2.8
" Na "	0.8	1.3	3.2	2.3	3.4
Sum of cations	8.7	10.2	34.3	16.5	33.5
Base sat. %, pH 8.2	50	60	100+	100+	100+
Base sat. %, pH 7.0	54	73	100+	100+	100+
ESP at pH 8.2	5	8	10	18	13
Texture lim. pretreatment:					
Sand % 2.0-0.05 mm	24	26	19	32	10
Silt % 0.05-0.002 mm	52	46	39	40	30
Clay % 0.002-0 mm	24	28	42	28	60
Texture class	L	CL	C	CL	C
Texture USDA:					
Sand % 2.0-1.0 mm	Tr	2	Tr	2	1
" " 1.0-0.50 mm	Tr	2	Tr	3	2
" " 0.50-0.25 mm	3	3	1	6	2
" " 0.25-0.10 mm	5	5	2	9	2
" " 0.10-0.05 mm	4	3	1	5	1
Total sand %	12	15	4	25	8
Silt %	54	43	21	62	21
Clay %	34	42	75	13	71
Bulk density (g/cc)	1.08	1.46	1.34	-	-
Moisture % w/v at:					
pF 0	54.5	44.0	58.7	-	-
pF 2.0	48.2	38.9	50.0	-	-
pF 2.3	44.8	35.9	45.8	-	-
pF 2.7	42.5	33.8	43.6	-	-
pF 3.7	32.9	33.8	34.5	-	-
pF 4.2	27.1	29.3	31.9	-	-

Fertility aspects: (0-30 cm) Lab. no. 4763/78	Available nutrients	Total nutrients
Ca (me/100g)	4.4	-
Mg "	1.5	3.5
K "	0.3	1.8
P (ppm)	7	55
Mn (me/100g)	0.5	-
Exch. acidity (me/100g)	0.3	-
$pH-H_2O$ (1:1 v/v)	5.0	-
C %	2.7	-
N %	0.27	-
CEC-clay (me/100g)	40	-
CEC-carbon (me/100g)	400	

Clay mineralogy: Montmorillonite

Unit LPa4p, Profile no. 88

Soil classification: solodic Planosol; aeric Tropaqualf, very fine clayey, montmorillonitic, isothermic
Ecological zone: Semi-humid
Observation: 134/1-88; Nyandarua District; E32.1, N26.0; 2767m; 25/5/78
Geological formation: Pyroclastic rocks and sediments
Local petrography: Tuff
Physiography: Plain
Relief-macro: Flat
Relief-meso, micro: Nil
Vegetation/land use: Dominantly of nut grassland for livestock with planted Eucalyptus saligna and Cupressus lusitanica
Erosion: Nil
Sruface stoniness: Nil
Slope gradient: 0%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Imperfectly drained

Profile description

Apg	0-15 cm	dark greyish brown (Ped-10YR 6/2 dry, 10YR 4/2 moist; crushed-10YR 7/2 dry, 10YR 4/2 moist), common medium distinct dark reddish brown (10YR 3/4) mottles; loam; moderate very fine, fine and medium angular blocky structure; friable to firm when moist, sticky and plastic when wet; few very fine pores, very few fine pores; common very fine roots; some sanidine minerals; clear and smooth transition to: (sample no. 134/1-88a)
Eg	15-36 cm	dark grey (Ped-10YR 7/2 dry, 10YR 4/1 moist; crushed-10YR 7/2 dry, 10YR 4/2 moist), common medium distinct dark brown (7.5YR 4/4) mottles; silt loam; moderate to strong very fine, fine, medium and coarse angular blocky structure; friable to firm when moist, sticky and plastic when wet; common to many very fine pores, common fine pores; few medium pores; few to common very fine roots; few fine roots; some sanidine minerals; abrupt and smooth transition to: (sample no. 134/1-88b)
Btc	36-56 cm	dark brown (10YR 5/2 dry, 7.5YR 3/2 moist); clay loam; moderate to strong very fine, fine and medium angular blocky structure; firm when moist, sticky and plastic when wet; few very fine and fine pores; many hard manganese and iron concretions (10%, 2-10 mm in size); few very fine roots, very few fine roots; some sanidine minerals; slow hydraulic conductivity; gradual and smooth transition to: (sample no. 134/1-88c)
Btg	56-74 cm	very dark brown (10YR 3/2 dry, 10YR 2/2 moist), few fine faint dark brown (10YR 3/3) mottles; clay; strong medium and coarse prismatic peds falling apart to very fine and fine angular blocky structure; firm when moist, sticky and plastic when wet; few thin clay cutans, few weak slickensides; very few very fine and fine pores; very few fine roots, some dead roots; some sanidine minerals; very slow hydraulic conductivity; clear and smooth transition to: (sample no. 134/1-88d)
B	74-110 cm+	dark yellowish brown (10YR 3/3 dry, 10YR 3/4 moist); clay; strong very fine, fine and medium angular blocky structure; firm when moist, sticky and plastic when wet; few very fine and fine pores, very few medium pores; some sanidine minerals; very slow hydraulic conductivity. (sample no. 134/1-88e)
NB		Bulk density more than 1gm/cc throughout profile

Laboratory no. ..../78	6044	6045	6046	6047	6048
Horizon	Apg	Eg	Btc	Btg	B
Depth (cm)	0-15	15-36	36-56	56-74	74-100
pH-H_2O (1:2.5 v/v)	5.7	5.9	6.4	7.2	7.1
pH-KCl	4.8	4.8	4.8	5.4	5.4
EC (mmho/cm)	0.12	0.07	0.14	0.30	0.30
C (%)	1.8	1.2	1.4	0.8	0.4
N (%)	0.18	-	-	-	-
C/N	10	-	-	-	-
CEC (me/100g), pH 8.2	13.0	11.0	22.3	43.0	46.0
CEC (me/100g), pH 7.0	11.0	10.5	21.7	38.0	42.0
Exch. Ca (me/100g)	3.6	3.6	8.4	22.0	21.0
" Mg "	1.4	1.2	2.3	6.5	6.5
" K "	0.6	0.4	1.0	2.3	2.3
" Na "	1.0	1.2	1.6	3.2	3.4
Sum of cations	6.6	6.4	13.3	34.0	33.2
Base sat. %, pH 8.2	51	58	60	79	72
Base sat. %, pH 7.0	60	61	61	89	79
ESP at pH 8.2	8	11	7	7	7
Texture, lim. pretreatment					
Sand % 2.0-0.05 mm	22	22	26	18	18
Silt % 0.05-0.002 mm	52	54	38	10	12
Clay % 0.002-0 mm	26	24	36	72	70
Texture class	L	SiL	CL	C	C
Texture USDA:					
Sand % 2.0-1.0 mm	2	2	4	1	1
" " 1.0-0.50 mm	1	1	4	1	6
" " 0.50-0.25 mm	3	3	3	1	1
" " 0.25-0.10 mm	5	5	4	1	1
" " 0.10-0.05 mm	3	4	3	1	1
Total sand %	14	15	18	5	10
Silt %	53	58	34	12	12
Clay %	33	27	48	83	78
Bulk density (g/cc)	1.07	1.24	1.40	1.35	-
Moisture % w/v at:					
pF 0	52.7	47.6	44.3	58.4	-
pF 2.0	38.6	37.1	35.2	53.1	-
pF 2.3	36.4	35.4	32.0	50.6	-
pF 2.7	33.4	33.3	30.8	47.1	-
pF 3.7	23.2	32.3	31.3	43.6	-
pF 4.2	18.8	25.0	28.6	40.6	-

Fertility aspects: (0-30 cm) Lab. no. 5956/78	Available nutrients	Total nutrients
Ca (me/100g)	3.2	-
Mg "	1.2	8.3
K "	0.3	2.8
P (ppm)	6	48
Mn (me/100g)	0.5	-
Exch. acidity (me/100g)	-	-
pH-H_2O (1:1 v/v)	5.6	-
C %	2.0	-
N %	0.18	-
CEC-clay (me/100g)	Increases with depth from 36 to 64 cm	-
CEC-carbon (me/100g)	200	

Clay mineralogy: Top-dominantly amorphous; sub-montmorillonite and illite

Unit LPa7p, Profile no. 86

Soil classification: eutric Planosol; abruptic Tropaqualf, very fine clayey, montmorillonitic, isothermic

Ecological zone: Sub-humid
Observation: 134/1-86; Nyandarua District; E.32.1, N 34.3 2733 m; 24/5/78
Geological formation: Pyroclastic rocks and sediments
Local petrography: Tuff
Physiography: Plain
Relief-meso, micro: Nil
Relief-macro: Flat to gently undulating
Vegetation/land use: Dominantly Kikuyu grass and Eragrostis tunidolia pasture for livestock grazing with planted Eucalyptus saligna and Cupressus lusitanica
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 3%; middle
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: Imperfectly drained

Profile description

Apg 0-23 cm — dark greyish brown (Ped-10YR 6/2 dry, 10YR 4/2 moist; crushed-10YR 6/2 dry, 10YR 4/2 moist), common medium distinct dark brown (10YR 3/3) mottles; clay loam; moderate to strong medium and coarse angular blocky peds; falling apart to moderate to strong very fine sub-angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; many very fine pores, common to many fine pores, few to common medium pores; many very fine and fine roots; some insect and earthworm activities; sanidine minerals; clear and smooth transition to: (sample no. 134/1-86a)

Ec 23-35 cm — dark brown (Ped-10YR 5/3 dry, 7.5YR 3/2 moist; crushed-10YR 5/2 dry, 10YR 3/2 moist); sandy clay; moderate very fine, fine and medium sub-angular blocky structure; firm when moist, sticky and plastic when wet; many hard iron and manganese concretions (10%, 2-20mm in size) at bottom of horizon; very few very fine and fine roots; insect and earthworm activities; sanidine minerals; abrupt and wavy transition to: (sample no. 134/1-86b)

Bt1 35-65 cm — very dark brown (10YR 3/2 dry, 10YR 3/2, moist); clay; strong very fine, fine, medium and coarse angular blocky peds tending to be prismatic in structure; firm when moist, sticky and plastic when wet; few thin clay cutans, common weak slickensides; few very fine pores, few to common fine pores; very few hard iron and manganese concretions (1%, 2-5mm in size), some sub-rounded gravels; very few very fine and fine roots; some sanidine minerals; slow hydraulic conductivity; clear and smooth transition to: (sample no. 134/1-86c)

Bt2 65-84 cm — dark brown (10YR 3/2 dry, 7.5YR 3/2, moist); clay; strong very fine, fine, medium and coarse angular blocky structure; firm when moist, sticky and plastic when wet; few weak slickensides; very few but dying roots; some sanidine minerals; very slow hydraulic conductivity; clear and smooth transito to: (sample no. 134/1-86d)

Bg 84-108 cm — dark brown (10YR 3/3 dry, 10YR 3/3 moist), black mottles, most probably due to initial stages of manganese concretion formation; clay; strong very fine, fine, medium and coarse angular blocky structure tending to be sub-angular blocky; firm when moist, sticky and plastic when wet; few weak slickensides; some sanidine minerals; very slow hydraulic conductivity; (sample no. 134/1-86e)

NB — This profile does not have a conspicuosly bleached horizon like in other profiles occurring in the same landscape. Bulk density is more than 1 gm/cc throughout the profile.

Laboratory no. ..../78	6173	6174	6175	6176	6177
Horizon	Apg	Ec	Bt1	Bt2	Bg
Depth (cm)	0-23	23-35	35-65	65-84	84-108
pH-H_2O (1:2.5 v/v)	5.8	6.4	6.6	6.4	6.8
pH-KCl "	5.0	5.1	5.4	5.4	5.2
EC (mmho/cm)"	0.05	0.05	0.13	0.18	0.16
C (%)	1.4	1.0	0.7	0.5r	0.2
N (%)	0.18	-	-	-	-
CEC (me/100g), pH 8.2	14.5	17.6	28.0	28.0	28.0
CEC " " , pH 7.0	13.0	15.0	27.0	28.0	29.0
Exch. Ca (me/100g)	7.3	6.9	17.7	18.5	19.6
" Mg "	2.0	1.9	5.8	6.7	8.6
" K "	0.2	0.7	1.6	1.8	1.6
" Na "	1.4	0.4	1.7	1.9	1.9
Sum of cations	10.9	9.9	26.8	28.9	31.7
Base sat. %, pH 8.2	75	56	96	100+	100+
" " %, pH 7.0	89	66	99	100+	100+
C/N	8	-	-	-	-
Esp at pH 8.2	10	2	6	7	7
Texture, lim. pretreatment					
Sand % 2.0-0.05 mm	20	46	20	16	20
Silt % 0.05-0.002 mm	52	18	14	14	10
Clay % 0.002-0 mm	28	36	66	70	70
Texture class	CL	SC	C	C	C
Texture USDA:					
Sand % 2.0-1.0 mm	1	11	1	1	Tr
" " 1.0-0.50 mm	1	13	1	Tr	1
" " 0.50-0.25 mm	3	6	2	4	2
" " 0.25-0.10 mm	7	4	2	9	3
" " 0.10-0.05 mm	6	3	2	5	2
Total sand %	18	37	8	19	8
Silt %	57	20	36	58	59
Clay %	25	43	56	23	33
Bulk density (g/cc)	1.24	1.30	1.37	-	-
Moisture % w/v at:					
pF 0	50.9	43.2	53.1	-	-
pF 2.0	42.1	33.3	48.9	-	-
pH 2.3	40.1	31.4	47.4	-	-
pF 2.7	37.7	30.1	45.7	-	-
pF 3.7	30.8	26.4	44.7	-	-
pF 4.2	24.6	23.4	44.8	-	-

Fertility aspects: (0-30 cm) Lab. No. 5481/78	Available nutrients	Total nutrients
Ca (me/100g)	3.6	-
Mg "	1.5	-
K "	0.2	-
P (ppm)	7	-
Mn (me/100g)	0.8	-
Exch. acidity (me/100g)	0.5	-
pH-H_2O (1:1 v/v)	5.4	-
C %	2.0	-
N %	0.19	-
CEC-clay (me/100g)	39	-
CEC-carbon (")	300	-

Clay mineralogy: Top-dominantly amorphous; sub-montmorillonite, illite and kaolinite

Unit BPp, Profile no. 69

Soil classification: humic Gleysol; aeric Tropaquept, fine clayey, isothermic
Ecological zone: Sub-humid
Observation: 134/1-69; Nyandarua District; E.39.9; N.21.2; 2800m; 17/5/78
Geological formation: Pyroclastic rocks with intercalated Laikipian type basalt
Local petrography: Alluvium/colluvium
Physiography: Bottomlands
Relief-meso, micro: cowfoetoes; Relief-macro: Flat
Vegetation/land use: predominantly swamp vegetation/sometimes used for cattle grazing; also planted Cupressus lusitanica and Eucalyptus globulus.
Erosion: Nil
Surface stoniness: Nil
Slope gradient: 0%
Salinity/sodicity: Nil
Surface sealing: Nil
Drainage class: imperfectly drained to poorly drained

Profile description

Ag	0-30 cm	very dark grey (Ped-5YR 2.5/2 dry, 10YR 3/1 moist; crushed-10YR 4/3 dry, 10YR 2/2 moist), common to many fine distinct dark brown (7.5YR 3/2) mottles; clay loam; moderate fine, medium and coarse sub-angular blocky structure; friable when moist, sticky and plastic when wet; many very fine pores, common fine roots; clear and smooth transition to: (sample no. 134/1-69a)
Bg	30-65 cm	dark brown (Ped-5YR 3/3 dry, 7.5YR 4/4 moist; crushed-10YR 4/3 dry, 10YR 2/2 moist), common to many fine distinct dark reddish brown (5YR 3/3) mottles; clay; moderate very fine, fine and medium sub-angular blocky structure; friable to firm when moist, sticky and plastic when wet; many very fine roots, few to common roots; clear and smooth transition to: (sample no. 134/1-69b)
C	65cm+	weathered rock-like material; looks like indurated iron.

Laboratory no. ..../78	6138	6139
Horizon	Ag	Bg
Depth (cm)	0-30	30-65
pH-H_2O (1.2.5 v/v)	5.4	5.8
pH-KCl "	5.0	5.0
EC (mmho/cm)"	0.08	0.03
C (%)	4.3	1.0
N (%)	0.49	-
C/N	9	-
CEC (me/100g), pH 8.2	16.5	17.0
CEC ("), pH 7.0	15.7	16.5
Exch. Ca (me/100g)	2.9	3.9
" Mg "	1.3	1.1
" K "	0.8	0.5
" Na "	0.7	0.8
Sum of cations	5.7	6.3
Base sat. %, pH 8.2	35	37
Base sat. %, pH 7.0	36	38
ESP at pH 8.2	4	5
Texture, lim. pretreatment:		
Sand % 2.0-0.05 mm	34	34
Silt % 0.05-0.002	34	24
Clay % 0.002-0 mm	32	52
Texture class	CL	C
Texture USDA:		
Sand % 2.0-1.0 mm	-	3
" " 1.0-0.50 mm	-	3
" " 0.50-0.25 mm	-	2
" " 0.25-0.10 mm	-	3
" " 0.10-0.05 mm	-	2
Total sand %	-	13
Silt %	-	27
Clay %	-	60
Texture class	-	C
Bulk density (g/cc)	-	-
Moisture % w/v at:		
pF 0	-	-
pF 2.0	-	-
pF 2.3	-	-
pF 2.7	-	-
pF 3.7	-	-
pF 4.2	-	-
Fertility aspects	Available nutrients	Total nutrients
(0-30cm) Lab. No. 5973/78		
Ca (me/100g)	1.2	-
Mg "	1.1	8.8
K "	0.5	2.8
p (ppm)	6	110
Mn (me/100g)	0.7	-
Exch. acidity (me/100g)	0.6	-
pH-H_2O (1:1 v/v)	5.2	-
C %	5.3	-
N %	0.48	-
CEC clay (me/100g)	30	-
CEC-carbon (")	150	-

Clay mineralogy: Top-kaolinite; sub-dominantly amorphous

ANNEX 4: Proposal for grading of land qualities (partly after Van de Weg and Braun, 1977).

1. Availability of water

Grade	No. of continuous moisture sufficiency months	Requisite available moisture carrying capacity (mm)
1. very high	above 10	above 200
2. high	6 - 10	125-200
3. moderate	3 - 6	90-125
4. low	below 3	below 90

2. Chemical soil fertility

class R_1	I m.e% CEC or sum cations	Rating T_2	Hp m.e%	Exch. K m.e%	II Avail. P ppm	P sorbtion %	C%
1	above 16	1	0-tr	above 0.6	above 60	below 25	above 2.5
2	12-16	2	tr-0.5	0.2-0.6	20-60	25-50	1.5 2.5
3	6-12	3	above 0.5	0-0.2	below 20	above 50	0-1.5
4	2-6	-	-	-	-	-	-
5	0-2	-	-	-	-	-	-

III
25% Extractable nutrients

Rating T_3	Ca m.e%	Mg m.e%	K m.e%	P ppm
1	above 75	above 40	above 25	above 500
2	25-75	10-40	5-25	250-500
3	0-25	0-10	0-5	0-250

Class R_2	Sum T_2	Class R_3	Sum T_3
1	0-5	1	0-4
2	6-10	2	5-8
3	11-15	3	9-12

Final grading is combination of classes, R_1, R_2 and R_3 as follows:

Grade of fertility	Combination							
1	111	211						................very high fertility
	112	212						
2	113	213						................high
	121	211						
	122							
3	123	222	311	321				..........moderate
	131	223	312	313				
4	132	231	323	332	412	432		.....low
	133	322	331	411	413	422		
5	232	333	432	511	513	522	531	533 .....very low
	233	423	433	512	521	523	532	

3. Presence/hazard of alkalinity/sodicity/alkalinization

Grade	ESP 0-30 cm	ESP 30-100 cm
1	less than 6	less than 15
2	6-15	15-30
3	15-30	30-50
4	30-50	more than 50
5	more than 50	more than 50

4. Resistance to sheet erosion
Determined by the sum of classes of slope class, climate, slope length and erodability.

Grade	Sum of classes of slope, climate, slope length and erodability
1. very high resistance	3- 5
2. high resistance	6- 8
3. moderate resistance	9-11
4. slight resistance	12-14
5. very slight resistance	15-17

5. Possibility to use mechanical implements cultivation by hand only

possibility	Lowest class allowed for slope	stoniness	workability
1. very high	1	2	2
2. high	2	3	3
3. moderate	3	4	4
4. low	4	5	5
5. very low	5	5	5

Cultivation with mechanical implements

Grade of possibility to use mechanical implements	slope oxen	slope others	Lowest class allowed for stoniness	work-ability	slope length	width of field
1. very high	1	1	1	3	1	1
2. high	2	1	2	4	2	2
3. moderate	3	2	3	5	3	3
4. low	-	3	4	5	3	3
5. very low	-	4	5	5	5	5

6. Presence/hazard of waterlogging

Grade	Drainage class	Colour and mottling
1. none	good to excessive drainage	no distinct mottling within 90 cm and/or reduced colours within 120 cm
2. slight	moderate drainage	no distinct mottling within 50 cm and/or reduced colours within 120 cm
3. moderate	imperfect drainage	no reduced colours or distinct mottles within 50 cm
4. high	poor drainage	partly reduced colours and distinct mottles within 50 cm
5. very high	very poor drainage	predominantly reduced colours

7. Hinderance by vegetation

Grade	Physiognomic type
1. none to very slight	grassland, bushed wooded grassland and wooded grassland
2. slight	bushed grassland, and wooded bushed grassland
3. moderate	bushland, wooded bushland, bushed woodland and woodland
4. high	dense bushland, dense wooded bushland, dense bushed woodland and dense woodland
5. very high	bushland thicket and wooded bushland thicket

8. Risk of overgrazing

Grading based on visual observations and estimates in the field.

Grade	Index
1. none to very slight	actual biomass production is 80% to 100% of potential one
2. slight	actual biomass production is 60% to 80% of potential one
3. moderate	actual biomass production is 40% to 60% of potential one
4. strong	actual biomass production is 20% to 40% of potential one
5. very strong	actual biomass production is zero to 20% of potential one

9. Conditions for germination

	Grade	Topsoil structure	Erodability based on sum of classes of organic matter, flocculation index, silt/clay ratio and bulk density
1.	very high	single grain, crumby granular	4-5
2.	high	medium sub-angular blocky	6-7
3.	moderate	coarse sub-angular blocky	8-9
4.	low	massive	10-11
5.	very low	platy	12

10. Availability of foothold for roots

	Grade	Depth to bedrock or a pan
1.	very high	more than 150 cm
2.	high	80-150 cm
3.	moderate	50- 80 cm
4.	low	25- 50 cm
5.	very low	less than 25 cm

11. Availability of drinking water

Grade	
1	very high
2	high
3	moderate
4	low
5	very low

12. Presence of forest fire hazard

Grade	
1	very low
2	low
3	moderate
4	high
5	very high

13. Presence of windfall hazard

Grade	
1	very low
2	low
3	moderate
4	high
5	very high

14. Risk of periodically occurring pests and diseases

Grade	
1	very low
2	low
3	moderate
4	high
5	very high

15. Availability of conditions for pond construction

Grade	
1	very high
2	high
3	moderate
4	low
5	very low

ANNEX 5: The current land suitability for small scale rainfed arable farming for non-cereal annual crops at low level of management (i.e. assuming low input)

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
Upr1			X	
UPr2			X	
UPr3			X	
UPb1			X	
UPb2			X	
UPb3			X	
UPb4			X	
UPb5			X	
UPb6			X	
UPb7			X	
UPb8			X	
UPb9			X	
UPb10			X	
UPb11			X	
UPb12			X	
UPb13			X	
UPb14			X	
UPb15			X	
UPb16			X	
UPb17			X	
UPb18			X	
UPap			X	
LPa1			X	
LPa2				X
LPa3p				X
LPa4p				X
LPa5p				X
LPa6p				X
LPa7p				X
LPa8p				X
LPa9p				X
LPa10p				X
LPa11p				X
BPp				X

ANNEX 5B: The current land suitability for small scale rainfed arable for non-cereal annual crops at intermediate level of management (i.e. assuming medium input).

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
UPr1			X	
UPr2			X	
UPr3		X		
UPb1			X	
UPb2		X		
UPb3			X	
UPb4		X		
UPb5		X		
UPb6		X		
UPb7			X	
UPb8p			X	
UPb9p			X	
UPb10p		X		
UPb11p		X		
UPb12p		X		
UPb13p			X	
UPb14p			X	
UPb15p			X	
UPb16p			X	
UPb17p			X	
UPb18p			X	
UPap			X	
LPa1			X	
LPa2				X
LPa3p				X
LPa4p				X
LPa5p				X
LPa6p				X
LPa7p				X
LPa8p				X
LPa9p				X
LPa10p				X
LPa11p				X
BPp				X

ANNEX 5C: The current land suitability for medium scale rainfed arable farming for wheat/barley/oats at intermediate level of management (i.e. assuming medium input).

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
UPr1			X	
UPr2			X	
UPr3		X		
UPb1			X	
UPb2		X		
UPb3			X	
UPb4		X		
UPb5		X		
UPb6		X		
UPb7			X	
UPb8p			X	
UPb9p			X	
UPb10p		X		
UPb11p		X		
UPb12p		X		
UPb13p			X	
UPb14p			X	
UPb15p			X	
UPb16p			X	
UPb17p			X	
UPb18p			X	
UPap			X	
LPa1			X	
LPa2				X
LPa3p				X
LPa4p			X	
LPa5p				X
LPa6p				X
LPa7p				X
LPa8p				X
LPa9p				X
LPa10p				X
LPa11p				X
BPp				X

ANNEX 5D: The current land suitability for small scale rainfed arable farming for fruit trees at intermediate level of management (i.e. assuming medium input).

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
UPr1		X		
UPr2			X	
UPr3		X		
UPb1			X	
UPb2		X		
UPb3			X	
UPb4		X		
UPb5		X		
UPb6		X		
UPb7			X	
UPb8p		X		
UPb9p		X		
UPb10p		X		
UPb11p		X		
UPb12p		X		
UPb13p			X	
UPb14p			X	
UPb15p			X	
UPb16p			X	
UPb17p			X	
UPb18p			X	
UPap			X	
LPa1			X	
LPa2				X
LPa3p				X
LPa4p			X	
LPa5p			X	
LPa6p			X	
LPa7p				X
LPa8p				X
LPa9p				X
LPa10p				X
LPa11p				X
BPp				X

ANNEX 5E: The current land suitability for small scale grazing for cattle and sheep at intermediate level of management (i.e. assuming medium input)

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
UPr1		X		
UPr2		X		
UPr3	X			
UPb1		X		
UPb2	X			
UPb3		X		
UPb4	X			
UPb5	X			
UPb6	X			
UPb7		X		
UPb8p		X		
UPb9p		X		
UPb10p	X			
UPb11p		X		
UPb12p	X			
UPb13p		X		
UPb14p			X	
UPb15p		X		
UPb16p		X		
UPb17p		X		
UPb18p		X		
UPap		X		
LPa1			X	
LPa2				X
LPa3p				X
LPa4p			X	
LPa5p			X	
LPa6p			X	
LPa7p				X
LPa8p				X
LPa9p			X	
LPa10p				X
LPa11p			X	
BPp				X

ANNEX 5F: The current land suitability for tree production for firewood and building poles (i.e. assuming medium input).

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
UPr1	X			
UPr2		X		
UPr3	X			
UPb1		X		
UPb2	X			
UPb3		X		
UPb4	X			
UPb5	X			
UPb6	X			
UPb7		X		
UPb8p	X			
UPb9p	X			
UPb10p	X			
UPb11p	X			
UP12p	X			
UPb13p		X		
UPb14p		X		
UPb15p		X		
UPb16p		X		
UPb17p			X	
UPb18p			X	
UPap			X	
LPa1			X	
LPa2				X
LPa3p			X	
LPa4p			X	
LPa5p			X	
LPa6p			X	
LPa7p			X	
LPa8p			X	
LPa9p			X	
LPa10p				X
LPa11p			X	
BPp			X	

ANNEX 5G: The current land suitability for fish pond for fish production (i.e. assuming medium input).

Suitability class soil unit	1.1 highly suitable	1.2 moderately suitable	1.3 marginally suitable	3 unsuitable
UPr1				X
UPr2				X
UPr3				X
UPb1				X
UPb2				X
UPb3				X
UPb4				X
UPb5				X
UPb6				X
UPb7				X
UPb8p				X
UPb9p				X
UPb10p				X
UPb11p				X
UPb12p				X
UPb13p				X
UPb14p				X
UPb15p			X	
UPb16p			X	
UPb17p				X
UPb18p			X	
UPap		X		
LPa1		X		
LPa2		X		
LPa3p		X		
LPa4p		X		
LPa5p		X		
LPa6p		X		
LPa7p		X		
LPa8p	X			
LPa9p		X		
LPa10p	X			
LPa11p		X		
BPp		X		

ANNEX 6: Scientific names of the crops mentioned in the report.

Common name	Scientific name
Apples	*Malus pumila*
Bananas	*Musa spp.*
Barley	*Hordeum spp.*
Beans	*Phaeseolus vulgaris*
Beet/Mangold	*Beta vulgaris*
Cabbages	*Brassica oleracea (Capitata* group)
Carrots	*Daucus sativa*
Cassava	*Manihot spp.*
Cauliflower	*Brassica oleracea (Botrytis* group)
Coffee	*Coffea*
Kale	*Brassica oleracea (Acephala* group)
Leek	*Allium porrum*
Linseed	*Linum usitatissimum*
Maize	*Zea mays*
Mangold/Beet	*Beta vulgaris*
Oats	*Avena sativa*
Onion	*Allium cepa*
Pawpaw	*Carca papaya*
Peaches	*Prunus persica*
Pears	*Pyrus communis*
Peas	*Pisum sativum*
Plums	*Prunus domestica*
Potatoes	*Solanum tuberosum*
Pyrethrum	*Crysanthemum cinerariaefolium*
Rice	*Oryza sativa*
Sorghum	*Sorghum vulgare*
Sunflower	*Helianthus annuus*
Sweet potatoes	*Ipomea batatus*
Wheat	*Triticum spp.*

N.N. Nyandat

CLIMATE AND SOILS OF THE SOUTH KINANGOP PLATEAU OF KENYA
Their limitations on land use

Thesis
Submitted for the degree of
doctor of agricultural science
of the Agricultural University
at Wageningen

CURRICULUM VITAE

The author was born on Kenya on 16 june 1937. He obtained his Cambridge School Certificate in Kenya at the C.M.S. Maseno School in 1958 before proceeding to Makerere University College in Uganda where he obtained a B.Sc. degree of the University of London in 1963. In 1965 he went to the University of Reading in England where, in 1967, he obtained a M. Agric. Sc. degree with specialization in Soil Science.

From 1964 to 1980 the author was employed as Agricultural Research Officer in the Ministry of Agriculture and carried out a number of soil surveys as well as laboratory soil investigations. He rose to the position of the Head of Soil Survey in 1972 before becoming the Director of the National Agricultural Laboratories in 1978. In 1981 he transferred to the Kenya Ministry of Environment and National Resources to be the Deputy Director of the National Environment Secretariat. For a period of three years, from 1982 to 1984, he was on secondment to Egerton College in Kenya where he was a Principal Lecturer in Soil Science.