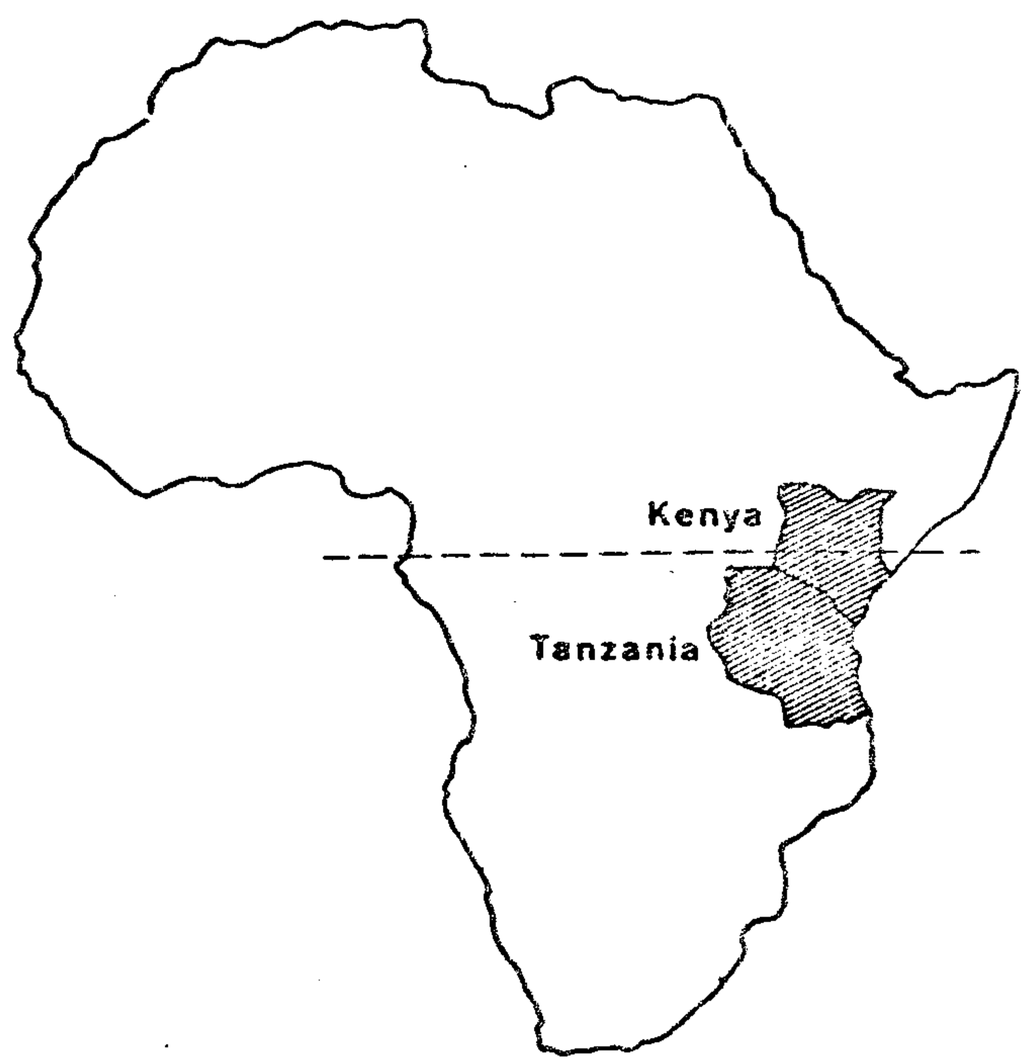
LAND USE IN KENYA AND TANZANIA

THE PHYSICAL BACKGROUND AND PRESENT SITUATION AND AN ANALYSIS OF THE NEEDS FOR ITS RATIONAL PLANNING

Edited by

BJÖRN LUNDGREN



ROYAL COLLEGE OF FORESTRY

International Rural Development Division

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PREFACE

The present report has been prepared on request by the Agricultural Division of the Swedish International Development Authority (SIDA). A working group, made up of experts in various fields related to land use, and with experience from developing countries, was first convened in January 1974.

There are many reasons why it has taken almost two years to complete the report. It first took five or six meetings, extended over half a year, to agree upon the aims and scope of the work. Secondly, the work has been carried out in spare time by most members of the group. The contents of the report, furthermore, gradually became much more extensive then was originally anticipated. The undersigned, who has served as coordinator of the work since June 1974, must take the full blame for this growth of the contents. In January 1975, I spent one week each in Dar es Salaam and Nairobi respectively, to collect relevant information for the study. As a result of this, a thorough revision was necessary to up-date all work that had been done until then. The editorial work, finally, has been very time-consuming and labourious.

Considering that only a symbolic remuneration has been paid to compensate the groupmembers for their work and that the amount of leisure time used by the individual member for the work, by far has exceeded what he originally had expected, it is surprising that nobody, for these reasons, has jumped off. This is due to the professional conviction, shared by all in the group, that the report will, if properly used, serve an important purpose.

When it became clear that the work should be fairly extensive, SIDA transferred the administration of the work to the International Rural Development Division at the Royal College of Forestry. It is also the staff of this Division that should have much of the credit for the smooth running of the work. We owe particular debt to Miss A. M. Samuelson, who for the last half year has shared the ungratifying task of coordinating much of the editorial work. Not only has she done this in a very competent way, she has also given many valuable comments on the contents of the report and on the design of figures and maps. Thanks are also due to Mrs E. Arvidsson, Mrs E. Nilsson and Mrs A. Örtenblad for valuable assistance, and naturally to the Head of Division, Mr S. Norén for giving high priority to this work by allocating much of the time of his staff to the work.

The visual result of the work - the report you are holding in your hand - is the result of two persons' skilful and patient work; Mrs K. Jordansson who has done the typescript and Miss G. Karlsson who has drawn all the maps and figures.

To all those persons, too many to mention individually, who have in one way or another helped individual group members, we extend a collective thank. I would also personally like to thank my Head of Department, Prof. T. Troedsson and the Principal of the College, Prof. M. Bendz, for having been lenient with my neglect of my ordinary duties for the last year.

Finally, we regret that the limited funds have not allowed a scrutiny, by a competent person, of the treatment of the English language in the text.

Stockholm in November 1975

Björn Lundgren

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Presentation of the authors

The group that has prepared the final version of this report consists of seven members, each with experience in practical and/or theoretical work on various aspects of land utilisation in developing countries. As a service to those readers who might want to know more about specific problems dealt with in the report, the individual members are presented below, together with a list of the chapters and sections they have been responsible for. In the initial phases of the work Dr. Nils Nykvist, now Forest Ecologist in Tanzania, and Dr. Jürg Mahner, now at the Swedish Ministry of Foreign Affairs, also participated.

Erik Danfors (ED), Senior Lecturer in Soil Science and Biohydrology, Department of Land Improvement and Drainage, Royal Institute of Technology, Stockholm.
Ph. D. (Soil Science) from Michigan State Univ., 1961.
President of the Swedish Soil Science Society 1974-77.
Research on soil aeration and soil water balance in USA, Australia and Sweden. Development of measurement techniques for oxygen diffusion and water distribution in soils.
Leader of Post-Graduate courses in Israel (1969, 1971), Cyprus (1969) and Kenya/Tanzania (1974).
Editor of the text-book "Arid Zone Irrigation" (1973), Springer Verlag.

Chapters and sections: 3.1./3.5./4.4./4.6./5.3./6.3.1./6.3.3.3. (together with AP)/6.4.1.1. (together with BL)/ 6.4.3. (together with BL)/6.5.4./.

Anders Hjort (AHj), Acting Head of the Development Section at the Department of Social Antropology, University of Stockholm.
Work and research on rural development in Kenya 1972-74.
Publications:
"Socio-economic effects of rural electrification in Kenya" (1974)
"Ethnicity and economy in a savanna town" (1975)

Chapters and sections: 2.1./2.2./2.3.1./2.3.2./2.3.3. (together with HL)/4.1./5.1. (together with AR)/5.2./6.3.4./6.6.1./6.6.2./6.9.1. (together with HL)/6.9.2./.

Harald Linder (HL), Licentiate of Agronomy, Head of Department at the Swedish National Board of Agriculture, Jönköping.
Head of Crop Production Department at CADU and Assistant Head of Extension Department at EPID, Ministry of Agriculture, Ethiopia, 1966-73.
Agricultural consultant in appraisal teams in Ethiopia and Tanzania, 1974.
Publications:
"Crop production improvement - an integrated part of agricultural development. Activities in CADU 1966-1970". Thesis (1974).
Various reports on agricultural conditions and on research and survey work at the CADU project.

Chapters and sections: 2.3.3. (together with AHj)/4.2.1./4.2.2./4.2.3./ 5.5.1. (together with AP)/6.5.1./6.8./6.9.1. (together with AHj)/6.9.3./.

Björn Lundgren (BL), Research assistant, Department of Forest Soils, Royal College of Forestry, Stockholm.
Lecturer in Forest Biology at Makerere University, Kampala, Uganda 1972-73 and at the University of Dar es Salaam, Tanzania 1973-74.

Research on forest soils and ecology in Ethiopia 1969 and in Tanzania 1970-75.
Various publications on soils and ecology of East African natural and plantation forests.

Chapters and sections: 1./3.4./3.6./4.5./6.1./6.2./6.3.2./6.3.3.1./ introduction to 6.4./6.4.1.1. (together with ED)/6.4.1.2./6.4.1.3/ 6.4.1.5./6.4.1.6./6.4.3. (together with ED)/introduction to 6.5./ introduction to 6.6./6.6.3./6.9.4./6.10. (together with AP)/Coordinator of the work and editor of the report/.

Anders Persson (AP), Licentiate of Forestry, Research Leader, Department of Forest Genetics, Royal College of Forestry, Stockholm.
Forest Research Officer at the Silviculture Research Station, Lushoto, Tanzania 1969-1972, in charge of tree breeding, species and provenance trials and related subjects.
Publications:
"Feasibility study of RUVU forest plantation project". 1972.
Various publications on tree breeding and silviculture in Tanzania.

Chapters and sections: 4.3./5.5.1. (together with HL)/5.5.3./5.5.4./ 5.6./6.3.3.3. (together with ED)/6.5.3./6.10. (together with BL)/.

Sven Persson (SP), Animal husbandry advisor at the County Agricultural Board, Malmö, Sweden.
Head of Animal husbandry and breeding section at CADU, Ethiopia, 1970-73.
IBRD consultant in the Agricultural Sector Survey team in Tanzania 1973.
Publications:
"An illustrated guide to the grasses of Ethiopia", CADU, 1974 (together with B. Fröman).
"Cattle production in Africa", Uppsala, 1974 (together with K. E. Sjöberg).

Chapters and sections: 4.2.4./5.5.2./6.5.2./.

Anders Rapp (AR), Associate Professor in Physical Geography at the University of Uppsala, Deputy Director Secretariat for International Ecology (SIES), Stockholm.
Leader of the Dar es Salaam/Uppsala Universities Soil Erosion Research project (DUSER) in Tanzania 1968-72. Member of expert panels in UNESCO and FAO on soil erosion and sedimentation.
Field research on gemorphology, particularly erosion and sedimentation, in Tanzania, Kenya, Leshoto, Tunisia and the Sudan.
Publications:
"Studies of soil erosion and sedimentation in Tanzania". Geogr. Ann. (1973).
"A review of desertization in Africa - Water, Vegetation and Man", SIES (1974).
"Drought and soil erosion - two major factors in Africas environmental crisis", Svensk Naturvetenskap (1975).
Various (about 50) scientific publications.

Chapters and sections: 3.2./3.3./5.4./6.3.3.2./6.4.1.4./6.4.2./6.5.5./ 6.7./.

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1. INTRODUCTION

Social and economic development is a many-faceted problem. To achieve development, one of the most fundamental prerequisites is to use the land resources in a way that not only meets the immediate requirements to feed people, but also creates the surplus necessary for growth. The crucial role of a rational, non-destructive land use for the developing countries was, for example, strongly emphasised at the UN Conference on the Human Environment in Stockholm 1972 and at the FAO World Food Conference in Rome 1974.

Two major bottlenecks are, a) inadequate knowledge about the physical resources, and, b) lack of expertise to evaluate and translate existing knowledge into sound land use practices.
One of the principal trends in international aid and cooperation has therefore been, and will continue to be, the transfer of know-how within practically all fields related to land use.

Knowledge and experience from developed countries in temperate regions are, however, not directly applicable to the ecological conditions in the humid and arid tropics and to the socio-economic conditions in developing countries. An early, illuminating example of the validity of this basic statement is the large Groundnut Scheme in Central and South East Tanganyika in 1947-53, by which the British Government in a short period invested enormous amounts of capital to establish, with modern techniques, large groundnut plantations. The more or less complete failure of this project was attributable to inadequate knowledge of local conditions of soil, climate and vegetation, as well as to improper prefeasibility studies of labour and transport conditions.

The present report has been compiled to enable the Swedish International Development Authority (SIDA), and technical personnel working for it, to better understand the difficulties and problems connected with land resources development in Kenya and Tanzania.

The original request from SIDA, when convening the working group that has prepared the report, was to make a concrete land use potential assessment for physically defined regions within a number of countries receiving Swedish aid. The ultimate aim should be to enable SIDA to establish policy priorities concerning the types of land use development that Swedish aid should concentrate on in the different regions.

It was soon realised by the group, that making such an assessment, as a desk and literature study thousands of kilometers away from countries that some had never seen, was not feasible. It would lead no further than the more or less well founded generalisations about land use potential found in any National Atlas or geography and agriculture text-book in the countries in question.

The very request from SIDA, however, served the purpose to convince us that there is a basic lack of understanding of the complexity of the problems concerning land use potential in tropical developing countries, as well as an ignorance about the actual level of knowledge about the physical conditions in these countries.

After lengthy initial discussions about the aims, extent and limitations of the work, the following points were decided upon:

- the study should be limited to Kenya and Tanzania, partly because all groupmembers were familiar with these countries, partly because they are main receivers of Swedish aid in the rural development sector,

- the report is primarily directed to
  (a) technical aid personnel dealing with various aspects of land utilisation in the field in Kenya and Tanzania, and
  (b) the SIDA administration,

- based on the above point, the two over-all aims of the report are
  (a) to describe the physical background and present land use, i.e. to serve as an introductory reference book for field personnel, and
  (b) to analyse the information requirements, needs and problems in land potential surveying and land use planning, i.e. to enable SIDA to adopt sound methods and policies in connection with planning land development projects.

To achieve these aims, the report has been divided into three main parts:

I. A background description, made up of chapters 2 and 3. In chapter 2, the geographic, historic, demographic and economic settings are briefly described. In chapter 3, the basic physical characteristics - climate, geology, landforms, soils, hydrology and vegetation - are described and their relevance to present land use and land potential are shortly explained.

II. A description of present land use, made up of chapters 4 and 5. Chapter 4 begins with a description of the historical development of land use policies and land tenurial practices. Comprehensive accounts are given of patterns and trends of the main forms of land use - agriculture, including animal husbandry, forestry, fisheries, wildlife and tourism and utilisation of water resources. In chapter 5 some major problems and conflicts in present land utilisation are focused upon, to give substance to the alleged need for land use planning.

III. An analysis and discussion of the problems of planning future land use, given in chapter 6. A separate introduction gives the aims and scope of that chapter.

The chapters are divided into sections (2.1., 3.1., etc.), each of which treats a well defined subject, except in chapter 6 where the sections make up a logical sequence in an analysis. In chapters 2-5, however, the sections can be read in isolation by anyone interested in a particular aspect of land use - e.g. the forester may get a comprehensive account of forestry in section 4.3., the botanist will find an introductory description of the vegetation in 3.6., the soil conservationist can get a regional description of soils in 3.4. and of soil erosion in 5.4., etc. Used in this way, the report will serve as an introductory reference work for various specialists.

For those, however, who will work with more integrated types of problems in connection with land development projects, it ought to be useful to read the whole report to obtain a picture of the complexity of land utilisation in Kenya and Tanzania. This is because there are valuable analyses and discussions in the descriptive chapters as well as much tangible information in the analysing chapter 6.

To those administrators, finally, who want to deduce some policy guidelines concerning methods and resource allocation in connection with land development aid projects, the main conclusions of chapter 6 are summarised in section 6.10. To understand, to the fullest extent, the importance of these conclusions, it is however necessary to read the elaborations in the previous sections of the chapter.

Some final introductory remarks should be made on the extent of the subject. "Land use" is not a well defined academic discipline, it is a collective term for practically all human activities which in one way or another affect, or are affected by, the physical and other features together constituting "land" (see further definitions in 6.2.). A minimum of reflection will make anyone realise that it is an impossible task to give a full account of all aspects of "land use".

We are well aware of the biases and incomplete coverage of this report. Nothing is mentioned, for example, about urban and industrial uses of land. Furthermore, economic considerations are only superficially treated. Within fields, which are not entirely inside the competence range of the group, we have probably rendered ourselves guilty of impermissible generalisations. The scrutinizing reader will most likely also be able to find contradictory statements, for the simple reason that there are different opinions on many important issues where knowledge is inadequate. These, and other, shortcomings should, however, not conceal the great value of the report as the first comprehensive compilation of information, focusing on present and potential rural land use in Kenya and Tanzania and its dependence on local physical and social features.

Although personal experience and original research findings and conclusions by the group members are integrated in the report, it is mainly for obvious reasons, a compilation of existing, published information from other texts. The literature on various aspects of land use in Kenya and Tanzania is far more extensive than is probably realised by people dealing superficially, or for a short time only, with land use questions in those countries. At the same time, it is very difficult to survey this rapidly growing amount of published material and many publications are practically inaccessible. As a service to those who want to penetrate further into some aspects of land utilisation, a bibliography has therefore been compiled and published under separate cover.

2. THE COUNTRIES AND THEIR PEOPLE

2.1. Geography and history

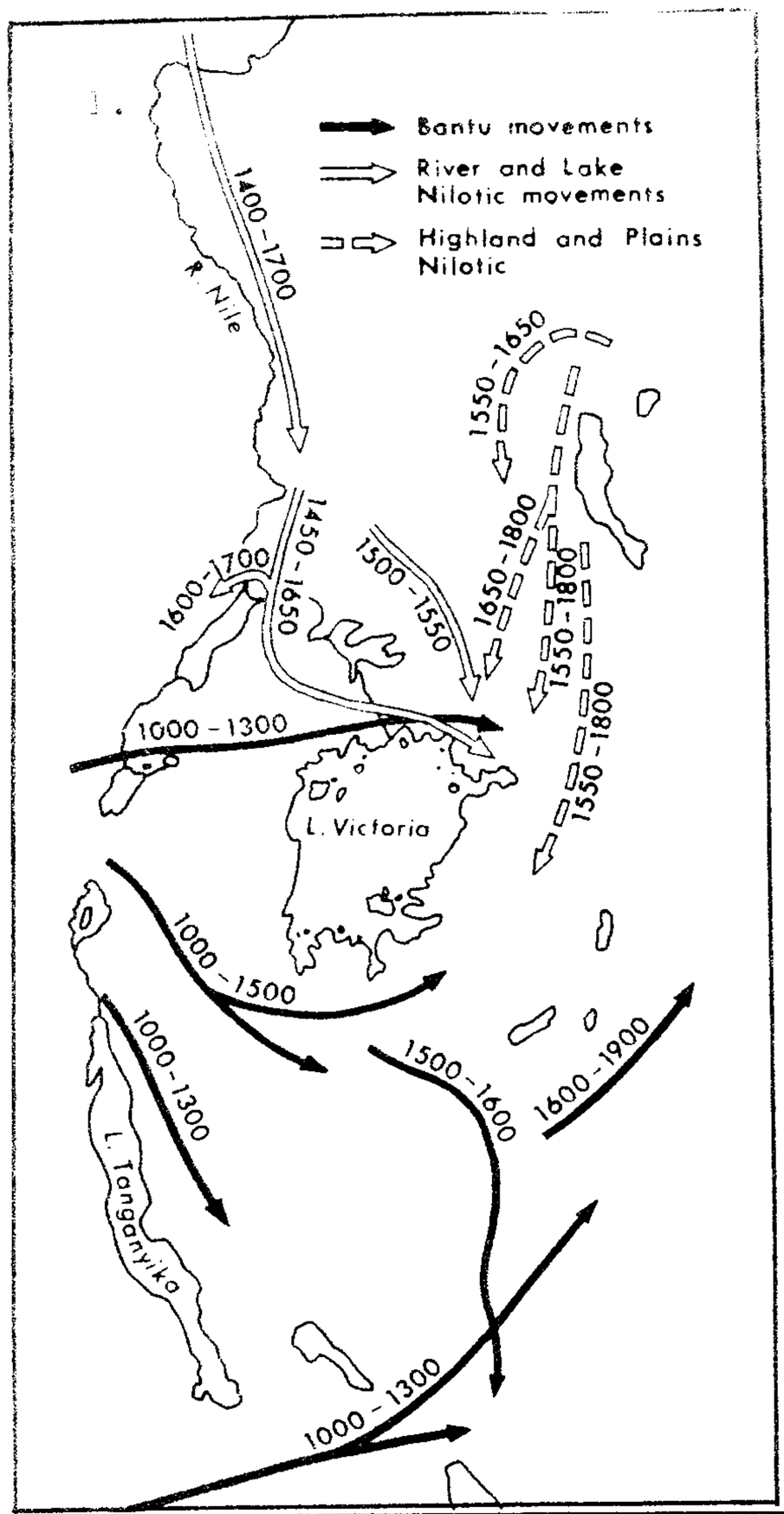
2.1.1. Geographic position

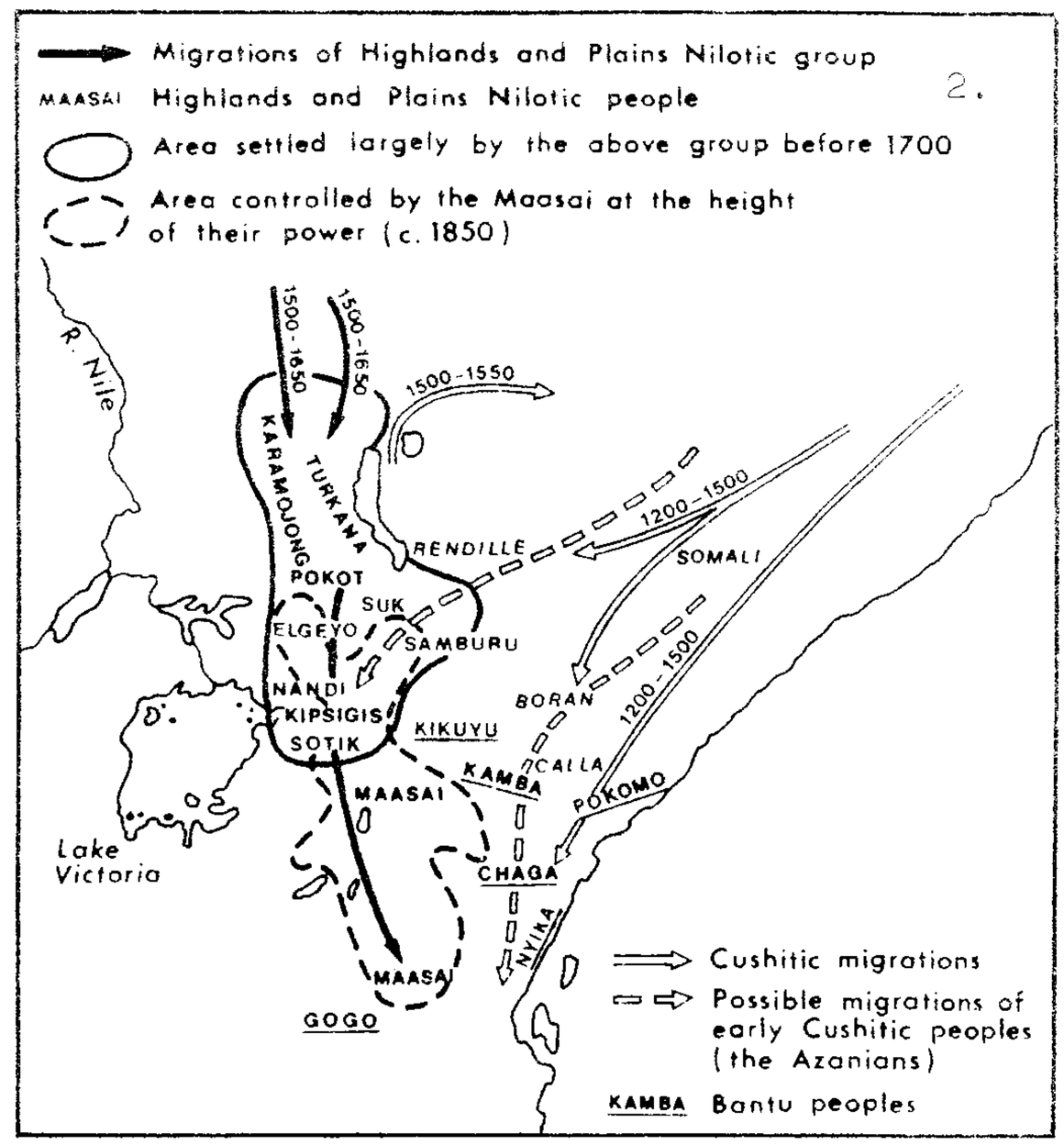
Situated on the Eastern side of the continent of Africa (see map on front page), between latitudes 4°30'N and 11°30'S, the two countries of Kenya and Tanzania cover an area of appr 1,510,000 km2 (Kenya 580,000 and Tanzania 930,000). Large parts of the region are made up by the East African plateauxlands a division of the African continent which is known to geographers as High Africa.
From its frontage on the Indian Ocean the East African region stretches inland to the western Rift Valley, to the west of which the well-marked basin of the Congo, with its floor at 500 m or less above sea-level, belongs to the different terrain of Low Africa. Frontage on the Indian Ocean comprises an important element in the space relations of East Africa. For many centuries there have been maritime contacts between the various coastlands of the Indian Ocean.

2.1.2. Pre-colonial history

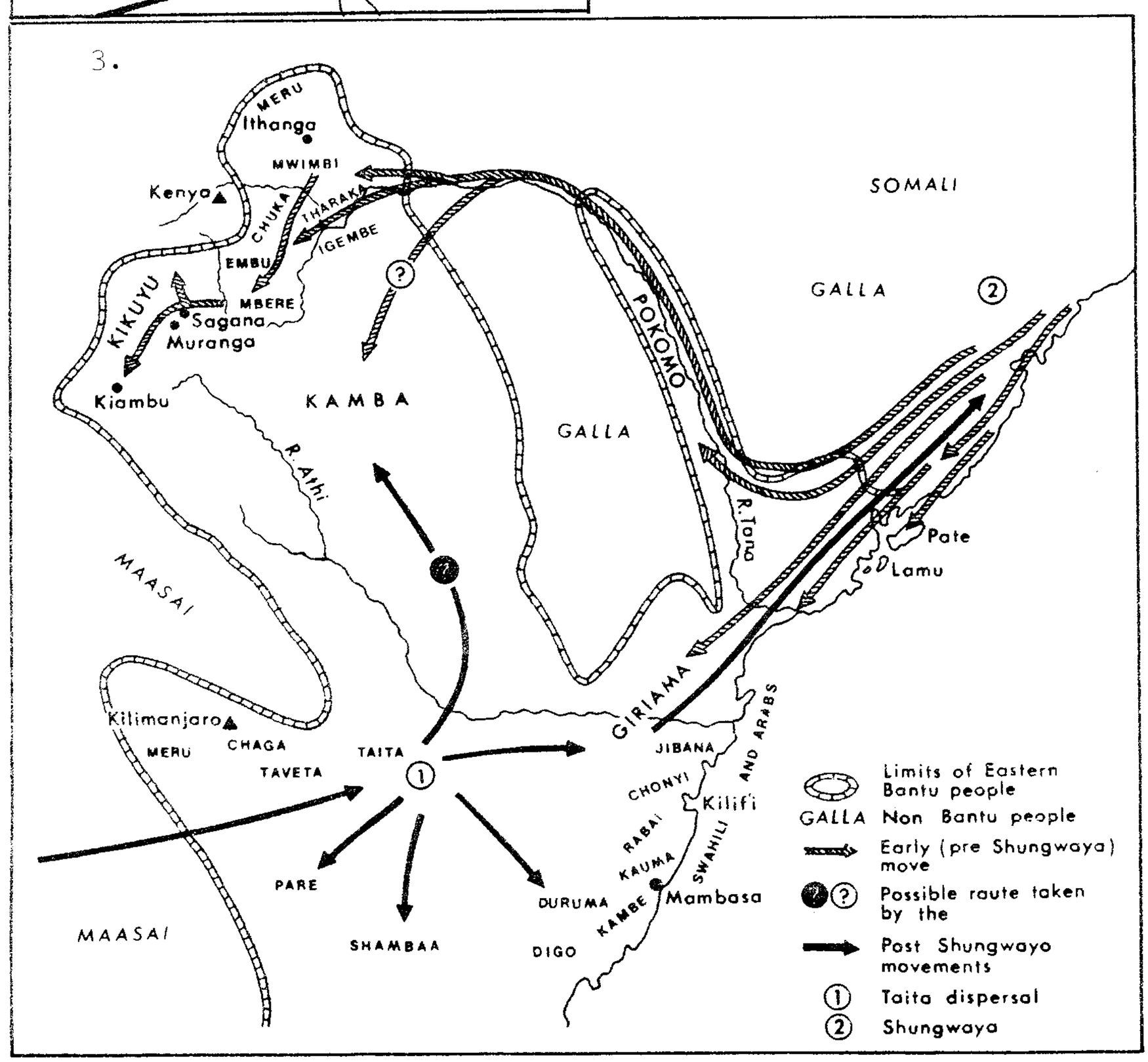
The origins of the ethnic groups in Kenya and Tanzania go back far beyond the range of tradition. Large movements of peoples happened right up to the beginning of colonial rule. Peoples replaced one another, groups of people were assimilated voluntarily or by force. All societies observable today or recently have changed during the past century or less. Many of their traditions have held sufficiently firm for the trained observer to spot the important point of transition and to list to some extent the consequential changes.

At the arrival of colonial rule (i.e. towards the end of the 19th century) the different groups had reached a territorial distribution where the characteristics of the areas they occupied were largely suited to their respective occupation. From map 3 one can distinguish a Bantu area roughly covering the southern two thirds of the East African interior and a Nilotic area in the north-west and enveloping on both sides an area of Nilo-Hamitic peoples in the north-center. Both of the northern areas extended into the Bantu area - a zone of Nilotic influence down the western side of East Africa and a zone of Nilo- Hamitic influence down the eastern part of the interior. There is a third, the coastal zone, inhabited by Bantu influenced partly from Hamitic, partly from overseas sources. This situation had developed through a complicated process of migrations. Figures 1-3 show the probable routes and times for the most important of these migrations.
It should be emphasized that especially the history of the Eastern Bantu is debated. The most accepted version, which is presented here (see fig. 3), says that the present Mt. Kenya inhabitants have their origin in the Shungwaya dispersal. The last of these groups arrived by the end of the 17th century, and the first in the beginning of the 14th century. Another version which has some backing in the Kikuyu oral traditions is that the Kikuyu and related groups came from the coast.
Influence from the coast was, generally speaking, very limited and reduced to slave trade and trade in ivory.





FIGURES 1-3. Probable migrations and dispersal of various peoples at different times in East Africa.
Source: Were & Wilson (1972)



In pre-colonial Africa migration and warfare, conquest and settlement, were not always the unmitigated evils they have been painted. Mostly, they were in fact - what later imperialism claimed to be - the means of communicating the achievements of the strong and successful to the weak and outpaced.

2.1.3. Colonial and post-colonial history

From 1899 onwards the British consolidated and expanded their control over Uganda. In connection with this the British East Africa Protectorate, which was established in 1895, spread its effective control slowly from the coast of Kenya towards the inland. Between 1904 and 1913 the Masai were moved several times and their land was occupied by white settlers (part of the former "White Highlands").

German East Africa was established in 1888 and was soon faced with resistance due to conflicting views on the land use. For example the Maji Maji Rising in 1905-1907 was sparked off by a cotton-growing scheme. In Kenya the Kikuyu Association was formed by Harry Thuku in 1920. Its goal was to defend Kikuyu land interests against the settlers´.

After World War I Great Britain was given a mandate over former German East Africa (after 1920 known as Tanganyika). Tanganyika´s economy had been hard hit by the war and it took several years from 1920 to put the plantations back into production. In Kenya, soldier-settlement schemes were introduced, but often unsuccessfully. Plantation agriculture took an important place in the economy.
It was not possible for Africans in Kenya to grow most cash-crops while in Tanganyika the Land Ordinance of 1923 made this possible. Especially in Kilimanjaro district the Chagga produced the greater part of Tanganyika´s coffee exports.

The different interests in British East Africa were focused on the land issue and can be summarized as follows:

1. British Government: European and African partnership, East African Federation, firm control from Britain, keep settlers under control, train Africans for Government "sometime".

2. Settlers: settler control of politics, white racial superiority, financial control for settlers, more European agricultural development, more independence from Britain, separate development of European and non-European communities.

3. Africans: greater share in Government, more land, better labour conditions, better educational opportunities, no racial discrimination.

4. Christian missionaries: faster advancement of Africans, more education for Africans, opposition to settler attitudes, dislike of some African customs, desire to "civilize" Africans, keep British control over settlers.

5. Asians: more land for Asians, greater share in Government for Asians, no racial discrimination.

During World War II Africans in Kenya were for the first time encouraged to produce cash crops and the people found a market for any foodstuffs they could sell. The number of political associations refusing European leadership grew. The settlers in Kenya, however, took the opportunity of Britain´s occupation with the war to strengthen their own political position.

In Tanganyika a programme for ultimately reaching self-government was drawn up. In 1954 Nyerere became president of TANU and, partly under the influence of experiences from the Mau Mau Emergency in Kenya, British authorities speeded up the development towards independence (1961). The United Republic of Tanzania was formed in 1964.

In Kenya tension grew between settlers and especially the Kikuyu over the right to land and trade. This led up to the Mau Mau Emergency 1953-60. Partly as a result of this a constitutional conference was convened and Kenya became an independent state in 1963.

As one result of independence in Kenya the former White Highlands are now open to African farmers, though only a few people have so far benefited from these measures. Furthermore, settlement schemes have enabled at least 35,000 peasant farmers to settle. Kenya favours a policy of private enterprise in conjunction with a wide measure of state control. The distribution of land as a property is considered to be the responsibility of the Government.

Tanzania has stated that her aim is to develop into a socialist state. At a conference in Arusha the TANU party decided to nationalize all major means of production. One result of the Arusha Declaration is the policy of Ujamaa Villages (see 4.1.), where land is owned on a cooperative bases.

2.2. Peoples and demography

2.2.1. Peoples

The conventional tribal classification of East African peoples distinguish between approximately 110 different groups in Kenya, Tanzania and Uganda. There are however no clearly marked territorial or cultural boundaries between them. Tribal groupings can be made according to ethnicity and culture or according to traditional economic systems. No total correlation can be stated between economic categories and historico-cultural clusters, as economic systems are primarily related to the existing environment. Normally environmental factors also influence non-economic aspects of social life strongly.

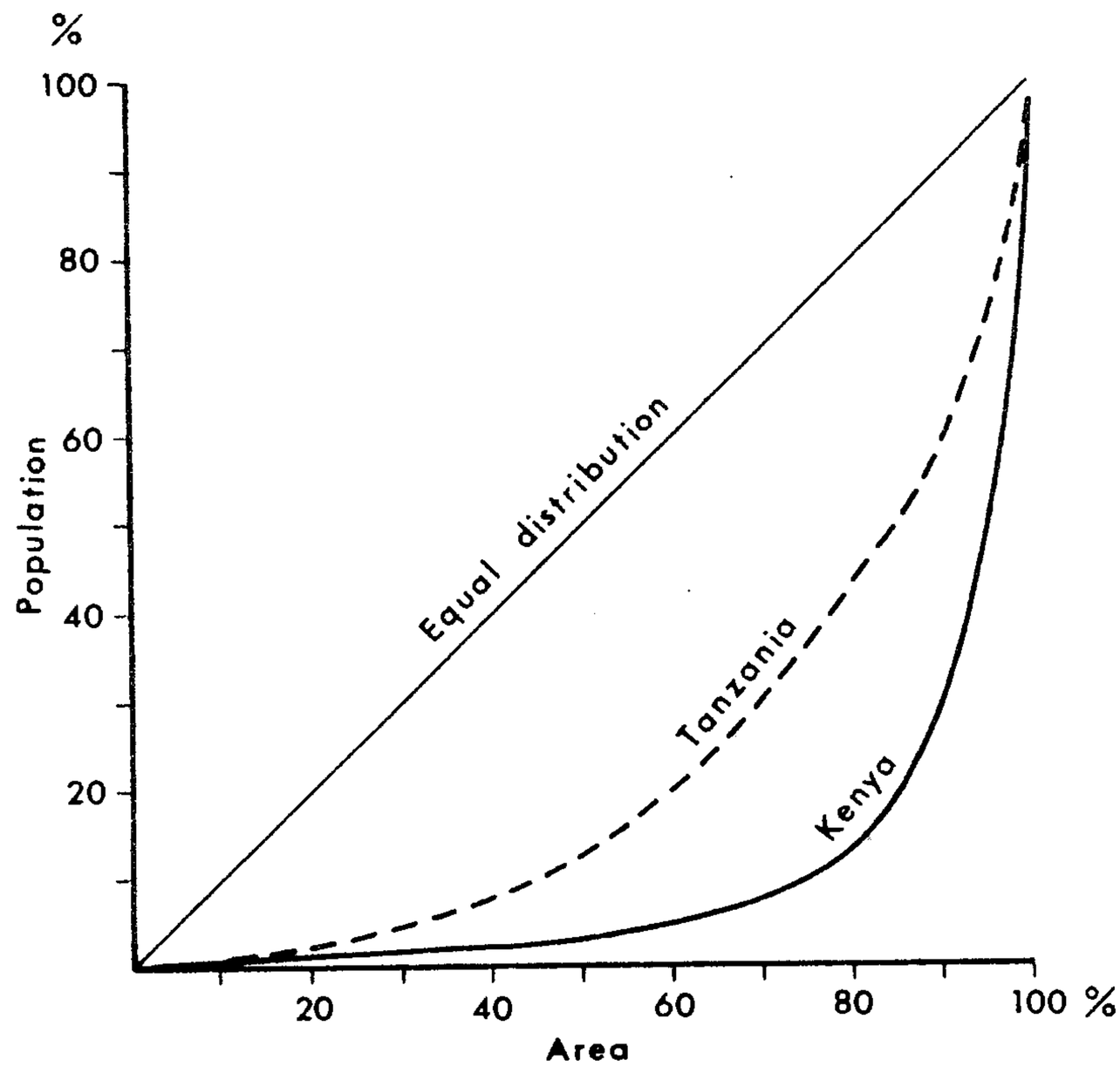
The basic changes that thave occurred in the last couple of decades have been towards agricultural development on the local level caused by an increase of population pressure and an increasing demand and necessity for cash income (cf. 5.1. and 5.2.).
A mixed economy has been established virtually everywhere outside the arid regions. These can only support smaller numbers of more or less mobile pastoralists. Whether the emphasis in these mixed economies is on crop production or on animal husbandry depends on a combination of environmental and demographic factors.

The manner in which the environmental possibilities are utilized depends on cultural factors and social organization. In the IBRD Report on Kenya, for example, two major reasons for the extreme variations in population densities are distinguished: that land is regarded as the exclusive domain of a particular tribe and that some land was set aside for large scale farms or set aside as Government Land. Both in crop production and animal husbandry we find a whole range of systems as radically different as complete individual control and action to cooperation, corporation and an emphasis on unity.
If the economic life of East African peoples were more influenced by environmental than cultural factors economic change through the introduction of new technologies would be relatively uncomplicated. That this has not ocurred to a larger degree in East Africa than is the case could be blamed on cultural conservatism. However, closer study suggests that when a people truly understands that changing conditions are to their advantage, then changes also do occur. Conservatism, especially in the economic sphere, seems less linked to cultural patterns than to feelings of insecurity when pople are faced with outside pressures and changes which are not properly understood (see also chapter 6.).

2.2.2. Demography

Environment is thus promoting certain economic systems and these systems are correlated to the demographic distribution of people. The population distribution (map 2) of the two countries clearly shows the concentration of people in the high and medium potential agricultural areas (see table 11). Population density figures for the countries in toto are not alarming (Kenya 23/km^2 and Tanzania 17/km^2). The uneven distribution due to the environmental conditions results however in very heavy population concentrations. The relative concentration of population can be illustrated with so called Lorenz curves (see fig. 4), where the cumulative % of population is ploted against the area, starting from the areas of lowest concentration.

FIGURE 4. Lorenz curves for Kenya and Tanzania.
Source: Morgan (1973)



In many areas around Lake Victoria densities of over 77 persons/km2 are common, even reaching such high numbers as around 385 in some subdistricts (among the highest in all Africa). Similarily the coastal belt shows high numbers, constantly increasing because of immigrant labour from all parts of East Africa.

TABLE 1. Population 1974.

	Kenya 1974	Tanzania 1974
African	12,660,000	14,730,000
Non-African	290,000	170,000
Total	12,950,000	14,900,000

NOTE: Figures extrapolated from last censuses (Kenya 1969, Tanzania 1967).

Population growth figures given for the two countries should be taken with care due to differences in reliability between consecutive censuses. They vary between 2.7% (Tanzania) and 3.5% (Kenya). Over half of the population is below 15 years of age. The previous censuses were not all too reliable and figures based on them are hardly accurate - in addition there was heavy immigration into the countries.
The number of Europeans and Asians or Arabs in the two countries are negligible in comparison to the total population though their economic influence is important, particularly in Kenya. Asians dominate the small trade though their influence is gradually reduced. Europeans still dominate industrial

investments, whereas their direct political influence has been reduced considerably and their land in Kenya to a large degree has been transferred to partly small-scale, but also large-scale African farmers. The figure for Arabs is incorrect in all censuses - due to political and status reasons the figure of those describing themselves as being "Arab" will always be unreliable.

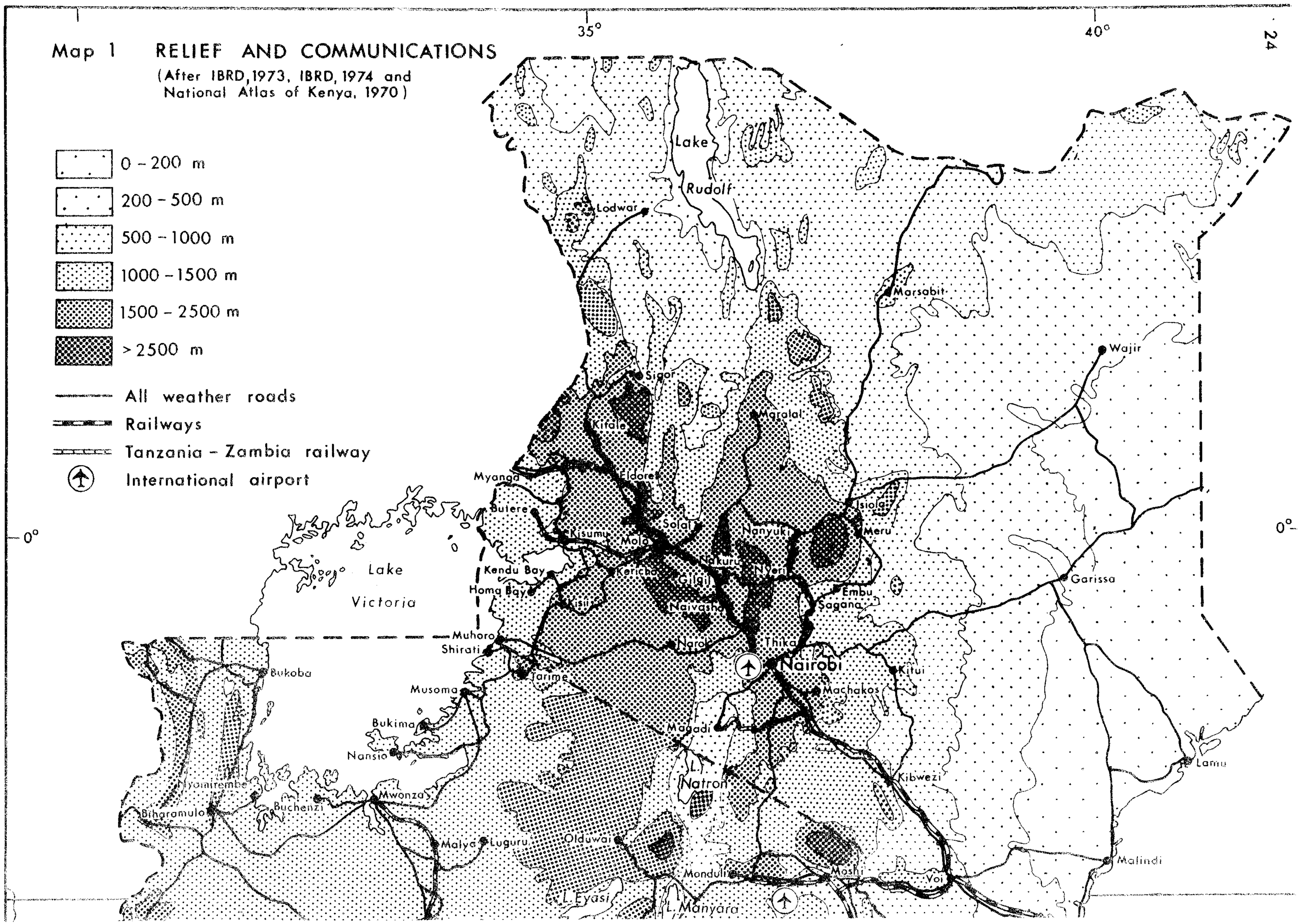
2.2.3. Migration and urbanization

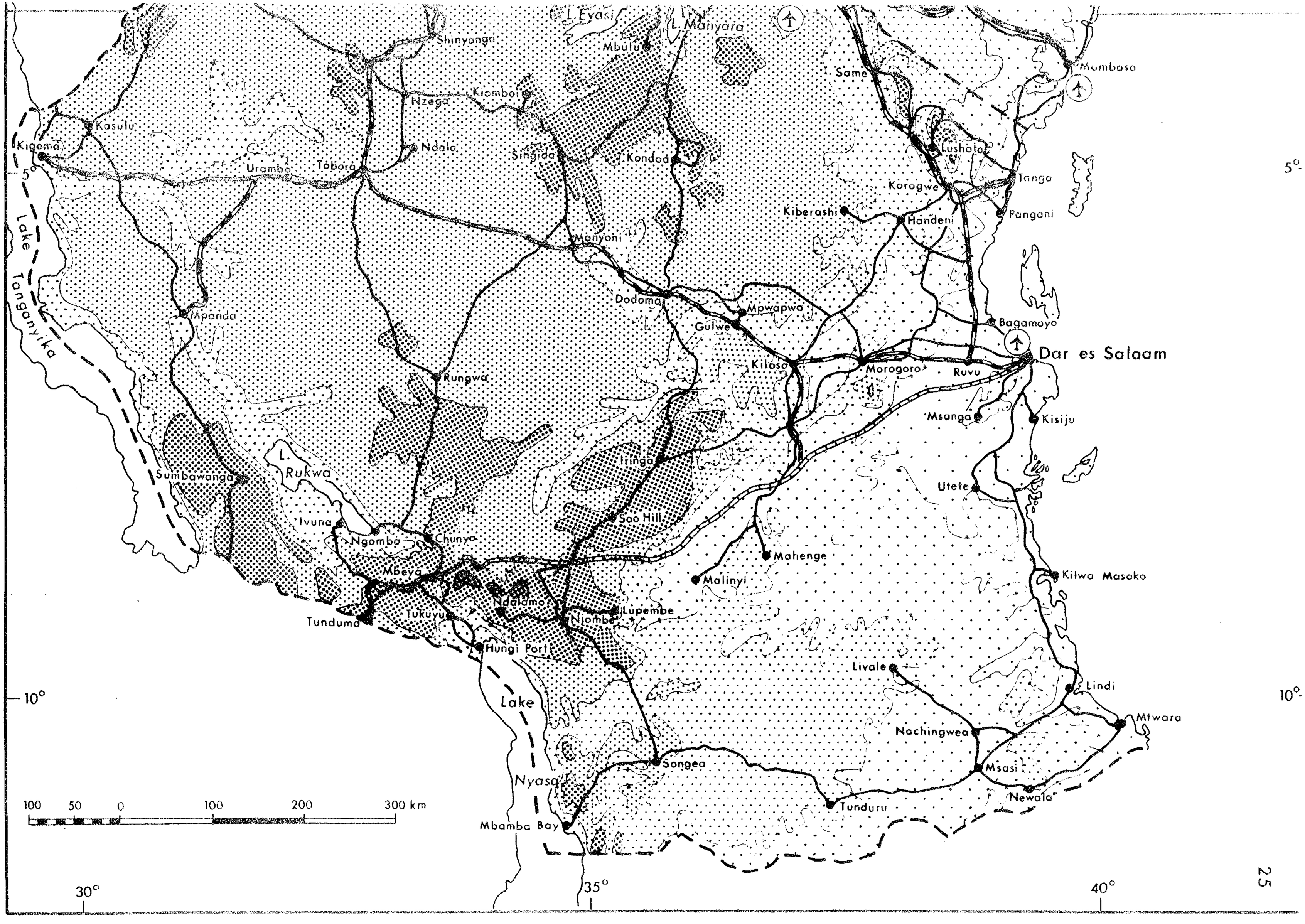
It is possible to distinguish two kinds of rural-urban migrants. The first category is made up of predominantly men who are landless or, maybe more often, whose farming efforts give too little yield to suffice for food and cash expenses. They tend to move to large urban areas (e.g. Nairobi, Mombasa, Nakuru in Kenya and Dar es Salaam, Arusha, Moshi in Tanzania) in steps, starting with the nearest local town, in search for jobs. During this search they rely on relatives or friends for housing and support. The second category consists of school leavers in search for job opportunities. Here the migration pattern is different in that they circulate between urban areas. They often have the possibility to return to their parents' farming activities. The expectations of this category is generally higher; they can be said to be moving in search for an improved standard of living whereas the first category moves out of pure necessity.

Migration has been increasing during the last ten years but not yet reached an extreme level. In Kenya, where migration is the largest problem, about 10% of the population live in urban centres of 2000 or more in size. Out of these, 70% live in Nairobi and Mombasa. In view of the migration pattern, however, these figures are unreliable and probably under-estimated. Also, the rate of growth has been extremely rapid in the last years.

Map 1 RELIEF AND COMMUNICATIONS

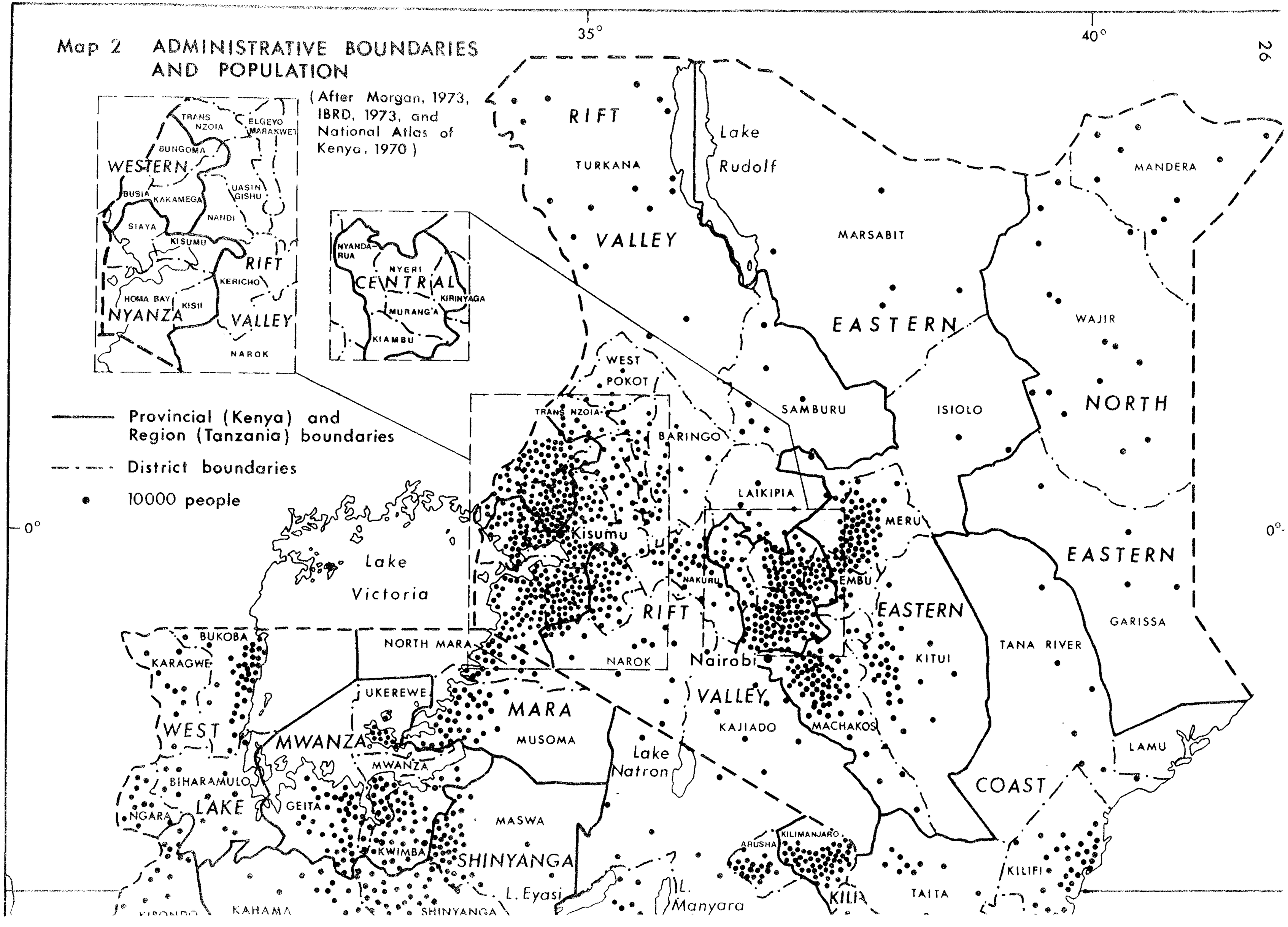
(After IBRD, 1973, IBRD, 1974 and National Atlas of Kenya, 1970)

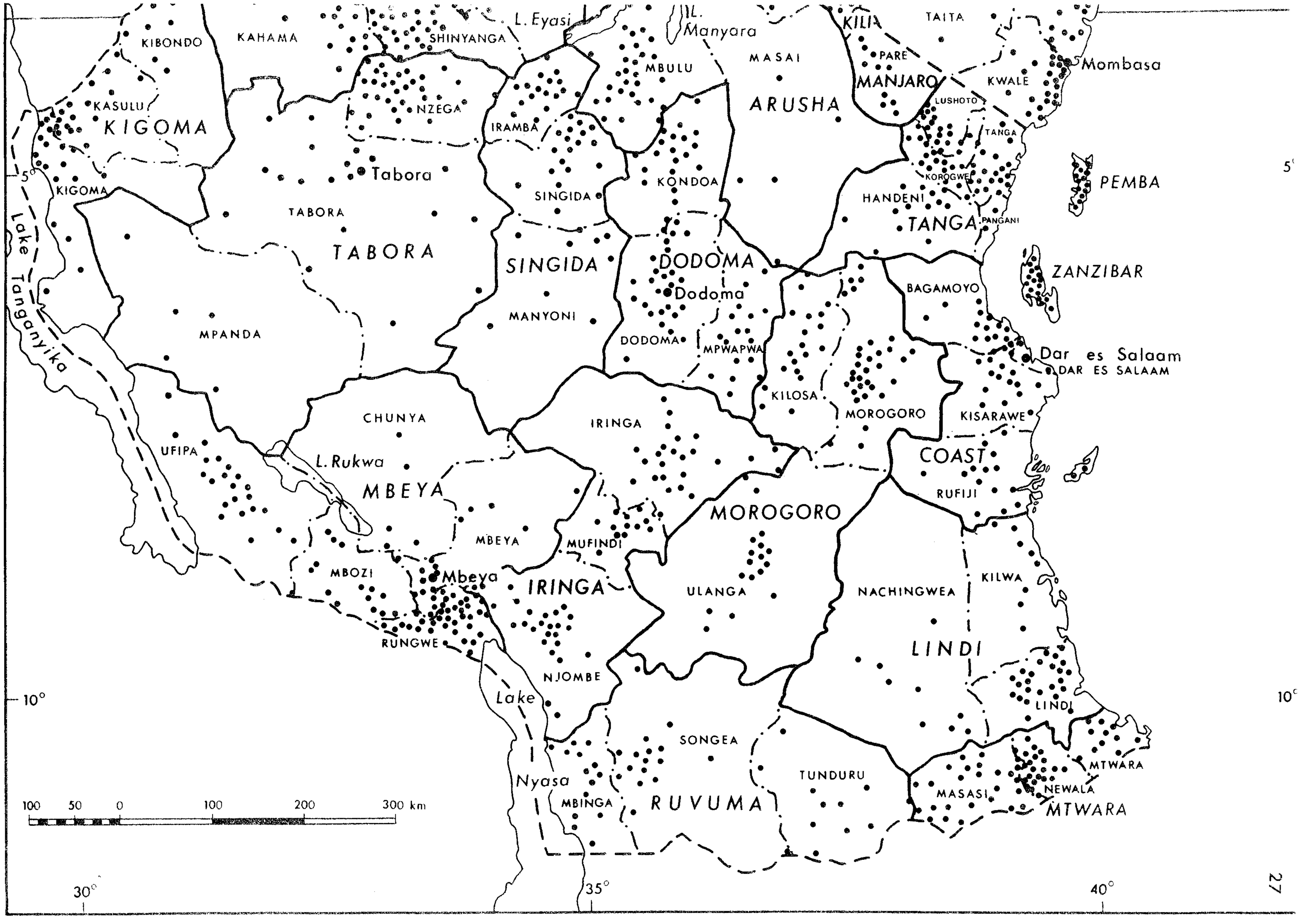



L. Eyasi
L. Manyara
Shinyanga
Mbulu
Same
Mombasa
Nzega
Kiomboi
Kasulu
Kigoma
Ndala
Singida
Kondoa
Lushoto
Urambo
Tabora
Korogwe
Tanga
Kiberashi
Handeni
Pangani
Manyoni
Lake Tanganyika
Dodoma
Mpwapwa
Mpanda
Gulwe
Bagamoyo
Dar es Salaam
Kilosa
Morogoro
Ruvu
Rungwa
Msanga
Kisiju
Iringa
L. Rukwa
Sumbawanga
Utete
Sao Hill
Ivuna
Ngombo
Chunya
Mahenge
Mbeya
Malinyi
Kilwa Masoko
Ndalamo
Lupembe
Tukuyu
Njombe
Tunduma
Hungi Port
Livale
Lindi
Lake Nyasa
Mtwara
Nachingwea
Songea
Msasi
Newala
Tunduru
Mbamba Bay
100 50 0 100 200 300 km
5°
10°
30°
35°
40°

Map 2 ADMINISTRATIVE BOUNDARIES AND POPULATION

(After Morgan, 1973, IBRD, 1973, and National Atlas of Kenya, 1970)




KIBONDO
KAHAMA
SHINYANGA
L. Eyasi
L. Manyara
KILIA
TAITA
PARE
MANJARO
KWALE
Mombasa
MASAI
ARUSHA
MBULU
NZEGA
IRAMBA
KASULU
KIGOMA
KIGOMA
Tabora
TABORA
TABORA
SINGIDA
KONDOA
SINGIDA
DODOMA
Dodoma
DODOMA
MPWAPWA
MANYONI
MPANDA
Lake Tanganyika
LUSHOTO
TANGA
KOROGWE
HANDENI
TANGA
PANGANI
PEMBA
ZANZIBAR
BAGAMOYO
Dar es Salaam
DAR ES SALAAM
KILOSA
MOROGORO
KISARAWE
COAST
RUFIJI
CHUNYA
IRINGA
UFIPA
L. Rukwa
MBEYA
MBEYA
MUFINDI
MOROGORO
MBOZI
Mbeya
IRINGA
ULANGA
NACHINGWEA
KILWA
RUNGWE
LINDI
NJOMBE
Lake Nyasa
LINDI
SONGEA
TUNDURU
MTWARA
MASASI
NEWALA
MTWARA
MBINGA
RUVUMA
5°
10°
30°
35°
40°
100 50 0 100 200 300 km

2.3. Economy

2.3.1. Colonial heritage

The economy of East Africa was shaped in little more than half a century of colonial rule to exporting a few raw materials and importing manufactured goods. Two or three agricultural products provide over half of the total export earnings (coffee, cotton and sisal in Tanzania and coffee, tea and sisal in Kenya). During colonial times limited agricultural development was encouraged to produce agricultural products for the overseas markets. Little industry was established, predominantly in Kenya, and this industry was serving only the common East African market.
The resulting economy has been described as a dual economy, i.e. an enclave dependent on the sale of raw materials to the world markets and the import of manufactured goods in finished or semi-finished form primarily for the limited high income groups in the export enclave markets; and a hinterland characterized by low productivity, low-income agriculture which provided low cost labour for export enclave production.

2.3.2. Post-colonial industrial development

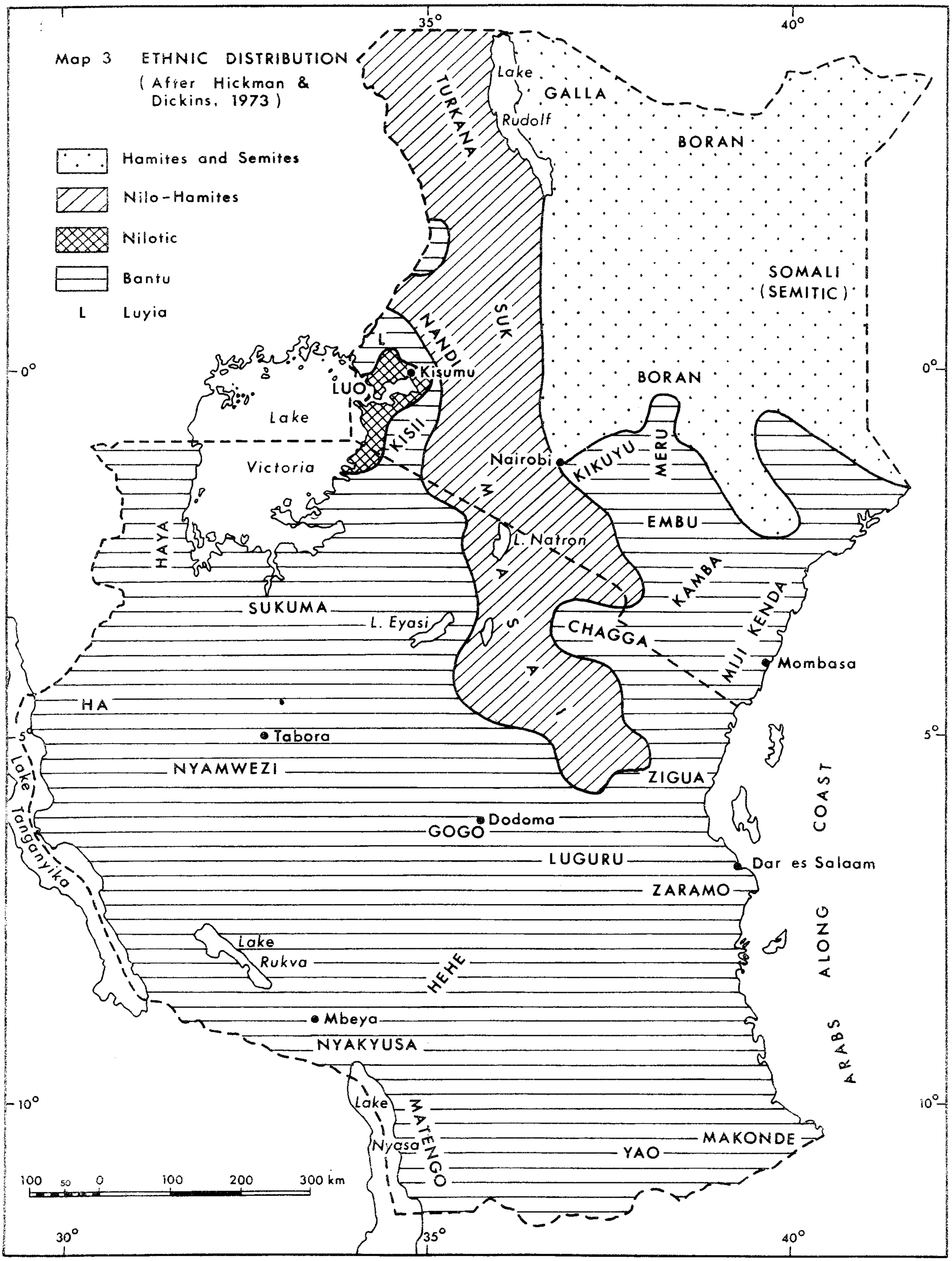
Most industries have continued to invest in fields which serve the existing market. Outside agricultural production investments have been made in particularly the luxury item industry, cigarettes and beer, processing of imported parts and last stage assembling. Most of these industries continue to be localized in urban areas like Nairobi and Mombasa. No attempt has been made to create labour-intensive industries apart from Government investments in small-scale industry (the industrial estates in Kenya are an example). These timid attempts to counteract the concentration of international firms in urban areas have not succeeded to really break free from patterns established by the former type of industry.

Tanzania has made attempts to change the institutional structure in line with her socialist policies through acquisition of majority shares in large firms and the creation of the National Development Corporation. The problems encountered by the NDC are i.a. to harmonize its relation to Government, financial agents assisting Government and private partners.

2.3.3. Agriculture and nutrition

Agriculture is still the backbone of the economies of the two countries. Both try to develop agriculture as the foundation for further development. The diversification of agriculture taking place after independence has been a success in that the output for export increased.
This development has, however, taken place partly on behalf of the nutritional standard of the rural people. Many have diets deficient in calories, protein and vitamins A, B2 and C (cf. table 18, section 4.2.3.5.). The deficits vary with the seasons. In pre-harvest periods it is estimated that 25-30% of rural families consume less than 60% of sufficient caloric requirements and that more than a quarter of all children suffer from some form of malnutrition. The position may be worsening for three reasons: (1) The pressure on land is increasing and people move to more marginal areas. (2) Maize has largely taken over from more protein rich millets and sorghums. (3) The official policies put an emphasis on cash crops.

Kenya's plans aim at expanding export crops combined with the recent heavy emphasis on livestock products. Tanzania's attempts to diversify the agricultural sector have been only relatively successful. Due to the constantly


Map 3 ETHNIC DISTRIBUTION
(After Hickman & Dickins, 1973)
Hamites and Semites
Nilo-Hamites
Nilotic
Bantu
L Luyia
35°
40°
0°
5°
10°
30°
Lake Rudolf
GALLA
BORAN
TURKANA
SOMALI (SEMITIC)
NANDI
SUK
LUO
Kisumu
Lake Victoria
KISII
Nairobi
KIKUYU
MERU
EMBU
L. Natron
MASAI
KAMBA
KENDA
MIJI
CHAGGA
Mombasa
HAYA
SUKUMA
L. Eyasi
HA
Tabora
NYAMWEZI
ZIGUA
Lake Tanganyika
Dodoma
GOGO
LUGURU
Dar es Salaam
ZARAMO
ALONG COAST
ARABS
Lake Rukva
HEHE
Mbeya
NYAKYUSA
Lake Nyasa
MATENGO
MAKONDE
YAO
100 50 0 100 200 300 km

worsening terms of trade Tanzania has had to concentrate the efforts on meeting the need for domestic foodstuffs and raw materials. Both countries remain largely dependent on the sale of agricultural products to always uncertain and often infavourable world market prices.
Land policies followed in the rural areas are different in Kenya and Tanzania. They are described briefly in section 4.1.

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3. PHYSICAL FEATURES AND THEIR RELEVANCE TO LAND USE

3.1. Climate

3.1.1. General features

The main factors which control climate are latitude, altitude, character of prevailing winds, the distance from the sea, or from any sizeable water-body, and topography. Vegetal cover is also important, but normally it is the result of the other factors mentioned above. Also important is the occurence of pressure belts which shift in accordance with the movement of the sun and thereby inflict seasonal weather patterns.
An important pressure belt is the Intertropical convergence zone (ITCZ), which is the broad low pressure zone where the NE and SE trade winds of the two hemispheres meet. It follows the sun's latitudinal movement with a lag of about one month and gives rise to rain due to its convergence of air masses.

Broadly speaking there are two main synoptic subdivisions of the annual weather pattern, the period from early June to early October and the period from November to the end of April. Late October and May can be considered as merely transitional stages. From June to October a low pressure over Uganda and a high pressure ridge over the Tanzania coast assist in giving rise to the average rainfall pattern (see map 4). Then, in the second period, a number of synoptic situations can exist, situations that are identified by the upper air pressure fields and the pressure patterns in the middle tropical latitudes. It is because these situations may occur at any time during the period that variations in rainfall amount are so great, while the patterns of rainfall occurence from day to day often appear unrelated.

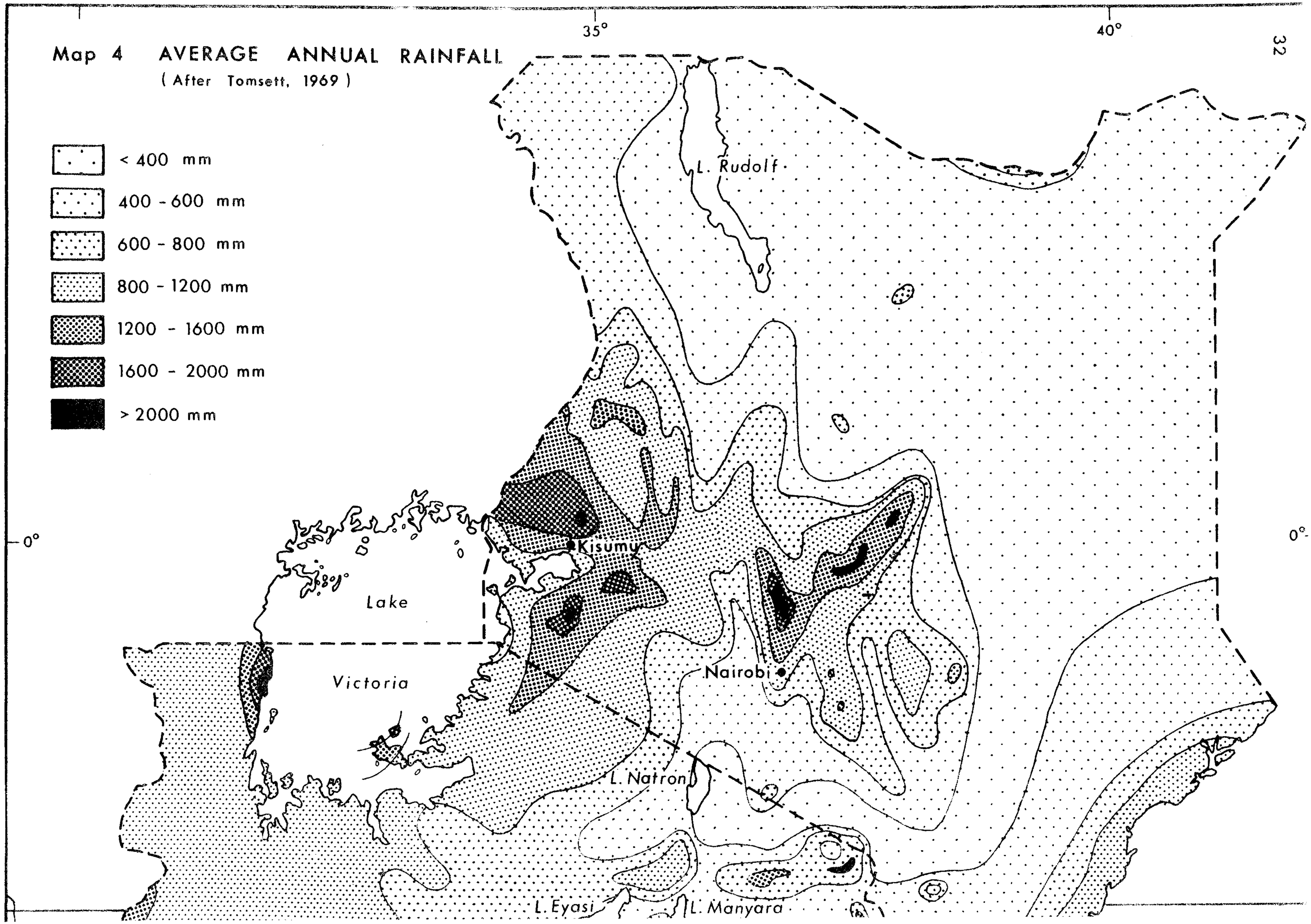
3.1.2. Rainfall

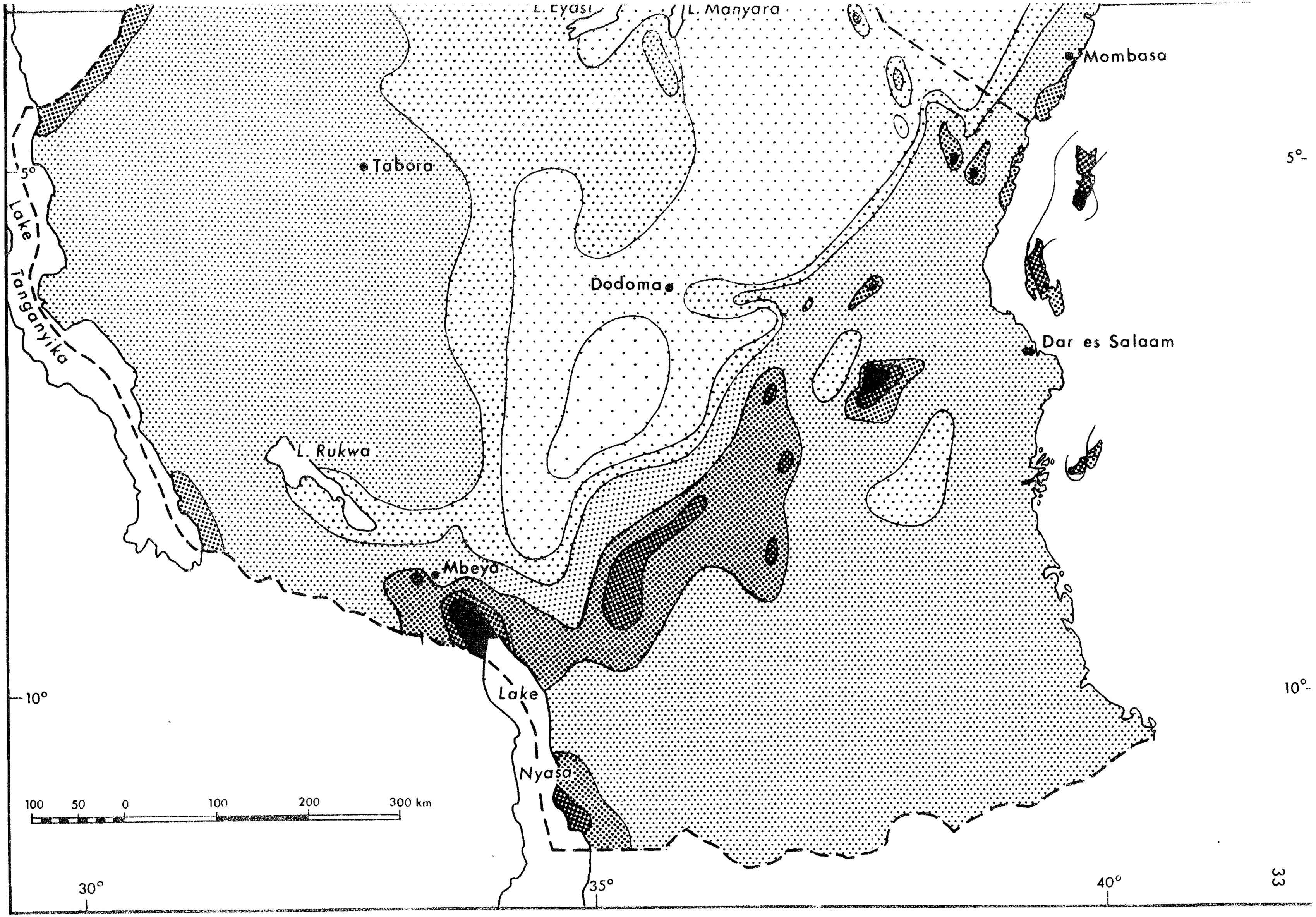
Much of the area has too little rainfall (see map 4) for permanent agriculture and, in addition, the year to year variation is large. In temperate regions of the world the annual variation is relatively small but in East Africa many stations have recorded maximum annual rainfalls of more than four times the minimum. Further, there is a wide variation in the time of the year when the rain falls for, as can be seen from table 2 and map 5, nearly two-thirds of the area suffers a drought of six months or more while only 2 per cent of the country has reasonable rainfall (over 50 mm) in every month.

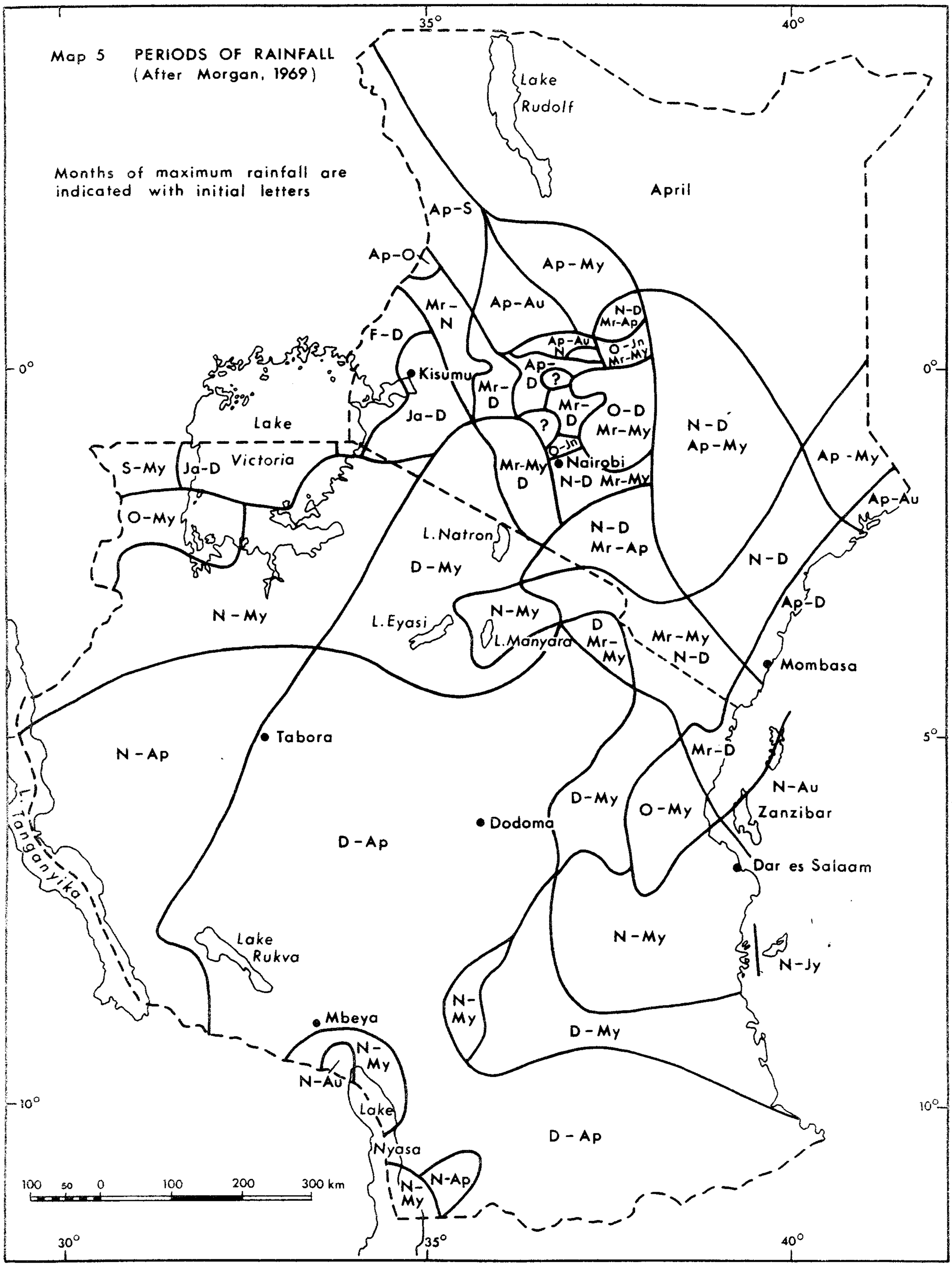
TABLE 2. Areal distribution of given rainfall regimes in East Africa (including Uganda)
Source: Morgan (1969).

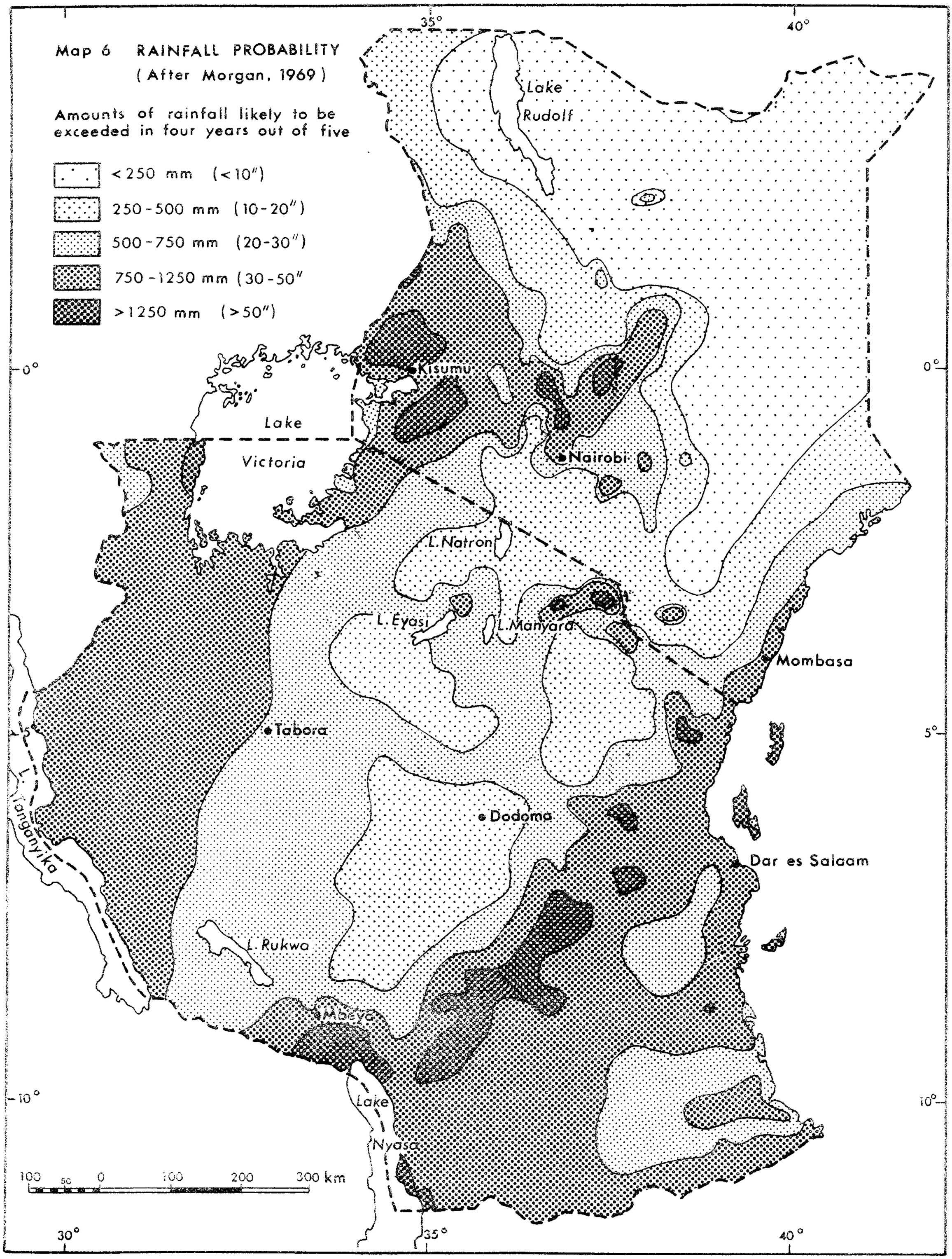
Single period		Double period		
No. of wet months	% area	No. of wet months	(wet-dry-wet-dry)	% area
12	1.8	7	4 - 1 - 3 - 4	0.2
11	3.7	7	4 - 2 - 3 - 3	1.0
10	3.5	6	5 - 2 - 1 - 4	0.2
9	6.9	5	2 - 2 - 3 - 5	2.3
8	3.2	4	2 - 2 - 2 - 6	1.3
7	12.3	4	1 - 2 - 3 - 6	1.4
6	16.4	4	2 - 3 - 2 - 5	2.0
5	22.7	3	2 - 3 - 1 - 6	3.5
2	2.6	unidentified	-	0.2
1	14.8			
	87.9			12.1

Map 4 AVERAGE ANNUAL RAINFALL
(After Tomsett, 1969)




L. Eyasi
L. Manyara
Mombasa
Tabora
5°
Lake Tanganyika
Dodoma
Dar es Salaam
L. Rukwa
Mbeya
10°
Lake Nyasa
100 50 0 100 200 300 km
30°
35°
40°
5°
10°


Map 5 PERIODS OF RAINFALL
(After Morgan, 1969)
Months of maximum rainfall are indicated with initial letters
Lake Rudolf
April
Ap-S
Ap-O
Ap-My
Ap-Au
Mr-N
F-D
N-D Mr-Ap
Ap-Au N
O-Jn Mr-My
Ap-D
Kisumu
Mr-D
Ja-D
Mr-D
O-D Mr-My
N-D Ap-My
Lake Victoria
S-My
Ja-D
O-Jn
Mr-My D
Nairobi
N-D Mr-My
Ap-My
Ap-Au
O-My
L. Natron
N-D Mr-Ap
N-D
D-My
Ap-D
N-My
L. Eyasi
N-My
L. Manyara
D Mr-My
Mr-My N-D
Mombasa
N-Ap
Tabora
Mr-D
N-Au
Zanzibar
D-My
O-My
Dodoma
D-Ap
L. Tanganyika
Dar es Salaam
N-My
Lake Rukva
N-Jy
N-My
Mbeya
D-My
N-My
N-Au
Lake Nyasa
D-Ap
N-Ap
N-My
100 50 0 100 200 300 km
0°
5°
10°
30°
35°
40°


Map 6 RAINFALL PROBABILITY
(After Morgan, 1969)
Amounts of rainfall likely to be exceeded in four years out of five
< 250 mm (< 10")
250 - 500 mm (10 - 20")
500 - 750 mm (20 - 30")
750 - 1250 mm (30 - 50"
> 1250 mm (> 50")
35°
40°
0°
5°
10°
30°
Lake Rudolf
Kisumu
Lake Victoria
Nairobi
L. Natron
L. Eyasi
L. Manyara
Mombasa
Tabora
Dodoma
Dar es Salaam
L. Tanganyika
L. Rukwa
Mbeya
Lake Nyasa
100 50 0 100 200 300 km

Because of the great variability of the annual totals at any one station it is necessary, for agricultural and hydrological purposes, to introduce some factor that takes account of the rainfall reliability. It can be shown following H. L. Manning's initial work (Manning, 1956) that most of the records fit some simple mathematical distribution, and by identifying these the possibility that a given place will receive a certain annual rainfall can be worked out. The Rainfall probability map shows the minimum annual rainfall to be expected in four years out of five (see map 6). From this map the percentage of the total area receiving certain reliable amounts of rainfall can be obtained, and table 3 gives these for selected annual totals.

TABLE 3. Percentage of land area receiving selected amounts of annual rainfall in four years out of five. Source: Morgan (1969).

Rainfall	Kenya	Tanzania
< 20" (< 500 mm)	72	16
20" - 30" (~ 500 - 750 mm)	13	33
30" - 50" (~ 750 - 1250 mm)	12	47
> 50" (> 1250 mm)	3	4

The implications of such a table are obvious. Kenya receives a reliable 30 in. (750 mm) per annum in only 15 per cent of the territory, compared with about half of Tanzania. Kenya is so poorly placed that even if irrigation enabled the 20-30 in. (500 mm - 750 mm) areas to be used for crop production, there is still nearly three-quarters of the land that is not usable.

The areas of over 50 in. (1250 mm) fall, which include most of the areas from which water can be harvested, are relatively small in both countries and this emphasises the vital need for strict and sensible hydrological, agricultural and forestry practices in these regions if the rivers are to have a dry season flow. (This aspect is discussed in more detail in chapter 5.3.).

Rainfall intensities are not recorded at many stations but, generally, it may be reckoned that over periods of a few minutes, about 250 mm per hour is the maximum rate. For longer periods, half to one hour, 100 mm per hour is very high. Maximum daily falls vary appreciably with location, but rarely does more than 200 mm fall in the coast, 150 mm. over high land (above 1800 m) and 100 mm over plateaux. However, falls of over 250 mm in a day have been recorded, for example:

Vanga	381 mm	(Oct., 1953)-South Kenya Coast
Kaloleni (Mazeras)	356 mm	(Oct., 1938)-Just inland from Mombasa
Witu	335 mm	(Oct., 1961)-Just inland north Kenya Coast
Kilifi	292 mm	(May, 1947)-Near Mombasa

Monthly falls of over 500 mm are very rare in inland Kenya and central Tanzania but totals of over 1000 mm have been recorded at the coast, in the Kilimanjaro-Usambara region and in the Lake Nyasa region.

3.1.3. Temperature

The mean annual maximum and minimum temperatures are, as expected, very closely correlated with altitude, but the constant of such a regression varies geographically, although the lapse rate (the decrease of temperature with height) remains reasonably constant.
The daily average may be taken as half the sum of the maximum and minimum values.
There are very few places that regularly report screen frosts (temperatures below -1°C) and ground frosts seldom occur below 2400 m , except in the Southern Highlands of Tanzania in July and August, and occasionally in cold air drainage hollows down and about 1800 m. Temperatures in excess of 38°C are very rare and only Magadi in S. Kenya has recorded above 40°C.

The diurnal variation at nearly all stations is in the range of 8-13°C except above 2000 m in the Kenya Highlands, where it is about 14-17°C, and the coast and islands where it is between 6-8°C.

Concerning soil temperatures there is, unfortunately, relatively little data but table 4 summarises information for stations representative of the coast, Kenya Highlands and Lake Victoria area.

TABLE 4. Soil temperatures at selected stations. Source: Morgan (1969).

Station	Altitude (metres)	Mean air temp. (°C)	Mean soil temp. (°C)	Mean range at 15 cm (°C)	Mean range at 122 cm (°C)	Excess of mean soil temp. over mean air temp.
Dar es Salaam	0	26	29	7	4	3
Entebbe	1190	22	24	-	1	2
Kabete (Nairobi)	1800	18	22	5	2	4
Muguga (near Nairobi)	2100	16	21	6	2	5

3.1.4. Radiation

In table 5 mean sunshine hours are given for a selection of stations. It is clear that East Africa receives an average of about 7 hours per day, corresponding to about 2500 hours per year, a very high total, while in Central Tanzania and the Northern Province of Kenya over 3000 hours are recorded. Lyamungu on the southern slopes of Kilimanjaro receives only some 1600 hours per year. The monthly averages vary with the rainy seasons and it must be noted that individual months can show a 15 per cent standard deviation.

It should be observed that Dar es Salaam and Equator have very similar sunshine, and therefore radiation income, but have very different temperatures; annual means are 26°C and 13°C respectively. The temperature, therefore, does not only depend on the incoming radiation load.

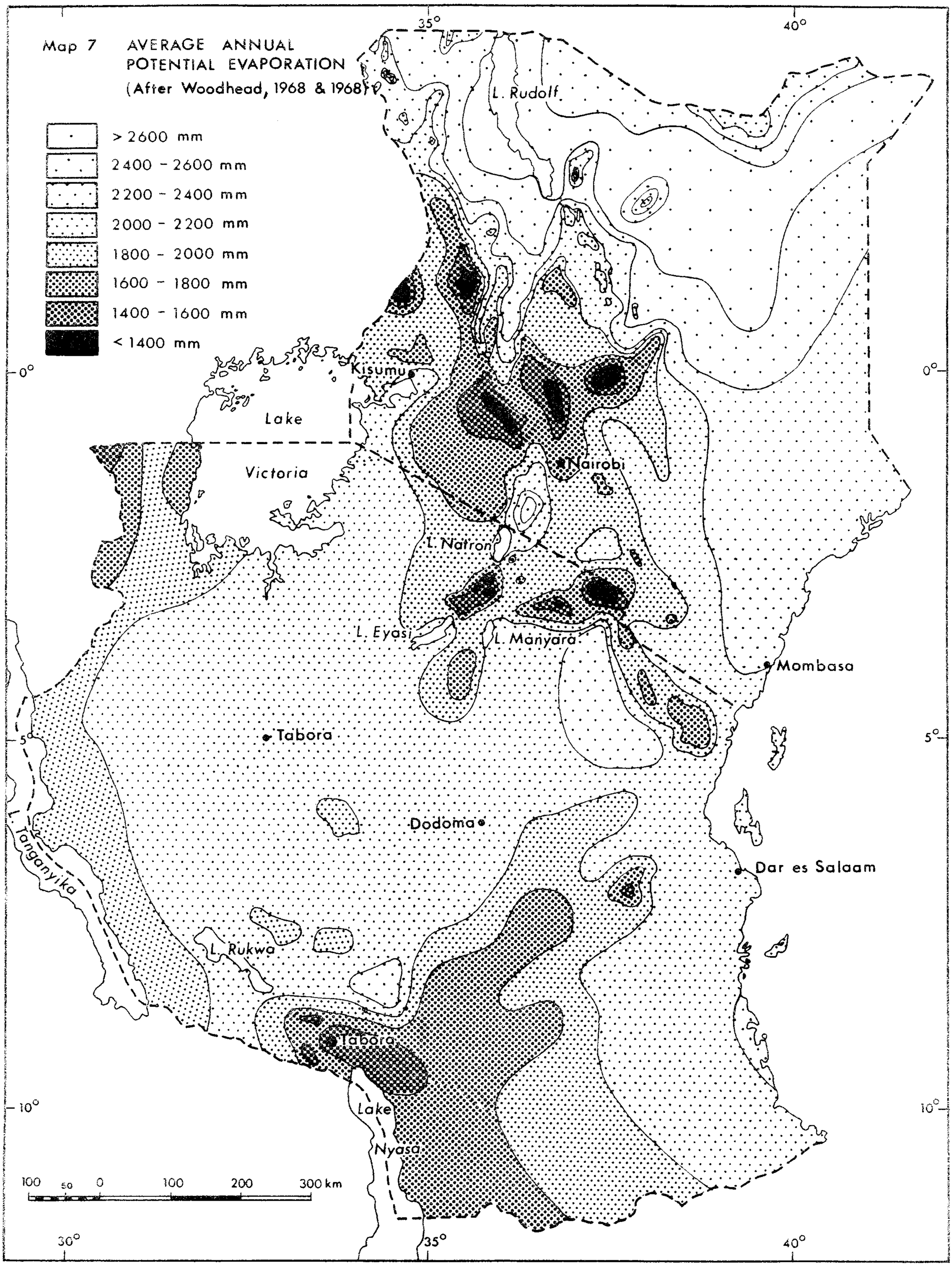

Map 7 AVERAGE ANNUAL POTENTIAL EVAPORATION
(After Woodhead, 1968 & 1968)
> 2600 mm
2400 - 2600 mm
2200 - 2400 mm
2000 - 2200 mm
1800 - 2000 mm
1600 - 1800 mm
1400 - 1600 mm
< 1400 mm
35°
40°
L. Rudolf
0°
Kisumu
Lake
Victoria
Nairobi
L. Natron
L. Eyasi
L. Manyara
Mombasa
5°
Tabora
Dodoma
Dar es Salaam
L. Tanganyika
L. Rukwa
Tabora
10°
Lake
Nyasa
100 50 0 100 200 300 km
30°
35°
40°

TABLE 5. Hours of bright sunshine at selected stations
Source: Morgan (1969)

Station	Altitude (metres)	Mean hours	Sunniest month	Dullest month
Lodwar	520	9.8	10.7 (Sept.)	8.4 (July)
Tabora	1280	8.6	10.5 (July)	6.9 (Jan.)
Dar es Salaam	0	7.7	9.0 (Nov.)	5.2 (April)
Equator	2770	7.5	9.1 (Feb.)	5.2 (July, Aug.)
Kabete	1830	6.9	9.5 (Feb.)	4.2 (July, Aug.)
Nanyuki	1950	6.0	7.5 (Jan.)	4.1 (Nov.)
Morogoro	580	5.1	6.2 (Feb.)	3.7 (May)
Lyamungu	1250	4.3	6.4 (Jan., Feb.)	2.4 (June)

3.1.5. Evapotranspiration

Of the total water precipitated at any place, some is lost by evaporation and some is absorbed by the roots of plants before being transpired through the leaves. These two ways of disposing of some of the precipitation are collectively known as evapotranspiration. The rest of the precipitation will constitute that which infiltrates into the soil or reaches the rivers and seas as run-off.

Evapotranspiration is governed by a number of factors - air temperature, insolation, wind velocity, length of day and humidity. The maximum rate of evapotranspiration that these factors can cause is called potential evapotranspiration (E_T) and assumes the presence of a complete vegetal cover that has unlimited access to soil water. Actual evapotranspiration (E_a) is the rate of water loss under prevailing meteorological, soil and biological conditions.
The evaporative demand of the atmosphere, potential evaporation (E_o) is the quantity of water vapour that can be emitted from an open water surface. E_o generally exceeds E_T by about 20% mainly because of higher radiative reflection (albedo) of the plant cover compared with a water surface. The ratio E_T/E_o is used as a measure of the evaporative character of the actual plant cover.

Direct and reliable measurements of open water evaporation are difficult to obtain. Accordingly, recourse is made to indirect estimates based on relevant meteorological observations. For East Africa, the method devised by Penman (1948) has been found to be most satisfactory. Over a period of several years, meteorological stations, adequately equipped for measurements of the key parameters, especially solar radiation, have been set up in East Africa and the collection of data is now sufficient to enable a map of evaporative demand to be drawn with moderate confidence, as shown on the small scale map 7. It should be noted that this map refers to evaporative demand rather than actual transpiration, as in many areas of East Africa the transpiration is strictly limited by the rainfall, which might be as low as one tenth of the evaporative demand.

Evaporation rates are in excess of 2500 mm per annum in the drier areas of northern and eastern Kenya, falling to 1100 mm and less in the cloudy areas at altitudes of 2750 m or more. As evaporation depends heavily on solar radiation and less heavily on temperature, the distribution of evaporation reflects the frequency of cloud cover and to a lesser degree the decrease of temperature with altitude. The high frequency of cloud over the northern and western edges of Lake Victoria is shown up by evaporation

rates appreciably less than those on the eastern and southern edges where clouds are tending to disperse due to the air stream from the east descending after crossing highland areas.

3.1.6. Climatic regions

Kenya and Tanzania may be subdivided into nine climatic regions (see map 8). These regions may be characterized briefly as follows:

Rainy season savanna has two periods of overhead sun close together in one half of the year so that a prolonged season of 7-10 months of rainy season is created with a marked but relatively short dry season in between. The rainfall is substantial, 750-1500 mm and gives rise to a rich savanna of broadleafed trees. Cotton is a particularly suitable crop.

Dry season savanna where the rainfall maxima months coalesce to a shorter 5-6 months rainy season and a severe and prolonged dry season. The rainfall is between 500-1000 mm. The characteristic vegetation is woodland or "miombo" (cf. 3.6.5.). This region covers a greater part of Tanzania. Large parts are uninhabited and infested with tsetse fly.

Desert and semi-desert cover a large part of northern Kenya and has so little rain that desert conditions prevail. The rainfall is between 100-250 mm and very unreliable.

Lake basin involves the north shore of Lake Victoria and has no marked dry season. Rainfall varies between 1000-1800 mm and is well distributed throughout the year.

Kenya Highlands has a complicated pattern of climates due to the sharp relief variabilities. Temperatures are reduced due to high altitudes. Rainfall varies from 750-2000 mm and is divided into "long" and "short" rains, each of 2-3 months duration.

Semi-arid twin season has twin rains like the Highlands but of lower magnitude - total of 250-750 mm. The region comprises inhospitable Acacia bushland and is inhabited by nomadic pastoralists.

Coastal climate which stretches along all of Kenya's and half of Tanzania's coast (1-10° south latitude). It is relatively humid but bounded by a drier interior. Rainfall rarely exceeds 1250 mm and is less efficient than the corresponding amount of rainfall would be in the highlands due to high evaporation rate.

Savanna-highland climates has rainfalls ranging between 1250-1750 mm combined with a pronounced dry season. Vegetation is of a savanna, miombo or grassland type, usually of a luxuriant type.

Rungwe at the northern end of Lake Nyasa has a remarkably high rainfall of 2500 mm or more.

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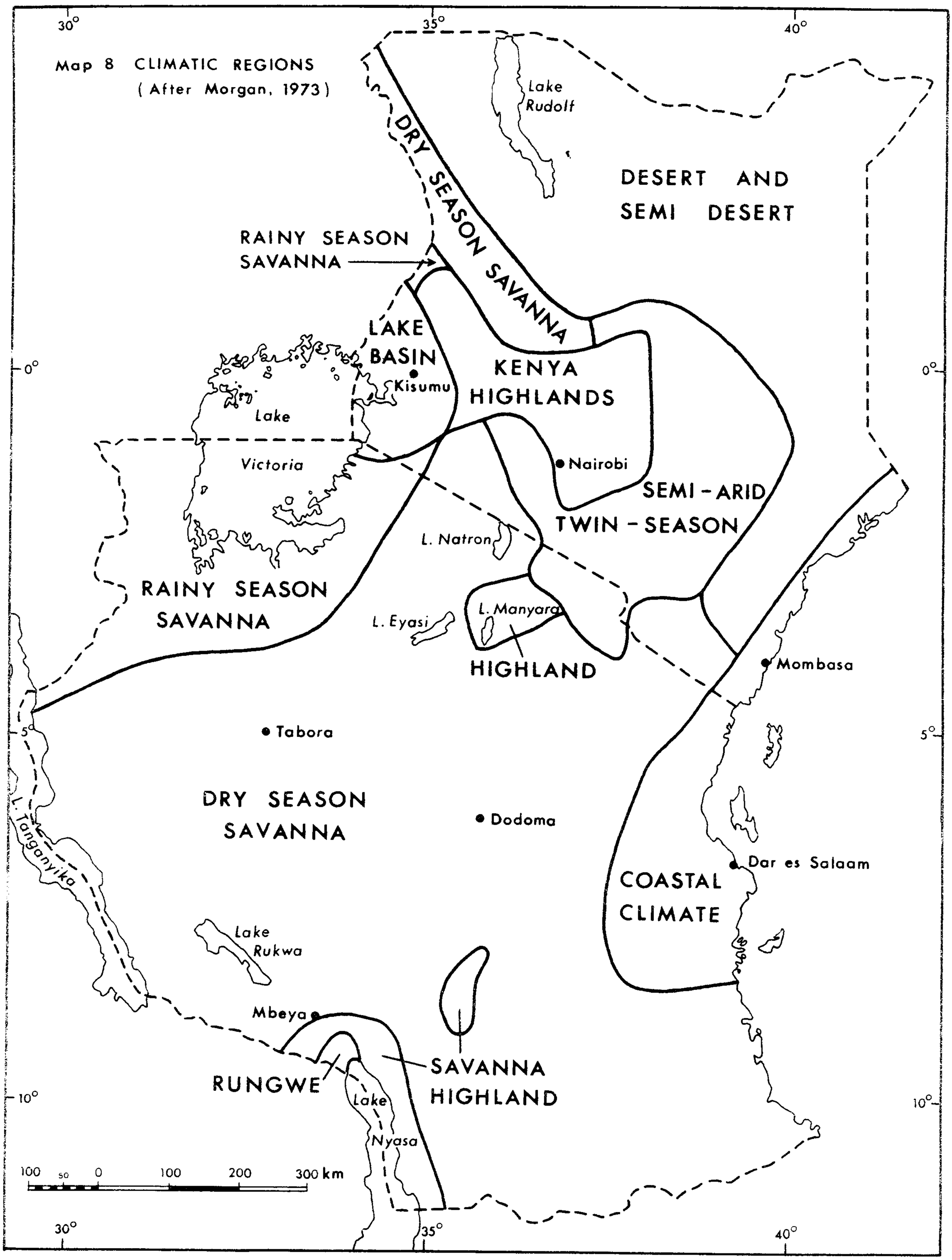
Map 8 CLIMATIC REGIONS
(After Morgan, 1973)
30°
35°
40°
0°
5°
10°
Lake Rudolf
DRY SEASON SAVANNA
DESERT AND SEMI DESERT
RAINY SEASON SAVANNA
LAKE BASIN
Kisumu
KENYA HIGHLANDS
Lake Victoria
Nairobi
SEMI - ARID TWIN - SEASON
L. Natron
RAINY SEASON SAVANNA
L. Eyasi
L. Manyara
HIGHLAND
Mombasa
Tabora
DRY SEASON SAVANNA
Dodoma
L. Tanganyika
Dar es Salaam
COASTAL CLIMATE
Lake Rukwa
Mbeya
SAVANNA HIGHLAND
RUNGWE
Lake Nyasa
100 50 0 100 200 300 km

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3.2. Geology

3.2.1. Introduction

The bedrock is one of the major natural resources. Consequently geological mapping is one of the basic resource surveys in any country. Geological maps show a mosaic of different kinds of bedrock, which are important to know, not only for prospecting of ores, oil and groundwater, but also for construction of roads and buildings, and for the understanding of land-forms, soil types and to some extent vegetation. Mineral nutrients to the plants are under natural conditions supplied mainly as weathering products from the bedrock (see 3.4.2.).

The following summary of the geology of Kenya and Tanzania is based on E. P. Saggerson's chapter "Geology", in Morgan (1969). The geological map (map 9) is a generalized version of Saggersons's map of 1967 to the chapter mentioned above. The legend has been condensed to the following six symbols:

PC = Pre-Cambrian rocks, older than 600 million years
M = Paleozoic/Mesozoic rocks, 600-70 million years
T = Tertiary sediments
Tv = Tertiary/Recent volcanics
Q = Quaternary sediments, less than 1 million years
/ = Tertiary/Recent Faults

The bedrock provinces mentioned above offer very different parent material for soil formation. As a very rough rule to the following description of bedrock provinces in Kenya and Tanzania, the following relations between bedrock and soil types are indicated (cf. also chapters 3.4.2. and 3.4.4.).

The "Precambrian rocks" (shield areas) cover most of central and western Tanzania and a belt east of the Rift zone in Kenya. The shield is predominantly built of granites and gneisses, which weather into sandy, latosolic soils of rather low fertility. In depressions and floodplains of this zone are alluvial (river-transported) sediments, which generally are richer in silt, clay and organic material, and have a higher agricultural potential. Larger basins of recent alluvial material are marked as "Quaternary sediments" (see also figure 5).
The "Paleozoic/Mesozoic rocks" and the "Tertiary sediments" of the map are more heterogenous. They vary from sandstones, quartzites and coral limestones with usually poor sandy soils - to shales, mudstones and clays, generally with more finegrained soils of somewhat higher fertility.
The most fertile soils are produced by weathering of rocks belonging to the group "Tertiary/Recent volcanics" e.g. in the Kenya highlands and the Arusha-Moshi area. Some of the young volcanic rocks are very weathering-resistant and produce poor soils, e.g. the so called "lahar" volcanic mud-flow covers on the northern and eastern footslopes of Meru.
The above examples, andthe occurrence of soils in "catena" successions show that there is no simple relation between rock type and soil type.

3.2.2. Precambrian rocks

In the absence of fossils of zonal value in rocks of Precambrian age in East Africa it has been necessary to correlate rocks on a regional scale. These may be regionally divided into three groups (see figure 5):
1. The Nyanza Shield (including the Central Shield of Tanzania).
2. The Karagwe-Ankolean belt, including rocks of the Ubendian System.
3. The Mozambique belt.

Map 9 GEOLOGY

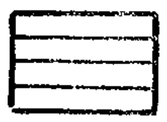
(After Morgan, 1973)

Quaternary sediments

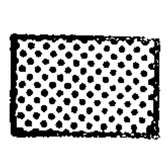
Tertiary sediments

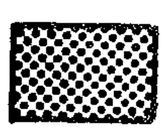
Tertiary recent volcanics

Paleozoic sediments
Karroo Jurassic and Cretaceous

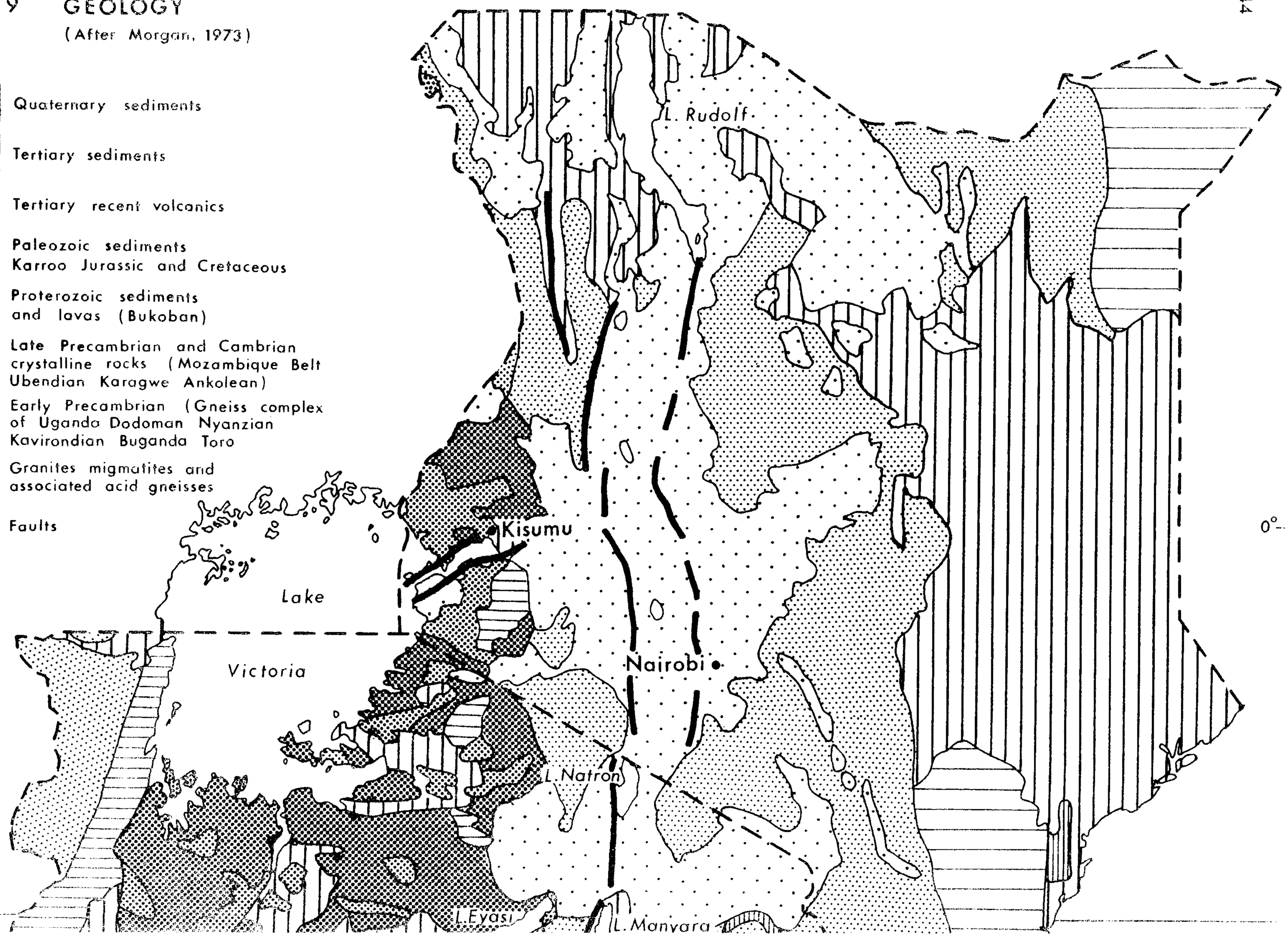

Proterozoic sediments
and lavas (Bukoban)

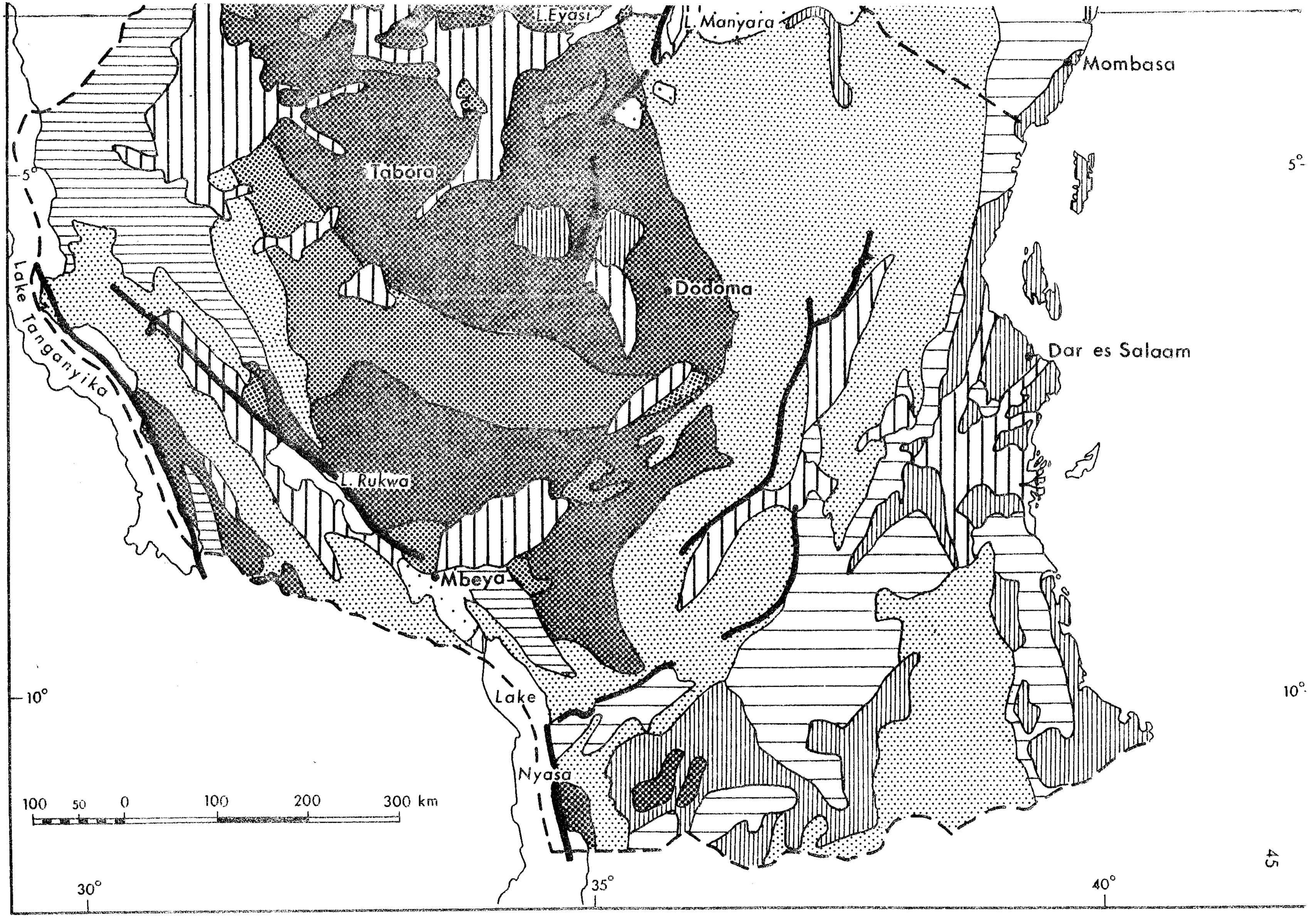
Late Precambrian and Cambrian
crystalline rocks (Mozambique Belt
Ubendian Karagwe Ankolean)


Early Precambrian (Gneiss complex
of Uganda Dodoman Nyanzian
Kavirondian Buganda Toro


Granites migmatites and
associated acid gneisses

Faults




L. Eyasi
L. Manyara
Mombasa
Tabora
Dodoma
Dar es Salaam
Lake Tanganyika
L. Rukwa
Mbeya
Lake Nyasa
5°
10°
100 50 0 100 200 300 km
30°
35°
40°

The stable shield comprising rocks of the Gneiss Complex of northern Uganda, the Nyanzian-Kavirondian Systems, the Buganda-Toro Systems, the Dodoma Systems and the Central Shield of Tanzania has a predominantly E-W trend. Apparently older gneisses are overlain by less metamorphosed cover rocks. These rocks were probably originally deposited during the same episode and later metamorphosed, granitised and intruded by granites to different degrees.

Dodoman System. The rocks of this system have only been recognised in Tanzania. They consist of coarsely crystalline metamorphosed rocks and associated gneisses and granites occupying a part of the Central Tanzania Shield. Quartzites, schists, amphibolites and hornblende gneisses are common. The absence of crystalline limestones in the Dodoman is noteworthy.

Nyanzian System. The rocks of the Nyanzian System are developed around Lake Victoria where they are associated with intrusive, gold-bearing granites. Typically, the Nyanzian contains banded ironstones with quartzites, which are mainly developed east of the lake. Both the Nyanzian and Kavirondian Systems are between 1600 and 3000 million years old.

Kavirondian System. Kavirondian rocks are found in the two countries, associated with Nyanzian strata. The type area is north of the Kavirondo Gulf where alternating sandstones and mudstones with water-laid conglomerates are developed. South of the gulf the system is represented by boulder conglomerates, grits (gravelly sandstones), mudstones and in one locality, schistose rocks; in the Mara and Musoma Districts of Tanzania similar rocks together with quartzites are developed. Granites with associated gold-bearing quartz veins occur in the Kavirondian rocks. The rocks of the Nyanzian and succeeding Kavirondian System have been shown to be older than rocks of the Mozambique belt.

Bukoban System. The group of rocks collectively known as the Bukoban System is distributed upon the margins of the Nyanza Shield and is subdivided into numerous local members.

Mozambique Belt. Metamorphic rocks within the Mozambique belt cover a wide area of East Africa, extending from the Sudan-Ethiopian border in the north to the Mozambique border in the south. An eastern area forms the principal north-south Mozambiquian belt in Kenya and Tanzania and extends westwards into Uganda. Recent determinations made on minerals from the belt reveal that the rocks are affected by intense regional metamorphism accompanied by orogeny between 410 and 650 million years ago, i.e. in Cambrian times. The age of the original sediments is still in doubt.

3.2.3. Paleozoic and Mesozoic rocks

During the Karroo Period, Southern Africa formed part of the super-continent Gondwanaland consisting of large parts of Africa, India, Australia and Antarctica where Paleozoic and Lower Mesozoic rocks were laid down in an essentially sedimentary environment. The period is noteworthy in that it followed an era of which no record is retained in the rocks of East Africa. It also marks a period of terrestrial and marine sedimentation when organized animals and plants flourished. Sediments of Karroo age in East Africa are mainly found in or near the coastal regions from about latitude 2° 00'S., south to the Mozambique border. Other outcrops occur inland.

In Kenya, Karroo sediments grouped as the Duruma Sandstones occupy a strip of country between 65 and 90 Kms wide along the southern half of the coast.

In the west, a series of massive grits, sandstones and shales locally overlie a tillite. Traces of coal are common.

The type succession of Karroo rocks in Tanzania occurs in the southern part of the country. The deposits are significant for their coal-bearing beds. Other important coal-bearing strata are found in the Lake Rukwa area. In north-east Tanzania the Tanga beds represent a southerly continuation of Karroo rocks described from Kenya.

The Jurassic System in Kenya is developed in the north-east and along the coast. It contains limestones, shales and gypsiferous beds.
In Tanzania, Jurassic rocks occur in three areas; the Tanga area, the hinterland of Dar es Salaam, and southern Tanzania. The rocks are marine sediments consisting of a succession of felspathic sandstones, grits and limestones.

3.2.4. Tertiary and Quaternary

Throughout the Tertiary era the greater part of East Africa was above sea-level and marine transgressions occurred only along the coastal area. Lower Tertiary deposits are exposed only in the southern part of Tanzania where they occupy a narrow strip inland of Kilwa and Lindi (limestones, sandstones and clays).
The upper Tertiary is represented by clays, sands and subordinate limestones of the Tanga area and siliceous colluvial deposits near Dodoma.

In Kenya the lower Tertiary does not crop out, though considerable thickness of early Tertiary strata have been penetrated in boreholes north of the Tana river in the coastal region.
In the coastal area of Kenya near Malindi are Pliocene sands, sandstones, clays and conglomerates.

Deposits of Quaternary age cover large areas of East Africa; most are terrestrial in origin and frequently have been dated by their fossil content, usually mammals, and by artefacts. Most important of the fossils are the human remains found at Kanam in Kenya and Olduvay in Tanzania. With certain exceptions, the sequence of climatic changes that occurred during the deposition of the East African Quaternary sediments is at present imperfectly understood.
The effect of Quaternary movements at the coast is evidenced by fossil and modern coral reefs. The raising of Pleistocene reefs, some more than 30 m above sea-level was followed by submergence when estuaries were drowned and wave-cut platforms were eroded. Subsequent raising of the coast relative to the sea brought these benches once more to sealevel and allowed the growth of modern off-shore coral reefs.

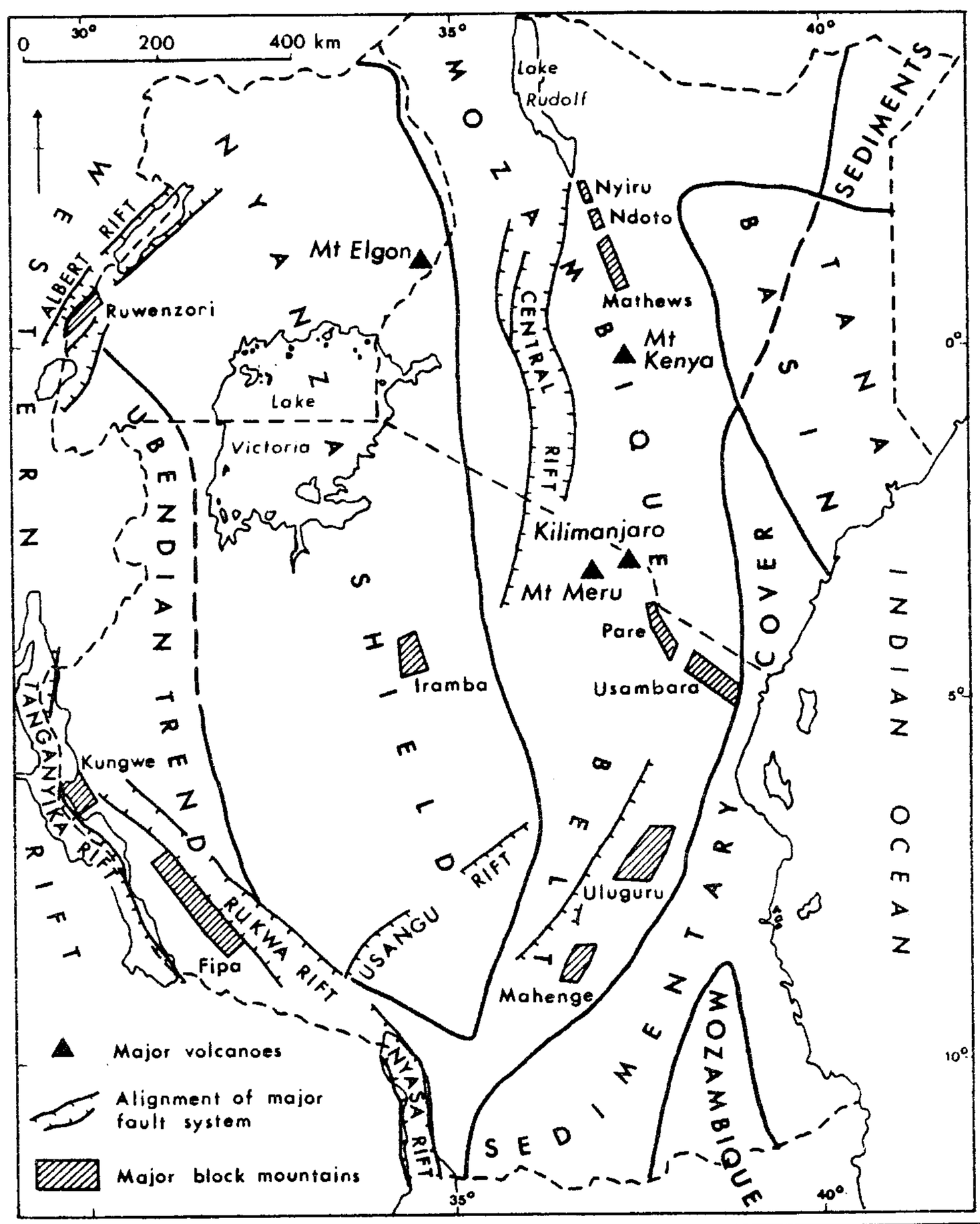
Evidence of Pleistocene to Recent glaciation is found on the higher mountain peaks and ranges of East Africa where moraines, solifluxion deposits and other glacial phenomena are seen. The Ruwenzori Mountains, Mount Kenya and Kilimanjaro still maintain glaciers.

Soils and alluvial deposits are the principal sediments of Recent age, and throughout East Africa thick sands and terrestrial deposits cover large areas, notably in eastern Kenya and the area between the Rufiji and Pangani rivers and north of the Ruvuma river in Tanzania. Hot spring deposits, gypsum, limestones, sands, clays and silts deposited in restricted areas and basins and stratified alluvial fan deposits are also of widespread occurrence.

3.2.5. Tertiary to Recent volcanic activity

The Tertiary to Recent period is significant for its volcanic activity, mainly associated with rift faulting of the east Rift. From Lake Rudolf in the north to Lake Manyara in the south stretches a vast field of lavas that extend both eastwards and westwards of the eastern Rift Valley (see map 9). Innumerable volcanic cones with some calderas are associated with the Rift Valley and flanking lava fields. In Tanzania the lava areas tend to be dominated by a number of large isolated volcanoes (see figure 5).
Major central volcanoes are Mounts Elgon, Kenya and Kilimanjaro and the Aberdare range. Many of the larger volcanoes are situated either along the margins of the Rift or are concentrated in zones where block-faults intersect.
East Africa's only active volcano is Ol Doinyo L'Engai near Lake Natron, though legend suggests that a number of others, particularly in Kenya and near Rungwe in Tanzania, erupted in historical times. Eruption of lava occurred in the crater of Mount Meru in 1877 and Teleki's volcano at the southern end of Lake Rudolf erupted at the end of the last century.

FIGURE 5. A structural sketch of East African geology
Source: Morgan (1973)



3.2.6. Faults

The general picture of the history of the Rift Valley is a structural and volcanic cycle which was repeated in both the Miocene and end-Tertiary deformations with varying emphasis.
The Quaternary period is significant for changes in sea-level, rift faulting, erosion, and the infilling of several independent basins. The separation of Zanzibar from the mainland probably took place in Quaternary time.

The Geological Map shows the principal faults: broadly speaking they can be divided into three groups: (a) an arcuate fault-zone extending from the Sudan to Lake Nyasa - the western Rift Valley; (b) a central meridional fault-zone extending from Lake Rufolf to near Dodoma, and thence to Mbeya - the eastern or Gregory Rift Valley; and (c) an arcuate eastern fault-zone extending from central Kenya to Lake Nyasa characterised by block faulting. Movements consequent on the crustal disturbances responsible for these fault-zones have taken place at different periods.

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3.3. Landforms

The landforms of an area influence many environmental factors, e.g. climate, micro-climate, water supply, soils, vegetation and agricultural potential. In order to make the complex terrain pattern of East Africa possible to grasp in a map view, the land is generalized into twelve major physiographic regions on map 10 (cf. figure 5).
The following regions are distinguished on the map:

1. The coastal margins. A narrow zone of coastal lowland in a 5-20 km wide belt along the whole coast of Kenya and Tanzania. The islands of Pemba, Zanzibar and Mafia are also included. The coastline is low and indefinite, whith small creeks and inlets and extensive mangrove forests. Coral reefs and banks are common up to 15 to 20 km from the main coastline. The deltas of the major rivers, particularly the Rufiji delta, differ from the coral limestone coast. The deltas are generally areas of very low relief, clayey sediments, annual flooding and intense cultivation.

2. The coastal hinterland is delimited as a narrow belt of low, dissected plateau country, parallel to the coastal margin. It is on young sedimentary rocks, with marked river valleys, in contrast to the less dissected interior plateaux.

3. Alluvial plains. Wide and vast floodplains are typical of tropical rivers, depending on great differences of flow during extreme flooding in some rainy seasons and annual low water flow. Rivers with large alluvial plains are the Tana and Galana in Kenya and the Pangani, Wami, Ruvu, Great Ruaha, Kilombero and Rufiji in Tanzania (see map 12).

Some of the floodplains are limited by fault lines in the bedrock, creating interior basins from Tertiary times. The alluvial basins can be divided into two parts: the lower flood plain along the river, and the margins of the basin where sediment brought by tributary streams has built up a series of gently sloping fans.
The flatter central portions of the flood plains are considered to have great development possibilities, particularly for irrigation farming (cf. 3.4.4.). The margins of the alluvial plains with sandier soils are characterized as follows: "Considerable development of the margins of the basins can take place as more limited investment can utilize the good soils and available water as at Kilombero." (Berry 1967 p. 61).

4. The south-east plateau of Tanzania.

5. The masai plateau.

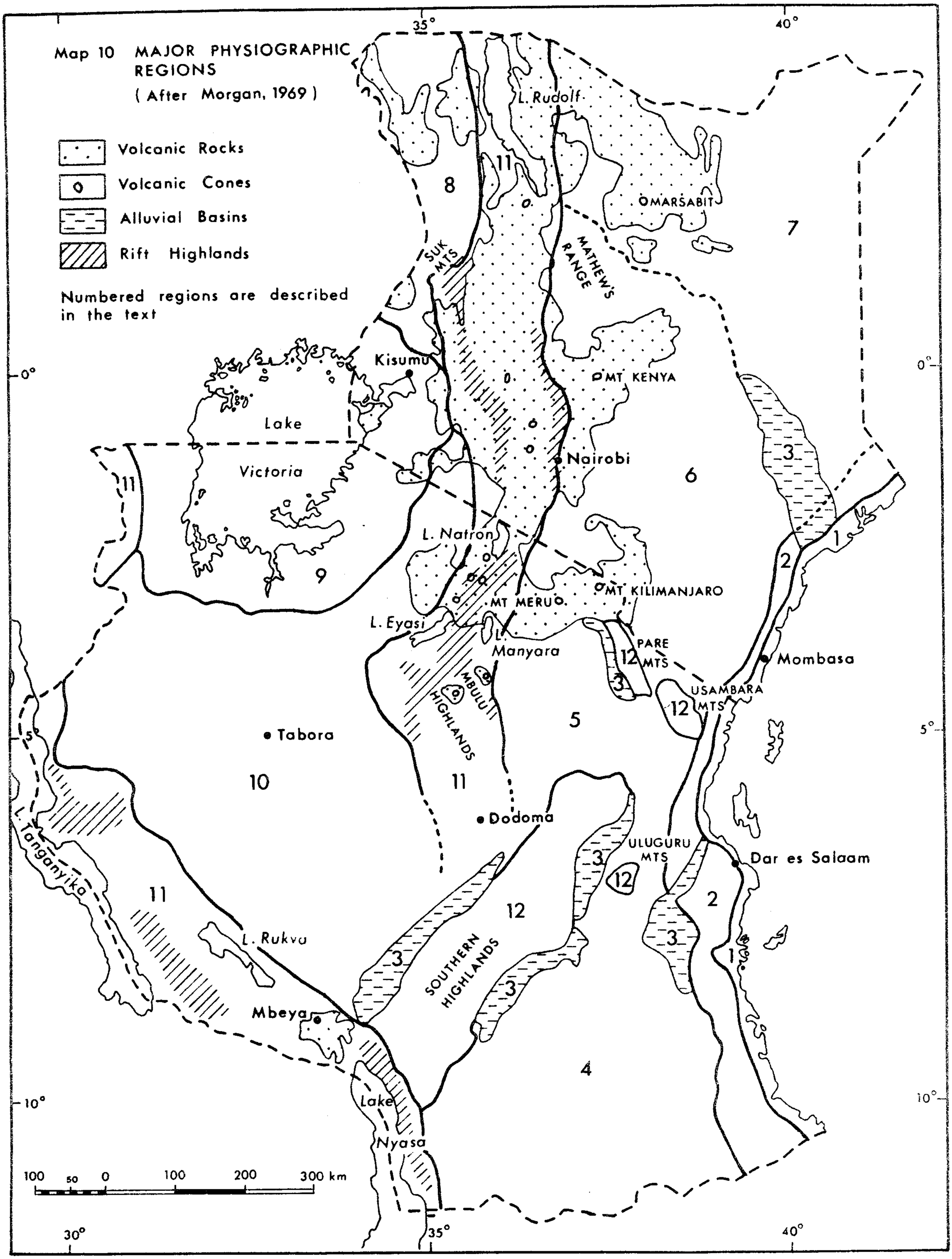
6. The plateau of eastern Kenya.

7. The plateau of northern Kenya.

8. The central plateau of Uganda.

10. The central plateau of Tanzania. All these (4 - 8 and 10) are interior high plains at about 500 - 1500 m elevation above sea level. Their monotonous flatness is broken by inselbergs (erosional bedrock hills) in granite or gneiss or by young volcanoes in the volcanic areas.

These vast interior plains occupy by far the largest areas of East Africa. They are generally characterized by semi-arid savanna vegetation, long dry seasons and frequent droughts.


Map 10 MAJOR PHYSIOGRAPHIC REGIONS
(After Morgan, 1969)
Volcanic Rocks
Volcanic Cones
Alluvial Basins
Rift Highlands
Numbered regions are described in the text
35°
40°
0°
5°
10°
30°
L. Rudolf
OMARSABIT
SUK MTS
MATHEW'S RANGE
Kisumu
MT KENYA
Lake
Victoria
Nairobi
L. Natron
MT KILIMANJARO
MT MERU
L. Eyasi
L. Manyara
PARE MTS
Mombasa
USAMBARA MTS
MBULU HIGHLANDS
Tabora
Dodoma
ULUGURU MTS
Dar es Salaam
L. Tanganyika
L. Rukwa
SOUTHERN HIGHLANDS
Mbeya
Lake
Nyasa
100 50 0 100 200 300 km

Although the areas are marked as uniform physiographic regions on generalized maps, they offer a wide variety of ecosystems, partly due to the great influence of topography upon drainage (see 3.4.3.). The typical sequence of landforms on the high plains underlain by granite or gneiss is as follows (cf. figure 6 in 3.4.2.):

a) Inselberg, partly bare bedrock. High runoff.
b) Upper pediment slope. 3°-10° of gradient. Sandy, red soils, much erosion, high water losses. Grazing.
c) Lower pediment slopes, 3°-4°, silty and sandy soils. Cultivation. Moderate water losses.
d) Floodplains (mbugas). Clayey soils, water logging. Grasslands for dry season grazing. Cultivation in many places.

9. Lake Victoria basin. Essentially an inselberg plain with laterite-capped plateau hills (cf. figure 7) and small valleys. The gradient of the streams is low and swamps or papyrus marshes are common.

11. Rift valleys and fault-scarp zone. On either side of the central plateau the East African rift features constitute a striking element in the landscape. There are several related facets of this landscape; the rift valleys themselves, the highlands on the margins of the rift and the volcanic features which are associated with the two.
The isolated volcanic cones rising 1000-5000 m above the surrounding plains are centres of high agricultural production and important source areas for rivers.

12. Block mountains. Most block mountains are found in Tanzania. The Pare mountains, Usambara, Uluguru, and the Southern Highlands are all bounded by major faults. So are also the Taita Hills in Kenya. As in the case of the volcanoes, the block mountains form important water catchments, forest reserves and agricultural zones.

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3.4. Soils

3.4.1. Introduction

It can justly be said that rainfall and potential evaporation - total amounts and seasonal distribution - are the main factors deciding the theoretical potential for vegetative growth. Within a region of uniform climate there are normally, however, pronounced differences in actual growth, manifested in varying yields of cultivated crops or natural vegetation of different physiognomy and species composition. These differences can in most cases be attributed to variations in soil physical and/or chemical characteristics.
The ability of the soil to store moisture in the root-zone of the plants and to slowly release it after the rains have ceased, is a factor of decisive importance over much of East Africa with seasonal and unreliable rainfall (see 3.1.2.). Likewise, the low chemical fertility of many of the old soils, characteristic of the plateaux peneplains, sets a limit to potential growth.

It is therefore quite natural that some kind of soil survey, either direct by sampling and analysis, or indirect by air photo interpretation or by looking at indicator vegetation and plants, normally forms one of the bases for decisions on land use. Indeed, soil maps are often directly transferred to maps of potential land use (cf. 6.3.3.2. and 6.4.1.2.). This may be relevant for small, climatically uniform areas and where detailed and accurate soil maps are available, but otherwise climatic and topographic variation must be taken into account.
In the following a very brief introduction to soil formation, classification, characteristics and distribution of the major soil types of East Africa will be given.

3.4.2. Soil formation

The characteristics of a soil of any particular place are the results of the interaction of the soil forming factors - climate, living organisms, parent material, time and topography - and the soil forming processes that these give rise to.
There are some aspects of the action of the soil forming factors in East Africa (and the tropics as a whole) that are of such great importance for the understanding of the use potential of the soils that they motivate some elaboration.

Climate is considered the most important soil forming factor, both through the direct influence of rainfall and temperature and indirect through its influence on vegetation (organic matter production) and topography (erosion). The feature of tropical climate mostly responsible for the differences in soil formation compared to temperate regions are the constantly high temperatures. In the presence of soil moisture this favours a high degree of chemical decomposition and weathering of the primary rock minerals. If rainfall is high and the drainage not impeded, the dissolved components from the weathering are leached out of the soil to the groundwater or they are concentrated at depth. The remaining components are iron and aluminium oxides, quartz and secondary clay minerals, mainly kaolinite. It is the iron oxides that give the characteristic red colour to many tropical soils. Red soils develop over a great variety of geological material in the tropics, from basaltic lavas to sandstones, where rainfall is high to moderate and drainage good, and they can be considered as the climatic, or zonal, soil type.

It should however be noted that there are large variations in the characteristics of the red (latosolic) soils, depending on rainfall, time, topography, parent material etc. - from deeply weathered, highly leached soils, completely devoid of all mineral nutrients, to very fertile red loams developed on fairly recent lavas, like in the Kenya highlands and on Kilimanjaro in Tanzania.
In areas of low rainfall, like in Northern Kenya, physical weathering dominates and the soils are often coarse and made up mainly of primary rock fragments.

Living organisms, including soil-living microorganisms, vegetation, macrofauna and man, have a profound influence on the structure, texture, chemical fertility and stability of the topsoil. A vegetative cover protects the soil against erosion (cf. 5.4.), produces organic matter and recycles nutrients which otherwise should be lost through leaching. The roots increase the permeability of the soil, thereby decreasing surface run-off. The organic matter produced is decomposed by microorganisms into inorganic compounds and to humus, which is incorporated into the topsoil where it improves the structure, waterholding capacity and nutrient absorbtion capacity. On old kaolinitic soils the productivity is almost entirely dependent on the organic matter fraction. The apparent sharp decline in fertility resulting from clearing of forest vegetation depends on the gradual disintegration of humus when fresh organic matter through litter fall is no longer added. Leaching and compaction of the soil also increases.

Termites, of which there are a variety of species (not only the conspicuous moundbuilders), play an important role in that they bring up smaller particles from deeper layers to the topsoil with a consequent concentration of gravel and stones at depth. They also improve drainage and on soils with impeded drainage, islands of bushy vegetation are often seen on termite mounds.

The influence of man is, apart from where he actively works the soil for agriculture, mainly indirect via manipulation of the vegetative cover. In many cases the influence is negative in that removal of vegetation through clearing, burning and grazing of domestic stock increase erosion and decrease the organic matter content of the topsoil.

Parent material is described more in detail under the Geology section (3.2.). Although the climatically determined soil processes in principle are the same in humid and sub-humid regions on well drained soils, the parent material very much influences the soil characteristics. In Kenya and Tanzania, rocks of the basement complex, such as granites and gneisses, cover the largest part (see map 9), with considerable areas of volcanic rocks and ashes in connection to the Rift Valley and sedimentary rocks along the coast and in south-east Tanzania. Rocks rich in quartz and other primary minerals resistant to weathering, e.g. sandstones and some granites, give rise to coarse-textured, sandy soils, often very infertile because of small content of mineral nutrients, with excessive drainage and leaching and high erodibility.
Some lavas and other rocks, poor in quartz but rich in more easily weathered minerals, give rise to fine-textured soils.

The chemical composition of the rock, apart from directly influencing the fertility by the amount of nutrients released on weathering, also to a certain degree influences the formation of secondary clay minerals, like kaolinite and montmorillonite, and thereby the ability of the soil to store nutrients and water.

Parent material also have an impact via the differences in the geological erosion processes and, hence, the topography.
In drier regions the relative importance of parent material is more pronounced as well as it is more important the shorter the time the rock has been exposed to climate. In areas of high rainfall and old soils the differences caused by variation in parent material tend to be smaller.

The time that the soil forming processes have been active on the substrate is thus of importance and decides the maturity of the soil. Geologically recently exposed surfaces - like the Rift Valley volcanics, or redistributed and continously rejuvenated substrates like alluvial deposits, or steep slopes where erosion removes the weathered products - have young soils with weak profile development. On old, flat peneplains where erosion is at a minimum, the time has had its greatest effects and soils are often deeply weathered and leached. Under certain conditions (see below) lateritic crusts cover the soil and protect the underlying rock from intensive weathering.

It is important to bear in mind the very considerable age, often millions of years, of the surfaces of the East African peneplains. Weathering has been going on under a variety of climates and reached very deep. The land surface have also been subjected to very great changes due to tectonic activity and changes in base level due to erosion. Therefore, the soil lying on a hilltop today may originally have been formed in a valley bottom and vice versa. Proper understanding of tropical soil formation must therefore take into consideration the geological and geomorphological history of the area.

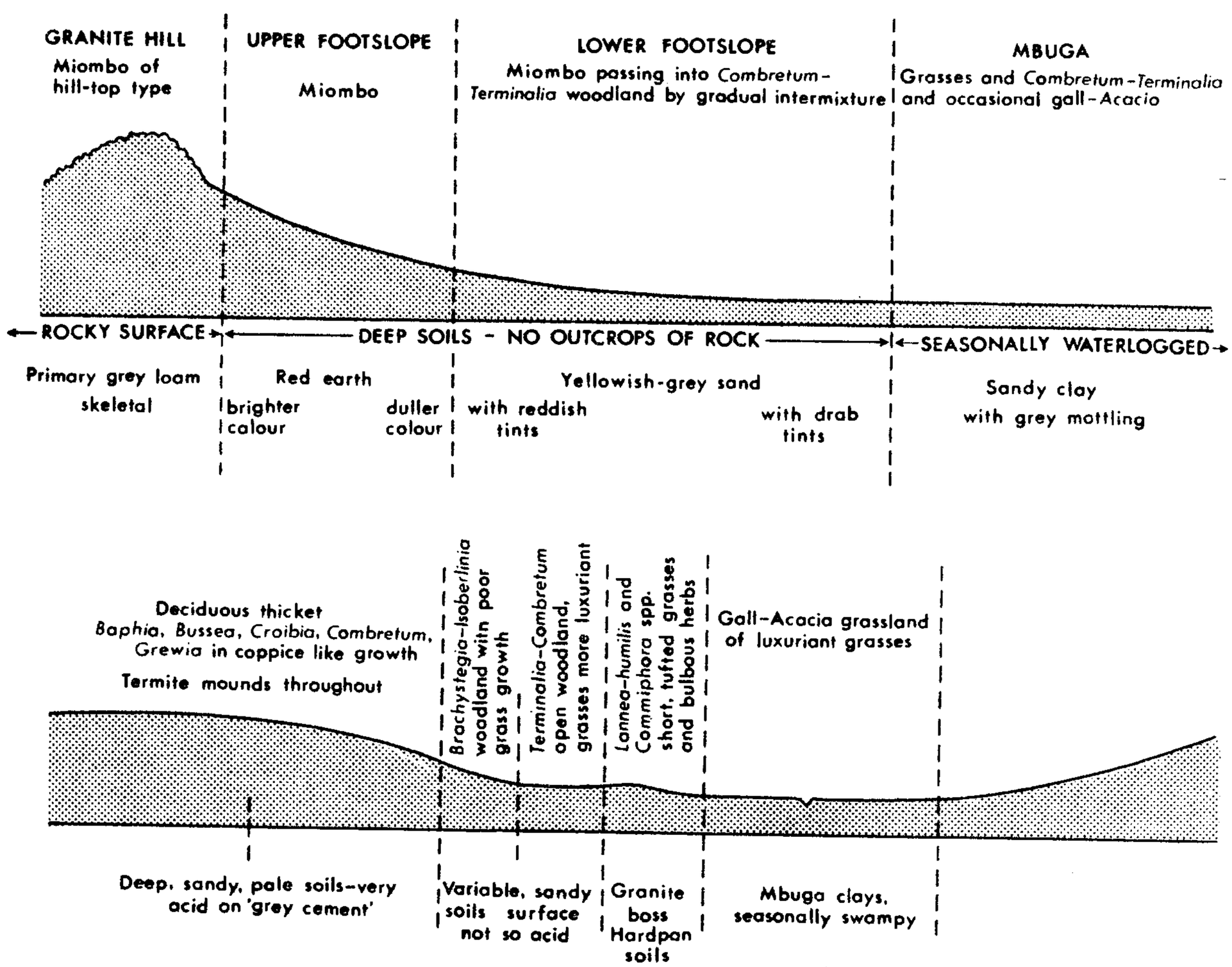
Topography influences the soil formation in that soil moisture and dissolved material from weathering not only moves vertically downwards but also laterally down the slope. Colluvial movement of mineral soil also takes place, as erosion or soil creep. On very steep slopes of highly dissected mountains, the removal of mineral matter through erosion is often so rapid that the soilforming processes are not given time to develop any profile.

Most of Kenya and Tanzania are made up of plateaux peneplains with gently undulating topography or almost flat land with isolated hills and inselbergs (cf. 3.3.). Under these conditions the movement of soil particles through erosion and soil creep is slow enough to allow the soilforming processes, including the lateral movement of dissolved material in the soil water, to develop a sequence of characteristic soil types along the slopes. In principle, the soils on the upper slopes, that are formed directly from the underlying parent rock, are normally red, welldrained and deeply weathered zonal soils. Rock outcrops may occur on the hilltops. On the lower slopes an accumulation of both transported, dissolved material in the soil and of coarser particles like sand on the soil takes place. The soil type is thus formed on material originating from higher up (colluvium). In the flat valley bottoms, clays and bases (like calcium) dissolved in the drained water accumulate. These dark clay soils, locally called "mbugas", are very characteristic for depressions in much of East Africa.

These soil toposequences along slopes occur in a recurrent pattern over vast areas with similar climate, topography and parent material. They are called "catenas" and are of great significance in land use planning in East Africa because of the very different characteristics of the soils within small distances on different positions along the slopes.

Two examples of soil catenas with associated vegetation from Tanzania, typical for much of the "miombo" area, are shown in figure 6.

FIGURE 6. Two soil-vegetation catenas from Tanzania, the upper from Unyanyanbe, Tabora, the lower from Kazi-Kazi, Uyansi plateau. Source: Milne (1947)

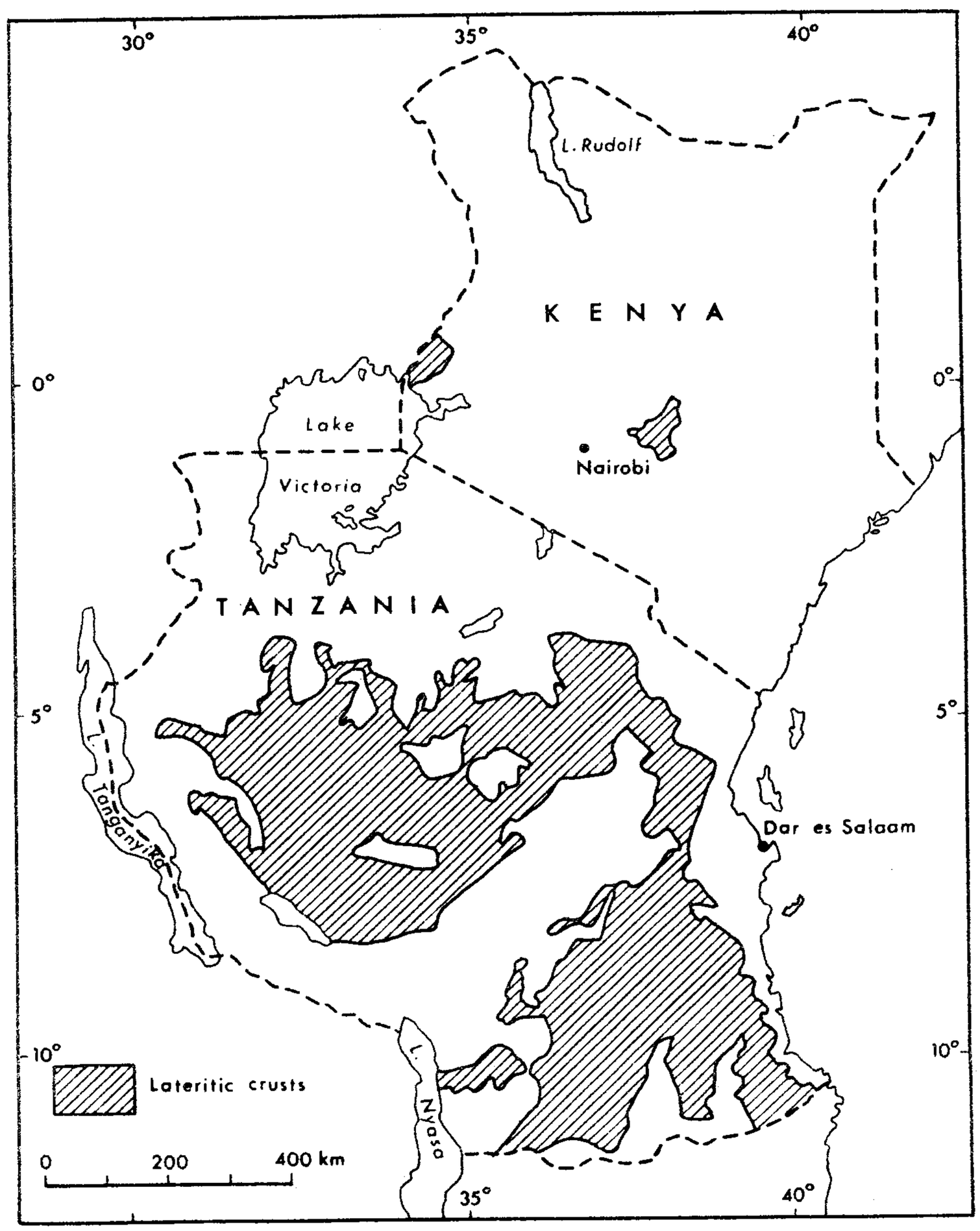


Hardpans are often formed in the section of material accumulation on the lower slopes, often where the drainage is impeded. Some types of accumulation and processes give rise to so called laterites.
The term laterite was originally applied to a particular type of ironrich material which, when exposed to the air, hardened irreversibly and was (and is) used as building material (later = latin for brick). The word has then been much used and misused, and a common misconception is that all red soils in the tropics are laterites. The unfortunate name "latosol" or latosolic soils for the red soils in general is an example of this.

Very simply - the question of how laterites are exactly formed is still somewhat disputed - laterites are formed in places where an absolute concentration of freemoving iron oxides occurs under conditions of fluctuating groundwater table and impeded drainage so that iron hydroxides are formed. This occurs mainly on the lower slopes, in areas of high rainfall (> 1000 m), on parent material fairly rich in iron, and under forest cover. It normally first forms as mottlings, which chemically consist of iron hydroxides and oxides, aluminium oxides, silica and kaolinite, in the zone of groundwater fluctuations. As long as a layer of freedraining soil overlies it and forest

vegetation prevents the erosive removal of this layer, the material remains soft and permeable (and as such is often called "soft plinthite").
When exposed to the varying dry and wet conditions of the air, the iron hydroxides form crystals that cement it into very hard ironstone ("hard plinthite").
Through secondary processes, both pedological and geomorphological, the mottles of laterite can be transformed into continuous pans which, if hardened by exposure through erosion or clearing of vegetation, are very resistant to further weathering and erosion, as well as almost impermeable to water and root penetration. These laterite surfaces, due to their age and resistance, are often found on hilltops and flat peneplains and in semi-arid areas, i.e. in topographical positions and under climatic conditions where they were probably not originally formed. These types of laterites are fairly common in East Africa (see figure 7).

FIGURE 7. Areas with lateritic (ferruginous) crusts.
Source: D'Hoore (1964)



In comparison, the process of "latosolisation" (or ferrallisation) refers to the more general case where weathering and leaching of primary minerals on free draining soils result, among else, in a relative concentration of iron- and aluminiumoxides in the upper part of the soil. Naturally these two processes are related since the latosolisation process is one of the conditions for the formation of laterites, but not the only one.

3.4.3. Soil classification

The combined effect of the various soil forming factors is rarely identical from one place to another and, consequently, there are always geographical variations in soil characteristics. These variations in soil physical and chemical properties may either be continuous along climatic gradients, when all other soil forming factors are the same, or they may be abrupt along topographic or geological boundaries.
For numerous, obvious reasons man has tried to bring order into this continuously changing medium by classifying soils into larger and smaller units.
Unfortunately, a very great number of international soil classification systems have been proposed, and partly accepted, why there is an annoying confusion regarding terminology in maps and publications. This is particularly the case with tropical soils, partly because most systems have mainly been developed for temperate regions, partly due to the relative scarcity of basic data on tropical soil characteristics and distribution. The result has been that most classifications overgeneralises tropical soils, both with regard to their properties and to their distribution.

The criteria used when classifying soils into different units are almost as many as there are systems. The first level of classification is normally based on genesis and maturity of the soil. Genesis refers to the combinations of soilforming factors which cause the different soilforming processes. These processes give particular sets of soil characteristics, depending on the maturity (age) of the soil.

Second and subsequent levels are variously based on diagnostic horizons, colour, texture, drainage conditions, parent material, depth, dominant clay minerals, base saturation etc.
Naturally, those systems of classification where grouping of the soils are made according to features which are correlated to the productive capacity of the soil are the most relevant for land use planning purposes. It is not possible here, however, to evaluate the merits of the many systems that have been used for soil maps and descriptions in East Africa.

In the outline below of major characteristics and distribution (map 11) of East African soils the classification of D'Hoore has been used. It has got the advantage of having been worked out particularly for African soils and as such has been widely accepted in Africa. The soil names are based on standard British and French soil terminology which have been in use in Africa also prior to D'Hoore's system.

It should be mentioned that the FAO/Unesco Soil Map of the World project recently (1974) published their 1:5 mill. Soil Map of Africa.

3.4.4. Distribution and characteristics of major soil groups

Although most small scale regional or national soil maps and surveys are accompanied by statements of their lack of accuracy and limited use for specific soil capability conclusions for smaller areas, they are repeatedly misused in land planning operations (cf. 6.3.3.2.).

There are two main reasons why the greatest care must be exercised when interpreting such soil maps (e.g. the ones in the Kenya and Tanzania National Atlases, as well as map 11).

One is that only major soil groups and, in some cases, the first subdivisions of these, are mapped. Even if there is a correlation between soil capability and the characteristics used to define these soil groups, there are by no means correlations to all soil features that are of importance to crop production potential. For example, soil groups which are generally considered as having a low land use potential may locally be quite good due to favourable texture or, soils normally designed as highly productive may locally have serious deficiencies of vital micronutrients.

The second reason is that the soil maps are based on very little factual soil observations in the field. No systematic soil surveys have yet been completed, although one is under way in Kenya and one is planned for Tanzania.
Existing maps are based on scattered observations from limited soil investigations, the techniques and data of which vary considerably with the aims. These scattered observations have then been extrapolated with the aid of climatic, geological and topographical maps, many of these being inaccurate in themselves. The result is that the maps are very generalised indeed and, except where sharp topographic discontinuities affect soil distribution (e.g. along the Rift Valley, larger flood plains etc.), map boundaries between soil groups may in reality represent transitional zones of hundreds of kms width. This is particularly the case with the different types of red and yellow soils that are so common in East Africa.

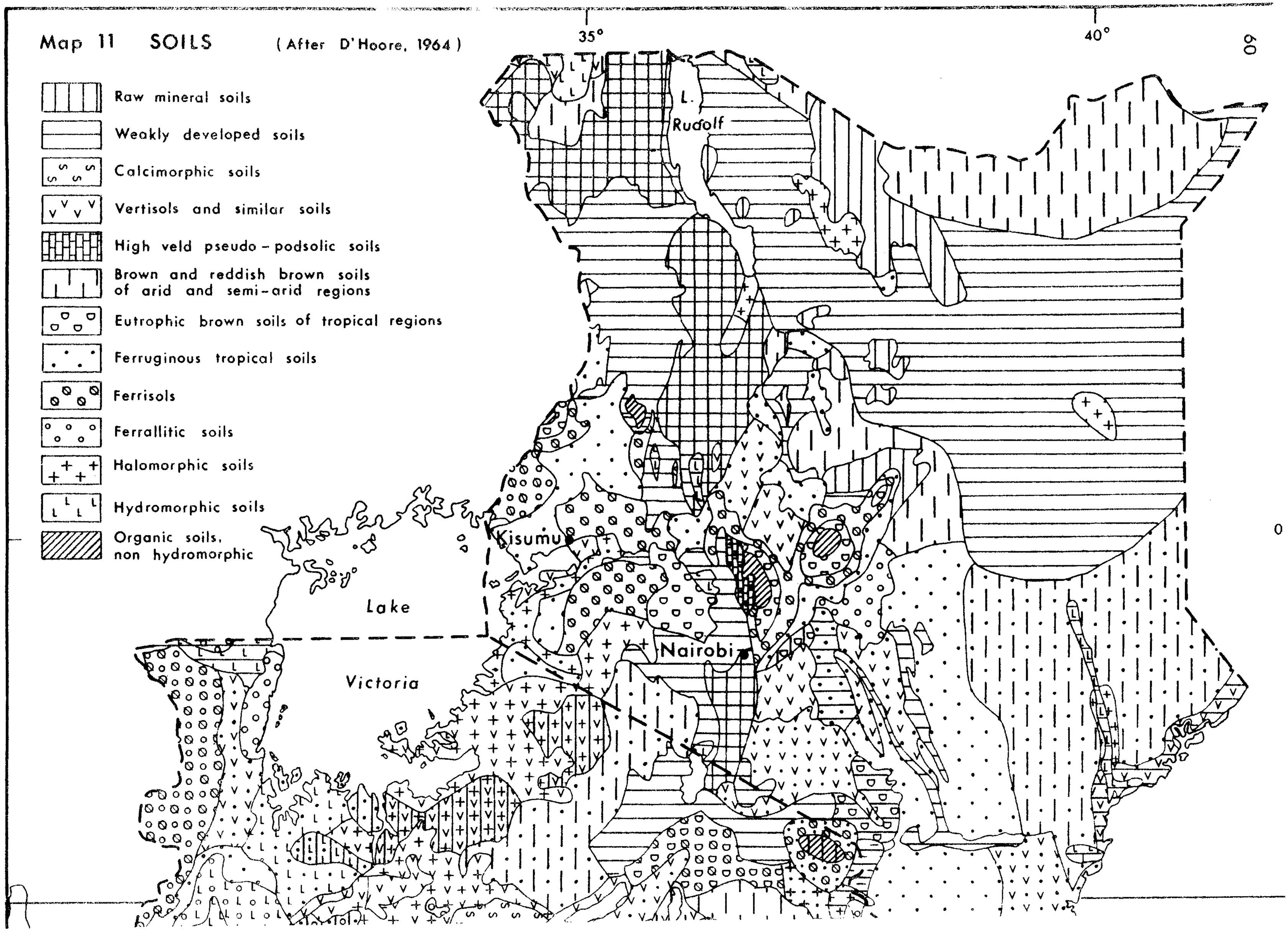
Another disadvantage is that only the dominant soil types in the catenas (see above) are represented on conventional maps. This can of course be overcome if the catenas are used as mapping units, as is the case in Scott's soil map in Morgan (1969). That approach is more relevant for land use surveys, particularly on larger scale (cf. 6.4.2.). It requires, however, a very elaborate explanatory legend and description, why it is not used here.

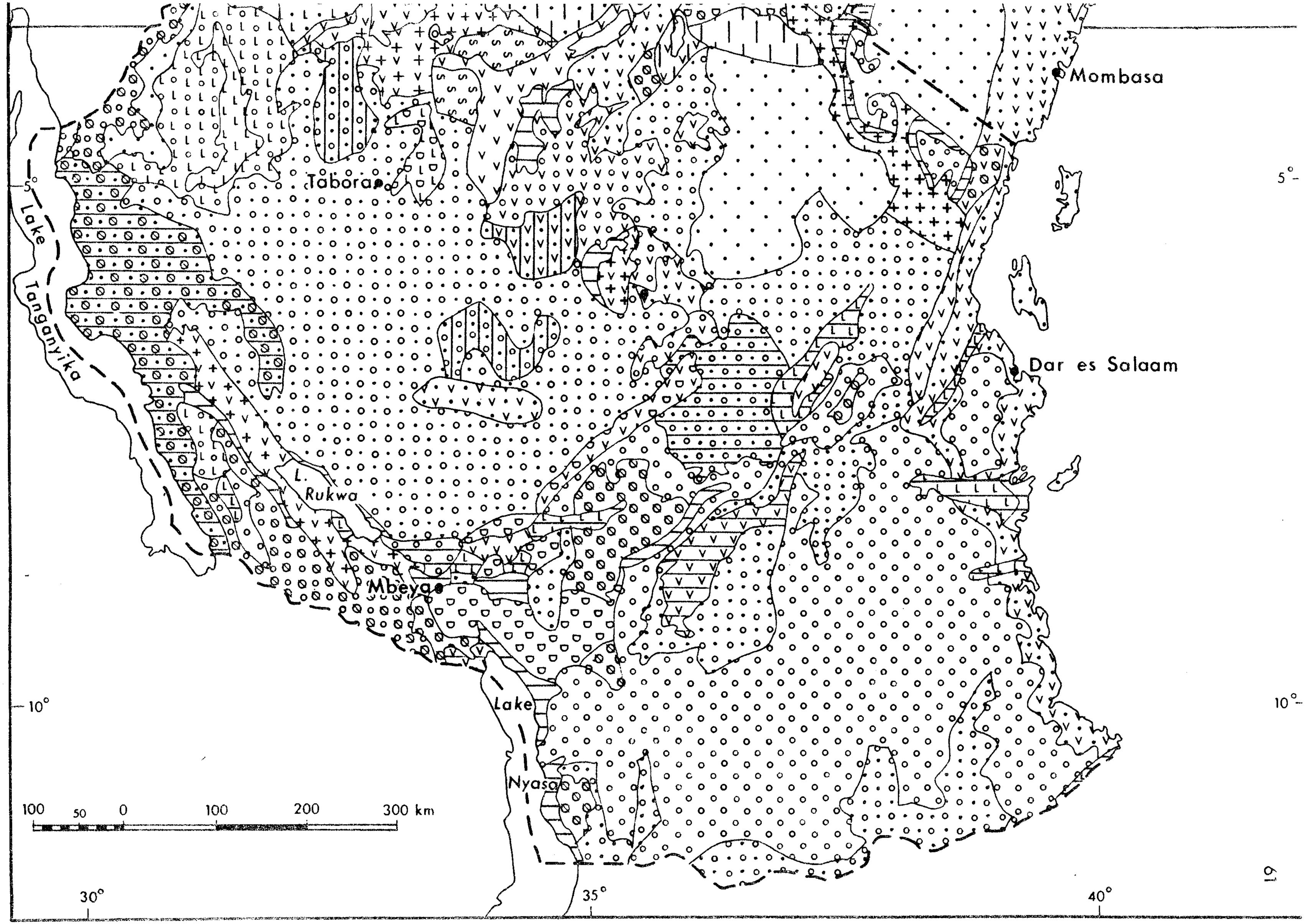
With all these restrictions in mind, the small scale maps are justified as introductions to the occurence and approximate distribution of major soil groups and as coarse indicators of crop production capability on a national or regional scale.

Raw mineral soils are made up of rock and rock debris which show little or no chemical weathering. They are subdivided according to what type of rocks they are derived from.
Extensively, they are only found in the north-west Kenyan semidesert around Lake Rudolf. Otherwise they are local on top of inselbergs or on steep slopes in the higher mountains.
They have no agricultural potential.

Weakly developed soils include a number of quite separate soils with the common feature that they lack profile development.
Very shallow types are called lithosols (or skeletal soils). They occur widely in arid and semi-arid regions, often together with raw mineral soils, in north Kenya and in the Rift Valley down to north Tanzania on lava. Lithosols are also found on steep slopes, e.g. rift escarpments and river-banks. In areas where erosion, either geological or accelerated, has removed most of the soil down to the underlying rock or ferruginous crust (laterite), lithic soils (shallow, coarse) are found. These soils are very prominent

Map 11 SOILS (After D'Hoore, 1964)




Mombasa
Tabora
Lake Tanganyika
Dar es Salaam
L. Rukwa
Mbeya
Lake Nyasa
5°
10°
30°
35°
40°
100 50 0 100 200 300 km

over much of central and south-east Tanzania, where they normally occupy the upper parts of the catenas.
Sub-desert soils without profile development, but not necessarily very shallow, are confined to north Kenya where they grade into brown and reddish brown soils as the rainfall increases.
Juvenile soils on recent deposits also lack profile development. They occur on volcanic ash, as in the dry bottom of Rift Valley around Lake Natron and Lake Magadi with extensions to the plains below Mts Meru and Kilimanjaro, and on riverine, lacustrine and fluvio-marine alluvium.
Apart from the lithic soils on eroded land, the weakly developed soils often have appreciable mineral nutrient reserves due to low degree of chemical weathering. In arid and semi-arid regions they have a high potential for crop production provided good quality water could be made available for irrigation.

Calcimorphic soils are developed in semi-arid areas on lime-stones, volcanic ash and lava and on old calcareous lacustrine sediments. They are variously mapped separately as rendzinas or brown calcareous soils or they are incorporated as calcic variants of juvenile soils (e.g. the ash soils of the semi-arid Rift Valley plains and around Mt Meru) or in the brown and reddish brown semi-arid soils. The common feature is the presence in the profile of large amounts of relatively soluble compounds of calcium. The only large area of typical calcareous soils are found south-west of Lake Eyasi and up to the East Serengeti plains in Tanzania.
Very high content of calcium in the soil immobilises the uptake of potassium which may cause problems in the utilisation of these soils. Apart from that, they have a fairly high potential for crop production, but since they are formed in dry regions (otherwise they would not have been calcareous, since calcium is easily leached out of the soil under moderate or high rainfall) they require irrigation.

Vertisols are heavy-textured, often dark clay soils, mainly formed on alluvial or colluvial material in flat valley bottoms and depressions with impeded drainage, under warm or hot climates with alternating dry and wet seasons. They are characterised by a dominance of montmorillinitic clays, the physical properties of which cause the soils to shrink and crack up in a polygonal pattern during dry seasons and swell again and become very sticky during the wet seasons. The soils are normally rich in calcium and magnesium.
Vertisols and similar soils are very common in catenary associations, where they occupy the flat depressions between ridges and hills ("mbugas"), in both Kenya and Tanzania. They are also developed on some large plains, where conditions for their development are favourable, such as the Athi Plains south of Nairobi and south-west of the Mau Escarpment in Kenya, on the Wembere Flats south-west of Lake Eyasi and around Lake Rukwa in Tanzania.
Their high natural fertility, uniformity and occurence on large plains, make them interesting for mechanised agriculture. The potential is however reduced by the unfavourable physical properties with bad drainage and seasonal cracking and swelling which destroy the roots of plants. The range of crops that can be grown is therefore limited. Trees are for example very difficult to raise on vertisols (the natural vegetation is edaphic grassland), whereas crops like cotton (cf. the often used name Black Cotton Soils on the vertisols), rice, wheat, sorghum, sugar-cane or ground-nuts can be grown.

Brown and reddish brown soils of arid and semi-arid regions is a loosely defined group of climatic soils which occur in dry or very dry land. They

do show slight profile development in that calcium and gypsum concentrate at some depth (where percolation of the small amounts of rain stops) and sometimes there are also textural horizons. Physical weathering is prominent but some chemical weathering also occur during the short and erratic times when the soils are moist. In the drier range they grade into weakly developed sub-desert soils and in the wetter into ferruginous soils.
In East Africa, the semi-arid and arid soils are confined to two large blocks, one covering large areas of north-east Kenya, the other the Masai Steppe in north-east Tanzania.
Their agricultural potential depends entirely on availability of water for irrigation. Great care must be taken so that they do not develop halomorphic characteristics. Chemically, they often have large reserves of unweathered minerals. The normal land use on these soils is extensive grazing by pastoralists' stock. They are very susceptible to erosion.

Eutrophic brown soils, according to D'Hoore's classification, include two quite separate soils with the common feature of having high organic matter content and high chemical fertility. One is developed on ash and lava in the higher rainfall areas on the East African volcanic mountains, e.g. Mts. Kenya, Aberdares and Elgon in Kenya and Kilimanjaro, Meru and Rungwe in Tanzania. In most other classification systems they are called andosols.

The other type is developed on alluvial deposits in some river valleys. Even if the andosolic soils cover a small fraction only of the total area in the two countries, they are of extreme importance due to their high agricultural potential. They are already heavily utilised, and there is a risk of increasing erosion damages (due to their situation on mountain slopes) if even further pressure on them leads to the abandonment of the present wise crop combinations with an emphasis on permanent crops like coffee under a shade of planted or natural trees.

Ferruginous soils, ferrisols and ferrallitic soils represent stages of increasing weathering in tropical regions. They are the normal, climatic soils on older surfaces of humid and sub-humid areas with free drainage. Various expressions of the degree of weathering, e.g. relative amounts of clay minerals, silt/clay ratio, ratios of SiO_2/Fe_2O_3, base saturation and soil depth are used to separate them. Due to the confusion in terminology and the need for laboratory analysis for safe identification, there are large variations in their delimitation on different maps. A further point of confusion is that they may occur in areas where present day climate is not typical for their formation. In the Atlas of Tanzania for example, large areas are mapped as ferrisols, which, according to D'Hoore, are ferrallitic.
They all occur widely in East Africa, often in catenary association with lithosols and vertisols. Ferruginuos crusts (laterites) are found in all of them, where conditions have been favourable for its formation (see above and figure 7).

Ferruginous soils are developed in areas of moderate to fairly high, but markedly seasonal rainfall. They are red or reddish in colour due to the presence of iron oxides, a result of the weathering and leaching processes. These processes are fairly, but not extremely, intensive. Another result of the weathering is the dominance of kaolinitic clays. Unlike the ferrallitic soils there are, however, also other secondary clay minerals, like illite, and a higher reserve of unweathered primary minerals.

Extensive areas are found from the coast up to the Rift volcanic area in Kenya (e.g. most of the Tsavo National Park) and in north-east Tanzania. On the large Central Plateau in Tanzania they are mixed with old ferrallitic soils.
The agricultural potential depends very much on the parent material, ranging from very infertile, sandy soils along the coastal belt, to rather fertile clay loams on rocks rich in ferromagnesian minerals. The depth of the soil is also important. Due to their free drainage they are suitable for irrigation. Erodibility is often high, and areas of ferruginous soils which have been intensively used are often seriously affected by erosion, like the Machakos area in Kenya.

Ferrisols represent a transitional stage of weathering and fertility between ferruginous and ferrallitic soils. They still have reserves of unweathered minerals but a fairly low base saturation. They are mainly developed in areas of high rainfall but somewhat cooler climate than the typical ferrallitic soils. Ferrisols are also important in areas where weathering is intensive, but has not acted for a very long time, such as on the lower slopes around Kilimanjaro, Mt. Kenya, Aberdares and the Mau Escarpment, where fairly recent lavas form the substrate. They also occur on the slopes on the rain aspect sides of granitic and gneissic mountain massifs where a slow but continuous rejuvenation of the soils take place due to geological erosion. The eastern slopes of the Usambara and Uluguru Mts. are examples of this.
The high altitude, gently rolling grasslands around Sao Hill in south Tanzania are also mapped as ferrisols on map 11. Finally, they occur in a belt from Lake Nyasa along Lake Tanganyika up to the West Lake Region in west and south-west Tanzania.
Many ferrisols are quite good agricultural soils in spite of their fairly low fertility. Particularly the highland ferrisols, which often have a high organic matter content and always good physical properties are intensively used. The often better rainfall distribution than on the ferruginous soils is also an advantage.

Ferrallitic soils are intensively and deeply weathered, strongly leached soils with a complete dominance of kaolinite in the clay fraction and with high concentrations of iron- and/or aluminium-oxides. They are low or very low in all nutrients except iron. Their physical properties - drainage and water retention - are normally good.
High and evenly distributed rainfall and high temperatures are climatic conditions for their formation. They are developed on old, flat or gently undulating surfaces, where erosion is at a minimum.
In East Africa, true ferrallitic soils occur extensively in south-east Tanzania and together with ferruginous soils and ferrisols in catenary associations in central and east Tanzania.
Without fertilising they have a low potential for crop growth. A wide range of deficiencies occur, mainly of nitrogen and phosphorus, but also micronutrients. Toxic levels of iron and aluminium are also common. Shifting cultivation is the traditional form of land use due to the need of restoring organic matter in the soil, which disappears a few years after clearing of natural vegetation.
Due to their vast extent in tropical regions, free drainage, occurence in favourable climates and on flat ground, suitable for mechanised farming, they receive much attention in management research throughout the tropics at present.

Halomorphic soils are saline and alkali soils, with concentrations of soluble salts in the rootzone to levels inhibiting plant growth. They are mainly developed in warm or hot, arid and semi-arid areas, where drainage is poor, either on old marine sediments or where seasonal flooding or brackish water occurs. Rainfall is too low to wash out the salts from the topsoil. An elaborate classification of these soils exists, based on the dominant ions or salts in the soil, but it would lead too long to bring it up here. In East Africa they occur in some poorly drained swamp and alluvial flats, e.g. the Lorian Swamp and the Tana River basin in north-east Kenya and in the Pangani River Valley in north-east Tanzania. Typically, both Tana and Pangani Rivers originate on recent volcanic mountains, where large amounts of mineral salts are leached out of the fertile soils.
Halomorphic soils, in catenary sequences with e.g. vertisols, also occur in a large area south and south-east of Lake Victoria, e.g. on the west Serengeti Plains, and on the Katavi Plains in the Lake Rukwa Rift Valley in south-west Tanzania.

The agricultural potential is very low unless sufficient amounts of very high quality water can be used to wash out the harmful salts.

Hydromorphic soils are all soils influenced by seasonal waterlogging or high groundwater, which do not qualify as vertisols or halomorphic soils. They are subdivided into mineral and organic variants, both of which occur locally in Kenya and Tanzania, e.g. in the Wami and Rufiji River basins and the large swamps around the Moyowosi and Malagarasi Rivers and the seasonal Lake Sagara in west central Tanzania, and on the Rift Valley floor between Naivasha and Nakuru in Kenya.
Their agricultural potential is considerable, but they often require drainage measures.

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3.5. Hydrology

3.5.1. Lakes

East Africa is fortunate in containing a large proportion of the total area of freshwaters on the African continent (table 6), including not only the Great Lakes, but also numerous smaller lakes, swamps and impoundments, as well as several thousand kilometres of permanent and seasonal rivers. Most of these waters occur in tropical areas of low altitude, where biological productivity is high.

TABLE 6. Approximate areas of lakes in Kenya and Tanzania and in the rest of Africa.
Source: Morgan (1969, modified)

Lake systems	Kenya (km^2)	Tanzania (km^2)	Max. depth in m
Amboseli	100		2
Bahi (seasonal)		155	2
Baringo	170		8
Elmenteita	25		-
Eyasi		1,035	2
Hannington	35		2
Jipe	20	20	-
Kitangiri		155	5
Lorian (seasonal)	4,900		2
Magadi	100		2
Malagarasi (seasonal)		9,325	2
Manyara		450	2
Naivasha	200		15
Nakuru	50		2
Natron, Ngare Ngiro (seasonal)	25	?	2
Nyasa, Malawi		7,500	1.400
Rudolf	9,300		75
Rukwa		2,850	10
Tanganyika		13,200	1.400
Victoria	4,400	34,500	75
TOTALS	19,325	69,190	

Rest of Africa	(km^2)
Ugandan waters	36,120
Waters neighbouring East Africa	71,850
Upper Niger waters	3,100
Chad	21,700
Congo waters	5,700
Ethiopia waters	7,250
Zambia waters	4,900
Botswana waters	1,300
Total outside Kenya and Tanzania	151,920

As can be seen from table 6, Kenya and Tanzania account for about 40% of the total lake resources of the African continent. Their combined land area only amounts to the order of 5% of the total surface of the continent. Some of the lakes listed for these countries are, however, alkaline (e.g. Lake Nakuru) and thus of limited utilisation value.

Only a few percent of the land surface of Kenya and Tanzania receive rainfall that exceeds the potential evapotranspiration. Areas that provide dry weather streamflow are very limited indeed.
It is therefore imperative to maintain these stream source areas in a system of land use that will facilitate percolation of rainwater into the soil, thus reducing the twin hazards of flood runoff and soil erosion whilst replenishing to the fullest extent the ground water reserves responsible for the steady streamflow.

3.5.2. Drainage basins of East Africa

The drainage structure of East Africa may be divided into four main basins (cf. map 12):

I A western basin which drains into the Atlantic Ocean
II A northern basin which drains into the Mediterranean Sea
III An eastern basin which drains into the Indian Ocean
IV Internal basins which have no external runoff

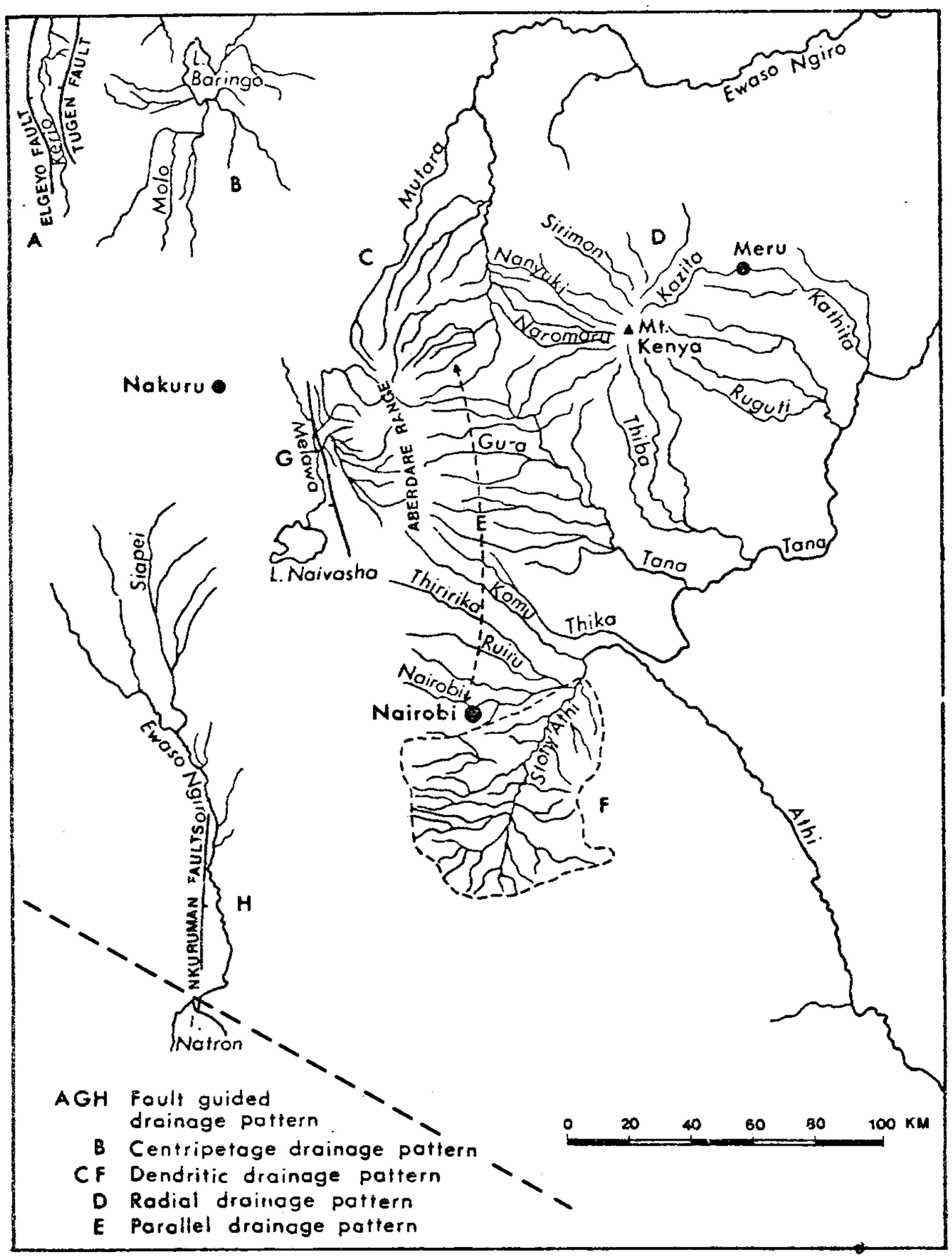
Each of these four major drainage basins may then be divided into a number of composite river basin (map 12). The internal basins involve the trough-like and of faults composed Rift Valley, which is occupied by many lakes: Tanganyika (725 km long, 50-70 km wide and over 1400 m deep), Nyasa (560 km long, 50-70 km wide and about 1000 m deep) and Albert (150 km long, 50 km wide and only 51 m deep) are the most important. The Rift Valley walls are usually steep and up to several hundred metres high. A major break in these walls is where the Malagarasi basin enters Lake Tanganyika.

3.5.3. Drainage pattern of Kenya

The drainage network of Kenya is fairly simple since the main rivers radiate either from the central Kenya Highlands or from the southern foothills of the Ethiopian Highlands. Thus, Mt. Kenya, Mt Elgon and Mt. Rift Valley cones are drained by simple radial streams. In the Rift Valley many of the rivers are guided by the occurrence of faults (see figure 8).

The lakes may, as regards origin, be divided into 4 main categories: tectonic, volcanic, glacial and coastal or flood plain.
Examples of tectonic lakes are Victoria and the lakes of the lowest parts of the Rift Valley - Rudolf, Nakuru, Naivasha, Magadi, etc.
Volcanic crater lakes are Simbi near Kendu Bay and Paradise in Marsabit.
The glacial lakes are small, rather tarns, the main ones of which are Michaelson, Hohnell and Enchanted.
The coastal lakes include those that occupy marshy ground both along the Indian Ocean and Lake Victoria. Many are ox-bow lakes, such as those in the lower part of the Tana River - Shakababo.

FIGURE 8. Some examples of drainage patterns in central Kenya.
Source: Ojany & Ogendo (197)



In Kenya the major river basins are:

I The Lake Victoria Basin - 49,000 km^2
II The Gregory Rift Basin - 127,000 km^2 which largely consists of an area of internal drainage
III The Indian Ocean drainage system with two major river basins, namely
a) The Athi River Basin - 70,000 km^2
b) The Tana River Basin - 132,000 km^2
IV The Ewaso Ng´iro System - a series of swampy drainage areas rising from the eastern highlands of Kenya and largely disappearing in the arid and semi-arid lands of the North-Eastern Province.

According to the department charged with water development, Kenya has limited surface water resources, and in the future greater reliance may have to be put on the underdeveloped groundwater resources for long-term development. There are only 4000 km of major rivers and 19,000 km^2 of lake area. Secondly, it is estimated that only 5% of the total annual precipitation goes into run-off and eventually feeds the rivers, swamps, and lakes, and large amounts of this finally disappear into the sea.
Special problems to be resolved within a coordinated water planning scheme involve the high rates of evaporation and the high rates of ground water absorption in certain districts. Ground water resources of the country are known to be extensive and underutilised in many districts excluding the Nairobi area. Control over the use of underground water has been imposed in Nairobi with a view of conservation, and mainly because it has the densest network of boreholes in the country.
In recent years the development of rural water supplies for agricultural and other purposes has led to the first steps towards the exploitation and utilisation of the underground water resources of the country. The Government's water development policy includes, among other things, the need "to improve the state of knowledge of the country's water resources and hydrology and to develop adequate long-term master plans for urban and rural water development".

3.5.4. Drainage pattern of Tanzania

Mainland Tanzania may be divided into 13 administrative hydrological regions. Each region represents a district drainage basin or a hydrological unit. The regions I, II, IV and V are drained to the Indian Ocean. Region VI in the central area is drained to internal lakes sited on the east branch of the Rift Valley. This region has no outlet to the oceans. Regions VII and VIII are drained to the Mediterranean and Atlantic via Lake Victoria and Lake Tanganyika respectively. The region IX, the basin of Lake Rukwa, has no outlet to the oceans. Like region VI it is a closed basin. Region III involves Lake Nyasa to the south.

Hydrological data in Tanzania are collected by the Water Development and Irrigation Division (W. D. & I. D.) from as early as 1952. A national hydrological network was set up from 1963. Hydrological research is now being built up through the National Water Research Council and the University of Dar es Salaam. River basin research can then be fitted into the overall development programmes for regional planning. At the national level overall comparative assessments of water resources need to be made regularly.

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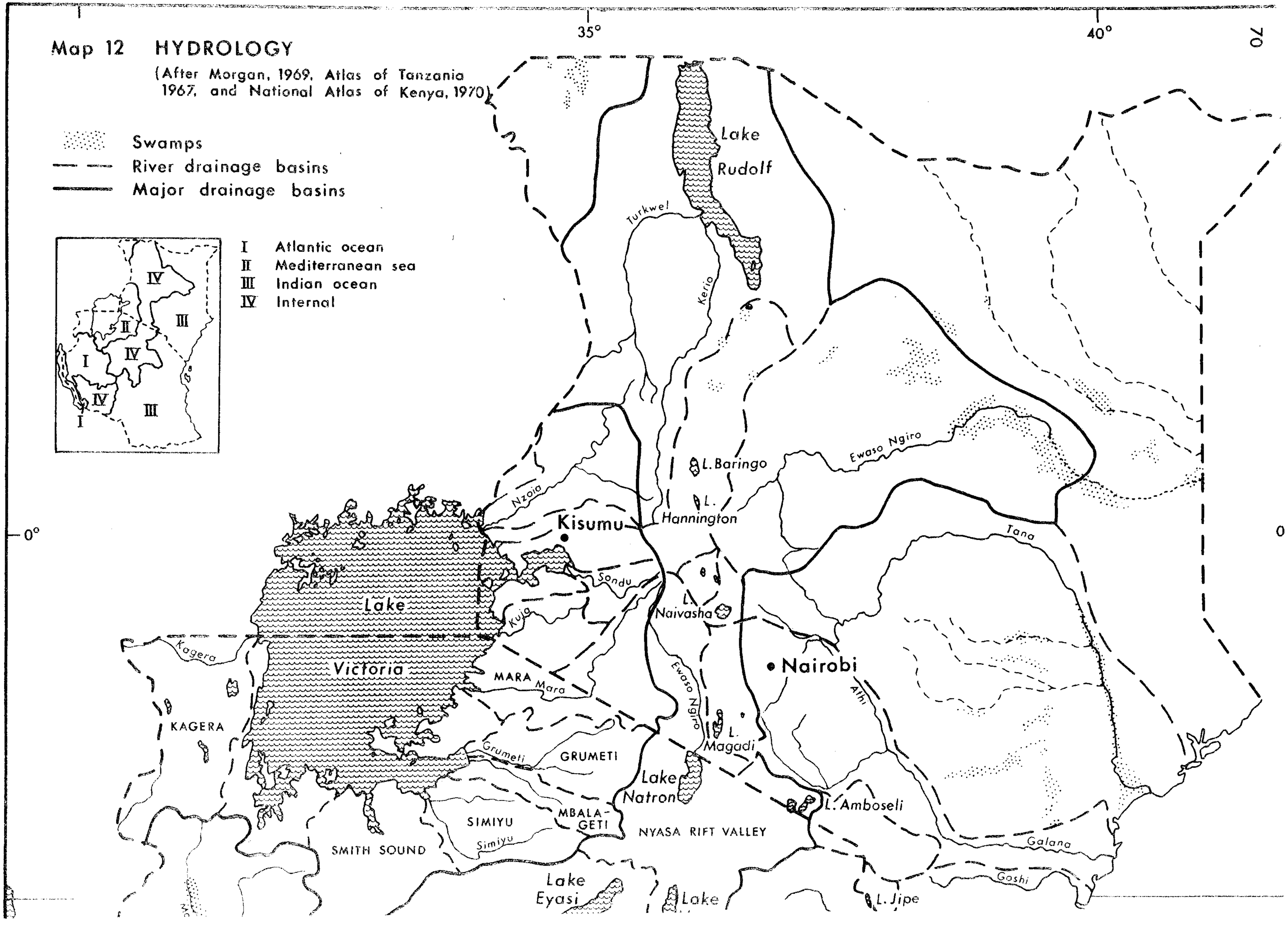
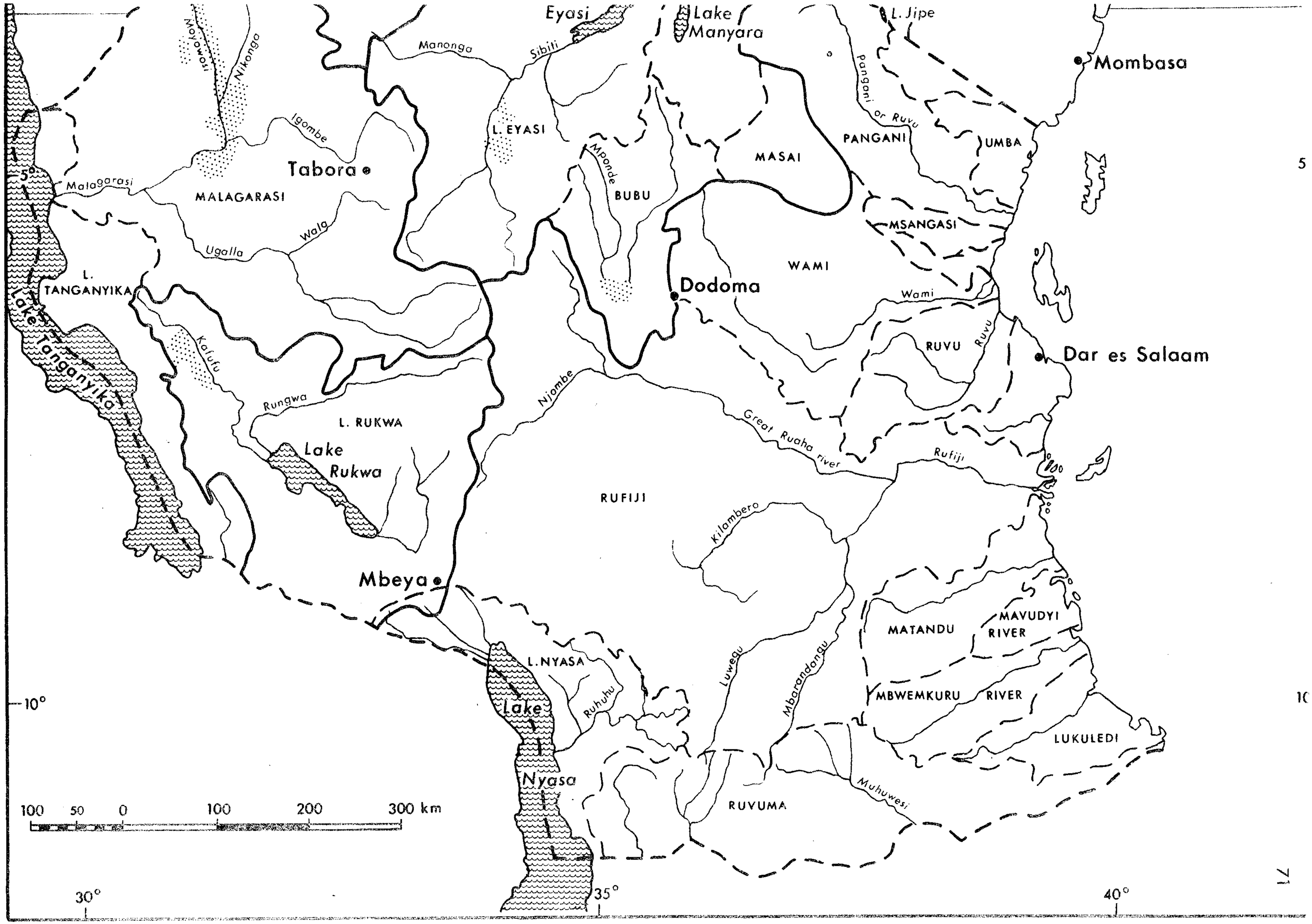
Map 12 HYDROLOGY

(After Morgan, 1969, Atlas of Tanzania 1967, and National Atlas of Kenya, 1970)




Eyasi
Lake Manyara
L. Jipe
Mombasa
Mayowosi
Nikonga
Manonga
Sibiti
Pangani or Ruvu
PANGANI
UMBA
Igombe
L. EYASI
Tabora
Malagarasi
MALAGARASI
Mponde
BUBU
MASAI
MSANGASI
Ugalla
Wala
WAMI
Dodoma
L. TANGANYIKA
Lake Tanganyika
Wami
RUVU
Ruvu
Dar es Salaam
Kafufu
Rungwa
L. RUKWA
Lake Rukwa
Njombe
Great Ruaha river
Rufiji
RUFIJI
Kilambero
Mbeya
MATANDU
MAVUDYI RIVER
L. NYASA
Luwegu
Mbarandangu
Ruhuhu
MBWEMKURU RIVER
LUKULEDI
Lake Nyasa
Muhuwesi
RUVUMA
100 50 0 100 200 300 km
5°
10°
30°
35°
40°

3.6. Vegetation

3.6.1. Introduction

Looking at the vegetation for guidance on how to use a particular area of land has always been an important part of the everyday life of agriculturalists and pastoralists all over the world.
Knowledge about the ecological factors determining the distribution of individiual taxa and about the environment in which particular plant communities develop, gives to the experienced farmer, forester or scientist indications about climatic and soil conditions. Using this knowledge wisely may prevent unnecessary mistakes in selecting suitable crops for an area, reduce costs for expensive soil investigations and compensate for the lack of detailed climatic information.
Description and mapping of the natural vegetation, and its interpretation in terms of soils, climatic and other information, must therefore be indispensable parts of any serious land use planning operation, particularly in areas where detailed information on soil and climate are insufficient, as is often the case in East Africa (cf. 6.4.1.5.).

Natural vegetation, in the sense of climax communities developed over long periods of time under the sole influence of soil and climate and in equilibrium (selfperpetuating, without gains or losses in biomass) with the environment, rarely exists in East Africa today. The influence of man has more or less modified the vegetation over most areas accessible to his activities, such as agriculture (permanent and shifting), grazing of domestic stock, use of fire and, more recently, use of pesticides e.g. for bush clearing in tsetse infected areas.
When using the term "natural vegetation" here, as well as in most literature on the topic, it must be borne in mind that, unless otherwise stated, it refers to all more or less disturbed vegetation that is <u>not actively established</u> by man and which is mainly made up of indigenous plants. Many types of natural vegetation thus defined, which to a layman may seem undisturbed, are in fact actively managed and/or maintained in that state by man's activities.

3.6.2. Classification

No final classification system and terminology of East African natural vegetation have as yet been generally agreed upon. For small scale maps (say 1:1 mill. or smaller) and broad regional descriptions of the vegetation the classification and terminology used by Trapnell and Langdale-Brown (1962 and 1969 in Russel and Morgan resp.), which in turn is a synthesis of the Yangambi system (1956) and Greenway (1943), seems to be the most widely accepted, why it is also used in the following account.
In a recent, comprehensive, monograph on East African vegetation, the first of its kind and highly recommended to those who want a more full knowledge of these questions, Lind and Morrison (1974) avoid the use of the term "savanna". It will, however, be retained here since it is still widely used.

The broadest categories of vegetation distinguished by Trapnell and Langdale-Brown are separated on the basis of their physiognomic (height, density, growth form, stratification and ground cover) characteristics. These are called <u>vegetation types</u>, the distribution of which are mainly governed by the general climatic conditions (zonal) - high mountain, forest, woodland, savanna, bushland/thicket and semi-desert vegetation - or by particular, normally edaphic, factors - grasslands and swamps. The next subdivision normally reflects different climatic conditions in terms of seasonality in rainfall or variations in temperatures - e.g. evergreen or

deciduous forms, high or low altitude forms etc. Further still, a subdivision is, where appropriate, made on taxonomic (mostly at generic level) dominance, normally reflecting soil or human influence factors.
If mapping and description are made on larger scales (>1:1 mill.), plant communities are separated, based on certain combinations of species dominance.

When preparing a vegetation map of East Africa on a small scale (map 13) large generalisations are necessary due to the topographic influences, which create an irregular pattern of ecological conditions, in contrast e.g. to the fairly regular climatic and vegetational north-south gradients in West Africa. It is particularly clear on the many isolated volcanoes and mountain massifs, where a distinct zonation of vegetation occurs along a steep gradient of rainfall and temperature (see figure 9). But also on small hills and ridges, where there are only very small differences in climate between top and foot, the vegetation changes along the soil "catena" (see 3.4.2. and figure 6) due to marked differences in available soil moisture and drainage conditions. Thus, bad waterholding properties of the soil gives a vegetation normally found in drier areas and vice versa.
On map 13 only the dominant vegetation types in the catena are indicated.

The approximate area covers of the different vegetation types described below are given in table 7.

TABLE 7. Areas of different vegetation types.
Source: Derived from planimetric calculation of the Vegetation map in Morgan (1969)

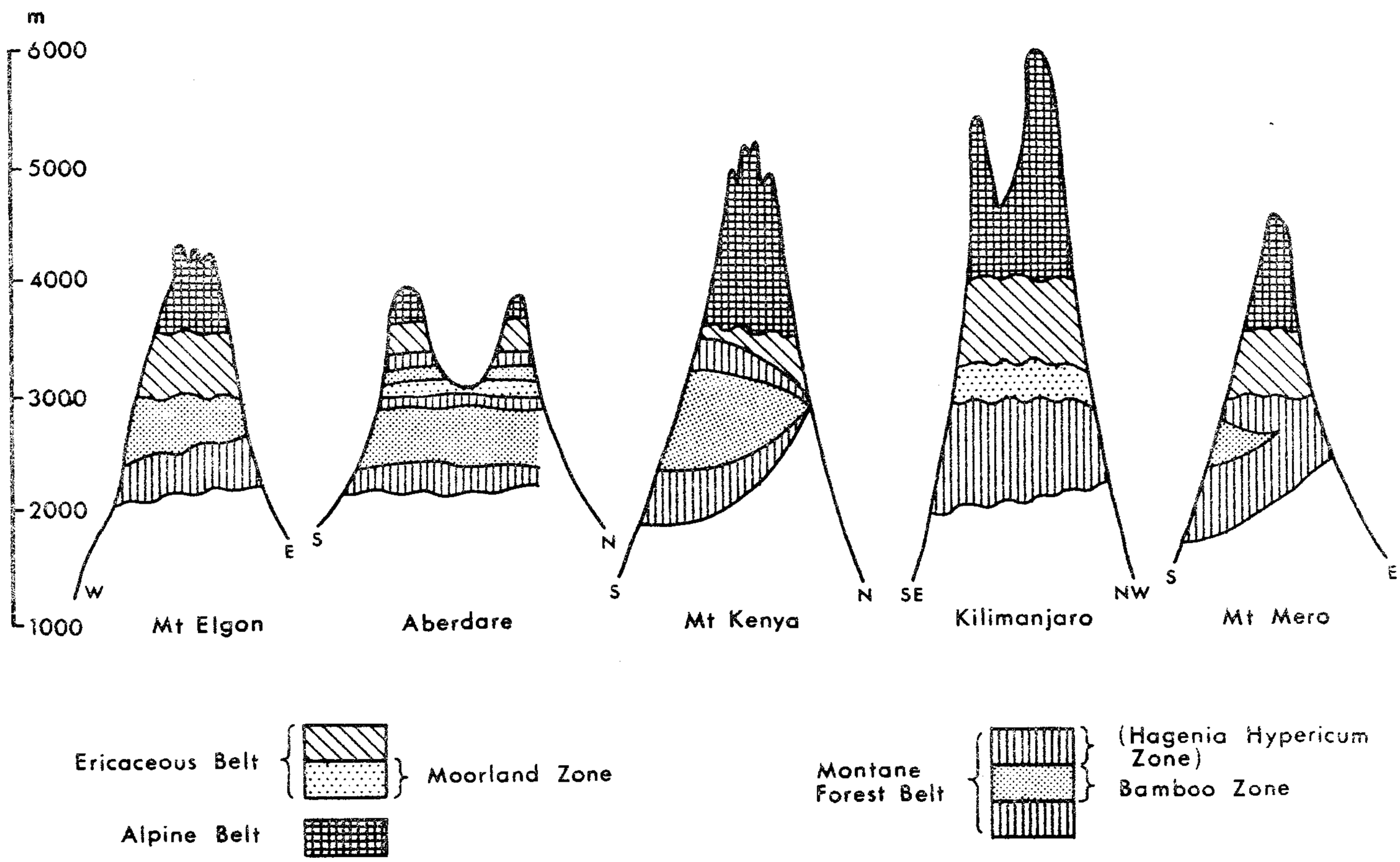
Vegetation type	Kenya		Tanzania	
	%	km^2(,000)	%	km^2(,000)
Afro-Alpine heath and moorland	0.2	1	0.1	1
Forest and forest grassland mosaic	6.6x	38	1.8xx	16xx
Woodland	-	-	45.7	405
Savanna	18.5	106	26.9	239
Grassland	0.3	2	9.1	81
Bushland and thicket	42.6	243	15.6	138
Semi-desert	28.8	164	-	-
Desert	2.4	13	-	-
Swamps (incl. mangroves)	0.7	4	0.8	7
Total land	100	571	100	887

NOTES: x/ 1.9 % or 11,000 km^2 is pure, closed forest (see table 27 in 4.3.3.).
xx/ The planimetric calculation from the small scale map gives an underrepresentation of forests (0.3 % only). The quoted figures are from table 27.

3.6.3. High mountain vegetation

The highest parts of the big East African mountains - e.g. Mts. Kenya, Elgon and Aberdares in Kenya and Mts. Kilimanjaro and Meru in Tanzania - have climatic conditions that do not support forest growth. Above appr. 3000 m (varying between different mountains and aspects of the same mountain) the forest gives way to what is often referred to as afro-alpine plant communities, which extend to the upper, thermal limit of plant growth at about 5000 m (see figure 9).

FIGURE 9. Vegetation zonation on the highest mountains in Kenya and Tanzania
Source: Hedberg (1951)



NOTE: The wettest side of each mountain is turned to the left

Although the total area of these vegetation types is very limited, they are of great phytogeographical interest due to their isolation and to the similarities and differences that exist in the flora on the different mountains.

Most of the high altitude regions on the mountains are now set aside as National Parks and Game Reserves to protect the unique flora and fauna. This has been relatively easy to do since the afro-alpine regions, due to climatic conditions, hold little attraction for other forms of land use.

The distribution of different communities is governed by altitude (climate) and soil moisture conditions. Above the forest, at approximately between 3000 and 4000 m, there is a belt of ericaceous woodland, made up of shrubs and small trees of Erica spp., Philippia spp, and Stoebe kilimandscharica along with some smaller trees which also occur in the upper forest, e.g. Rapanea spp. and Hypericum spp. Often these woodlands, particularly on the drier mountains, are thinned out and sometimes replaced by grassland due to fires.
Above this zone there is a belt of true alpine vegetation ("paramos"), made up of woodlands of the peculiar giant Senecio spp. (Dendrosenecio) and Lobelia spp. and grassland and scrub communities on drier sites, with e.g. Helichrysum spp.
Many of these plants show interesting physiological and morphological adaptations to the climatic regime, with large annual variation in rainfall and very pronounced diurnal variations in temperatures with frequent frosts during the night, and day temperatures around 10-15°C.

3.6.4. Forests

High or closed forest is normally defined as vegetation mainly made up of a dense growth of tall trees forming a closed canopy that prevents extensive grass growth.
It develops in areas of high (> 750 mm) and well distributed rainfall or where this is compensated for by high groundwater tables, as along rivers (riverine forest) or in swamps (swamp forests).
Large areas of East Africa, particularly in highland and coastal regions, have climatic conditions favourable to forest development, but extensive clearing of forest by man has reduced the area, so that today Kenya and Tanzania have only about 2 % of their land areas under high forest.
These remaining forests are almost entirely confined to Forest Reserves, set aside in the beginning of this century to protect water catchments and timber resources, mainly in mountain areas (cf. 4.3.).

Most classification systems of East African forests are based on two easily visible gradients of change. The first is along an altitude gradient, where lowland forests tend to be floristically richer and more complex in structure than mountain and highland forests under similar effective rainfall conditions. The other is a moisture gradient, which partly is correlated to altitude, but also to relief, direction of rain-carrying winds and evaporation, with moister forest more complex and species-rich than drier types. Thus, a division of the forests is made into lowland, intermediate and highland forms with dry and wet types of each. Often the degree of deciduousness, i.e. the number of species shedding all their leaves at some time of the year, is also included in the primary level of classification, distinguishing three classes - evergreen, semi-deciduous and deciduous.
Consequently, one can e.g. classify a forest as being "moist evergreen mountain forest" or "dry semi-deciduous intermediate forest", etc. All these different types merge into each other as one moves along the gradients, without clear boundaries in species composition and structure. For convenience, however, limits of appr. 1800 m altitude and appr. 1200 m annual rainfall are used to separate highland and wet forests from intermediate respectively dry types.

Intermediate and lowland forests are of very limited extent in Kenya and Tanzania. Moist forests of these types are found on the lower, eastfacing slopes of hills and mountains close to the coast - e.g. the Shimba Hills in Kenya and the Usambaras, Ngurus and Ulugurus in Tanzania - and in the Lake Victoria basin, such as the Kakamega forest in Kenya and some lakeside

and island forests in Bukoba and Mwanza districts of Tanzania.
These forests are the botanically richest and the most complex type of vegetation in East Africa and some of them are of great phytogeographical interest as indicators of previous larger distribution of lowland rain forests in Africa. The most notable are the forests of the East Usambara Mts, which show relations to the Congo rain forests, from which they are now separated by vast areas of dry land.
Each of these forests have indivudual combinations of dominant species why it should lead too long to give an account of all communities. The most important are Cephalosphaera-Allanblackia-Isoberlinia-Newtonia-Parinari combinations in the East Usambaras, Maesopsis-Croton in Kakamega and Chlorophora-Sterculia-Antiaria-Khaya in various coastal forests.
Dry semi-deciduous and evergreen types are found in flat coastal plains in north-east Tanzania and south-east Kenya, dominated by Brachylaena-Cynometra-Manilkara, and on the lowest slopes of some of the inland mountains. An example of the latter type is the Karura forest in Nairobi with Croton-Brachylaena-Calodendrum.

Highland and mountain forests are more common and occur in forest reserves on many of the isolated mountains and massifs around Kenya and Tanzania. Although individual characteristics in species dominance are found, the mountain forests show a striking similarity in species composition and zonation in view of the often long distances separating them.
On the rain aspect side of the mountains, between appr. 2000 and 2500 m altitude, evergreen or semi-deciduous moist mountain types are developed, dominated by combinations of Ocotea-Podocarpus-Olea-Aningeria-Pygeum-Croton-Albizia-Macaranga-Neoboutonia-Polyscias and many other co-dominant species.
The side of the mountains in rain shadow carry dry evergreen mountain forests, dominated by the conifers Juniperus and Podocarpus together with Olea, Nuxia, Dombeya, Cassipourea, Teclea and others.
Higher up, between 2500 and 3000 m, the forest is replaced by dense thickets of the mountain bamboo, Arundinaria, and/or a belt of low forest characterised by trees of Hagenia and Hypericum. These merge into the Ericaceous belt on its upper limits (see figure 9).
Edaphically controlled forests include the mangrove forests of the East African coast, riverine (riparian, gallery) forests along streams and rivers and semi-swamp forests (in the Bukoba district of Tanzania).

3.6.5. Woodlands

As defined by Trapnell and Langdale-Brown (after the Yangambi system) woodland is: "A mantle of trees of one or at most two storeys whose crowns more or less touch so as to form a light but mainly continuous canopy. The trees often have spreading crowns and the canopy height is from 8 to 18 m. The canopy species are normally deciduous and are commonly leafless for several months of the year. Woodland in this sense carries a ground vegetation of grasses mixed with herbs and shrubby plants". See figure 10.

By far the largest single vegetation type in Tanzania is the so called "miombo" woodland, covering around half the area of the country and mainly confined to two large blocks in the south-west and south-east with an extension up to south-east Kenya.
Tree species of the Leguminoseae family are completely dominant and among them the closely related genera Julbernardia and Brachystegia often make up 80 % of the trees. Locally co-dominant are the very valuable timber species Pterocarpus angolensis and Afzelia cuanzensis.

FIGURE 10. Brachystegia ("miombo") woodland.
Source: Pratt et al. (1966)

The miombo occurs from sea level up to about 1600 m and in areas of annual rainfall in the range 600 to 1200 mm, falling in a single season, with a long severe dry season when the trees are leafless.
Over most of its range the miombo is sparsely populated by man due to the presence of tse-tse (Glossina) flies, infertile soils and shortage of open water.
The fairly high, though unfavourably distributed, rainfall makes it a challenge for efforts to find productive use of this vast reserve of land.
Fires are frequent, often set by hunters and honeyseekers, and it has been an issue of dispute whether the miombo is maintained by fires or is a climatic climax. It seems as, if fireprotected, the woodland, at least in the higher rainfall range, develops into a dry semi-deciduous forest type vegetation with gradual suppression of grasses and increased complexity in structure.

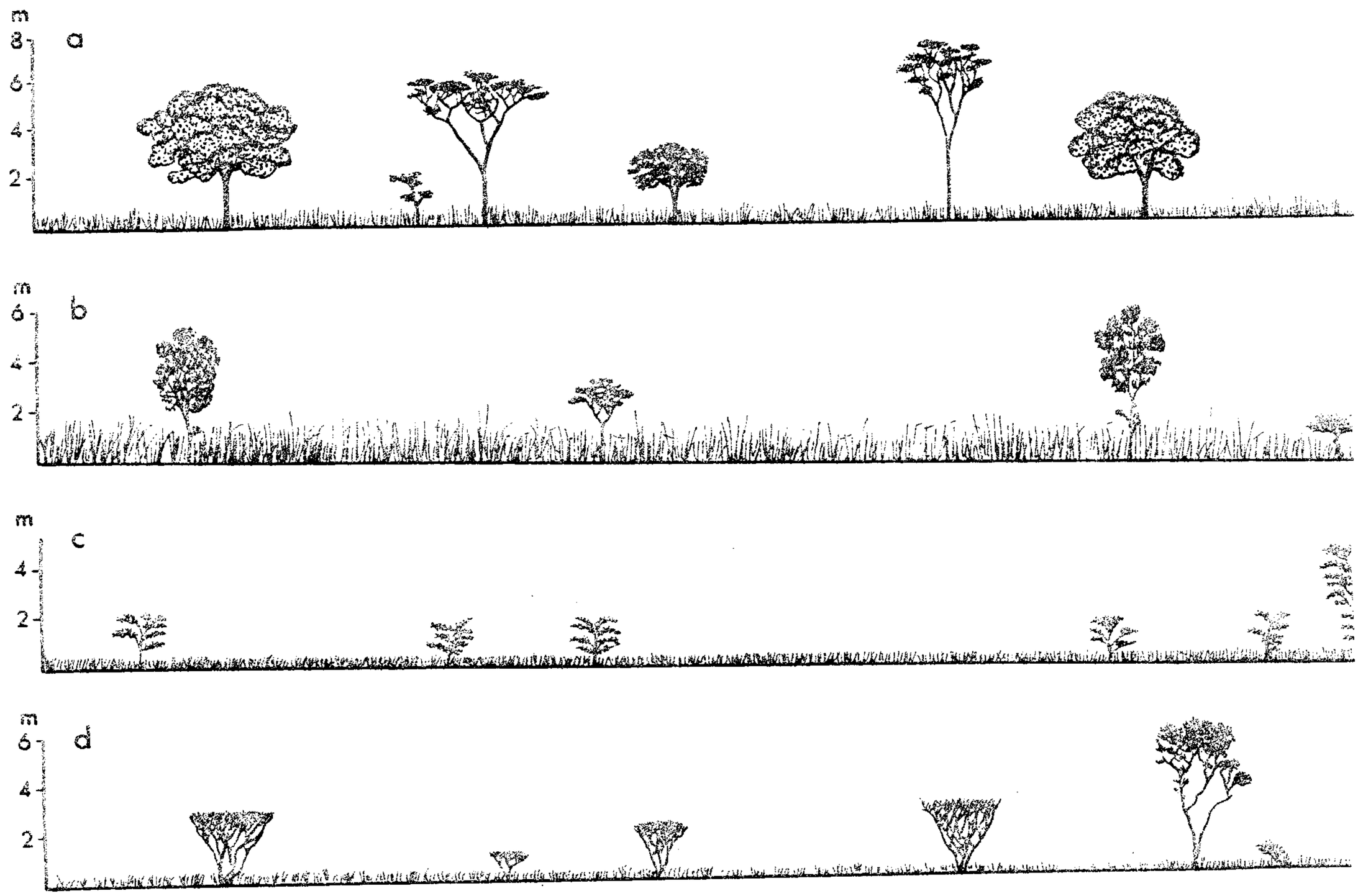
Other woodland types are e.g. the highland Acacia (A. lahai and A. abyssinica) woodlands of Kenya and north Tanzania, most likely derived from forest through the influence of man.
At lower altitudes other Acacia species locally form woodlands, particularly on alluvial flats.

3.6.6. Savannas and grasslands

Most of the confusion regarding the terminology of East African vegetation concerns the definition and use of the term savanna, and delimitations of savannas towards woodlands and bushland.
Trapnell and Langdale-Brown uses the Yangambi definition: "Open mixtures of trees and shrubs, with less than 50 % ground cover, in a tall growth of grass." The more open forms are referred to as "tree or shrub savanna" and closer forms as "wooded savanna" (see figure 11) In some literature the term savanna is replaced by "wooded grassland".

Open grasslands without woody constituents are normally separated as a special type because they are often edaphically controlled.
The most important ecological features of the savannas are the dominance of grasses and the frequent, normally annual, fires during the dry seasons.
Savannas occur under a wide range of climatic conditions and would, with the exception of the edaphic grasslands, turn into other types of vegetation if not repeatedly burnt, e.g. into forest or woodlands in areas of well respectively seasonally distributed high rainfall or into bushland/ thicket in areas of low rainfall.

FIGURE 11 a-d. Different types of savanna. a) wooded savanna (woodland), b) tree savanna (wooded grassland), c) dwarf tree savanna (dwarf tree grassland) and d) shrub savanna (bushed grassland)
Source: Pratt et al. (1966)



NOTE: Names in brackets refer to the terminology by Pratt et al., who do not use the term "savanna".

Overgrazing by domestic cattle in dry savannas in the Kenya and Tanzania Masailands often result in so called "bush encroachment" because, when the dry season arrive, the grass has been completely removed and the area does not burn. This permits the growth of thorny, unpalatable shrubs, which otherwise would have been prevented by fire, and eventually these shrubs, suppress grass growth and the carrying capacity for cattle decreases sharply (cf. 4.5.5.). This is a problem also in some National Parks with very high populations of ungulates, e.g. the Nairobi National Park. Controlled burning is therefore used as a management tool to maintain good grass growth.

The most widespread savanna types are characterised by broadleaved, small trees, of which the species-rich genus Combretum dominates, often together with Terminalia and, particularly in coastal and south Tanzania, Ostyroderris and Pericopsis. In drier areas Acacia and Commiphora become more and more prominent. In many well watered areas where savanna has been derived from forest, communities with Parinari, Protea, Erythrina, Rhus and others are developed.

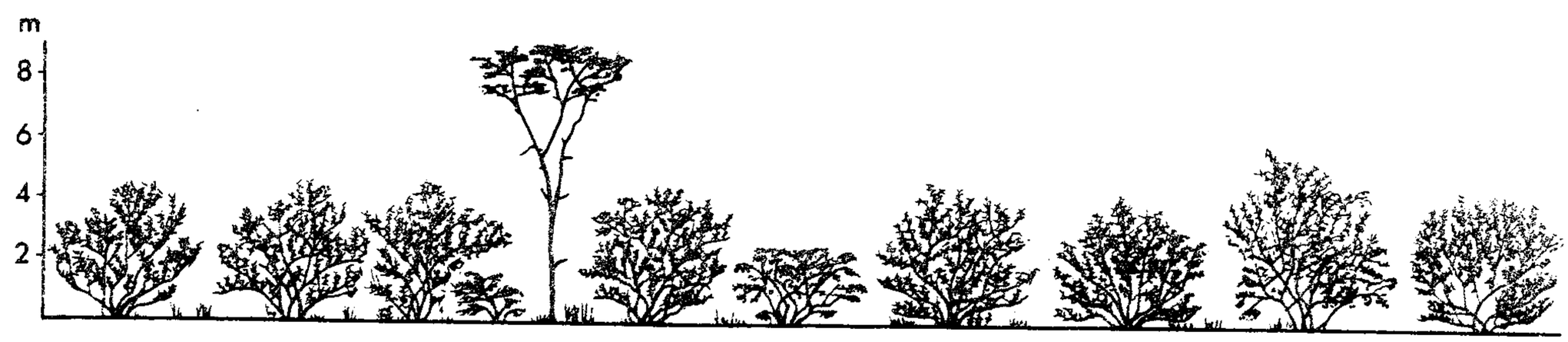
There are several types of Acacia savannas, some seemingly edaphic climaxes on flood-plains, seasonally water-logged soils and hard-pans, with dominance of species such as Acacia seyal and A. drepanolobium (the gall-Acacias) and A. tortilis. These types are important indicators in land capability studies (cf. 6.4.1.5.). Other Acacia-types are derived from bushland on drier sites and forests in moister mountain areas.
Apart from these main types there are several others, the dominant species varying according to the original vegetation from which the types are derived.

Pure grasslands, without woody vegetation, are confined to some highland areas, e.g. the Sao Hills of Tanzania and to soils with highly impeded drainage, e.g. underlain by shallow hardpans, or the "mbuga"-sites.

3.6.7. Bushlands and thickets

Vast areas of semi-arid East and North Kenya, central Tanzania and the Rift Valley in both countries are covered by various types of so called bushland and thicket vegetation communities. They are characterised by a mantle of small trees with a bushy habit (branching from the base) and bushes, often thorny, with a sparse growth of grass underneath. Occasional emergent trees may also be present. The denser forms, often impenetrable, are normally referred to as thickets and here the grass is almost totally absent. Fires are much less frequent than in the savannas due to the sparsity of grasses but in many regions the two are mixed and they can fairly easily be converted into each other by active use or prevention of fires or by the influence of animals (see 4.5.5.). The classificatory limit between "bushed savanna" and "bushland" is therefore normally arbitrarily set at some percentage ground cover of the woody plants, e.g. 50 %. Surface erosion is a common feature under bushland vegetation. At the drier end of their range the bushlands merge into semi-desert vegetation. See figure 12.

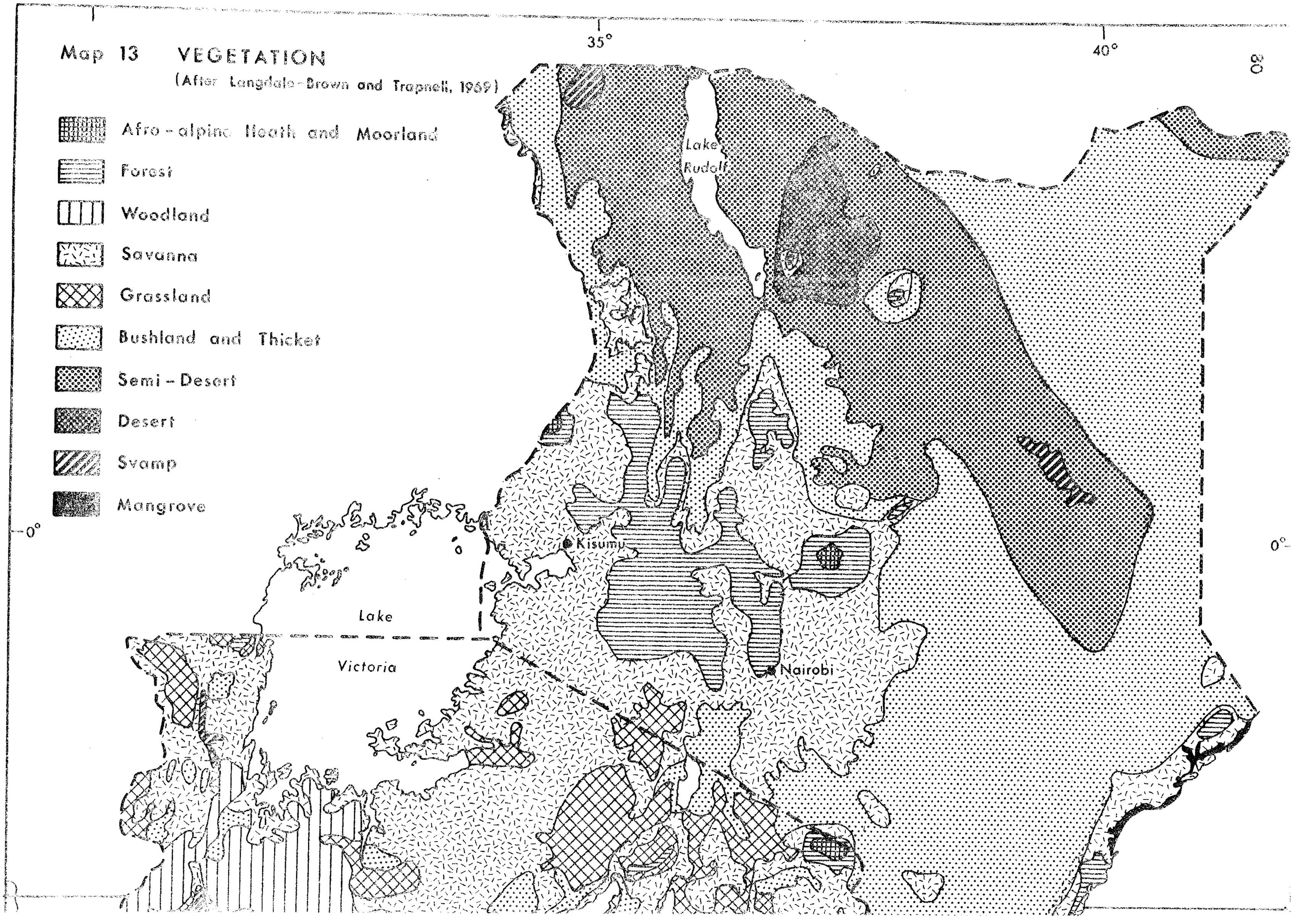
FIGURE 12. Bushland thicket.
Source: Pratt et al. (1966)

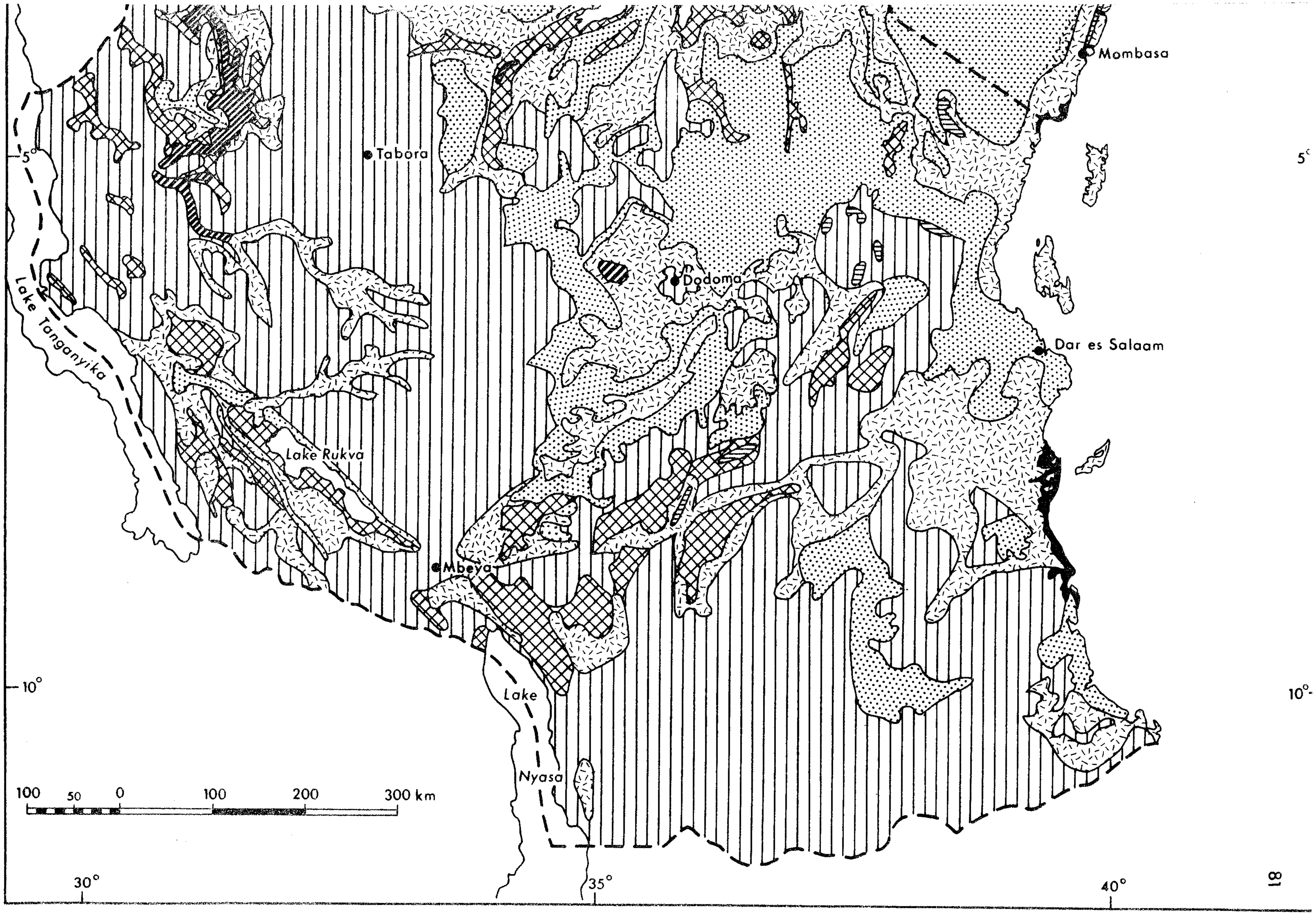


There is a very large number of different plant communities with different combinations of dominant species and genera forming bushlands and thickets. The most widespread in Kenya and in the north and Rift Valley parts of Tanzania are Commiphora (a genus with more than 40 species in Kenya only) and Acacia bushlands, and mixtures of the two. Emergent large specimens of the famous baobab tree (Adansonia digitata) often occur. Near the coast and on the steep, dry slopes of the Usambaras and Pares, communities dominated by Euphorbia are found.
In the Lake Victoria region, central and south-east Tanzania, rocky hills and inselbergs often carry thickets of Dalbergia (the wellknown East African blackwood, used for woodcarvings), Dombeya, Lannea and others.

Map 13 VEGETATION

(After Langdale-Brown and Trapnell, 1969)




Mombasa
Tabora
Dodoma
Dar es Salaam
Lake Tanganyika
Lake Rukva
Mbeya
Lake
Nyasa
5°
10°
100 50 0 100 200 300 km
30°
35°
40°

A botanically interesting community, suggested to be edaphically controlled, is the large Itigi thicket, on the central plateau of Tanzania, dominated by Baphia, Bussea and Pseudoprosopis. Other types occur in the Mpwapwa, Iringa, Kilosa, Handeni and Lindi Districts. In the south-east Tanzania lowlands, thickets are locally formed by the lowland bamboo, Oxytenanthera abyssinica.

3.6.8. Semi-desert vegetation

In the most arid parts of north Kenya quite large areas of semi-desert vegetation occur, characterised by widely spaced dwarf shrubs and bushes without any ground cover between them, except in the short and unreliable rainy season or where ground water is near the surface as in river valleys. Species of Acacia and Commiphora together with some other genera of woody plants and seasonal grasses make up the sparse vegetation. An area of true rock desert also exists east of Lake Rudolf, but this is little known botanically.

3.6.9. Swamps

Permanent or seasonal freshwater swamps are extensive only around Lake Victoria, but occur also in other areas with suitable conditions, e.g. the Lorian swamp in Kenya and the Usinge swamps in Tanzania. Many of these are dominated by Papyrus and Phragmites.

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4. LAND USE PATTERNS AND TRENDS

4.1. Land use and land policies

4.1.1. Land use in pre-colonial times

As mentioned in 2.1.2. the different tribal groups living in the two countries had reached a territorial distribution where the characteristics of the areas they occupied largely were suited to their respective occupation. The large areas unsuited for permanent agriculture were inhabited by various nomadic peoples and the highlying areas with sufficient rainfall and suitable soils were used by the agriculturalists. Population density in some of the latter areas had led to more sophisticated, sedentary land use practices, whereas in the less populated areas the slash and burn techniques were still used, agriculturalists encroaching on the forests where the hunters and gatherers (e.g. the Wandorobo) were living. It was in these areas that the concept of land as a resource like water and air was still alive. In many other areas though, e.g. Kikuyu, land was becoming a resource controlled by clans, lineages or families, and even individuals, on a base sometimes approaching western concepts of ownership.

4.1.2. Land tenure policies

4.1.2.1. Colonial land tenure policies. Prior to the declaration of British and German Protectorates in East Africa towards the end of the last century, Europeans as individuals and as companies had acquired land concessions and so called "treaties" from African "chiefs". In the declaration of British Protectorates, the administrations examined claims based on such grants and issued certificates which in practice became title deeds. No action was taken over remaining land either vacant or in African occupation. At this early stage there were no land policies.
There was no awareness of what African claims might customarily be made over vacant land. Land which appeared to be vacant or waste was granted under certificates similar to those used to recognize claims based on acquisition prior to the establishment of the Protectorates. As a result only persons who obtained such grants acquired some legal recognition of title, and African lands were left without any legal title in such public laws as then existed in these territories. This position in 1902 passed into the legal system of land in the Protectorates, and the decision of the constitutional question of the until then undefined authority of the Crown over the land in the Protectorates resulted in the legal assumption by the Crown of sovereign proprietorship and legal powers over vacant African land.

Crown Land. De facto Colonial Protectorates were growing up in which the Crown assumed responsibility for direct internal administration similar to that in a colony, although, unlike a colony, the Protectorates were not annexed. In 1894 a memorandum was issued stating that "whilst the Crown makes no claim to the general ownership of the land which is still regarded as vested in the chiefs and tribes except insofar as it has been duly alienated to grantees or consessionaires, all land outside African occupation is considered as waste Crown land". This was the first use of the term Crown Land in these areas.
By 1898 developments in East Africa connected with the need for the public acquisition of land for railways, and the acquisition of land near to them for other purposes, raised the need for a more precise definition, and in 1899 the Crown's legal advisers stated that in native states under H.M.'s protection, having no established indigenous government, the Crown' s authority extended over all the lands subject only to an obligation to

respect existing valid private titles. As a result of this ruling, new Orders in Council were issued in 1902 for all the East and Central African territories laying down the legal basis for this policy, and they defined as Crown Lands "all public lands in the Protectorate which are subject to the control of H. M. by virtue of any treaty, convention or agreement or of H. M.'s protectorate, and all lands which shall have been acquired by H. M. for the public service or otherwise". The rights of H. M. were declared to be vested in the Governor on behalf of the Crown who was to have authority to lease, grant or sell such lands.

Native Reserves. These orders in Council were the starting point of long lasting land problems. They were the origin of the creation of native reserves to provide for future African land needs by African access to land. By adopting English legal concepts of title to designate categories of land in terms of their ownership, the existence of customary African systems of land tenure was disregarded. The situation was further confused since there was a provision that in dealings with Crown Lands "native rights and requirements" were to be respected, but no such rights were defined or legally recognised.
The consequences were that on the one hand the indisputable nature of the Crown's rights became more and more clear, whilst on the other the steady increase in African population made the need to restrict the amount of land which might be freely alienated to any applicant more and more pressing. This was most acute in areas where European settlement was taking place or was likely.

In Kenya a new Crown Lands Ordinance was passed in 1915. This categorically stated that lands reserved for tribal use still continued to be Crown Land, but also required the Governor to reserve areas of Crown Land from alienation which he might consider needed for the use of the African population. Such reserved areas were not, however, permanently set aside, nor were African occupiers of them vested with title.

In 1920 the large hinterland area of Kenya, hitherto a protectorate, was annexed as a Colony of the Crown, and in 1921, the Kenya Supreme Court held that by reason of all African lands being included in the definition of Crown Land by the Order in Council, it was precluded from taking cognizance of any native rights in land. All Africans on Crown Land were tenants at will of the Crown.
Meanwhile in Kenya a policy of setting aside Native Reserves was followed. This was primarily an administrative measure since no titles were provided for Africans in reserves. There was a constantly growing pressure of population on land in the Reserves, partly due to increasing population and partly to soil exhaustion. A policy was established to restrict grants of crown-land to non-Africans and sales of this type of land were curtailed or terminated.

Trust Lands. In Kenya the conflict of interests in land became a political problem, and it gave rise to some de facto degree of land segregation in an attempt to provide for African and non-African demands. Political suspicion was aggravated because local administrations were becoming increasingly liable to unofficial pressures.
These were conditions which paved the way for the introduction of the Trust Lands system. The basic problem of African security of occupancy for their lands which had existed from the beginning of the century still remained. In Kenya the Trust Lands Ordinance of 1930 proposed statutorily to declare reserves as lands set aside for the use and benefit of the African inhabitants in perpetuity, and to vest them and their control in a trust Board separate from the local administration; but shortly after, in 1933, the

Kenya Lands Commission criticised this solution as failing to provide any adequate legal security for Africans.

During the decade after the first World War the new idea of the trust as the basis of colonial policy, however, facilitated the development of the notion of Trust Lands. Other factors which influenced this new thinking were the acceptance by Britain of the League of Nations' mandate over Tanganyika, and the principles laid down by the West African Land Committee in 1917. The latter principles were applied in the Tanganyika Land Tenure Ordinance of 1923, which laid down the basic object of land policy as to assure, protect and preserve the existing customary rights of the communities to use and enjoy the land in order to provide for themselves, their families and posterity. All land other than that held under existing private titles was declared to be public land to be administered for the common benefit of the natives of the territory.

Individual title to land. The question of providing Africans with a recognised legal individual title was raised by the Report of the East African Royal Commission, published in 1955, and endorsed by the Arusha Conference held early in 1956 under the auspices of the Colonial Office. The idea however, was not completely new, because Lord Lugard had much earlier recognised a development in this direction as a strong probability in his Dual Mandate in British Tropical Africa.
The Arusha conference recommended that Governments should encourage the emergence of individual tenure in areas where conditions were ripe for it. The conference recognised that full individual tenure would often not be practicable in the case of grazing rights. Given the conditions suitable for the emergence of individual tenure it was recommended that grant of a negotiable individual title should be introduced; to provide such a title, a properly organised system of land registration should be established. This was regarded as being especially important where there was high incidence of litigation over land rights and boundaries. The aim was to dispel uncertainty of title, to facilitate agricultural credit and to provide for easy and reliable conveyancing where land was already becoming negotiable. It was also agreed that the consolidation of fragmented land could be promoted in the course of registration of title, and that some control on the subsequent subdivision of registered land could be excercised.

By far the most massive implementation of individual land tenure based upon the registration of title on the lines advocated by the Arusha conference was carried out in Kenya. The process there rested and continues to rest upon the adjudication of customary titles or customary existing rights in land. A new title is not conferred; rather statutory recognition is given to existing rights which acquire the legal status of a freehold. No attempt is made to reduce a man's rights by making them contingent upon good husbandry (cf. 4.5.4.). Land once registered is fully negotiable except in so far as certain transactions require the consent of Local Control Boards.

In 1958 the Tanganyika government published a Government Paper reviewing Land Tenure Policy; it proposed to encourage the change from customary tenure to freehold in appropriate areas, and to introduce legislation empowering the Governor to declare areas for conversion where land was in stable individual holdings and where there was a demand for change. Nyerere published what he then described as his personal views; he favoured individual titles in the form of leaseholds rather than freeholds and advocated that the ownership of land should be vested in the nation of Tanganyika.

4.1.2.2. Post-colonial land tenure policies. The land policies followed by the independent governments followed the trends set by the colonial governments. Kenya continued its land consolidation programme in all agricultural areas and converted in addition to this programme 1.2 million ha of formerly European owned land into low, medium, and high density schemes for African settlers, who received title deeds (cf. 4.2.2.3.). In addition to this the so called "Group Representatives Act" was created in 1969 to give nomadic people rights to land occupied by them in order to encourage them to develop the land as group-ranches.

In Kenya two land reform programmes began just before Independence and are still continuing:
(1) The adjudication and registration programme involves both consolidation of scattered fragments of land belonging to one farm and registration of consolidated holdings. This programme was originally known as Land Consolidation Programme.
(2) The land transfer programme aims at transferring land from Europeans to Africans, either in the form of smallholdings or of large-scale farms. Under this programme land has been bought from British nationals with loans from the British Government.

The implementation of the two land reform programmes has been much criticized within Kenya. It has, for example, been pointed out that the adjudication and registration programme only involves consolidation insofar as the regrouping of scattered pieces of land belonging to one farm is concerned. The term does not imply enlarging farms which have become subdivided into uneconomic size.
The land transfer programme, which deals mostly with the former White Highlands, is considered unsuccessful in certain areas, e.g. the Nyeri area, in that the absolute number of new small-holders is still low and in that many large farms have been bought by rich Africans with little benefit for the ordinary peasants. For many it is also not obvious that the land shall be purchased; they would rather see a confiscation of the farms.
Against this stands the opinion that the white farmers have made large investments in their farms and that they should be compensated for this. At present about half of the former White Highlands have been transferred to African owners. The pace of the transfer seems to be increasing.

In Tanzania registration of individual holdings increased just before Independence and thereafter. In the more crowded areas, like the Usambara and Pare Mountains, on Mount Meru and many of the cultivated highlands of the Northern Province, in Bukoba and North Mara and in Rungwe, individual tenure was reaching an advanced stage.
This development ceased with independence. Influenced by a World Bank Mission in 1959 and by political goals, a two-pronged strategy for rural development was established in the first five-year plan: (1) the Improvement Approach continued the pre-independence efforts to bring about increased production without changing legal or social structures; (2) the Transformation Approach aimed at rapid production increases through nuclear village settlement schemes, where the Government was to provide the necessary infrastructure. This programme envisaged a future conversion of the settlement schemes into cooperative societies.
Priority was given to the second approach because it was considered most likely to bring about most rapid increases in production. This failed, however, because the scheme was overcapitalized and created a dependency attitude among the settlers. The Transformation Approach was thus abandoned in 1966.

In January 1967 the Arusha Declaration was issued, committing TANU and the

Government to the creation of a socialist state. Major means of production were nationalized, and so was land.
The Ujamaa Village Programme was introduced with the aim of creating cooperative farm units as the foundation of the nation. This programme involves not only the creation of nuclear villages but also an integrated strategy encompassing such things as political participation by the farmers and the establishment of a particular way of production and marketing. The Ujamaa Village Programme was to consolidate political unity and fulfill the need for national defense.

Ujamaa villages have been established at a very high rate since 1968. As an indication of this, membership as a percentage of the total rural population (90-95% of Tanzania's population live in rural areas) increased from 4.3% in 1970 to 15.3% in 1972. This increase has been faster than the increase in the number of villages, which means that the villages tend to become larger (on the average 371 individuals per ujamaa village in March 1973).

The Ujamaa Village Programme has been criticized on several grounds. Implementations are sometimes poorly organized so that a village might become situated in an unfavourable place, building materials might be lacking etc. The absence of systematic data collecting and evaluation has limited the Government's ability to provide guidance to ujamaa villages. The growing number of inhabitants in each village creates subsistence difficulties.

African land tenure was previously misleadingly, and often mystically, described as communal tenure and dismissed as something much the same throughout Africa. Of the two countries, Kenya has developed a strong land policy building on the assumption that individualization of rights (to individuals or groups) will increase production and national income.
Tanzania has an ideological commitment to the state as landowner and to Ujamaa villages as a leasing group, but nevertheless individual rights or customary rights still exist as no juridical drive has been made to replace the one with the other like in Kenya.

4.1.3. Land use policies

Kenya is the only country to have presented a national plan for the environment and its conservation. Her problem will be how to coordinate the efforts of the various Government departments in implementation of the overall policy stated in the plan. Intensive research and compilation of existing data is proposed in order to achieve and develop i.a. a:

- land capability survey
- soil and water conservation programme
- watershed and catchment programme
- anti-water-pollution programme
- grazing control and restoration programme
- wildlife conservation programme
- restoration and reclamation research programme

It is pointed out in the 1974-1978 Development Plan that all the above programmes will necessitate changes in the traditional land use customs and attitudes. A research programme is proposed to measure the impact of technology on society and the individual and to establish the permissible speed etc., to bring about acceptance of these changes. The ambitious Plan will necessitate considerable resources in the form of Technical Aid personnel and finances. The present resources for environmental conservation in the Ministry of Agriculture are e.g. far too small to cope with anything but

minor emergencies. The national policies regarding conservation of natural resources will have to be translated into managable departmental plans and these plans will have to be coordinated both during the planning and implementation stages.

Tanzania has less well formulated national policies regarding the use of land. Proposals have been made regarding the use of the rangelands and forests and the use of water resources for irrigation schemes. However, no review of existing land and water resources has been made in order to establish priorities.
At present each District must organize its programme based on experience. In the future it is critical that a comprehensive effort is made to compile more detailed information on the production potential of different zones.

The difficulties that a programme including change in land tenure or land use will encounter have not been touched upon in the second five-year plan. Specific programmes have sometimes been presented in a social vacuum and it has been assumed that changes only depend on the availability of technical and financial resources. This is rather a paradox considering Tanzanias stated policy of building the Plan on the cooperation of the people.

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4.2. Agriculture

4.2.1. Introduction

In this chapter the land for agricultural use will be discussed mainly from a biological/technical point of view.
In an increasingly interdependent world the land and other resources available to agriculture are international problems. In East Africa there still seems to be areas of land available to utilize for profitable agricultural expansion. Furthermore, the present agricultural land is not properly used and, as a rule, it is not fully developed to its potential. The cropping systems, farming practices and overgrazing in many areas lead to a gradual deterioration of soil fertility. Unless measures are taken to rationally utilize and preserve the land resources suitable for agriculture, soil fertility and soil erosion problems are likely to become even greater.

In principle, the process of agricultural development, both on land presently under sub-optimal or directly wrong use and on new land, involves three basic aspects or steps.

The first step is to determine the natural conditions, such as soil, climate, water supply and vegetation. If properly interpreted this information will give us a first indication of the agricultural land potential in the areas concerned.
The general physical and biological features of Kenya and Tanzania are described in chapter 3 and the techniques to be used in collecting and interpreting this type of data are dealt with in chapter 6.

The second step will be to investigate the present agricultural pattern, with regard both to livestock and crop production. This involves e.g. types of farming, farm sizes, cropping systems and farming practices, crops grown and their yield and livestock carrying capacities, yields and management. This aspect is the main content of this section 4.2.

To be able to find methods and means to develop agriculture, the third step will be to conduct comprehensive experimental work applied to the actual farming problems and situations in close cooperation with the agricultural extension service, which have to dessiminate the innovations obtained to the farmers (see sections 4.2.3.6. and 4.2.3.7.). In connection with these activities the human nutrition patterns have to be considered (see sections 4.2.3.5. and 2.3.3.).

4.2.2. Land use potential

As stated in the previous section, 4.2.1., the development of agriculture, as well as any other form of land use, requires first a determination of the land use potential. A number of factors and combinations of factors are used to classify this potential, including physical, biological, social, legal and economic aspects. All these are discussed more in detail in other sections of this report, mainly in chapter 6.
It has been considered necessary here, however, to give an introductory presentation of the conventionally used land potential classifications in Kenya and Tanzania as a background to the following description of present agricultural land use and trends. A reason is that much of the available information and statistics on crop production and animal husbandry are based on these classifications.
The land use potential is here considered to comprise three basic components, the physico-biological potential, present land use and population factors and, finally, land tenure.

4.2.2.1. Physico-biological potential zones. Two different approaches have been used in Kenya respectively Tanzania to subdivide the countries into broad physico-biological potential zones. The basis for these classifications and their relevance are discussed more in detail in sections 6.3.3.1. and 6.3.3.2.

In the National Atlas of Kenya there is a map subdividing the country into six so called "Ecological potential zones". These zones are basically climatical, but due to the lack of climatic data vegetation type boundaries and indicator plants have been used to delimit them. The map is reproduced in section 6.3.3.1.
In table 8 the areas, features, potential and present land uses are summarised for the zones, all according to the Kenya Atlas.

According to this classification 106,000 sq.km , or 18% of the total land area of Kenya, have good potential for agriculture (zones II and III) and another 53,000 sq.km , or 9 % of the area, can be regarded as marginal agricultural land (zone IV). The rest, or 73 %, has very low or no agricultural potential.

In Tanzania, a "Potential land use" map is presented in the Atlas of Tanzania, based almost entirely on the soil map in the same Atlas. The land use potential map is reproduced in section 6.3.3.2. Eight classes are distinguished, their features and potentials are summarised in table 9. Each class covers a considerable range of soils suitable for various crops. This will be discussed more in section 4.2.3.4.

Unfortunately no systematic survey of soil erosion (cf. 5.4.) and fertility problems has been undertaken. It is, however, clear that these are major agricultural problems in the countries.
It has to be stressed again that the two land potential systems and maps presented here only give very rough, overall pictures of land areas of different productivity in the two countries and they do not allow any extrapolations to larger scales.

4.2.2.2. Present agricultural land use in relation to population. In section 2.2.2. the over all demographic characteristics of the countries have been described. The land areas divided by total population give average population densities which can not be considered high by international comparison (Kenya 23 pers/sq.km, Tanzania 17 pers/sq.km). The actual distribution of population is however very uneven (see figure 4 and map 2) and closely correlated to physical conditions favourable to permanent agriculture.
To evaluate the potential for further agricultural development it is necessary to have a clear picture of the degree to which areas of various physical potential are already utilised by the population.
In figure 13 the land of Kenya and Tanzania has been divided into some very broad categories of land use.

TABLE 8. Ecological zones in Kenya
Sources: IBRD (1973) and National Atlas of Kenya (1970)

Zones	Climate	Land description	Area: km^2	%	Agricultural potential	Present agriculture land use
I	Afro-alpine	High altitude above the tree line. Barren land common. Moorland and grassland	800	1	No potential agricultural use	Water catchment area and tourism
II	Equatorial climate	Forest and derived grasslands and bushlands	53 000	9	53 000 km^2 high potential, particularly in the highland. Intensive livestock production, carrying capacity 0.5-1.5 ha/LU[1/]	Cash crops: tea, coffee, pyrethrum. Cotton on lower altitudes. Livestock can be kept intensively
III	Dry sub-humid to semi-arid	Moist woodland[2/]	53 000	9	53 000 km^2 medium potential Considerable potential for expansion and improved productivity. Livestock carrying capacity 2 ha/LU	Mostly large scale mixed farming. Hybrid maize, wheat, barley, cotton, groundnuts, pulses, oilseeds, cashew and coconuts. Livestock intensively
IV	Semi-arid	Dry woodland and bushland	53 000	9	Marginal agriculture potential. Expanded land use requires increased research. Livestock carrying capacity 4 ha/LU	Commercial ranching. Subsistence crop farming and livestock in smallholder area. Maize, cotton, pulses, oilseeds. Game parks.
V	Arid	Dry thorn bushland	300 000	52	Moderate range land development potential. Livestock carrying capacity 5-10 ha/LU	Livestock. Subsistence-oriented shifting cultivation. Wildlife
VI	Very arid	Dwarf shrub grassland	112 000	20	Northern Kenya. Sustain only as nomadic pastoralists. Livestock carrying capacity 15p20 ha/LU	Nomadism of pastoral people
		Total	571 800			

Notes: 1/ LU = Livestock unit, equivalent to 450 kg liveweight
2/ Woodland in this classification corresponds to "savanna" in 3.6.

TABLE 9. Potential land use in Tanzania
Sources: IBRD (1974) and Atlas of Tanzania (1967)

Group	Soils[1] and topography	Climate	Land potential	Agriculture
1	Rock outcrops, very shallow soils of steep slopes with excessive drainage. Soils: A and Ba	Semi-arid	Game-reserves. Limited potential for forestry and for grazing in the wetter range	
2	Stony shallow soils on basic rocks, highly erodible. Soils: B, Ca, E and G	Semi-arid	Ranching or game reserves. Afforestation possible at high altitudes.	Limited cropping of sorghum, castor beans, groundnuts or beans. Soil conservation and rotation needed.
3	Suitable for cultivation, very erodible. Weak surface structure. Shortage of nitrogen. Soils: C, G and Db	Low rainfall High potential evapotranspiration	Soil conservation measures should include grass strips, ridge-cropping and grass/legume leys. Unsuited to continuous arable cultivation.	Livestock forming the main enterprise. Sisal, sorghum and cotton can also be grown. Wheat, seed beans, maize and sometimes irrigated coffee in more humid areas on high altitudes.
4	Soils on sandstone and sandy sediment. Low fertility. Some soils become badly eroded. Soils: F, K and J		Low potential without fertilizer	Low altitudes: sorghum, cassava, cashew, castor, simsim, groundnuts, cotton. High altitudes: Wheat, wattle, pasture, potatoes
5	Low to medium fertility. Erodible. Soils: J and K	Sub-humid	Soil conservation measures and fertilizers are needed to maintain production.	Sisal, groundnuts, sorghum, maize, soya, castor, cashew, cassava, beans, millets, cotton, tobacco

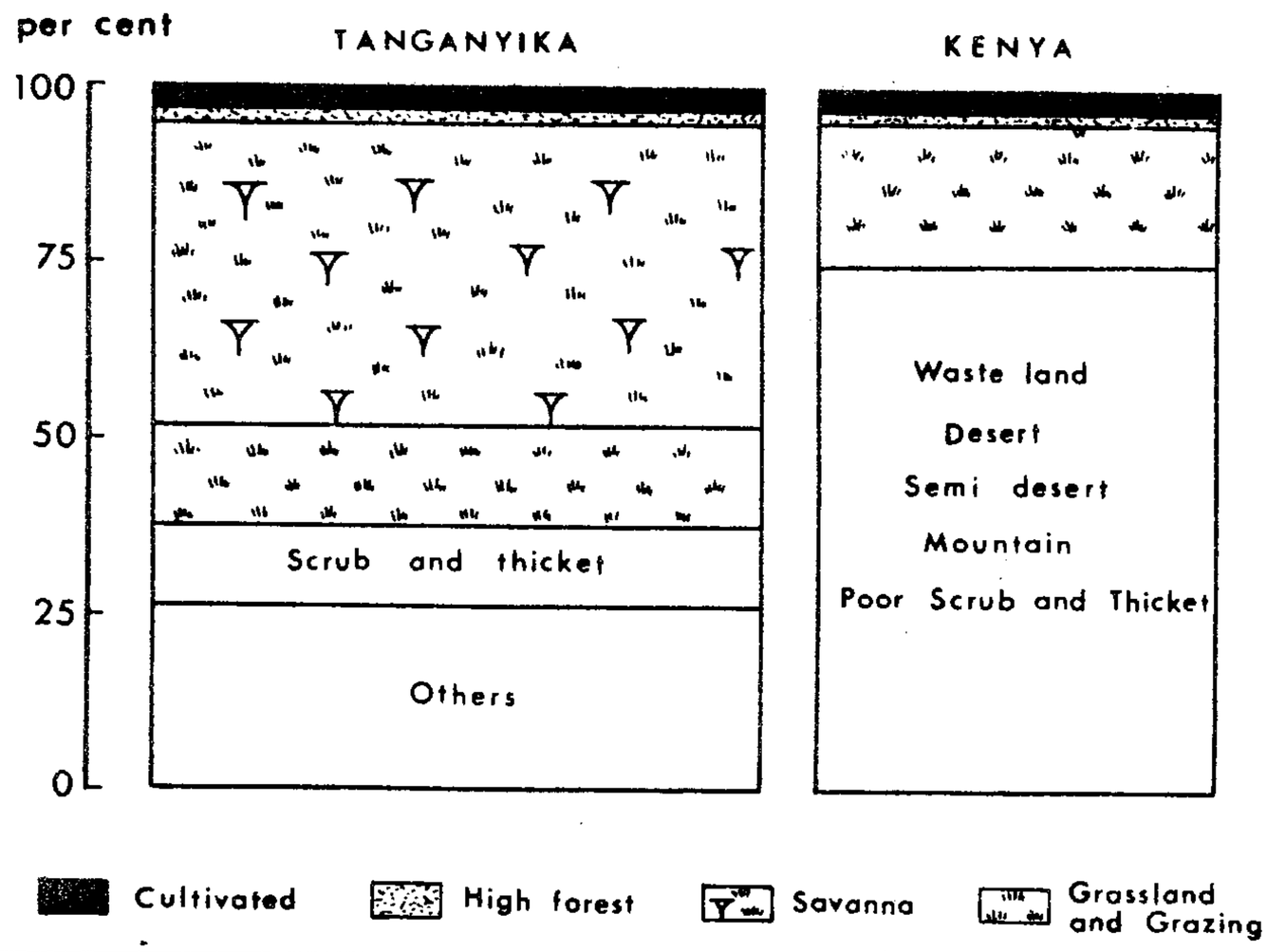
continued next page

TABLE 9. Continued

Group	Soils[1/] and topography	Climate	Land potential	Agriculture
6	Medium to high fertility. Steep slopes Soils: H, K	Medium-high rainfall	Highest present productivity. Good conditions for cultivation. Some soils respond to phosphorus and nitrogen. Soil conservation measures and rotation needed	High altitudes: Arabica coffee, wheat, onions, potatoes, pyrethrum, pawpaw, timber, fruits, grass/legumes and pasture. Low altitudes: Sisal, citrus, pastures, cocoa, robusta coffee, pawpaw, coconuts and spices. All altitudes: Maize, beans, bananas
7	Strongly acid leached soils. Soil erosion Soils: L	Over 1,350 mm of rain per year	Deficiencies of phosphorus, nitrogen and sometimes potassium	Cash crops: Robusta coffee, tea, timber. Food crops: Bananas
8	Various alluvial and colluvial soils. Poor drainage and structure. Some areas with fertile freely-drained soils Soils: Bn, H, Db, M and N		High to moderate fertility. Drainage needed to achieve the full production potential	Cash crops: Sugar cane, sisal, pawpaw. Food crops: Castor, cashew, fodder legumes, cotton, rice, coconuts and onions. On poorly drained soils: Cambered and ridge systems of cultivation

Note: 1/ Soil classification (see also 3.4.4.):
A - Raw mineral soils
Ba- Weakly developed soils
Bn- Juvenile soils on recent deposits
Ca- Calcimorphic soils
Db- Vertisols
E and F - Podsolic soils and soils lessivés
G - Brown and reddish brown soils of semi-arid tropical regions
H - Eutrophic brown soils of tropical regions
J - Ferruginous tropical soils
K - Ferrisols
L - Ferrallitic soils

FIGURE 13. Broad categories of land use
Source: Hickman & Dickens, 1973



NOTE: "Savanna" corresponds mainly to "woodland" in section 3.6.

The small areas of cultivated land are obvious. Based on more recent figures the present areas under various forms of agricultural uses are presented in table 10.

TABLE 10. Distribution of land according to use
Sources: IBRD (1973 & 1974)

Tanzania[1]			Kenya		
	sq. km	%		sq. km	%
Total land area	883,600	100	Total land area	569,250	100
Agricultural area:			Agricultural area:		
Rough grazing	442,450	50	Grazing (meadows, pasture)	85,653	15
Smallholders cultivation	38,800	4	Paddocks, fallows	2,471	<1
Large scale farms	5,850	1	Cultivated	20,096	4
Total agriculture	487,100	55	Total agriculture	108,220	19
Non-agricultural areas:			Non-agricultural areas:		
Woodlands, forests	376,600	43	Forests	22,670	4
High altitude	3,900	<1	Other, mainly desert	438,360	77
Other	16,000	2			
Total non-agriculture	396,500	45	Total non-agriculture	461,030	81

NOTE: [1]Excluding the islands of Zanzibar and Pemba

TABLE 11. Cultivated area, main crops and population densities by Regions (Tanzania) and Provinces (Kenya)
Sources: Various

TANZANIA Regions	Total land area, 1000 ha	Population density Persons/km^2	Total cultivated area 1000 ha	%	Main crops
Arusha	8,210	8.8	172.4	2.1	Maize, Beans, Wheat, Sorghum
Coast	3,380	16.3	253.5	7.5	Rice, Cashew, Coconut, Maize, Cassava, Sorghum
Dar es Salaam		4,599.3			
Dodoma	4,130	19.2	264.3	6.4	Maize, Millet, Sorghum
Iringa	5,685	14.1	238.8	4.2	Maize, Beans, Wheat
Kigoma	3,705	13.7	281.6	7.6	Maize, Beans, Cassava
Kilimanjaro	1,320	58.0	175.6	13.3	Banana, Coffee, Maize, Beans
Mara	2,175	29.6	204.0	9.4	Cassava, Cotton, Maize, Millet
Mbeya	8,315	13.4	257.8	3.1	
Morogoro	7,310	10.3	380.1	5.2	Rice,Maize,Sorghum
Lindi) Mtwara)	8,275	12.4 29.6	364.1	4.4	Cashew, Sorghum,Cassava, Rice
Mwanza	1,965	61.1	410.7	20.9	Cotton, Cassava, Millet, Maize
Ruvuma	6,125	7.3	122.5	2.0	Cashew, Cassava, Maize, Millet, Rice
Shinyanga	5,075	20.1	340.0	6.7	Cotton, Maize, Sorghum, Groundnuts, Millet, Rice
Singida	4,935	9.9	157.9	3.2	Sorghum, Millet,Maize
Tabora	12,200	5.1	219.6	1.8	Maize, Groundnuts, Sorghum, Cassava, Cotton
Tanga	2,680	32.7	340.4	12.7	Maize, Cassava, Banana, Coffee, Beans
West Lake	2,875	25.2	290.4	10.1	Banana, Beans, Coffee
TANZANIA, TOTAL	88,360	17	4,560.7	5.1	

Continued

TABLE 11. Continued

KENYA Provinces	Total land area, 1000 ha	Population density Persons/km^2	Total cultivated area 1000 ha	%	Main crops
Western	820	176			Maize, Cassava, Banana, Sorghum, Pulses, Cotton
Nyanza	1,250	192			Maize, Sorghum, Pulses, Cassava, Banana, Cotton, Groundnuts
Rift Valley	17,200	13			Maize, Pulses, Sugar
Central	1,310	137			Maize, Pulses, Coffee, Banana, Potatoes, Pyrethrum
Eastern	15,400	13			Maize, Pulses, Millet, Sorghum, Cotton, Sugar, Cassava, Banana, Coffee
North Eastern	12,500				Livestock keeping by pastoral tribes
Coast	8,500	9			Maize, Cashew, Coconut, Cassava, Banana
KENYA, TOTAL	56,980	23	2,257	4	

Land used for grazing occupies by far the largest parts of the agricultural land in both countries. In the dry bush and grassland areas, where the livestock carrying capacity is assumed to be around 10 hectares per livestock unit (LU), nomadic pastoralism is the predominant form of land use and population density is very low. In the semi-arid and drier sub-humid areas, with livestock carrying capacities of 2-4 ha/LU, cultivator pastoralists are common. Finally, in the wetter areas, intensive ranching (dairy and beef) is the dominant form of grazing land use. The carrying capacity is around 1 ha/LU. These areas also support intensive crop cultivation and the population density is consequently high.

The vast dry areas of nomadic pastoralism are found in Northern Kenya along the Rift Valley and in Central Tanzania (see e.g. Rainfall map). To people in these areas, cattle is often important not only as their only source of living, but also for various other purposes, e.g. as a yardstick of social wealth. The commercial production output is very low. Due, among else, to improved veterinary services and water hole digging overgrazing is very common and serious land degradation takes place, leading to desertification.

Reading about East Africa, people often get the impression that the dry areas are the main livestock production areas. This is not at all so. It is instead in the cooler and wetter highlands, particularly in Kenya and Northern Tanzania, that by far the highest beef and dairy production takes place, often in large, well-managed cattle ranches.

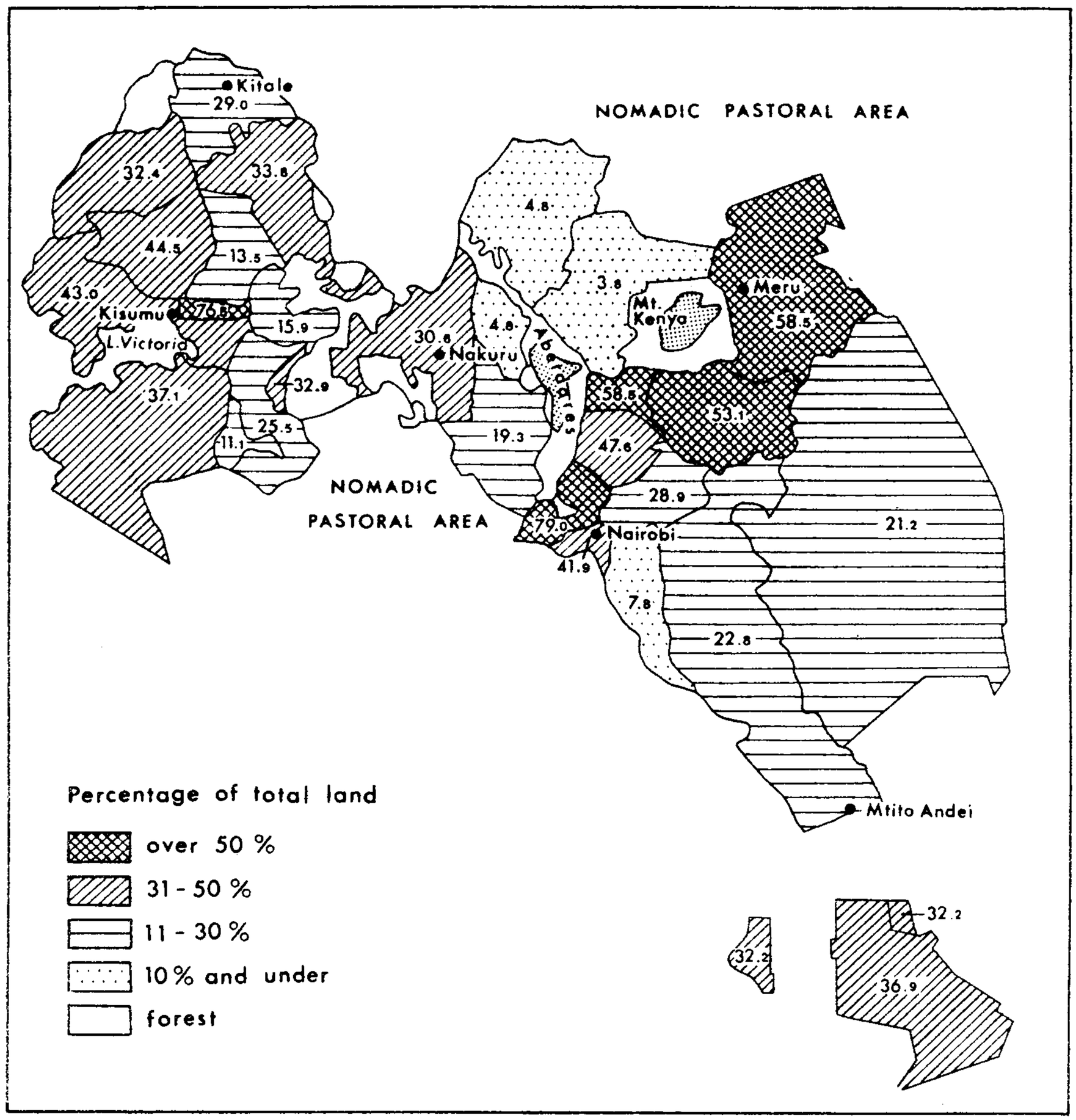
Land used for permanent crop cultivation occupies a very limited area in the two countries as shown in figure 13 and table 10.
In Kenya the most intensively cultivated land is concentrated to the highlands. The percentage cultivated land by Districts in the Kenya Highlands is shown in figure 14. The high plateaux and highlands, situated between 1500 and 2750 m altitude comprise some of the best land for agriculture in Africa. About 2.3 mill hectares, or 4 % of the total land area are under cultivation (see table 10). Cultivation is more intensively carried out in the Provinces of high agricultural potential, such as the Western, Nyanza and Central Provinces. This is shown in table 11.

The cultivated areas in Tanzania are more scattered over the country, situated wherever rainfall is adequate for crop production. High concentrations are found in the Northern Highlands (including Kilimanjaro, Meru, Usambaras and the Crater Highlands), in the Southern Highlands (Mbeya and Iringa), on the Coast and around Lake Victoria.
As seen in table 10, 4.5 million hectares, or 5 % of the total land, are occupied by small and large scale holders. In table 11 the cultivated land by Regions is shown.

In Kenya and Tanzania, like in most developing countries, agriculture is the main occupation of the population. FAO has estimated that 88 and 95 % of the total labour force in Kenya respectively Tanzania are engaged in agriculture. There is consequently a close correlation between population concentrations and land under intensive agricultural use.
In Kenya e.g. the area south of Mt. Kenya has got a population density of over 400 persons/sq.km. The Western, Nyanza and Central Provinces are partly considered as over-populated (see table 11).
In Tanzania the Regions of Kilimanjaro, Mara, Mtwara, Mwanza and Tanga are likewise regarded as partly over-populated, with average population densities ranging from 30-65 persons/sq.km.

It should here be emphasised that the use of the term over-populated is very subjective and it must always be seen in relation to the physical, social and technical potential of the land and people living there. If, for example, a criterium like "the maximum number of people that can be healthily supported with present agricultural techniques and without irreversible destruction of the land" is used to separate over- and under-populated areas, then the areas with the lowest population densities in East Africa can more justly be classified as over-populated than the densely populated highlands.
However, the large migration from the agricultural areas is a clear indication of over-population. The main reasons are rather shortage of arable land for the rapidly increasing population and a level of ambition concerning standards of living that has risen beyond a mere subsistence existense, than physical ability of the areas to keep people alive (cf. 5.1. and 5.2.).
In some mountain and highland areas, increased erosion and consequent decrease in agricultural production is also a significant reason for over-population (e.g. Machakos in Kenya and the Uluguru Mts. in Tanzania).

FIGURE 14. Cultivated land by Districts in the Kenya Highlands
Source: National Atlas of Kenya (1970)



4.2.2.3. Land ownership and tenure. Past and present land policies in relation to tenure and ownership are described in detail in section 4.1., and this section should be read as a supplement to 4.1.
The land ownership differs between the two countries. In Tanzania all land is held by the Government and there are various types of occupancy arising from African customary laws and right of occupancy by grant (e.g. ujamaa villages).

In Kenya three types of land can be recognised. Trust land, covering an area of about 420,000 sq.km or 74 % of the country, which is held under traditional tribal systems of allocation and rights. In the better range areas the Government policy is to establish private or group owned ranches. Private land, covering about 51,500 sq.km or 9 %, includes land under private ownership and land on lease from Government. Most of the high potential agricultural land belong to this class.

Government land for Forest Reserves and National Parks occupy about 50,000 sq.km.
In the Coast Province, large areas - about 46,000 sq.km - are available for disposition, i.e. they are not classified under any of the previous groups.

Land tenure in African tradition is a very complex problem involving a variety of attitudes and long established codes. In Kenya, e.g. at one extreme there are tribes like the Masai, and other pastoral peoples, which control large areas of land on a clan basis or as common property under the customary law. In such cases the land belongs exclusively to the tribe and sometimes to the respective clans and no member of the tribe has individual rights. At the other extreme, some tribes recognize individual rights to land, although no registered titles to such land have been given. The Kikuyu, e.g. have for generations recognized a form of outright extended family ownership of arable land although they have always regarded grazing areas as communal. It is upon such different traditions that successful development in land consolidation must be based.

The distribution of land in Kenya is unequal. A great part of the best land in the highlands is still owned by some thousands of European and African farmers and estate owners - private persons or companies.
In 1959, the colonial administration in Kenya came to the conclusion that a land tenure reform was the most important prerequisite to smallholder development (see 4.1.2.2.). This was therefore pursued with great vigour. The programme is for consolidation, registration and enclosures.
Parts of the big farms in the Kenyan highlands have been bought by the Kenyan state. This was mainly done within the "one million acre scheme". The bought land was distributed to landless Africans according to two systems. First in so called "settlement schemes", second, part of the land was sold to private persons or cooperatives.

The million acre scheme involved settling over 34,000 families on 135 settlement schemes, comprising Low Density scheme with an average farmsize of 15 hectares, and High Density schemes with an average farm size of 11 ha.

For Tanzania, land tenure may broadly be defined as falling into two groups:
1) The alienated land, so called because in pre-Independence days it was allocated by Central Government on a formal Right of Occupancy, usually to a non-African person or organisation. Most of this land is used by estates and large commercial farms, and it totals about 800,000 hectares. Formally a proportion of it was freehold, but since Independence all freehold rights have been abolished. Leases are normally for 99 years but occasionally for 33 years. Much of the most valuable cash cropping is on this land.

2) Land subject to the traditional patterns of land tenure. This is the land used by peasant smallholders. Such land carries no formal Right of Occupancy, but is under the control of the local land giver. This was formerly the tribal authority, but in recent years has become increasingly the Local Government authority.
There is considerable variation in such customary tenurial practices, the foundation of all being usufructory rights or the right of a man to a piece of land for as long as he uses it.
Thus, the overall picture of land tenure in Tanzania is one of relative lack of sophistication, but the country has reached the point where in some densely populated areas this has become limiting on agricultural development. The tendency is to spread out into new areas and to tackle the problem of uneconomical smallholdings by farming in groups.

4.2.3 Crop production

At present a very small, limited area of 2.3 respectively 4.5 million hectares are under cultivation in Kenya and Tanzania. Per capita of the total production this make 0.19 respectively 0.32 ha of cultivated land.

4.2.3.1. Types of farming and farm sizes. Farming in East Africa is either carried out on small scale subsistence farms, mainly producing staple food crops and cash crops for exchange of food crops, or on large scale commercial farms for production of cash crops. Naturally there are intermediate stages between pure subsistence and commercial types of farming. Subsistence farmers have, for example, started to go into commercial farming by growing such cash crops as cotton, sugar cane, pyrethrum, coffee, tea and vegetables.

Small scale subsistence farming. It has been estimated that subsistence farms cover about 40 per cent of the cultivated land of the world and support 50-60 per cent of mankind. The subsistence farmer either produce food on the whole area or exchange some of the production for staple food crops. The small farmer who trades most of his production for food is particularly vulnerable to market changes. Major innovations, such as high-yielding varieties of cereals, can substantially alter the supply situation and depress market prices to a point where larger farms with lower production costs dominate the market and smaller producers are unable to compete.
Small scale farming is traditionally very labour intensive due to lack of machinery, particularly the plough.

Large scale commercial farming. In contrast to the peasant smallholdings, there are the larger commercial farms, which are of three types, namely mixed farms, ranches and plantations. In the past these types of farms were established by European settlers in Africa. Typically, the size of the mixed farms ranges from 100 to 400 hectares. Many of them are found in areas of lower potential than the peasant farms. The capital input, particularly in machinery, permits more labour extensive cultivation in areas less suited to intensive peasant working.
The large farms are often responsible for a major part of the commercial food supply, particularly aimed at the local urban markets, including milk, high grade meat, cheese, wheat, barley, fruit and vegetables.

Another form of agriculture organization are the plantations, in which capital, land and labour are brought together in large quantity to produce one particular commodity aimed at the world market. The most common crops on plantations in East Africa are sisal, sugar and tea.
In areas suitable for livestock, ranches have been established for production of e.g. meat, wool and milk.

Out of the 1.7 million rural households in Kenya 1.2 million are small holders. It has been estimated that about 25 % of these holdings are less than one hectare and 50 % are less than two hectares. The small holders occupy around 75 % of the total cultivated land, see table 12. Around 50 % of the small holdings are managed entirely on a subsistence agriculture level and the rest have some kind of commercial agriculture.

TABLE 12. Distribution of land to small and large farms in Kenya in 1970
Source: IBRD (1973)

(1000 ha)	Cultivated land with crops	Paddock grazing, meadows	Temporary fallows	Uncultivated land	Forest	Total
Small scale farms	1,545.6	52.3	-	6,657.7	-	8,255.6
Large scale farms	463.9	98.9	95.9	1,997.6	123.1	2,779.4
Total	2,009.5	151.2	95.9	8,655.3	123.1	11,035.0

The distribution of cash-crop farming types in Kenya is limited by several considerations. The location of areas for commercial agriculture has for a long time been restricted to the former alienated land. Secondly, the location of commercial crops is limited by ecological considerations. E.g. coconuts and cashew nuts are grown at the coast, small grain cereals, like wheat, barley and oats, are largely found above 1800 m, pyrethrum preferably above 2000 m, coffee (arabica) mainly above 1350 m and tea can only be grown in areas with suitable soils (acid) and annual rainfall averaging at least 1250 mm (cf. figure 15).

Within the rangelands of Kenya there are appr. 740,000 subsistence cultivators occupying appr. 76,000 sq.km. All these suffer from a lack of water and poor agriculture. Grazing is communal although cultivation often becomes the permanent right of the cultivator. Most of these areas are overpopulated with respect to environmental factors.
Most of the rangeland areas are, however, occupied by pure pastoralists, of which there are an estimated 200,000 households.

Out of the 4.5 million hectares of land under crop production in Tanzania, small holders occupy around 87 per cent (see table 10). The average farm size among the small scale farmers is 1.2 hectares. In table 13 the distribution of farms according to sizes is shown.

TABLE 13. Farm size distribution in Tanzania (excl. estates)
Source: IBRD(1974)

Holding area by small scale farmers, hectares	2,941,100
Number of parcells	4,852,475
Number of holders	2,450,353
Holdings, smaller than 3 hectares, %	91
Holdings, 3 to 5 hectares, %	6
Holdings, larger than 5 hectares, %	3

4.2.3.2. Cropping systems. The most primitive and indigenous system of cropping is shifting cultivation, by which a piece of land is cleared from bush and trees, normally by using primitive tools, and then burned. Seed is then broadcast in the ashes. After some years of cultivation the soil is depleted of plant nutrients and has to rest for some years as grass or bush fallow, after which the process is repeated (cf. 4.6.).
Shifting cultivation is normally developed in areas where soils are infertile and where land is not a limited resource. It has been estimated that

approximately 20 % of the world's population obtain the bulk of food by this system. The amount of land under cultivation each year needed to sustain a family shows considerable variation, from 1 to 2 hectares on fertile, well drained soils to 10 hectares and more per shifting cultivator farming on rapidly depleted soils in humid lowland forest areas.
Generally, no systems of crop rotation are used and seldom fertilisers are applied. In more fertile areas the land is cultivated for longer periods and the fallow periods are shorter.
As population increases there is a strong tendency to shorten the fallow periods, also on infertile soils, which leads to a progressive reduction in yields.

Shifting cultivation is still practiced in the sparsely populated miombo belt of Tanzania (see map 13). However, with increasing population in the fairly limited areas where inhabitation is possible at all (due to lack of surface water and sleeping sickness over most of the miombo), the land availability decreases and the cultivators return to their old fields after progressively shorter fallow periods. The present drive in the country to bring people together in "planned villages", e.g. ujamaa, will certainly speed up the abolishment of shifting cultivation.
There is a considerable risk that serious soil deterioration will occur if the bush fallow periods are abandoned. On the infertile soils found in the miombo areas this must be compensated for by improved farming techniques, e.g. the application of fertilisers.

All cropping systems where the same field is cultivated year after year without extended fallow periods are collectively referred to as permanent cultivation.
Crop rotation is the practice when different crops are grown in a sequence, often with the aim of maintaining good soil conditions, e.g. by growing a crop of nitrogen-fixing legumes every third year.
In areas with a double rainfall pattern, where both wet seasons give enough moisture, double cropping is practiced, i.e. more than one harvest is reaped per year.
Mixed cropping, or intercropping, is when more than one crop is grown at the same time. This is very common in East Africa, and in most areas with subsistence or mixed subsistence and cash agriculture it is a traditional way of farming. A mixture of maize and pulses is particularly common. The advantages are, among else, that it provides a varied diet, it fully utilises the soil and, if wise mixtures are used, it improves the soil. Economically it may be very advantageous if perennial cash crops, like coffee, can be underplanted with food crops. For many cash crops it is however not satisfactory since it often makes the application of improved farming techniques difficult.

Naturally, crop rotation, double cropping and mixed cropping do not exclude each other. Depending on the environmental conditions, they can be combined in a variety of ways, as they indeed are in East Africa.
One of the more successful cropping systems is the so called banana-coffee system found in many well-watered mountain areas with fertile soils, e.g. Kilimanjaro, Meru, Bukoba. The bananas form the staple food, the coffee the cash crop. Often a third crop, like pulses, is grown on the ground below the other two.

4.2.3.3. Farming technology. In the small scale subsistence farming economy a very labour intensive cultivation is practised. The cultivation is normally done with the aid of traditional implements and panga, with which it is not physically possible for a family to cultivate a larger area. In fertile areas, only a few hectares are cultivated. In less favourable areas, the area of

cultivation can not be much larger, but instead rearing of livestock is often used as a supplement. The livestock has to be herded, which divorce the man from the task of cultivation or the children from attending school. Most of the arable land in East Africa is still farmed under intensive cultivation, without any use of inputs and improved implements.
The seed is broadcasted, weeding and harvesting are done by hand. The harvested crops are often threshed by treading cattle. The crops are kept in very simple stores, where insects and rodents may easily destroy a large amount of the stored products.
It has been estimated that 80 per cent of all farmers in the world are depending on their own power or on domestic animal power in cultivating the soil and manage the crop.

One important improvement in farming practice has been the introduction of the ox-plough, a much more efficient way of cultivation than a hoe. The use of ox-plough can be defined as a more extensive cultivation. If the farmers start to extend their areas of cultivation even further, they have to use tractors, which represent an even more extensive type of cultivation. Introduction of inputs such as improved seed, fertilizers and pesticides require capital and a change of the present farming technology. Presently, very few smallholders are using these types of inputs or improved farming practices such as rowplanting and proper weeding. In 1969/70 994,000 hectares were planted with maize in Kenya. Only on 147,000 hectares (15 %) improved maize seed were planted. Table 14 shows the extent to which certain inputs are used.

TABLE 14. Agricultural machines, fertilizers and pesticides
Sources: Various

	Kenya	Tanzania
Tractors, numbers (1970)	6,550	4,700
Combined harvesters, numbers (1970)	1,042	?
Total consumption of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) fertilizers, metric tons (1972/73)	56,568	18,800
Pesticides imported, metric tons (1972)	?	225

Kenya and Tanzania together consume only 0.1 % of the total world consumption of 77 million metric tons of fertilizers. Consumption per hectare of arable land will be as shown in table 15.

TABLE 15. Consumption of fertilizers
Source: FAO (1973)

		Kenya	Tanzania
N	(kg/ha)	14.0	0.5
P_2O_5	"	16.3	0.4
K_2O	"	3.6	0.2
Total	"	33.9	1.1
Per capita	kg	4.9	1.3

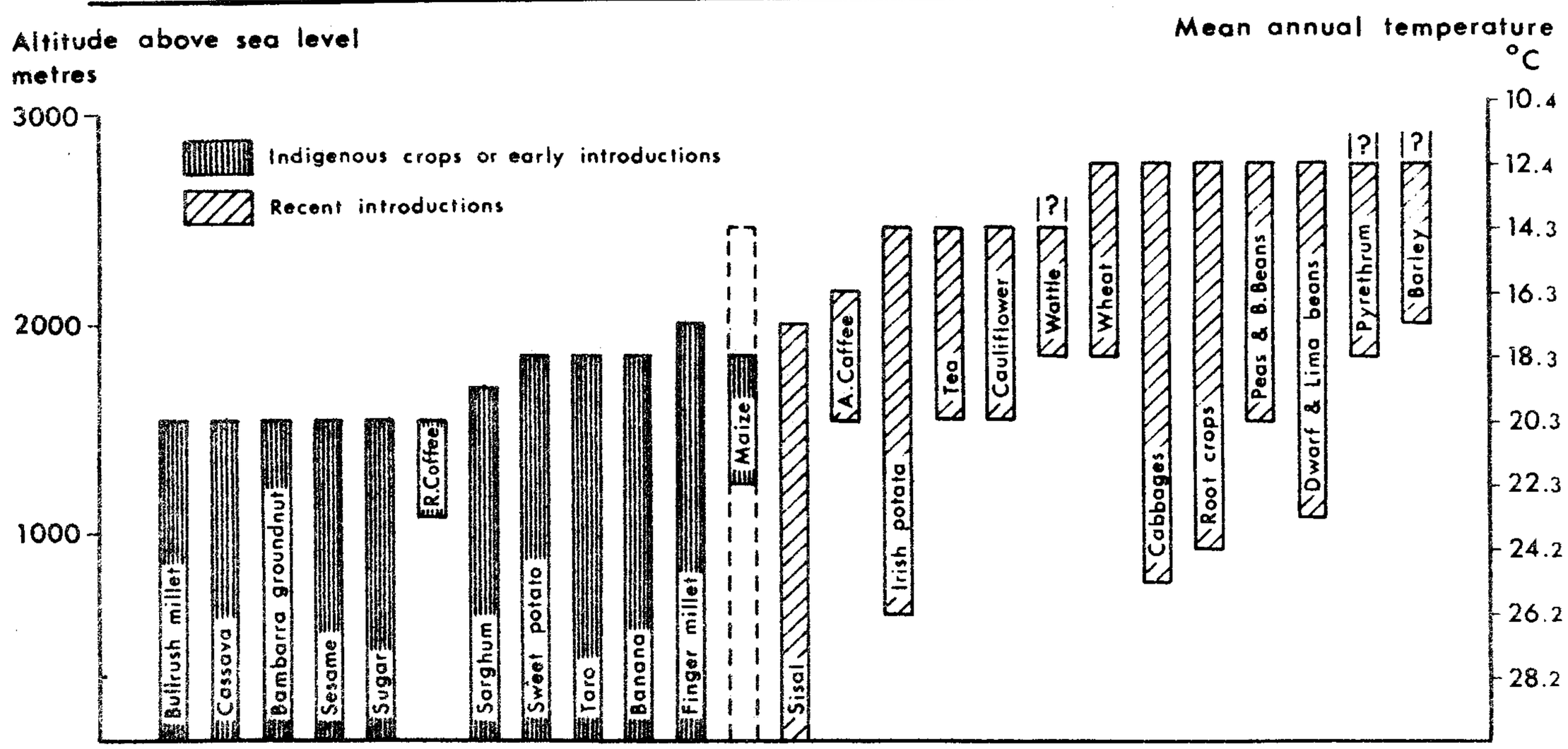
In Tanzania, mechanisation with ox and tractor is fairly high in the following districts: the Northern Highlands, the marginal areas bordering Masailand (which are used both by Masai pastoralists and, increasingly, by per-

manent mixed farmers, that tend to have fairly large farms and practice modern methods of cultivation), the Southern Highlands (with many large estates) and the Lake Victoria districts, where the main cotton belt is situated. The main mechanical equipments are tractors and ironploughs. In the rest of the country, mechanisation is very low. The common tools are hoe and sickle.

In Kenya as well, the major part of the land is cultivated with the help of hoes as the main equipment. Large estates situated in the highlands are mechanised to a very great extent, and show high productivity.

4.2.3.4. Crop pattern and potential. Due to the wide ranges of moisture and temperature, almost any crop in the world can be grown in East Africa. The major crops and their altitudinal limits are shown in figure 15. Many of the crops originate from outside Africa and have been selected for the different environmental conditions found in the countries.

FIGURE 15. Approximate altitudinal limits for indigenous and introduced crops in Kenya
Source: Morgan(1968)



Three important economic cash crops characteristic of East Africa are grown almost entirely in the highlands, namely coffee, tea and pyrethrum. In the coast regions, sisal, cashew and coconuts are grown. Together with the highland cash crops these account for a high percentage of the export trade and foreign exchange earnings as shown in table 16.

TABLE 16. Export of cash crops
Sources: IBRD (1973 & 1974)

	Kenya (1971/72) 1000 tons	Tanzania (1973) 1000 tons
Coffee	55.2	60.2
Tea	47	9.5
Pyrethrum (pyrethrins)	1.43	
Cotton		60
Sisal	34.7	113
Cashew	25	109.9
Tobacco		7.2

Due to the variety of human races and tribes, each with more or less different food preferences and degree of market orientation, several staple food crops are widely grown, such as maize, rice, wheat, cassava, sorghum, bananas and potatoes.

In Tanzania 1.4 million hectares, or 31 per cent, of the cultivated area are devoted to major export cash crops, with the remaining 3.1 million hectares (69 %) reserved for basic food crops. The area under irrigation is estimated at 127,000 hectares (less than 3 % of the cultivated area), mostly by smallholders. The major use of irrigation on large scale commercial farms is on the sugar estates.
In Kenya, approximately 30 per cent, or 0.9 million hectares, of the cultivated land are devoted to major cash crops. An area of 2 million hectares are covered with various food crops.

The areas and production of various crops grown in Kenya and Tanzania are summarized in table 17.
The sum of areas of various crops grown do not correspond with the total area under cultivation because the crops are normally grown in mixtures with each others.

Below follow short descriptions of the most important food and cash crops grown in Kenya and Tanzania.

Food crops. There is less information on food crops then on cash crops, since a large portion is grown on a subsistence basis or traded through unofficial channels.

TABLE 17. Crop areas and production in 1971
Sources: FAO (1971) and Acland (1971)

Crops	Kenya		Tanzania	
	Area 1000 ha	Production 1000 tons	Area 1000 ha	Production 1000 tons
Cereals				
Maize	1,100	1,400	1,015	650
Rice	6	28	153	185
Millet, sorghum	(235)	(330)	129	138
Wheat	150	210	51	62
Barley	10	13		
Oats	5	4		
All cereals	1,631	(2,000)	(2,163)	1,142
Pulses and oilcrops				
Beans			(272)	
Castorbeans	15	5	16	10
Groundnuts	4	2	63	38
Sesame	8	30	43	110
Sunflower	4	3	29	6
All pulses	620	280	475	196
Other crops				
Cassava	92	620	285	1,500
Potatoes	55	210	15	51
Sweet potatoes	55	463	40	310
Bananas			(98)	
Cash crops				
Sugar	(36)	(1,750)	(14)	
Coffee (mainly arabica)	(80)		(86)	
Cottonseed	81	12	470	128
Cottonlint	81	5	470	75
Sisal	80	48	230	180
Cashew			(400)	
Tea	41	37	11	9.7
Tobacco	1	0.1	22	15.3
Pyrethrum	(40)		(33.2)	

NOTE: Most figures are uncertain, those in brackets very uncertain.

Maize is the single most important cereal crop in Kenya and Tanzania and it is the staple food of much of the rural people. In Kenya smallholders (less than 5 ha) produce 90 % of the output and sell whatever is not needed for family consumption. Maize is mostly interplanted with pulses. It is grown almost all over the countries. Because of its importance the crop will be discussed more in detail.

Maize is originally introduced to Africa, probably originating from Mexico. Three types have been selected for cultivation on various altitudes, namely:

1. The "Caribbean Flint", suitable in lowland areas below 1500 m a.s.l.
2. "Flat White Complex" suitable in most of the main growing areas between 1500 m to 2200 m a.s.l.
3. "Cuzco" types which are found at altitudes of about 2400 m in cold climates in Kenya.

Synthetics, hybrids and composite varieties have also been bred for varying rainfall and temperature regions at various altitudes. For instance, Hybrid 632 requires 92 days from sowing to flowering and the hybrid variety 511 requires only 75 days for the same development.

Soil requirements. Maize requires a fertile, well drained, deep soil. In such soils the roots can penetrate down to 4 metres. Appropriate fertilizer application is often needed. Waterlogging and heavy black clay soils are fatal to maize.
Water requirements. During the growing period it needs about 750 mm rainfall. Lower rainfall results in yield reduction. Seedlings require rainfall equal to about half the potential evaporation. It develops a peak demand for water in the period of flowering. During the two last months of growth the water demand gradually reverts to about half of the potential evaporation. Excessive rain soon after planting will have an adverse effect upon the young plants.
Temperature. Maize can not be grown under very cold conditions and is not at all frost resistant. The critical temperature, below which maize will not grow at all, is estimated to be 8°C. The optimal growth is between 8-26°C.
Farming practices. Timely planting, a plant population of about 36,000 plants per hectare and proper weeding are all important measures to get optimal yield.
Hazards. The maize is not as easily attacked by birds as sorghum. However, there are some insects, such as army worms and stock-borers, and some diseases such as white leaf blight and rust, which may seriously damage the plants some years. During the storing period weevils are severe in moist and warm areas.
Yield. In the Western Province of Kenya, the potential yield under ideal environmental conditions and proper management is from 66 to 110 quintals per hectare.
The value of raising the yields on the existing area of maize is not only a matter of an increased total production but would also assist to bring about a much needed crop diversification on this land.
An increased yield would also contribute to a substantial surplus for livestock feeding.
The development of maize production has a top priority in the two countries. Improved technology is already more or less available, waiting to be introduced to the farmers.

Sorghum and Millet. The areas of sorghum and millet are declining in competition with maize. Both bulrush millet and finger millet are grown. They are grown in marginal drier areas, mainly in the Eastern Province and the

densely populated area of Nyanza in Kenya, and in the central areas of Dodoma, Mara and Singida in Tanzania. In Tanzania, 27 % of the production is marketed. Damage from birds is the major production problem. The average yield is very low, about 500 kg/ha. Very little improvement work has been done concerning these crops.

Wheat production is mostly confined to large-scale farms in the highlands (1850-3000 m a.s.l.) of Kenya and in the Arusha Region in Tanzania. Arusha accounted for 90 % of all wheat marketed in Tanzania in 1972. Improved varieties are available for various altitudes to be introduced to the farmers. There seems to be some potential for expansion in new areas, for instance in the Narok District in Kenya, one of the best potential wheat growing areas in the country.

Rice is only a minor food crop in Kenya, grown under supplementary irrigation, mainly in the Mwea Irrigation Scheme. The output is sufficient to meet the domestic demand. Also Tanzania is self-sufficient in rice production in a normal year. It is grown under rainfed and irrigation conditions in Tabora, Mbeya, Morogoro, Mwanza and Shinyanga Regions. Improved varieties and technique are available for the cultivation of rice.

Barley is grown to some extent in Kenya, mainly on contract for commercial breweries on large scale farms.

Pulses are very important as a source of protein in the human diet. In Kenya the pulses are probably second to maize in terms of planted area. Small scale farmers produce most of the output. It is frequently interplanted with maize and other crops and mainly consumed on the farms. 59 per cent of the area is estimated to be under beans, 23 per cent under pigeon peas and 12 per cent under cowpeas. In Tanzania, beans, cowpeas, soybeans, chickpeas, grams, bambarra nuts and field peas are grown, mixed with other crops in most regions. Kigoma, Mwanza, Tanga and West Lake Regions are the main producing areas. Unfortunately, very little improvement has been introduced to increase the production.

Cassava is a tuber crop widely grown in Tanzania, but also to some extent in Kenya as a food and famine reserve crop. The main production areas are found in Tanga, Tabora, Mara, Kigoma and Coast Regions in Tanzania. About 26 per cent of the total production is marketed in Tanzania. Cassava is grown on light and poor soils in areas with rainfall down to 750 mm a year. In areas of higher rainfall and richer soils it competes with the banana, which not only is a higher yielder but much more preferred as food. Cassava provides a poor diet and is not particularly palatable.

Irish potatoes and Sweet potatoes are grown to some extent, which is seen in table 17. Sweet potatoes require higher rainfall than cassava and is a higher yielder and more palatable than cassava. It is grown at higher altitudes, around 1500-1800 m a.s.l. Irish potatoes require even higher rainfall, and are normally cultivated at still higher altitudes.

There is a wide range of oilcrops grown in East Africa. Groundnuts, sunflower, sesame, castor beans, coconuts, palmfruit and soybeans make up the oil crop sector - excluding cotton seed which is a by-product from cotton. In Kenya the oilcrops are mostly grown by small-scale farmers, who rarely have more than 1 hectare. Coconuts are grown in the Coast Province. Sunflower is grown in the Western Province on altitudes up to 2600 m a.s.l. Groundnuts are grown mainly in the Nyanza Province. Sesame is grown under drier conditions, mostly for marketing.

In Tanzania, the oil crops are also grown mostly by smallholders. Groundnuts, palmfruit and coconuts are largely consumed within the country, while sunflower, sesame and castor seed are exported.
The main oilcrop producing Regions in Tanzania are Morogoro, Dodoma, Iringa, Shinyanga and Tanga. Groundnuts are grown at altitudes below 1500 m a.s.l. The perennial castor bean can be seen all over the country except in the driest areas and at the highest altitudes. It is self-seeded or semicultivated. It usually receives no attention, and is very low yielding - 200-300 kg/ha. Sesame is drought resistant and grown at low altitudes, mostly in the south eastern Provinces. Coconuts are also produced at low altitudes along the coast. Soybeans are grown on small areas by large scale farmers. Good yields have been achieved at lower altitudes.
Unfortunately the oil seeds produced in Tanzania are not sufficient to cover the domestic demand, why efforts should be made to increase the production.

Banana is an important staple food in high rainfall areas of Kenya and Tanzania. It is mostly grown as a subsistence crop like maize, although there is some internal trading. In Tanzania about 13 per cent of the total production of about 1.8 million tons is marketed.

Cash crops. Coffee is one of the most important export crops in the two countries. Both arabica and robusta coffee are grown.
In Kenya the coffee is produced both by estates and by smallholders. The average area of the 270,000 small growers of coffee is estimated at 0.2 hectare. Coffee occupies less than one per cent of the arable land but accounts for more than 30 per cent of all marketed agricultural output and about one third of the total export earnings. Exclusively arabica coffee is grown mainly in the Kikuyu-Meru zone, in the Western Highlands and Nyanza.
In areas of lower rainfall, overhead irrigation has been introduced for coffee.
In Tanzania, coffee is also predominantly of the arabica type (80 %). It is mostly grown in the Northern Highlands both in plantations and on peasant holdings. A large cooperative union organizes the entire Kilimanjaro area. About 19 per cent of the total export consists of coffee. The main areas of coffee production are shown in figure 16 a.

Tea is grown in highland areas with high rainfall. In Kenya the plantations are found in the Western Highlands around Kericho, situated at 1800-2400 m a.s.l. in areas with deep forest soils, weathered from volcanic ash under humid conditions. Although tea is best suited to largescale plantation management, it has started to be grown commercially also by smallscale farmers. Kenya is one of the few countries in the world with a successful smallholder tea programme. In 1968, they accounted for 38 % of the total tea area.
In Tanzania the most important tea estates are found in the Southern Highlands and the Usambara Mts. The production has expanded during recent years, and large scale tea development schemes are under way to increase smallholder production, among else, in the Usambara Mts.
The production areas are shown in figure 16 b.

Cotton is another important export crop. It requires a long period of rain and is grown below 1500 m a.s.l.
In Kenya, with the exception of one irrigated 400 ha project in the Lower Tana River Basin, the cotton is all rainfed and produced on small farms.
In Tanzania, 95 per cent of the crop comes from the Western Cotton Area, which include Mwanza, Mara, Shinyanga, Tabora and West Lake Regions. Cotton is the largest source of farmers income in most of these Regions.

on and production of coffee (a), tea (b)
sal (d).
e: Morgan (1973)

Cotton production areas are shown in figure 16 c.

Sisal is grown on large estates. It yields well in areas of high rainfall, but can also be grown in drier areas with poor soils, which permits the use of marginal areas with little alternative value.
In Kenya much of the production comes from estates in the Eastern Province. Tanzania accounts for about one third of the total world production of sisal. Approximately three quarters of the country's sisal is produced in the Tanga Region. See figure 16 d.

Cashew is found in most tropical countries but commercial production in quantity is confined mainly to India, Kenya, Mozambique, Tanzania and Brazil.
It is grown in the coast areas. Tanzania is the second largest producer of cashew nuts in the world after Mozambique. 75 per cent of the crop is found in Mtwara, Lindi and Ruvuma Regions. Almost the entire production is on small scale farms, where the holdings average 1 ha. It accounts for 8 % of the total export.
Kenya also produces some cashew for export and accounts for 6 per cent of world production.

Pyrethrum is grown at higher altitudes. As the world's largest producer, Kenya accounts for nearly 70 per cent of world production.
In Tanzania the two major producing areas are the Arusha and Kilimanjaro Regions in the North and the Southern highlands. All is produced by small holders.

Tobacco is an export crop in Tanzania. In 1972, 8,800 tons were exported.

Macadamia nuts are grown in Kenya on 3,200 ha. Only a very limited quantity reaches the world market.

Kenya's main exports of fruits and vegetables in 1971 were, beside canned pineapples, beans, peas and lentils.

4.2.3.5. Food consumption pattern. Reliable information about the nutritional conditions is in general very scarce in the countries (cf. section 2.3.3.). The nutritional level of the population may be serious due, among else, to the following facts:

1. Population pressure on land is increasing in the countries and small scale farming technology is not improving much.
2. Research workers do know very little about basic food crops and on farming systems related to them. The extension agents have little of use. to teach small scale farmers about such food crops as pulses, millets, fruits and vegetables.
3. People are more and more moving into marginal areas, where the best way to farm is not known. In these areas, with uncertain rainfall, maize is replacing the more nutritious and drought-resistant cereals, such as millet and sorghum.
4. Smallholders are starting to grow cash crops instead of food-crops.
5. Urban population are growing rapidly and are placing additional demands on the availability of nutritious food.

According to a national food balance survey in 1972, the average daily intake of calories in Tanzania was 2000 and protein 50 grams per capita, which is not sufficient. Also in Kenya there are symptoms of nutritional deficiences in some areas. See table 18.

TABLE 18. Daily per capita intake of calories and proteins in Tanzania and selected rural areas in Kenya
Sources: IBRD (1974) and Bohdal et al. (1969)

	Recommended standard	Tanzania	Kenya	Tanzania Plant origin	Tanzania Animal origin
				Per cent	
Calories	2,300	2,000	1.560-2,470	90.2	8.8
Proteins (grams)	60	33	45-166	72.7	27.3

A higher yielding agriculture must be a fundamental part of any programme devised to solve the long-term nutritional problems. An urgent task is to find drought-resistant varieties of cereals and pulses to be introduced to small scale farmers in the marginal areas. There is also a need of new, more nutritious crops and varieties in other areas of the countries. It also seems necessary with a review of the famine relief capability within the countries and to consider the possibilities of establishing a strategic food reserve.

4.2.3.6. Development of crop production. In Kenya and Tanzania the contribution of agriculture to the gross domestic product is estimated at 31 respectively 40 per cent. In both countries, more than 50 per cent of the export is made up of agricultural products. Economic growth is thus largely dependent on the development of the agricultural sector. As long as the countries do not have capital and markets created for their industrial commodities, improvement and development of the agricultural sector will have the highest priority.

Three main objectives for agricultural development can be recognized, namely:

1. Provision of livelihood to the majority of the population.
2. Provision of food surplus to the growing population.
3. Provision of export commodities for earning of foreign exchange.

To fulfil these aims the agricultural production should be encouraged and supported by starting new development projects in the rural areas. The main tasks must be to find means and methods to improve yields and to expand the area of arable land.
Before any action can be taken concerning agricultural development projects, thorough planning must be carried out in the areas concerned, including e.g. various surveys of the environmental conditions and of present farming conditions, such as land ownership, cropping systems and farm practices mentioned in the previous sections.

On the physico-biological potential maps prepared for Kenya and Tanzania (see 4.2.2.1. and 6.3.3.) some crops suitable for cultivation in various ecological zones are mentioned (see tables 8 and 9). However, these recommendations are very unprecise and detailed studies are needed to obtain exact information about the real agricultural potential in more specific areas. The farmers must know exactly which crops to grow, and how to develop the farming practices and cropping systems suitable for these crops.

Land available for development. In Kenya only 4 per cent (2.3 million hectares) of the total land area is presently used for crop production. According to figure 30 in section 6.3.3.1. and table 8, land of high agricultural potential seems to be available in Kenya. This category of land has been estimated at 6.7 million hectares, which shows that the cultivated area at least theoretically can be more than doubled.
Also in Tanzania there is land available for agricultural expansion. An estimated increase of the cultivated area with another 2.8 million hectares seems necessary to maintain the present cultivated area per capita. The introduction of ox cultivation and more efficient farming practices would enable farmers to cultivate areas twice the size of their present farms.

Land potential. Ecological land suitability is usually defined in terms of agro-climatological and soil variables, known to influence a crop. Soil surveys, preceeding the project implementation, should include e.g. soil erosion hazard and soil drainage as important elements in the evaluation of land capability and the recommended soil management practices (see 6.4.1.2.) The climatological surveys should include not only the total rainfall per year, but also other aspects of the climate regime, such as rainfall intensity and monthly distribution and frost appearance.

The potential production of various crops of the soils under various climatic conditions and improved farming practices and supply of inputs such as fertilizers and improved seed has been studied on agricultural experimental stations throughout the countries. The figures obtained from these experimental works give broad indications of the opportunities for crop production improvement, which naturally differ from one agro-economic zone to another. The results indicate that, with suitable innovations, it seems to be possible to more than double the yield of pyrethrum, cotton, maize, irrigated rice, sorghum, beans and cassava compared with present practices. The prospects for improvement of coffee, tea, tobacco, rainfed rice and wheat yields are also substantial. In table 19 the results of some fertilizer trials are shown, indicating the enormous yield increases that can be obtained with simple inputs.

TABLE 19. Results from maize fertilizer trials on small-scale farmer plots
Source: FAO Fertilizer Program, Kenya

Yield kg/ha Year	Control	Increase from P_2O_5 (60 kg/ha)	Increase from N and P_2O_5 (60kg/ha each)
1969	3820	955	1834
1970	3251	925	1882
1971	3135	983	2018

In table 20, the present yields of the most important East African food and cash crops are contrasted to the potential yields that can be achieved with improved practices.

TABLE 20. Present and potential yield of major crops in East Africa
Source: Acland (1971)

Crop	Yield with present practices		Potential yield with improved practices	
Banana	13,000-16,000	kg/ha	30,000	kg/ha
Beans	220-670	kg/ha	1,100	kg/ha
Cashew	590	kg/ha	1,500-2,200	kg/ha
Cassava	7.5-10	ton/ha	25	ton/ha
Castor	550	kg/ha	1,700	kg/ha
Citrus	13	ton/ha	26	ton/ha
Coconuts	15-20	nuts/palm	100	nuts/palm
Coffee (Arabica)	630	kg/ha	1,250	kg/ha
Coffee (Robusta)	500	kg/ha	1,900	kg/ha
Cotton	220-450	kg/ha	1,300-1,600	kg/ha
Groundnuts (shelled)	450-670	kg/ha	1,300	kg/ha
Maize: Kenya	1,100-1,350	kg/ha		
" Tanzania	670	kg/ha		
" long growing season			5,600	kg/ha
" short growing season			3,350	kg/ha
Pyrethrum	280	kg/ha	1,000-1,300	kg/ha
Rice	5,000-5,700	kg/ha	7,800-9,300	kg/ha
Sisal	11-12	ton/ha	17.5-20	ton/ha
Sorghum (dried grain)	550-1,700	kg/ha	3,400-4,500	kg/ha
Sugar cane	110	ton/ha	190	ton/ha
Sunflower	900-1,100	kg/ha	2,200	kg/ha
Sweet potatoe	1	ton/ha	12,5-17,5	ton/ha
Tea: Kenya	1,300	kg/ha	3,000	kg/ha
Tanzania	900	kg/ha		
Tobacco	300-500	kg/ha	900-1,100	kg/ha
Wattle (bark)	7,6	ton/ha	11	ton/ha
Wheat	1,100	kg/ha	2,000-3,000	kg/ha

NOTE: No systematic survey of present yields has been undertaken. The figures have been obtained by dividing the total production with total area figures (see e.g. table 17).

The following discussion on agricultural development is only slightly modified after Morgan (1969) and it may serve as a summary of the problems encountered.

"Many highland areas support dense populations of peasant cultivators, and where subsistence agriculture is today supporting families at half a hectare or less per head, it is doubtful whether any form of land use other than agriculture is worth while. The environment of the highlands allows certain crops to be grown, for which, compared with other parts of East Africa, the highlands have a distinct advantage. Thus, the highlands would be better used, not for growing a crop which can be widely grown, such as maize, but for growing potatoes, cabbagesand temperate vegetables and fruits which the surrounding plains can only grow with difficulty, if at all. This requires transport and a market mechanism which is not always present. The equatorial high mountains have a climate which is rare in the world and one particularly suited to supplying the industrialised nations of the temperate lands with fruits and vegetables.

Bananas and other crops produced in rain forest areas, could be in demand in the most extensive drier areas. In any case, increased exchange of food crops between such zones is here particularly desirable to reduce the excessive use of the nutritionally inadequate banana in the diet. In considering the best use to be made of various classes of land, it is also appropriate to consider what adaptations to social systems this may require.

In the highland and rain forest zones, cultivation is intensive and a family may be maintained on a small area. The scale of production can be small and there is no reason why a farmer should not own an individual plot and cultivate it himself.

In the more marginal areas of the wooded grassland (savanna) and miombo, there is some benefit in a larger scale of production. With more extensive cultivation, mechanisation becomes more profitable. Any one unit is likely to have a mixed production, perhaps of staple crop and of cattle, and each section will have a minimum desirable size. With less reliable climate, a larger unit benefits by being able to spread the risk and is also stronger financially to carry over the poor years into the good.
A nomadic system is the only possible where rainfall is unreliable and distributed so unevenly, that grazing must be sought out as it occurs and a regular circulation is not possible.

In Tanzania, the best parts of the land are already cultivated in full extent. Thus, the possibilities for development in these parts are to increase the yield by improvement of cultivation practices. Many of the defects in cultivation practices could be improved for better yield. They often are the results of lack of adaptation to changed conditions. Most of the crops are e.g. sown or planted too late in the rain period. Earlier sowing could reduce the erosion and give higher and more safe yields. Mostly, weed control is very insufficient, which is the major reason for reducing the yield. Planting and sowing are made without system, the area and seeds are used in an ineffective way.
Where the use of ox has been introduced, the plowing is made careless and imcomplete, and there is no equipment available for weed control by oxdraft. Erosion control is neglected, and small scale cultivators have difficulties to understand the need of this type of work.

The "Miombo"-woodland is the most important land reserve for agriculture in Tanzania. However, cultivation practices must be used that take into consideration the special conditions in this marginal type of land."

4.2.3.7. Services to agriculture. A programme of intensification of land use requires increased survey activities, applied experimental work, improvement of the extention service activities, easier access to agricultural inputs, credit facilities to the farmers and a continuous review of agricultural pricing and marketing policy.

In order to get reliable data about the present conditions in limited areas to be developed, surveys concerning climate, soil and present farming conditions have to be conducted (see 6.4.). A number of simple agro-economic surveys have been carried out by the Bureau of Resource Assessment and Land Use Planning (BRALUP) of the University of Dar es Salaam. Based on the agricultural conditions found in each District in Tanzania, the country has been divided into 16 agro-economic zonal groups, each divided into smaller zonal subgroups. The natural conditions, population, social pattern, land, crops grown, farming practices, farming types etc., have been described for each agro-economic subgroup. This will provide information about the

areas and form a basis for District level planning. It also provides a sampling frame for carrying out proper management studies, which will provide more detailed information on farming systems.

To get proper information agro-climatological stations have to be set up. Systematical soil surveys and a crop yield sampling must be conducted. Furthermore, erosion and soil fertility problems have to be studied.

Change of the farming pattern among the people is a very slow process and must be handled very carefully. Before any change is proposed a survey of present farming habits and social structure should be conducted.

In order to find ways and means to develop agriculture, experimental stations should be established in each ecological zone. The findings from these will provide data about crop-yields under present environmental, and underimproved conditions.
Our knowledge of subsistence crops is much less than that of cash crops. Ignorance is greater on those subsistence crops which are indigenous, such as sorghum and millet, or introduced in the distant past, such as cassava, banana and sweet potatoes. Very limited information on the environmental optima and limitations of these crops are available. The selection of better varieties within the species has made little progress.

Every crop has its specific requirements of water, temperature and plant nutrients during the growing period, all affecting the development of the cultivated plant and the final output. By experimental work the plant requirements and methods to improve the crop should be studied. The research should consist of trials of improved farming technology, such as soil preparation, sowing date and method, plant population, proper weeding and pest control and the use of various agricultural inputs like fertilizers, improved seed and pesticides.

The aims of the extension services are to introduce and disseminate technological innovations to the farmers in close liason with the research stations. Not only the positive effects of improved crops and techniques, but also possible negative effects, deserve attention in the implementation of a development project in agricultural areas.
The main methods of communication is by effective demonstrations of the whole package of farming practices and inputs, with the aid of elected model farmers. There will be no effect unless credit, inputs and marketing channels are available to farmers.

4.2.4. Animal husbandry

4.2.4.1. Livestock population and distribution. The population of livestock in Tanzania in 1972 was estimated to some 14.5 million head of cattle, 4.5 million goats, 2.8 million sheep, 22,000 pigs and 15-20 million poultry. Official figures up to 1972 are given in table 21.

TABLE 21. Livestock population in Tanzania (1000's)
Source: IBRD (1974)

Year	Cattle	Goats	Sheep	Pigs
1962	8,200	4,200	3,100	21
1965	10,000	4,100	2,800	15
1970	13,000	4,400	2,800	21
1971	13,700	4,500	2,800	21
1972	14,500	4,500	2,800	23

The agricultural census of 1972 gave, however, much lower figures and the cattle population was estimated to 9.4 million head. The Regional distribution of cattle according to the preliminary results of the 1972 census is given in table 22.

TABLE 22. Cattle population by Regions in Tanzania, 1972.
Source: Agricultural Census, Preliminary Results.

Region	1000 head	% of all cattle
Arusha	2,378	25.2
Coast	14	0.1
Dodoma	773	8.2
Iringa	239	2.5
Kigoma	80	0.8
Kilimanjaro	249	2.6
Mara	770	8.2
Mbeya	429	4.6
Morogoro	114	1.2
Mtwara/Lindi	9	0.1
Mwanza	874	9.3
Ruvuma	26	0.3
Shinyanga	1,382	14.7
Singida	778	8.3
Tabora	873	9.3
Tanga	209	2.2
W Lake	228	2.4
Total:	9,425	100.0

The livestock population in Kenya is given in table 23.

TABLE 23. Livestock numbers by species and category of farmers in Kenya, 1970.
Source: IBRD (1973)

Type of livestock	High potential smallholder Districts 1000 heads %	Range subsist. cultivator Districts 1000 heads %	Pastoralist Districts 1000 heads %	Large farm Districts 1000 heads %	Total 1000 heads %
Grade Dairy Cattle	418 (60)	57 (8)	1 (0)	226 (32)	702
Beef Cattle	35 (8)	42 (10)	- (-)	345 (82)	422
Indigenous Zebu Cattle	3,446 (39)	2,292 (26)	3,069 (35)	- (-)	8,807
Total Cattle	3,899 (39)	2,391 (24)	3,070 (31)	571 (6)	9,931
Sheep and Goats	2,312 (28)	3,018 (36)	2,719 (33)	268 (3)	8,317
Donkeys	36 (20)	30 (16)	116 (64)	- (-)	182
Camels	- (-)	- (-)	516 (100)	- (-)	516

The distribution of livestock in East Africa is very closely related to the distribution of the tse-tse fly. This is clearly shown in map 14. The indigenous zebu cattle are of a rather small, low-yielding and late-maturing type. Attempts have been made to improve the local type of cattle by crossing with exotic breeds like Friesian, Jersey, Guernsey, Ayrshire etc. or improved zebu types like Boran and Sahival. Both artificial insemination and natural service have been used.
There are about 15,000 grade cattle in Tanzania and some 700,000 in Kenya. Kenya is thus, in this field, far more advanced than Tanzania. The results of the upgrading have been good and many of the grade animals are very high-producing animals, especially when their production is related to their body-weights.

4.2.4.2. Breeding policy. In table 24 Meyn and Wilkins have given a breeding policy for different ecological zones, considering both subsistence smallholders and large scale commercial units. This table summarizes what has proved to be possible in Kenya and is also valid for Tanzania. However, dairying in semi-arid areas will be troublesome and is not likely to be economically competitive. Likewise in arid and very arid areas beef ranching and subsistence farming by nomadic or semi-nomadic pastoralists may not be competitive with game animals (cf. 4.5.4.). The zones are also very sensitive to overstocking.

TABLE 24. Cattle breeding policy for commercial and subsistence farmers in different ecological zones of Kenya.
Sources: Pratt et al. (1966) and Meyn & Wilkins (1974)

Ecological zone (cf.table 8)	Approx. annual rainfall (mm)	Percentage of surface area	Cattle population Millions	Stocking rate ha/livestock unit[1]	Breeding policy	
					Subsistence small-holders	Commercial large-scale
I to III	900	21	3.7	2	Dairying[2] European	(i)Dairying[2] (ii)Dualpurpose European breeds[3]
IV	600-900	9	2.5	3-4	Subsistence beef[4] European X zebu crosses	(i)Dairying[4] Ranching[5] (ii)Beef
V	400-600	50	1.9	5-10	Subsistence: beef-Sahiwal	Beef-Boran
VI	under 400	20	1.0	15-20	Subsistence: beef-indigenous zebu	----------

NOTES: [1]Livestock unit, equivalent to 450 kg liveweight
[2]Ayrshire, Friesian, Guernsey, Jersey
[3]Simmental, Brown Swiss, Red Poll
[4]Crisscrossing: Friesian, Simmental, Brown Swiss, Red Poll, with Sahiwal and Boran
[5]Commercial crosses: Charolais, Simmental, South Devon, Sussex, Hereford, Friesian, with Boran and Sahiwal

4.2.4.3. Beef production. In Tanzania the total offtake of the national herd is slightly below 10%. This figure is estimated from the total sales of hides. The official offtake calculated from market sales is between 2-3%. The difference is made up of local consumption and dead animals. The calving rate is estimated to be about 50%, calf mortality 20% and adult mortality 10%. There is evidently ample scope for improvement.
About half the cattle population is owned by farmers who also cultivate land. These cattle are mostly grazed on communal land. About 1.5 million head are owned by farmers in densely populated areas. These animals are grazed on or near the farms. Two million cattle belong to pastoralists and three million are to be found in more sparsely populated areas and are more or less unclassified.
In Tanzania there are some parastatal beef ranches. New ranches are planned to be established within the Ujamaa movement, but so far very little has been done.

In Kenya the land is shared in the following way:

a) Pastoralists 74%
b) Range subsistence cultivators 12%
c) High potential smallholders 10%
d) Large-scale farms and ranches 4%

Most of the land occupied by the pastoralists is too dry for arable farming. Milk is the only regular food. Low production range subsistence cultivators mostly live in low and medium potential areas. The animal production of the high potential smallholders is rather well developed, based on a high number of grade cattle. In the large livestock farms and ranches, of which there are around 90 units in Kenya with an average size of 10,000 hectares, the bulk of the cattle is made up of grade or improved animals. Milk yield from grade cows is stated to be about 1000 kg per annum.

In Tanzania slaughter-house capacity is very insufficient. Presently, there is only one plant in the country, at Dar es Salaam. This requires very long transports and gives high losses and low selling prices to producers. There are advanced plans for two more large abattoirs in Shinyanga and Mbeya (World Bank).
In Kenya there are better facilities with a big abattoir in Athi River and three smaller in Mombasa, Nakuru and Ngong.

Beef ranching is limited by the presence of the tsetse fly (carrying and spreading trypanosomiasis) which in Tanzania covers 65 % and in Kenya 25 % of the rangelands (see map 14). Cattle which have been infected with the protozoan blood parasite Trypanosoma carried by the tsetse fly, usually die unless they are treated with proper drugs. There is work going on to control the tsetse fly in different ways, e.g. by the use of insecticides, destroying of breeding grounds and release of sterile males. There are enormous areas that could be used if the tsetse could be controlled properly (cf. table 25). Up to now only rather limited areas have been reclaimed for ranching.
Another important factor is the annual rainfall, which is deciding the carrying capacity of the land. In table 25, a rough estimate is made to indicate the potential carrying capacity of the different ecological zones in Kenya and Tanzania.

It is of great interest to notice that in both countries the theoretically calculated number of livestock units that the areas could feed is lower than the actual. This indicates the most serious problem - the general overstocking of the land (cf. tables 21-23).

Beside trypanosomiasis, there are a number of tick-born diseases, of which the East Coast Fever is the main cause of cattle mortality. All cattle are supposed to be dipped or sprayed twice a week with tick-killing substances and an extensive net-work of dips have been built up (about 1000 in Tanzania only). It seems to be difficult to run the units properly. Rinderpest and Contagious Bovine Pleuro Pneumonia (CBPP) have been successfully controlled in Tanzania and in Kenya FAO has run extensive eradication campaigns. Foot and mouth disease (FMD) is wide-spread and is an important constraint to the export of meat to Europe. There are different types prevalent in East Africa. Grade cattle is more seriously affected than the local zebu. The disease is controlled by yearly vaccination campaigns and restricted movements of livestock, which often is violated by pastoralists.

Meat, hides and skins are important items on the export market of East African countries.

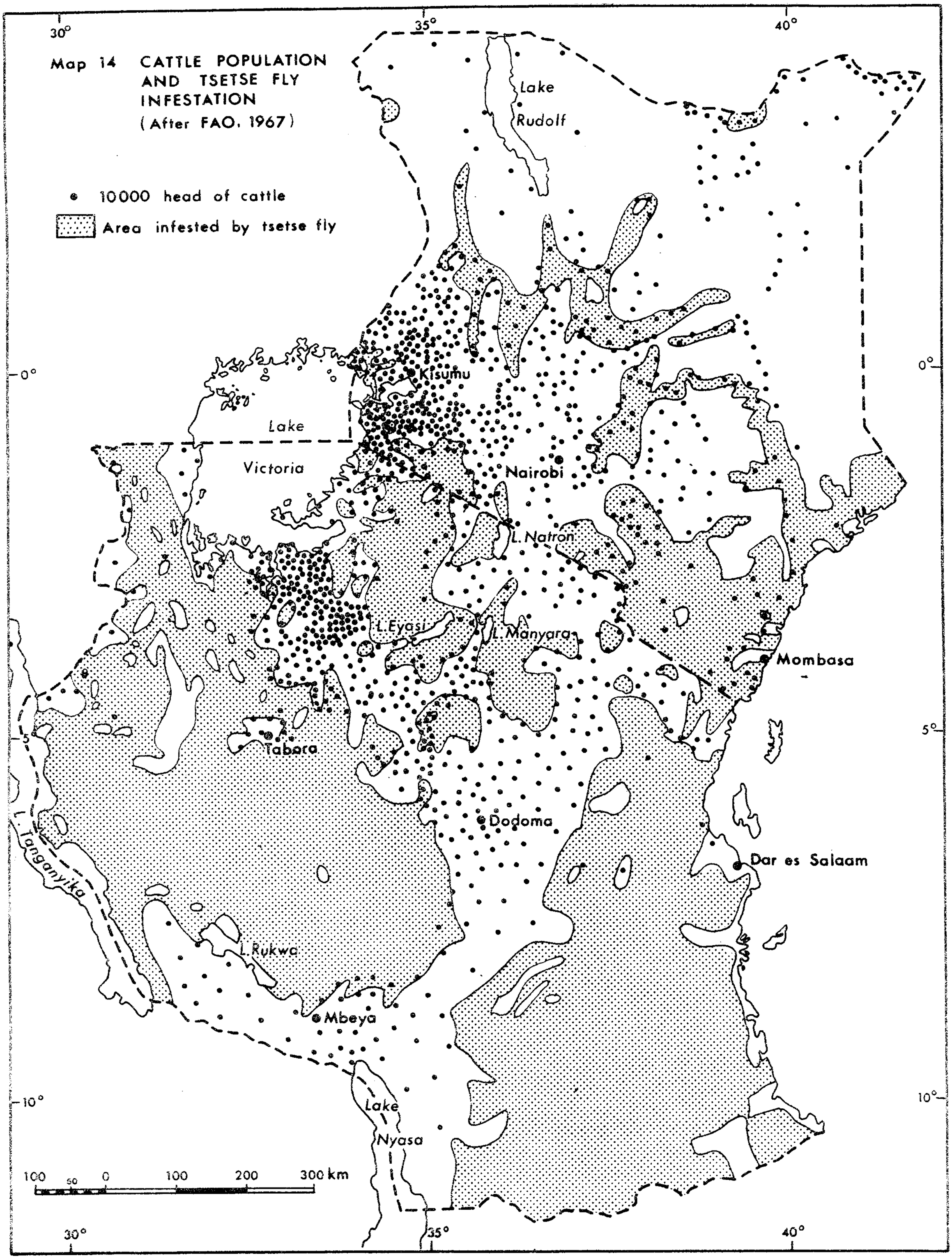

Map 14 CATTLE POPULATION AND TSETSE FLY INFESTATION
(After FAO. 1967)
10000 head of cattle
Area infested by tsetse fly
30°
35°
40°
0°
5°
10°
Lake Rudolf
Kisumu
Lake Victoria
Nairobi
L. Natron
L. Eyasi
L. Manyara
Mombasa
Tabora
Dodoma
Dar es Salaam
L. Tanganyika
L. Rukwa
Mbeya
Lake Nyasa
100 50 0 100 200 300 km

TABLE 25. Potential carrying capacity of the different ecological zones in Kenya and Tanzania
Source: Morgan (1969)

Zone	Annual rainfall mm	Potential carrying capacity LU/km	Range area, km² (excl. agricultural areas)		Total potential carrying capacity Million livestock units	
			Kenya	Tanzania	Kenya	Tanzania
I + II Agricultural potential	>1000	60	13,500	21,000	0.8	1.3
III Agricultural potential	a) over 1000			131,000		10.5
	b) over 875	80	10,000		0.8	
	c) 750-1000			130,000		10.4
IV Marginal Agricultural potential	750-1000	25		308,000 (miombo)		7.7
	625-875		53,000		1.3	
V Medium potential range	a) 500-750	20		243,000		4.9
	b) 300-625	10	303,000		3.0	
	c) 300-500	10		43,000		0.4
VI Semi-desert	<300	5	116,000	-	0.6	-
Total			495,500	876,000	6.5	38.8
Tse-tse affected areas			124,500	569,000	1.6	25.2
Area of total not available for grazing (Forest/Game areas)			34,000	40,000	0.4	1.8
Net area and potential			337,000	267,000	4.5	11.8

4.2.4.4. Dairy production. The dairy industry is rather well developed in Kenya, which also exports milk products to the other East African countries. The number of grade cattle is stated to be about 700,000. In Tanzania there is a shortage of milk and rather large quantities are imported from Kenya. Some areas, like Arusha and Mbeya, have a good potential for more intensive milkproduction. With financial and technical aid from Denmark two dairy plants have been built in the Mara region, the effects of which have been very much questioned because of too few grade cattle available in the area, poor road network and low milk price.
The Dodoma region will be in great need of fresh milk because of the moving of the capital, but intensive milkproduction is not possible there, except under irrigation.

Tanzania is in great need of grade cattle. Buying from abroad will be very expensive and an upgrading program seems to be the most realistic solution. Kenya has a well running Artificial Insemination station. Tanzania has an old AI-station in Mpwapwa and a new AI-center is under construction in the Arusha region (SIDA), which is supposed to serve the whole country.

4.2.4.5. Other types of stock. Sheep and goats are dominant in about the same areas as cattle. The numbers are given in tables 21 and 23. The total percentages offtake is much higher than that of cattle, or 20-30 % of the national herd. They are very hard on the natural vegetation and especially the goats are dangerous in heavily stocked areas and contribute to soil erosion. Horses, donkeys and pigs are only present in rather small numbers. About 1 million camels are kept by the nomadic and semi-nomadic people in the very dry areas of northern Kenya.

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4.3. Forestry

4.3.1. Forest policies

In both Kenya and Tanzania protection of available forest areas has been emphasized early, mainly by gazetting Forest Reserves (FR). The reason for establishing FR are various. In Tanzania, during the German time, the main reason was protection of catchment areas, and later, when Tanganyika was a British UN Mandate Territory, vast areas of miombo woodland were reserved, mainly for protection of the timber resources. More recently, areas have also been reserved for the establishement of forest plantations.
It is not an indispensable condition that a FR contains forest according to the definition given in section 3.6.4. A few FR's even mainly comprise grasslands.

For Kenya the forest policy aims are (Kenya 1974):

1. The basic objective in the development of the forest resources must be the protection of water catchment areas.
2. Other long-term objectives are:
   To assure the continued availability of wood and building poles for the domestic requirement of the rural population.
   To supply to the greatest extent possible the domestic demand for industrial timber.
   To promote the long-term growth in exports of wood products.

In Tanzania the policy stresses two main objectives (Morgan 1969):

1. Provision of forest products sufficient for all time.
2. Protection of the major water catchment areas.

These policies have essentially remained unchanged since before independence.

4.3.2. Forest types

The various types of forests and woodlands looked upon as plant communities are described in the sections 3.6.4. and 3.6.5. and here the emphasis is laid on their importance in producing various kinds of utilities.

Only a smaller part of the area which is dealt with under the heading "forestry" is actually covered by closed forests of the type common in e.g. West Africa. The larger part is actually covered with a more or less open stand, usually classified as different types of woodland.
In the following when the terms "forest", "forest products", "forest types" etc. are mentioned in general, also woodlands are included.

The main areas of closed forests are found in the mountains, but small areas are also found near lake Victoria and, very locally, along the coastline, where rainfall, soil or underground water are slightly more favourable than usual.
Among the economically most important forest species (spp) are the softwoods Podocarpus spp. (several spp. with similar wood properties, usually called Podo) and Juniperus procera, East African pencil cedar. Among the hardwoods Ocotea usambarensis (E. A. Camphorwood) is best known. Others are Olea hochstetteri (E. A. Olive) and Olea welwitschii (Elgon olive or Loliondo), Chlorophora excelsa (mvule) and Maesopsis eminii. The last one and Podo are general utility timbers, the rest are high to very high class furniture and cabinet timbers, but only exported to a very small extent, mainly because of insufficient supply.

The very small areas of woodland in Kenya are of limited importance as producers of timbers for sawing and export. Most of the wood is used locally mainly as firewood. The only species of any importance for export is Brachylaena hutchinsii (Muhuhu), excellent for flooring.

In Tanzania, on the other hand, it is the woodland which is producing the bulk of hardwood timbers for export. The most important type is the miombo. In this area Pterocarpus angolensis (Mninga) is to be found. It gives the highest income earnings of any single species. Another important species is Dalbergia melanoxylon (E. A. blackwood), producing one of the heaviest timbers known which is used for carvings and music instruments. More species than the mentioned can be utilized in these areas, an increased use of e.g. Brachystegia spp. is thus already under way.

During 1971-73 an extensive inventory of indigenous forests was carried out in five priority areas in Tanzania by the Canadian International Development Agency (Schultz 1973). Among other things, the study identified almost 800 tree spp. in Tanzania, of which only about 20 are utilized today. Some of the inventory results are shown in table 26, compiled from Schultz (1973) by Joszef Micski, personal communication (1975). Because of a somewhat optimistic calculation in the inventory of what is utilizable volume (more than 10 cm top diameter under bark, at least 1 m straight), which gives appr. 86 % of the gross volume as utilizable, it is probably realistic according to present technology to reduce the figures for utilizable volume to half of these in the table, except for Dalbergia, where the figure given is more realistic.

TABLE 26. Some results of the CIDA forest inventory in Tanzania 1971-73
Source: Schultz (1973)

Inventory block and forest type	Total inventoried area 1000 ha	Productive or semiprod. forest, % of area	Volume m^3/ha in forest area: Gross, to 10 cm under bark, all spp.	Volume m^3/ha in forest area: Utilizable, of commercial spp.[1)]	Commercial spp.
Mtwara (Miombo woodland)	2737	67	38	12	Julbernardia, Brachystegia, Pterocarpus, Millettia, Isoberlinia
				4	Dalbergia
Kilimanjaro (Montane forest)	36	63	274	151	Ocotea, Podocarpus, Macaranga
Tanga (mainly woodland)	1348	62	59	21	Isoberlinia, Julbernardia, Brachystegia, Khaya, Brachylaena
Kilombero (Mixed types)	533	60	74	13	Brachystegia, Chlorophora
Tabora (Miombo woodland)	2425	53	50	30	Isoberlinia, Julbernardia, Brachystegia, Pterocarpus, Afrormosia
Total	7079	61	50	20	

NOTE: 1) Overestimated. See text.

An according to area very small but economically very important forest type are the plantations. Because of her smaller resources in natural timbers, Kenya started earlier and on a larger scale in this field than Tanzania. Now both countries have embarked on extensive plantation programmes as can be seen in table 27. The locations of the main planting areas are shown on map 16.
The most important plantation species are pines and cypresses originating from Central America and southern USA, e.g. at higher altitudes Cupressus lusitanica, Pinus patula, Pinus radiata (planting now restricted because of susceptibility to the fungus Dothistroma pini) and Pinus elliottii, at lower altitudes Pinus caribaea and Pinus occarpa. There are also hardwood plantations, consisting of e.g. eucalypts, mainly for fuelwood, and teak. The only indigenous species used to any extent in plantations are Maesopsis eminii, Vitex keniensis and Olea welwitschii.

4.3.3. Forest areas

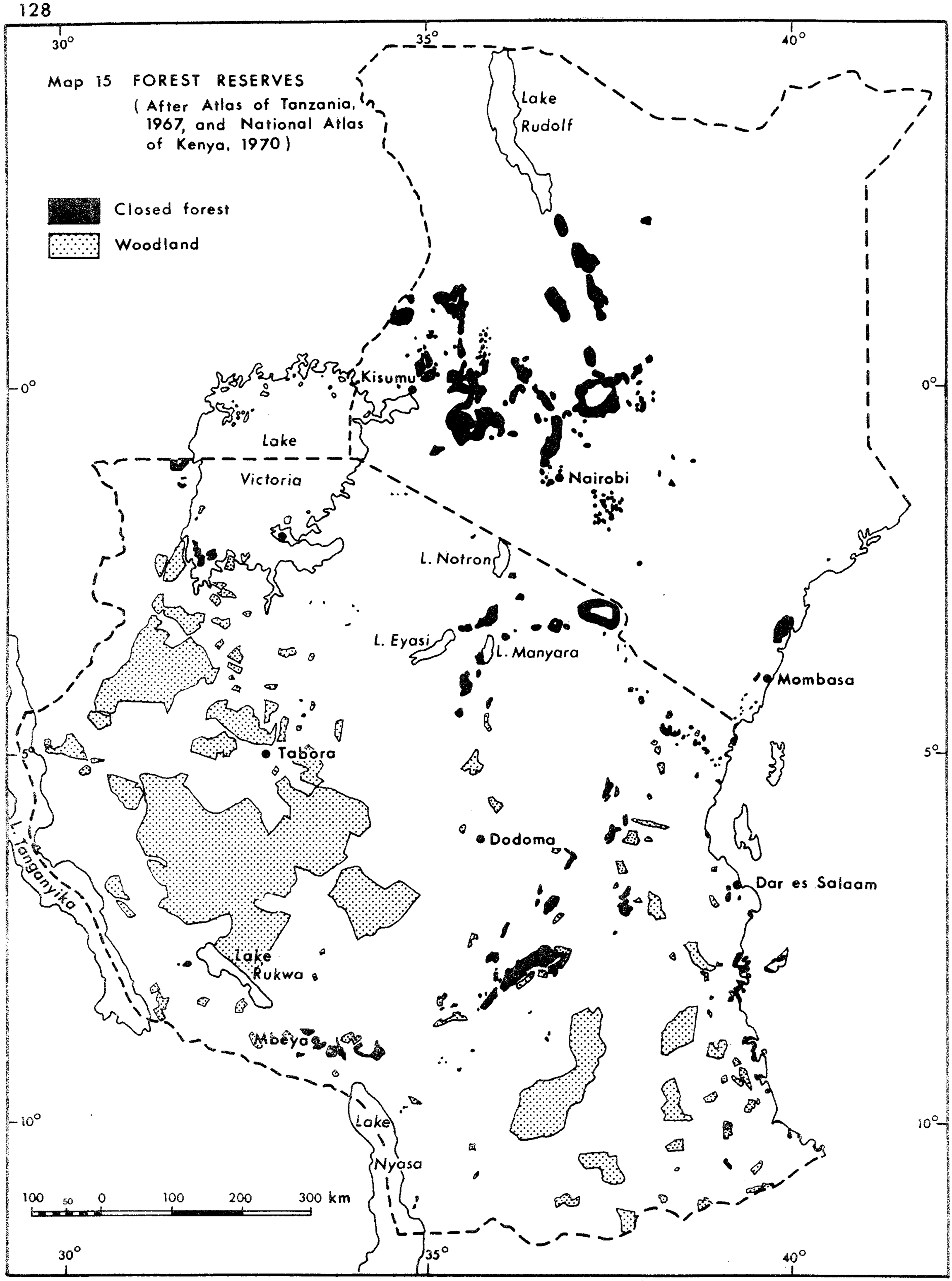
The forest areas of the two countries are shown in table 27.

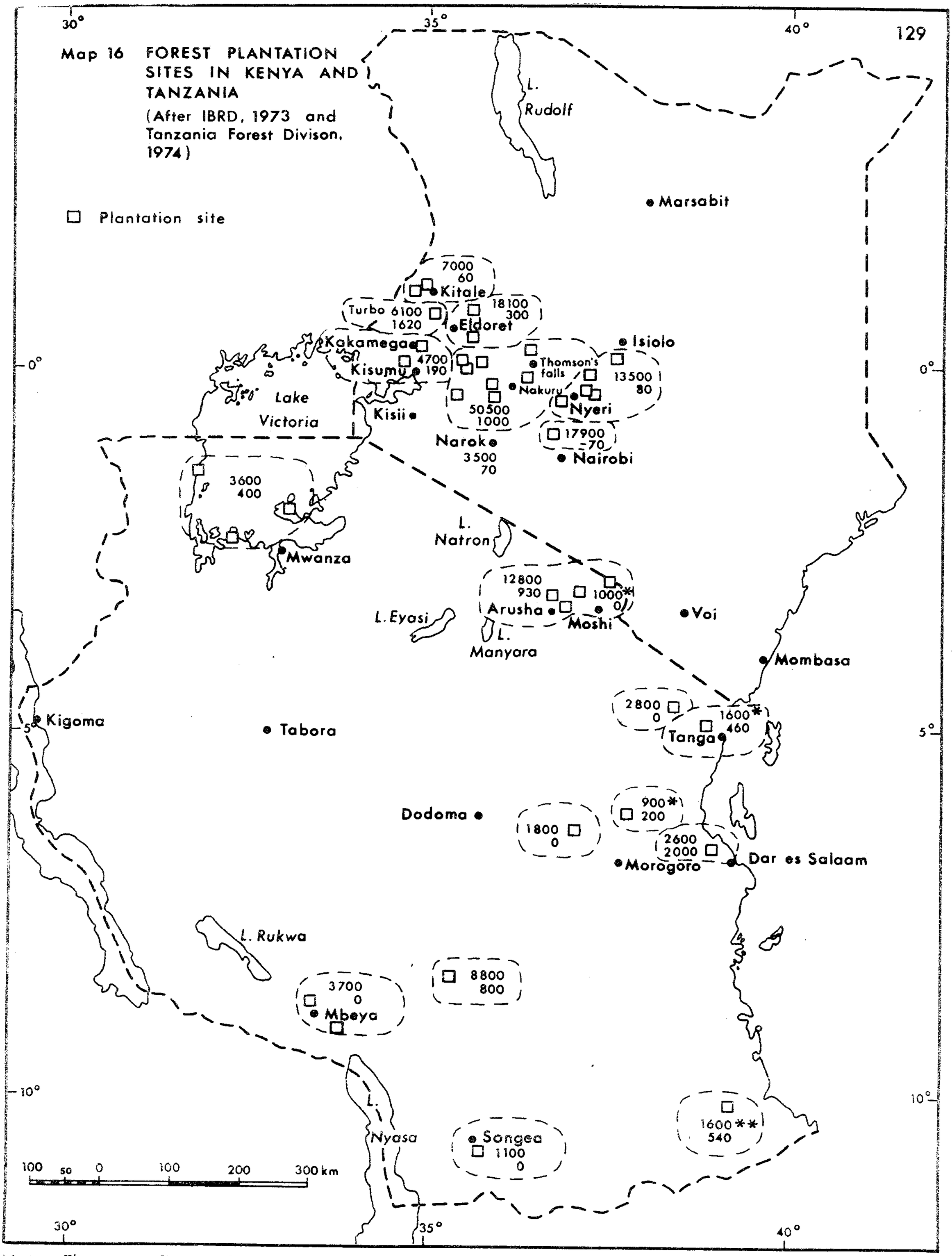
TABLE 27. Forest areas in Kenya and Tanzania
Sources: 1) Jörgensen (1971), 2) Morgan (1969), 3) IBRD (1973), 4) Tanzania Forest Division (1974)

	Kenya	Tanzania
Total forest and woodland area, mill. ha	2.1 1)	34 1) 44 2)
D:o, per cent of land area	4 1)	39 1) 50 2)
Tropical high forest, mill. ha	1.1 1)	1.6 1)
D:o, per cent of land area	2 1)	2 1)
Reserved forest area, mill. ha	1.7 2)	13.1 2)
D:o, per cent of land area	3 2)	15 2)
Plantations, total area in 1000 ha	122 3)	42 4)
Percentage softwood of plantations	87 3)	87 4)
Plantations, per cent of land area	0.21 3)	0.045 4)
Present annual planting rate, 1000 ha	7 3)	5 4)

The locations of Forest Reserves and forest plantations are shown in map 15 and map 16 respectively.

There is a great uncertainty about the total forest area in Tanzania. Among estimates other than the ones given in table 27 can be mentioned that, according to the 5-year-plan, the forest area is 43 % and according to FAO 36 %. Maybe the most accurate picture of our knowledge about the present land use pattern in Tanzania is given in FAO (1969) and here reproduced as figure 17 (cf. also table 10 and figure 13). There is, however, an increasing reduction of especially the unreserved forest land, because of cultivation for agricultural use.

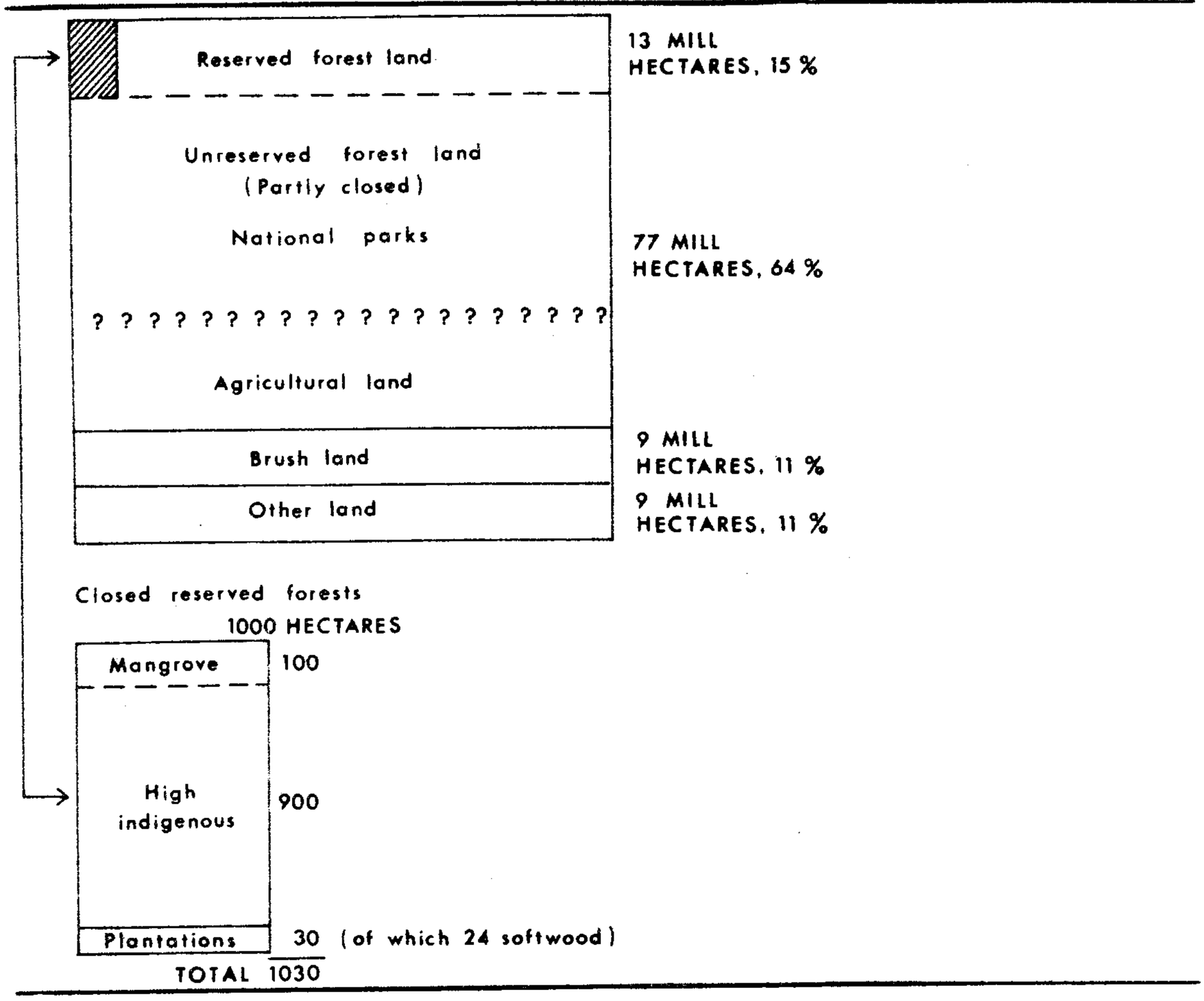

Map 15 FOREST RESERVES
(After Atlas of Tanzania, 1967, and National Atlas of Kenya, 1970)
Closed forest
Woodland
Lake Rudolf
Kisumu
Lake Victoria
Nairobi
L. Notron
L. Eyasi
L. Manyara
Mombasa
Tabora
Dodoma
Dar es Salaam
L. Tanganyika
Lake Rukwa
Mbeya
Lake Nyasa
100 50 0 100 200 300 km
30°
35°
40°
0°
5°
10°



Note: The upper figure gives the area planted at the end of 1972 (Kenya) and 1973 (Tanzania) in hectares. The lower figure gives the yearly net planting target (planted area – clearfelled area). Adjacent plantations have been summarized and are surrounded by a dashed line.

* after the figure denotes hardwood plantation; ** denotes mixed hardwood and softwood plantation. Others are all softwood plantations.

FIGURE 17. Land classification and use pattern in Tanzania
Source: FAO (1969)



4.3.4. Consumption and demand of forest products

In table 28 below estimated consumption of various forest products is shown. The figures for 1970 are usually updated FAO estimates based on assessments from around 1960.

TABLE 28. Consumption of forest products
Sources: FAO (1969 & 1970)

	Kenya				Tanzania			
	1970		2000		1970		2000	
	mill.m^3	%	mill.m^3	%	mill.m^3	%	mill.m^3	%
Sawtimber	0.25	2.1	1.07	4.3	0.31	1.8	1.18	3.7
Poles	0.5	4.1	0.8	3.2	0.7	4.1	1.3	4.1
Firewood	11	91.8	21	83.6	16	93.5	28	87.4
Pulp & paper	0.24	2.0	2.25	9.0	0.10	0.6	1.55	4.8
Total	12	100.0	25	100.1	17	100.0	32	100.0

Note: All volymes are given as m^3 round wood equivalent. For the sawtimber the recovery will probably be 45-50 %. 5 m^3 wood is used as equivalent for 1 ton pulp and paper. At 1970 all raw material for pulp and paper was imported.

It is clearly seen that both in 1970 and in 2000 the bulk of the wood will be consumed as firewood and poles. It is also expected that consumption will be nearly doubled during the 30-year period. In fact, the increase can be even faster as the estimates assume a yearly decrease of the annual consumption of 1 % per annum and capita from 1980 onwards. The assumption was that other fuels would gradually take over the role of the wood. Today this is not so obvious.

The wood raw material for the pulp industry has to come from plantations, softwood and/or hardwood. The indigenous forests will not be sufficient, because of either too small areas of closed forests or too small wood volume per unit area in the woodlands. It is also likely, although not thoroughly investigated, that many of the extremely hard timbers in the miombo are unsuitable as raw material for pulp.
Wood for the other purposes can be collected either from plantations or from natural forests. In Kenya, most of the sawtimber comes from plantations. The trend will probably be a more or less continuously increasing dependency on plantations for most products.

4.3.5. Purposes of the forests

Compared to Scandinavian forests, the two main purposes of which are wood production and recreation, the purposes of the East African forests are much more complex and difficult to combine in one single forest type.
An attempt to describe the purposes of the East African forests follows here:

1. Control of erosion and outflow of water
2. Provide the local population with firewood and simple building material, e.g. poles
3. Provide the domestic market with:
   a) Fuel (wood and charcoal)
   b) Sawn timber
   c) Chipboard and fibreboard
   d) Pulp and paper
4. Give possibilities of exporting the products under 3.

Comments:

1. The need of <u>erosion control</u> and <u>control of water outflow</u> can frequently, at least if the damage already inflicted is not too severe, be fulfilled by tending available vegetation, especially on the upper slopes of hills and mountains. Some controlled felling can be done, giving fuel and building material, in certain cases timber for sawing as well. There will not be any large quantities, however. Other possible products from such areas are honey, beeswax, fruits, seeds etc. Grazing has to be restricted if the forest will serve a protective purpose.
   The rainfall, both total amounts and distribution pattern, will, according to most investigations, only be marginally affected if the ground is covered with trees or not. The advantage of a forest cover is that it facilitates penetration of water into the soil and thus levels out violent outflows after heavy rain (cf. 5.3.). The tree roots also give the soil a good resistance against erosion. Over-grazing may, however, open the way for severe soil erosion even in cases when the trees are left more or less intact.

2. As can be seen in table 28, 96-98 per cent of the wood consumption consists of <u>firewood</u> and <u>poles for simple buildings</u>. Up to now this need has more or less been covered from indigenous forest. In larger cities,

where the distances to the wood sources are far, charcoal is much used. It has a higher content of energy than wood per unit weight and consequently it can bear long transports better than wood. But appr. 2/3 of the total energy content in the firewood is lost at the charcoal burning. The general tendency is that the transports of fuel are becoming increasingly longer due to the population growth, urbanization, cultivation for agricultural use etc. The increment of indigenous forests is low and subsequently fairly vast areas are needed to cover the requirements of firewood, areas which most likely are of interest for agriculture.
It is probably most suitable to have tended plantations near the population centres, consisting of fast-growing tree species, e.g. Cassia siamea, Azadirachta indica or eucalypts. As the transports are, and probably will remain, expensive, such plantations are in principle needed near every village or town.

3a. Because of the previously mentioned conditions with expensive transports, the production of fuel for marketing usually has to be combined with charcoal burning. Notwithstanding, it is important that the transports will be short and it is not feasible that e.g. the vast reserves of miombo woodland around Tabora will be used for burning charcoal for the Dar es Salaam market. Fairly soon, special plantations will probably have to be established.

3b. Sawn timber has up to now mainly been obtained from indigenous forests, although softwood plantations have played an increasing role in Kenya. In a not too distant future also Tanzania will have to rely on plantation-grown timber, especially in the urban areas.
Particle board and fibre board together with pulp and paper has mainly been imported, although nowadays there is a particle board factory running in Tanzania and by the end of 1974 a pulp mill came into operation in Kenya (Broderick Falls).
A rapidly increasing shortage of cheap hardwood timber from the indigenous forests has to be taken for granted. It may be physical as in Kenya or economical as in Tanzania, where it is likely that the better hardwood timbers have to be used mainly as an export product. Because of the slow and unreliable regeneration of the indigenous forests they will not be able to cover the need. With rising prices on hardwood timbers, various board materials, which can be produced from plantation-grown softwoods, will be increasingly attractive.

Various solutions are necessary to cover the needs under 3b, 3c and 3d. A sawmill does not necessitate huge investment and it is feasible to establish fairly small units, near the villages even. For the board industry larger units are necessary, some 3-5 industries of this type will be sufficient for the whole of East Africa. The very nature of the pulp industry is such that very large units are needed. With the current consumption, a medium-sized unit producing appr. 150,000 tons a year will be sufficient for Kenya and Tanzania together and also produce a surplus (see table 28). Such a factory must be established near the raw material source and also have good communications with the market. If export possibilities are considered, nearness to an export harbour is also of vital interest.

Export of timber (4a) is mainly carried out after felling in natural stands. The tree species mentioned under 4.3.2. are the most important.

4.3.6. Production potential

4.3.6.1. Environmental demands of various forest types. The conclusions below are

founded on experience from plantation trials and d:o projects in Tanzania, the results of which are correlated for Kenya with e.g. Mortenson (1968) and Lysholm (1974, personal communication). Mortenson builds his argumentation on a classification of Kenya rangelands (see table 8).
A good correlation between rainfall and development of various species can be found by using the rainfall probability map (map 6). Since the water requirements are smaller at higher altitudes than at lower, an attempt has been made to transfer these experiences to a map based on the Potential evapotranspiration ratio, according to similar methodsas Holdridge (1972) uses in constructing his life zone system.
Map 21 in section 6.3.3.3. gives only a very rough picture of the distribution, there are considerable variations within these areas both in total rain amounts and distribution, e.g. one or two rainy seasons per annum, there are soil differences etc.

Where the evapotranspiration ratio is 7-11, only planting of shrubby vegetation as erosion protection is possible, except in areas with a high ground water table, e.g. along rivers, and on land under irrigation.
In the areas with an evaporation ratio of 5-7, some firewood can be grown, although the dominating task for the forestry here is erosion control. This is the driest type of land to be found in Tanzania, the still drier parts mentioned above are confined to the north-eastern part of Kenya.
The area with an evapotranspiration ratio of 3-5 can be classified as a transitional area, where in the drier parts production of building material and firewood is doubtful. At the better localities, lowland pines such as Pinus caribaea and Pinus oocarpa and Callitris spp can be grown, aiming at sawtimber production.
Within the area with a ratio of 1-3, production of softwood for sawing or pulping is possible. Here the competition for land with agriculture is considerable. At certain localities even ratios lower than 1 are to be found. At lower altitudes, an annual rainfall of at least 1000 m will give possibilities for growing many fastgrowing hardwoods, suited for plantation forestry. Most important of these are teak (Tectona grandis), Terminalia ivorensis and Terminalia superba. These areas are fairly small, however, and because of usually fertile soils the agriculture is the first priority land use here. Thus, any considerable increase in forest production in these areas can not be expected.

4.3.6.2. Regeneration methods. With very few exceptions, no measures for regeneration are carried out after felling in the natural forests. One exception is camphor (Ocotea usambarensis) which, as a routine, is regenerated by tending the natural suckers and coppices coming after clearfelling. At some places Olea welwitschii is replanted after clearfelling. In other cases, the exploited area is just left to be occupied by various not so valuable secondary species. This is not necessarily because of not bothering about the problem, but rather a realisation that regenerating the indigenous species is a very delicate task. Some of the high forest species need a very exact balance between sun and shade to be able to survive the young stage at all.
Many of the Miombo species, e.g. Pterocarpus angolensis, start their life cycle with a 5-10 year period of annual die-backs, during which time the trees build up a vigorous root system that eventually will enable the plant to rapidly grow to a size which can stand the annual grass fires. Such an adaptation is, however, highly unfavourable when you want to establish plantations, as annual weedings are necessary for several years. The only "method" that can be used in practice is that frequent fires increase the percentage of Pterocarpus angolensis in the regeneration. But this in turn is depending on the presence of a sufficiently large number of seed-trees.

Other trees used in plantations are normally raised in nurseries by first

sowing in a seedbed, then transplanting the seedlings to polythene tubes filled with various soil mixtures. These tubes are then used for planting out. This is an expensive but usually very reliable method, because nearly all roots are left intact at the planting. In some moister areas also bare-root planting of pines and cypresses is carried out.
The plantations intended for sawtimber production are then tended with thinnings and prunings, while firewood plantations usually are left untended up to clearfelling. Most species used in firewood plantations have a good coppicing power, which will permit taking several generations on the same root system.

4.3.6.3. Yield per unit area. The possible yields from various types of forests are not thoroughly known. What is evident is, that the sustained yields from the high forests are much lower than usually anticipated. Also the miombo is not producing any higher amounts, 1 m^3 per ha and annum has been suggested. On the other extreme, *Eucalyptus* plantations in mountain areas are sometimes producing up to 80 m^3 o.b. (over bark) per ha and annum.
In pine and cypress plantations yields of 20-30 m^3 o.b. per ha and annum can be taken as rough means. There is a risk, however, that the second generation of softwood plantations will give 10-25 % lower yield than the first according to experience from other countries with similar conditions. For *Eucalyptus* plantations at 2100 m a.s.l. and a mean annual rainfall of appr. 1000 mm, Dyson (1974) has shown a sustained yield over three generations of approximately 24 m^3 o.b. per ha and annum. Still higher yields are to be expected in more favourable areas. For the dominating part of the land areas in the countries, the drier plateaux, the possible yields are not so well known. As an example, Persson (1971) gives the yield of some fuelwood species at a fairly dry area (mean annual rainfall 700 mm, hot climate) to 11-13 m^3 solid wood o.b. per ha and annum.

A large uncertainty in these calculations is that nearly all species used are exotic trees planted as monocultures. Experience has shown that such plantations are susceptible to various types of pests. This will justify a diversification of the species used and not necessarily an exclusive use of the most high-yielding species.

4.3.6.4. Necessary areas. For softwood plantations intended as raw material for pulp and sawn timber there is, according to the consumption figures in table 28, no need of using more than 0.5 % of the total land area. The main expansions will probably be in the coastal areas with sandy soils and low agriculture potential.
Concerning firewood and poles, the consumption estimated for Kenya and Tanzania year 2000 is appr. 50 mill m^3 of roundwood and, using a rough estimate of an average annual yield of 10 m^3 per ha in firewood plantations, the area needed will be appr. 5 mill ha or 3.4 % of the total land area. In fact, for quite a long time to come, most firewood will have to be collected from natural forests and the area needed will thus be larger. As shown in the examples above, the yield can vary considerably depending on the conditions. This excercise is only carried out in order to find which are the area requirements to fulfil the purpose of producing wood. In addition comes the needs for regulating water outflow etc., needs which are difficult to quantify.

4.3.7. Conclusions

The purpose of forests and forestry in East Africa are very diversified, but may be divided into two main groups.

4.3.7.1. Subsistence forestry, aiming at producing mainly firewood and building poles, possibly also raw material for local sawmills and/or pitsawers. The rural forestry can depend on either tending of natural forests or plantations or both. It has to be carried out by the village population with assistance of professional staff on a regional basis. One of the most important aims with this type of forestry is to make firewood and poles easily accessible to the people and thus avoiding unnecessary labour and costs, especially for the women, in order to collect these items. Finally, lack of firewood may lead to such destructive habits as burning cow dung, badly needed as fertilizer.
On top of this comes the role of forestry for protection, a purpose which cannot be fulfilled without close cooperation with especially the animal husbandry sector as excessive grazing will destroy much of the protective role of the forests.

4.3.7.2. Industrial forestry, which, if the aim is to be selfsupplying, only will occupy a minor part of the total land area, around 0.5 per cent. What is necessary are well situated and concentrated areas, where proper management by professional staff is carried out. The impact on the employment rate of the rural population is considerable, as shown by Persson & Mnzava (1972), but it is limited to the surroundings of the planting areas and to the industries. In order to avoid undue outflow of foreign exchange for importing products like sawn timber, fibre and particle board, pulp and paper, emphasis on this field is necessary. What can be questioned is the scale of the operations.

Some questions asked in FAO (1969) are still more or less unanswered:
Where, to what extent and how should forestry be developed or maintained for protective purposes? For autoconsumption in rural areas?
Can part of the miombo forests be transferred to closed forests, and how?
How much of the miombo can be exploited?
What happens, with regard to land deterioration, if the fuelwood removals are doubled or trebled within the next few decades and no measures for regeneration etc. are taken?
Can large-scale industrial forestry be developed within the coastal region without undue competition with agriculture? How to coordinate the planning of forest industries with the long-term afforestation programme? How to choose, generally speaking, areas for afforestation?

To the above questions can be added that according to experience large parts of the miombo can be transferred to plantations, at least there does not seem to be any biological obstacles. But the miombo is usually localized remote from population centres and export facilities. At the same time the miombo is expensive to transfer to plantations because of necessary heavy clearing.

The prospects of exploiting the miombo might seem gloomy, but by extrapolating the present trend of development, Procter (1968), an ecologist with a long experience from Tanzania, predicted that by the year 2000 nearly all natural ecosystems have more or less disappeared, except in reserved areas. Under such circumstances, it seems to be an advantage to the country to be able to combine cultivation, or whatever they decide on, of the miombo, with utilization of its timber resources rather than just waste them through clearing by shifting cultivators as is now often the case.

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4.4. Fisheries

East Africa contains roughly 2/3 of the total area of freshwaters on the African continent (i.e. 12,000 km^2), including not only the Great Lakes, but also numerous smaller lakes, swamps and impoundments, as well as several thousand kms of permanent and seasonal rivers (see 3.5.). The majority of these waters occur in tropical areas of low altitude, where biological productivity is high, and they contain an indigenous fish-fauna including species of commercial importance. Only certain high-altitude streams and crater-lakes lack a natural fish-fauna, but some of these waters have now been stocked with exotic fish populations.

The commercial importance of the indigenous freshwater fishing industry is difficult to assess; estimates of production must be based upon observations of representative catches landed, but landings tend to be numerous, widely dispersed and inaccessible, while there are considerable annual and seasonal variations in fishing effort and subsequent yield.
In 1965 the estimated landings of fresh fish in Kenya was of the order of 20,000 tons and in Tanzania 80,000 tons. Around 25,000 tons were taken from the East African coast.
The bulk of the fish caught is done by small groups of fishermen using unmechanized boats, without the use of ice or other preserving methods at sea. Thus the catch is limited to waters close to the markets and, as concerns marine fishery, to the continental shelf - in actual fact to the waters around Zanzibar. On the whole the East African continental shelf comprises only some 10,000 km^2 which, in comparison with other tropical continental shelves, is very small. The sea floor is covered with coral formations making trawling and bottom long lines practically impossible. Thus most of the marine catch relies on trapping techniques and handline fishing. With such techniques capital involvement is small and employment is open to large numbers of persons.
In tables 29 and 30 fishery statistics from Kenya respectively Tanzania are shown.

The fresh waters contain, among else, tiger fish, Nile perch, small mouth bass, trout "dagaa" (sardine), Tilapia, cat fish, Clarias and Barbus. The coastal waters contain the marlins, sailfish, tunas, barracudas, king fish, sharks, octopus, squid, shell-fish and crustacea. There is a small but useful export trade in such specialized marine products as dried shark fins, fish and Bêche-de-mer for the Far Eastern markets and of shells for the jewelry trades in Europe and America. There is also export of red sea weed for agar production.

Some lakes (Victoria, Naivasha, Baringo) show signs of being selectively overfished with declines in yields as a result. Also ecological problems such as heavy silting are reducing fish yields. The principal targets for improvement are:

- broadening the scope of fisheries research so as to determine for each fishery the level of production that can be maintained on a sustained yield basis
- revision of fisheries regulations to enforce regulations more consistently and systematically, so as to protect the yield potential of the national fisheries and particularly the breeding of commercially important species
- expansion of fish breeding research and the capacity to provide replacement stock for freshwater fisheries, fish ponds and sports fishing
- promotion of suitable fish farming practices for the different areas of East Africa. This includes improvement of capture and processing methods, better communications between fishing grounds, landing places and consumers.

TABLE 29. Fisheries in Kenya - quantity and value of fish landed 1966 and 1972 and projected for 1978
Source: Kenya Dev. Plan 1974-78

Area and main group	1966 (tons)	1972 (tons)	1978 (tons)
Fresh water fisheries			
Lake Victoria	15,445	15,989	17,500
Lake Rudolf	1,524	4,090	4,750
Lake Naivasha-Commercial	914	117	1,150
Lake Naivasha-Sport	-	144	200
Lake Baringo	610	58	700
Other Lakes	965	208	1,000
Rivers	1,524	1,624	1,600
Fish Ponds	203	-	100
Sub total	21,185	22,230	27,000
Marine fisheries			
Marine fish	6,507	7,411	7,600
Crustaceans	140	185	200
Other marine products	223	126	200
Sub total	6,507	7,722	8,000
Total fish landed	28,055	29,952	35,000
Total value to fishermen, K £	1,433,500	1,500,000	1,725,000

TABLE 30. Fisheries in Tanzania - quantity of fish landed 1965
Source: Atlas of Tanzania (1967)

Fishery	Landed weight (tons) 1965
Lake Victoria	46,800
Other major lakes	33,000
Minor waters	1,000
Total fresh water fisheries	80,800
Coastal fisheries	12,000
Crustaceans	300
Total production	93,100

Bêche-de-mer (lbs)	61,500	Sea-weed (lbs)	140,000

Owing to the shortage of fuel, fish processing is usually carried out by sundrying although hot smoking and frying are also practised. The distance from bulk-markets, the poor communications in the dry season, and the interruption of transport in the wet season, are major factors hindering development of the industry in many areas.
In connection with a large fishery development project in Lake Rudolf it has therefore been necessary to integrate an extensive road building program into the project to be able to take full advantage of the fishery in this remote, highly potential lake.

Fish consumption varies greatly among population groups, being traditionally greatest among the population adjacent to the principal fisheries. In the country as a whole, estimates of production and trade suggest that there are about 3 kilograms of fish available per person per year. This is extremely low, and there is no doubt that potential consumer demand greatly exceeds the volume of fish presently available.
Kenya and Tanzania are net importers of fish, primarily in the form of fish meal; exports are chiefly salted, dried and smoked fish. Fish can be an important source of protein in the diet of the low income rural population and a noticeable increase in demand has taken place in recent years.

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4.5. Wildlife and tourism

4.5.1. Introduction

Few aspects of East Africa as a region have attracted as much international interest as its national parks and the wealth of wildlife found in them. Also outside the parks vast areas of Kenya and Tanzania carry large populations of wild animals.
Like in few other areas of the world has wildlife as a form of land use, either exclusively as in the National Parks and Reserves, or in combination with other forms of use, been as seriously considered in national planning as in East Africa. The main reason for this is undoubtedly the rapidly growing economic importance of the tourism industry and its undisputed dependence on the wildlife as a major attraction.

The close relation between tourism and wildlife is recognised in both Kenya and Tanzania by the fact that these questions are under the same ministries, in Kenya the Ministry of Tourism and Wildlife and in Tanzania the Ministry of Natural Resources and Tourism. This is also the reason why they are considered under the same heading in this report. It should be stressed that tourism is primarily dealt with here as an economic form of land use, not as a social or political problem, although it must be borne in mind that these latter aspects play a prominent role in the internal East African policy debate.

It is not possible to give a strict definition of the word "wildlife" and it should be remembered that different writers and authorities may mean different things when talking about it. Most people probably think of big, wild animals when using the word, i.e. normally not including insects and smaller mammals and other animals like mice and frogs and the like. In a strict sense it ought to include all wild animals, i.e. those not domesticated by man, and the natural environment in which they live. When discussing wildlife as an economic resource and as a land use alternative in East Africa it is, however, normally referred to the larger elements of the mammalian, avian and reptilian faunas.

4.5.2. Wildlife in East Africa

The mammalian fauna of tropical Africa is richer and more diversified than in any other region of comparable size in the world. There are two main, seemingly contradictory, reasons for this.
First, the overall geological and climatic stability, free from catastrophic disturbances on a continental scale, like glaciations or volcanic events, during the last 50 million years has ensured a high degree of species evolution and survival. During this long time, two distinct faunas have developed, one adapted to the closed forests and one to the more or less open plains. Furthermore, the fauna of the evergreen, lowland rain forest is quite distinct from the mountain forest fauna. On the open plains there is a gradual change in the species composition, from predominantly grazing animals to very drought-resistant, mainly browsing animals as one moves from the well watered wooded savannas to the sub-desert shrub.

The second reason is the more or less pronounced fluctuations in climate that have occured in Africa during recent geological periods. Although these have not been of a magnitude that have resulted in large scale extermination of animal species, they have caused substantial expansions and retractions of the major vegetations types and the related faunas. Thus, the highland and lowland forest, savanna and desert faunas have sometimes occupied vast areas and then, when the climate has changed, been confined to small refuges where they have survived. These frequent isolations and rejoinings of the

various faunas have resulted in a high degree of speciation and sub-speciation.
There are many, both fossile and present, indications that this has occured. Desert sands are found under the Congo basin rain forests, savanna animal fossiles are frequent in the Sahara. The striking similarities between the montane flora and fauna on all high, isolated mountains from Ethiopia to South Africa can only be explained by a recent continuous distribution of the montane environment. This probably occured 50-20,000 years ago when the temperature in Eastern Africa is considered to have been 5° C lower than at present with a consequent lower limit of montane vegetation 1000 m below the present.
Another striking evidence is the occurence of one Northern and one Southern savanna fauna, widely separated by the miombo belt through Angola, Katanga, Zambia and Tanzania. The same species, like white rhino, wildebeest, oryx, lechwe, and giraffe, or closely related subspecies, occur in the two areas without any present possibilities for gene exchange.

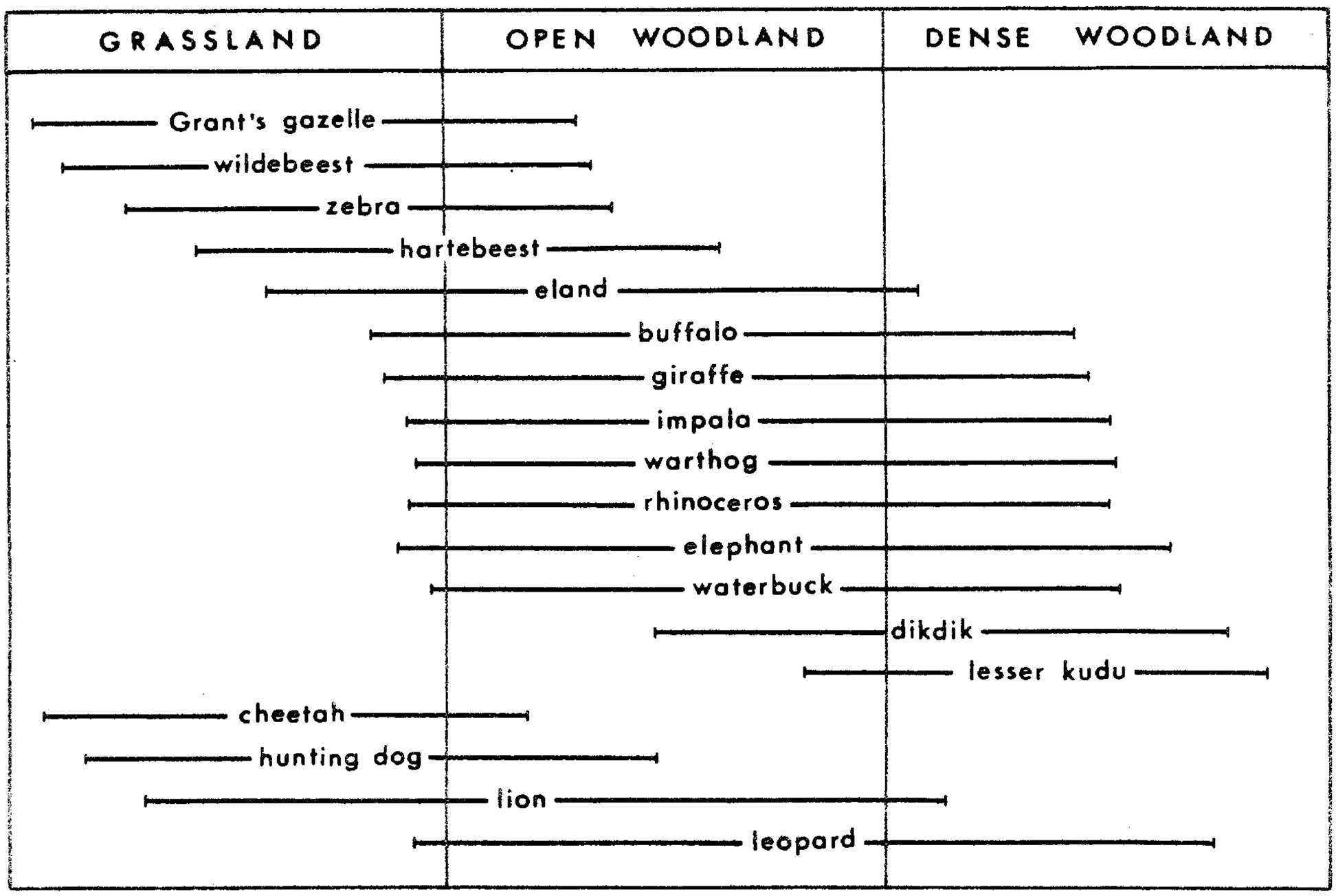
In North Africa, man-made desertification has more or less wiped out the fauna that existed there only 2000 years ago, in West Africa high population densities have considerably reduced it and in South Africa the long time settlement by European ranchers has had the same effect. Only in East Africa has the wild fauna until very recently been relatively undisturbed and no area of similar size in the world can nowadays show such a variety of animals. In Tanzania alone, there are around 290 different species of land mammals and in Kenya over 800 bird species are breeding and more than 1000 have been observed.
The wide array of ecosystems found in East Africa, from desert to rain forest, from sea level to almost 6000 m altitude, including all major vegetation and climatic types in tropical Africa, is one of the explanations. In table 31 animals typical for the major vegetation types are listed.

TABLE 31. Game animals characteristic of the major vegetation types
Source: Morgan (1969)

Montane forest	Elephant, buffalo, bongo, bushbuck, giant forest hog, chimpanzee, monkeys, leopard
Woodland	Sable antelope, roan antelope, greater kudu, Lichtenstein's hartebeest
Wooded grassland	Elephant, white rhinoceros, buffalo, giraffe, topi, impala, Uganda kob, lion
Bushland	Elephant, black rhinoceros, giraffe, lesser kudu, dik-dik, lion, striped hyaena
Grassland (incl more open wooded grassland)	Wildebeest and hartebeest, zebra, topi, Thomson's gazelle, lion, cheetah, hunting dog
Semi-desert	Reticulated giraffe, Grevy's zebra, ostrich, gerenuk, oryx
Swamps	Hippopotamus, sitatunga antelope

Many animals are obviously found in more than one type of vegetation. A detailed study of their food preferences made it possible for Lamprey to make a chart of the ecological separation and partial overlapping of animals in the Tarangire National Park in Tanzania (see figure 18).

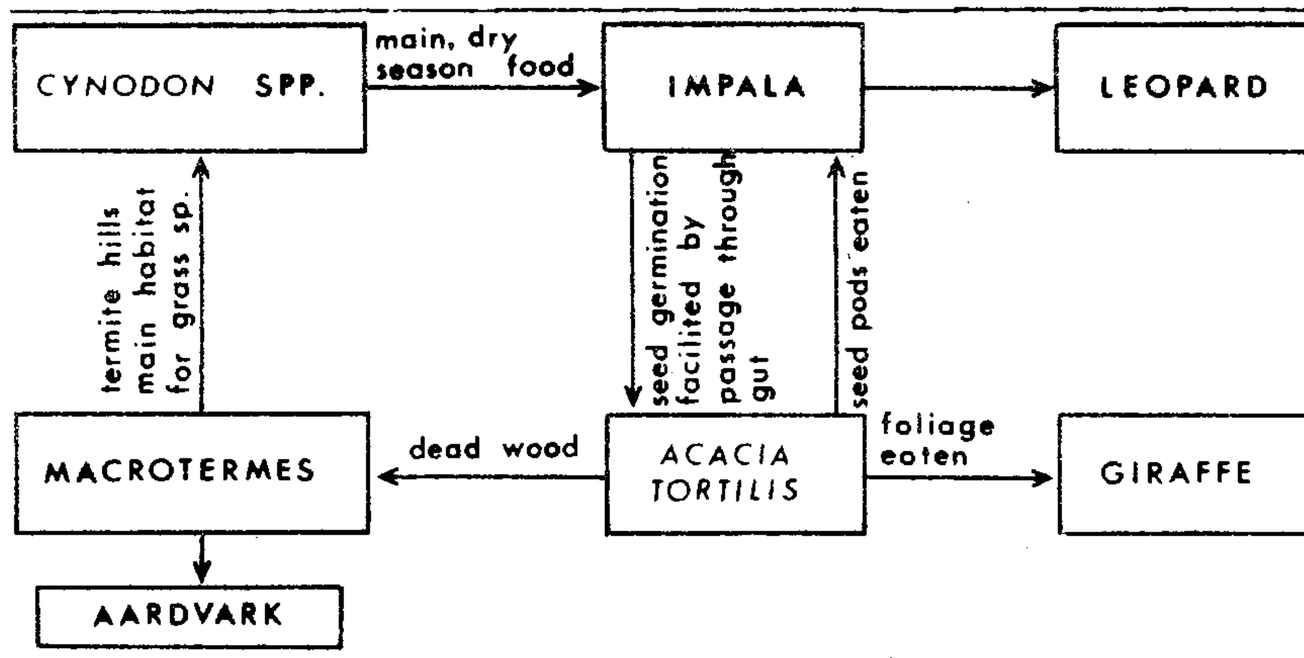
FIGURE 18. Food preferences of animals in the Tarangire Game Reserve
Source: Lamprey (1963)



What strikes the visitor to the East African National Parks is maybe not primarily the number of species but rather the sizes of the herds. Only in the Serengeti for example, there are between 500,000 and one million grazing and browsing mammals with accompanying predators. In the whole of Kenya it has been estimated that there are between 1.5 and 2 million larger mammals.
These high biomasses are made possible by the long co-evolution between flora and fauna, resulting in a high degree of ecological adaptation. Niche specialisation is very pronounced, i.e. different species of animals feed on different plant species, at different levels of the vegetation, at different stages of maturity of the plants etc. This facilitates a very efficient utilisation of the primary plant production by the animal consumers.

There is also in many cases a close dependence between different animal species in making food available to each other - larger, heavy animals like elephants and buffaloes break up the shrub, making it possible for medium sized grazing animals like zebra and wildebeest to reach the grass on the ground. Finally, gazelles move into the area and feed on the short grass left. These feeding sequences of animals are often referred to as "grazing successions".
Delicate ecological "sub-cycles" involving one or several plant and animal species are also developed within the large ecosystem and it is important to understand these before management practices are introduced. Many tree species in the savanna are for example dependent on a particular animal for their regeneration. An example of such an ecological interdependence cycle is shown in figure 19.

FIGURE 19. Diagram to illustrate the interdependence cycle of plant and animal species in the Tarangire Game Reserve
Source: Lamprey (1963)



Thus, it is important to stress that the high productivity of the East African savanna ecosystems is facilitated by the diversity of plants and animals. Another prerequisite for the survival of the great herds of plains animals is the possibility for their free migration between dry and wet season feeding places.

As late as in the middle of the 1950's it was stated by the East African Royal Commission:
"The preservation of game must not be allowed to stand in the way of the urgent need for proper land usages, but for the time being there is plenty of land in East Africa which man has not learnt to turn to productive use and which can be left to the game to enjoy."
Since then, the explosive increase in human population, intensified use of range land and changes in land tenure has brought about a rapid decrease of the game herds outside the National Parks and Reserves. The main mechanism is probably that the migration routes of the animals have been cut off. It has been estimated that the present game population in Kenya is only 30-50 per cent of what it was during the 1920's.
It is against this background that it is urgent to make an assessment of wildlife as a natural, renewable resource and as a land use alternative, also outside the Parks. This fact has been recognised by the East African governments.

4.5.3. Wildlife conservation areas

Various types of areas have been set aside in Kenya and Tanzania for the entire or partial protection and conservation of wildlife.
National Parks, of which there are a number in both countries, are areas where the flora and fauna are entirely protected and no human rights exist within them. They are managed exclusively to preserve samples of the main ecosystems in as natural a state as possible for aesthetic, cultural and scientific purposes and/or to provide recreational and educational opportunities for the citizens of the countries and for visiting tourists.

The positive attitude towards conservation of nature in the form of National Parks, thereby excluding all alternative forms of land use, that the East African governments have adopted, is no doubt partly a result of the growing economic returns from tourism (see 4.5.4.1.). These economic reasons should, however, not obscure the fact that there is also a genuine conviction that conservation of nature is a national and international responsibility to present and future generations. Both Kenya and Tanzania have thus

signed the 1968 "African Convention on Conservation of Nature and Natural Resources". Some of the problems in East African National Parks management are discussed in section 4.5.5. In table 32 the Nat. Parks are listed and on map 17 their geographic positions are shown.

In the Game Reserves in Tanzania, wildlife enjoy almost the same degree of protection as in the Nat. Parks. The difference lies in the way they are administered and in that certain other forms of land use may exceptionally be allowed with permission from the Game Department, e.g. tourist hunting in the Selous Game Res.
In Kenya, two forms of areas, except the National Parks, exist where wildlife is protected. The National Reserves, of which there are only three, are administered by the same authority as the National Parks (see below). They are areas where unique wildlife resources are protected but where other important forms of land use or human rights also exist, e.g. commercial forestry in the Shimba Hills.
The County Council Game Reserves are managed by the local authorities who also get the benefits from them. Other forms of land use are permitted to some extent e.g. cattle grazing in some parts of the Masai Mara Game Reserve.

Presently, the area of land where conservation of wildlife is the only or primary form of land use covers about 4-5 % of the total land area of Kenya. Many new Parks and Reserves are proposed in the 1974-78 Development Plan (see table 33) and if these are gazetted about 6-7 % of the land will be protected.
The National Parks and National Reserves are managed by the Trustees of the Kenya National Parks, an independent body. Outside the parks, all questions concerning game are the responsibility of the Game Department. These two will be (or have already been) merged into one body, the Wildlife Conservation and Management Service under the Ministry of Tourism and Wildlife. This step is but one of many major developments resulting from a changed Government policy expressed in the Development Plan: "Government policy changing from preserving wildlife wherever possible to promote the development of wildlife to ensure maximum benefits from land use".
In plain words this will mean that outside Parks and Reserves, wildlife will be considered as an economic land use alternative, and if not competitive as such, will have no or reduced legal protection (see also 4.5.4.).

The area of National Parks and Game Reserves in Tanzania covers about 10-11 per cent of the total land area. Also here the National Parks are managed by an independent trusteeship board, whereas all Game Reserves and other questions concerning game utilisation are the responsibility of the Game Department under the Ministry of Natural Resources and Tourism. The famous Ngorongoro Crater is part of the Ngorongoro Conservation Unit which is managed independently as a multiple land use area. The most recently gazetted National Park in Tanzania is the Kilimanjaro National Park. Like many of the other parks it was originally a Game Reserve. Also those areas that are presently suggested for National Park status are Game Reserves.

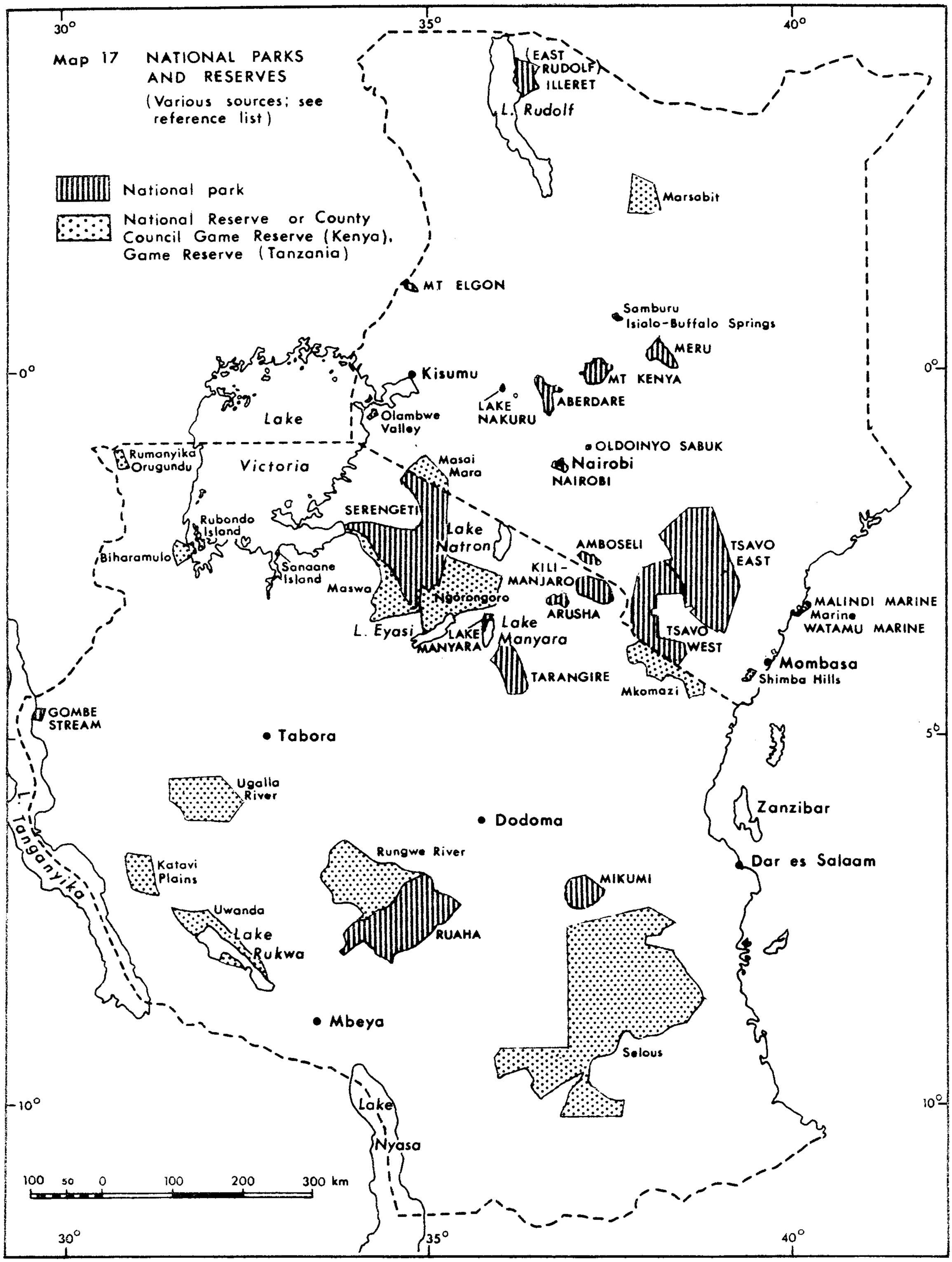

Map 17 NATIONAL PARKS AND RESERVES
(Various sources; see reference list)
National park
National Reserve or County Council Game Reserve (Kenya), Game Reserve (Tanzania)
30°
35°
40°
0°
5°
10°
EAST RUDOLF
ILLERET
L. Rudolf
Marsabit
MT ELGON
Samburu
Isiolo-Buffalo Springs
MERU
MT KENYA
Kisumu
LAKE NAKURU
ABERDARE
Olambwe Valley
Lake Victoria
OLDOINYO SABUK
Nairobi
NAIROBI
Rumanyika Orugundu
Masai Mara
SERENGETI
Lake Natron
Rubondo Island
Biharamulo
Sanaane Island
Maswa
Ngorongoro
AMBOSELI
KILI-MANJARO
ARUSHA
TSAVO EAST
TSAVO WEST
MALINDI MARINE
Marine
WATAMU MARINE
L. Eyasi
LAKE MANYARA
Lake Manyara
TARANGIRE
Mkomazi
Mombasa
Shimba Hills
GOMBE STREAM
Tabora
Ugalla River
Zanzibar
Dodoma
L. Tanganyika
Rungwe River
Katavi Plains
Dar es Salaam
MIKUMI
Uwanda
Lake Rukwa
RUAHA
Mbeya
Selous
Lake Nyasa
100 50 0 100 200 300 km

TABLE 32. National Parks and Reserves in Kenya and Tanzania
Sources: Various (see References list)

National Parks KENYA	Area (km^2)	Year of establ.	Other types of Game areas	Area (km^2)	Comments
Tsavo, E and W	20,800	1948	National Reserves		
Nairobi	120	1945	Marsabit	2,090	Prop NP
Aberdare	770	1950	Shimba Hills	190	
Mt. Kenya	700	1949	Marine	210	
Ol Doinyo Sabuk	20				
Meru	1,040	1967	County Council GR		
Lake Nakuru	60	1961	Masai Mara	1,670	
Mt. Elgon	170	1967	Samburu	100	
Amboseli	400	1974[1]	Isiolo-Buffalo Spr.	200	
Illeret		1974/75	Olambwe valley	120	
Malindi Marine } Watamu Marine }	25	1968			
TANZANIA			Game Reserves		
Serengeti	15,000	1951	Mkomazi	3,500	
Lake Manyara	260	1961	Rungwe River	13,000	
Tarangire	2,600	1970	Katavi Plains	1,870	Prop NP
Arusha	120	1967	Selous	39,000	Prop NP
Mikumi	1,200	1964	Biharamulo	1,200	
Ruaha	13,000	1964	Ugalla River		Prop NP
Gombe Stream	65	1968	Rubondo Island		
Kilimanjaro	760	1973	Saanane Island		
			Rumanyika Orugundu		
			Maswa		
			Uwanda		

Note: Amboseli was until recently a County Council Game Reserve with an area of 3,250 km^2

4.5.4. Utilisation of wildlife as an economic resource

As mentioned above the policy on wildlife in the East African countries has been strongly directed towards conservation and protection. This is not to say that economic benefits have not influenced the policy.
The intensive debate that has been going on for the last 10-15 years on the economic utilisation of East African wildlife has mainly centred on the vast non-protected areas - the economic role of wildlife in the Parks being undisputed (see 4.5.4.1.). Conservationists, concerned with the survival of both the unique quantities and qualities of the E. A. fauna and realising that the Parks are not enough to guarantee this, initiated the debate against the background of rapidly diminishing herds outside the Parks. In the course of the last decade, an impressive amount of information on the economical and ecological features of wildlife populations and species have been presented.

TABLE 33. Proposed Parks, Reserves and other Conservation and Wildlife viewing areas in Kenya
Source: Kenya Development Plan 1974-78

Proposed Parks/Reserves	Proposal[1]	Proposed Parks/Reserves	Proposal
Saiwa Swamp	NP	Ndotos/Mathews Range	?
Broderick Falls	O	L. Rudolf Reserve	CCGR
Mumias	CCGR	Malka Mari	CCGR
Nzoia Delta	CCGR/NR	Wajir	CCGR
Ol Pusimoro (West Mau)	CCGR	Lake Hannington	CCGR
East Mau	CCGR	Kirinyaga (Mt. Kenya Ext.)	CCGR/NP
Nguruman Escarpment For.	CCGR	Kilifi Creek Bird Sanct.	-
Ngong Hills	CCGR	Kerio Valley	CCGR
Chyulu Hills	NR	Cherangani Hills	CCGR/NR
Shimoni Marine	NP/NR	Oyugis Bird Sanctuary	-
Tana River Mangabey	?	Kesumu Heronry	-
Tana River Red Colobus	?	Kakamega Forest	?
North Lamu	NR/PLV	Lake Simbi Bird Sanct.	-
South Lamu	NR/PLV	West Kano Bird Sanct.	-
Mboni	CCGR	Tana River Delta	-
Hirola	CCGR	Arabuko Sokoke Forest	-
Rahole	CCGR	Mwea Game Reserve	-
Kora	CCGR	L. Rudolf Islands (N.Central)	-
Bisinadi	CCGR/NR	Loiolokwi Hill	-
Kindaruma Saba Hills	CCGR	Lake Elmenteita	-
Isiolo Extension	CCGR	Crater Lake	-
Samburu Extension	CCGR	Kisian/Kajulu Game Res.	-
Homa Hot Spring	-	Fourteen Falls (Thika)	-

Private Land Wildlife Viewing Areas

Name	Proposal[1]	Name	Proposal
Mara Dispersal Area	N	Hell's Gate	S
Lorsuate Hills and Plateau	PSC	Ol Kalou	S
Ewaso Nyiro Plain	PSC	Dondo/Mukogodo Forest	-
Mt. Suswa	S	Ndere Island	-
Kitengela Dispersal Area	PSC, N	Kiboko Research Station	-
Amboseli Dispersal Area	S	Pangani and Chesimba	-
Larogi Plateau	-	Limestone Caves	-

Other existing Sanctuaries and Recreational Areas

Motomo Hill	Lake Naivasha
Nomotio (Maralal)	Lake Chala

NOTES: 1/ NP = National Park, NR = National Reserve, CCGR = County Council Game Reserve, PLV = Private Land Tourism, O = Other, S = Studies on proposal taking place, PSC = Preliminary Studies complete, N = Negotiations taking place with competent authorities

That many of these findings are considered to present a strong case for wildlife as an economically competitive form of land use is shown by the following statement by the International Union for the Conservation of Nature and Natural Resources (IUCN): "Only by planned utilisation of wildlife as a renewable natural resource, either for protein or as a recreational attraction can its conservation and development be economically justified in competition with agriculture, stock ranching and other forms of land use."

Even if much remains to be found out before detailed, reliable cost/benefit analyses can be made on all forms of wildlife utilisation, the knowledge has been considered enough to propose a radical change in the wildlife policy in Kenya. Unfortunately the Tanzanian Development Plan for 1975-79, where possible policy changes would have been presented, was not available at the time of writing.

In Kenya, the land can be divided into three broad categories with regard to wildlife policy:

a) areas of intensive agriculture, plantation forestry and urban centres from which wildlife is excluded - about 15-20% of the total land area
b) National Parks and Game Reserves, exclusively for wildlife - about 5-6% of land
c) range areas with pastoralism and/or wildlife - about 75-80 % of land.

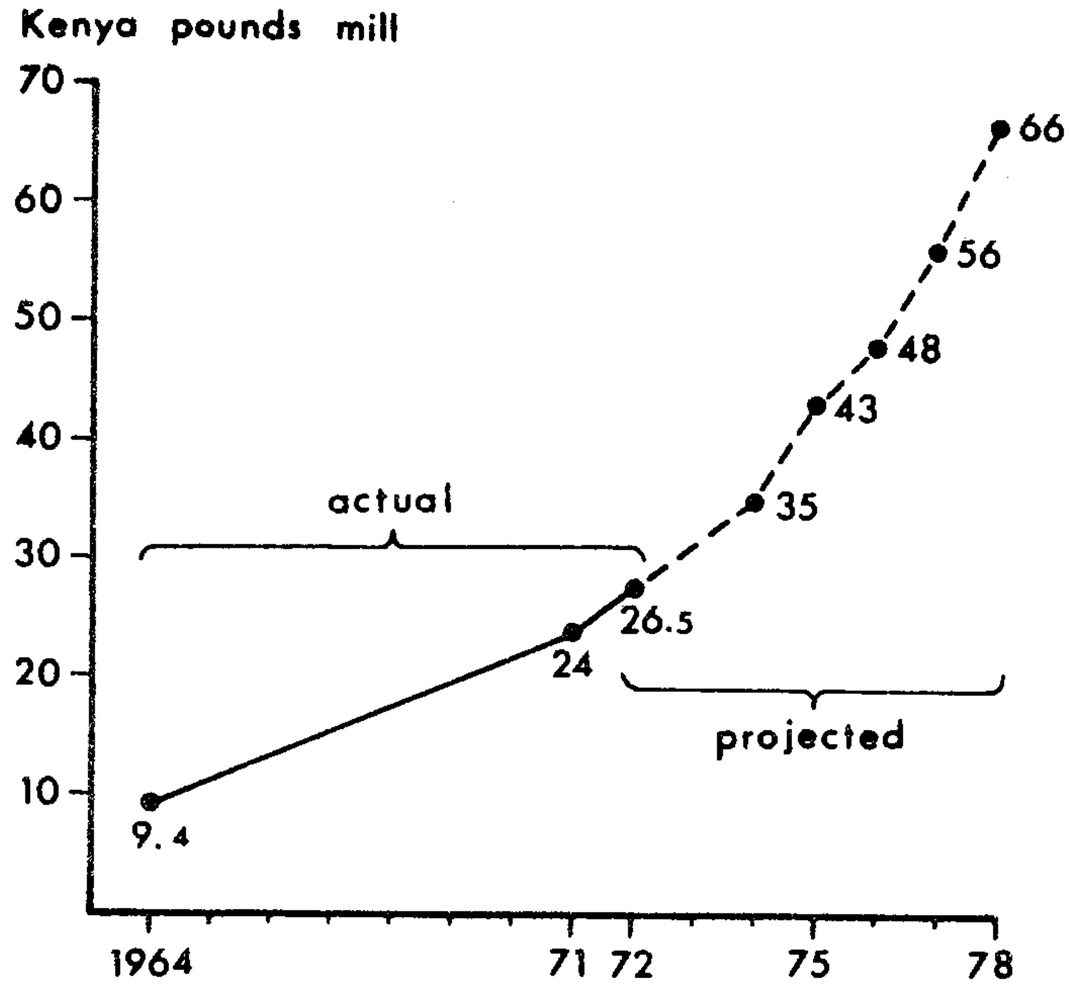
Substantial extensions are proposed of the b)-type (see 4.5.3.), otherwise no policy changes affect a) and b). It is in the range areas that the changes will occur. Most of these areas are presently Government Trust Land (see 4.1.2.1.) occupied by pastoral people on the basis of traditional rights. All game animals are considered Govt. property and can only be shot on license or, if they are proved to be a serious threat to life and property by Game Dept. personnel.

Increased overutilisation and destruction of the range areas by domestic animals have led the Government to the conclusion that only by shifting the tenure to privately owned individual or group ranches will there be a strong motivation for improved range and cattle management practices. In doing so, it will also be left to the owner to decide about the wild animals on his land - in principle he will be free to shoot out all wildlife. To prevent this from happening, a joint Game Dept./FAO/UNDP project, called Kenya Wildlife Management Project, was initiated in 1972 with the objects "to investigate, develop and implement programs to demonstrate economic returns from wildlife". Kajiado District is used as a test area, both of the Government policy and the project programs, and when it terminates in 1977 it is hoped that there will be a foundation of experience to formulate a national wildlife policy.
If any policy changes will occur in Tanzania it will likely be that the ujamaa villages will be entrusted more management rights of the wildlife resources in their areas.

4.5.4.1. Tourism. By far the most important economic role of wildlife in East Africa is its value as a tourist attraction. It has been estimated that 50 % of the foreign exchange earnings from visitors to Kenya can be directly attributed to wildlife.
Two main forms of attractiveness of wildlife as a land-requiring resource are obvious - game viewing in National Parks and Game Reserves and sport hunting.

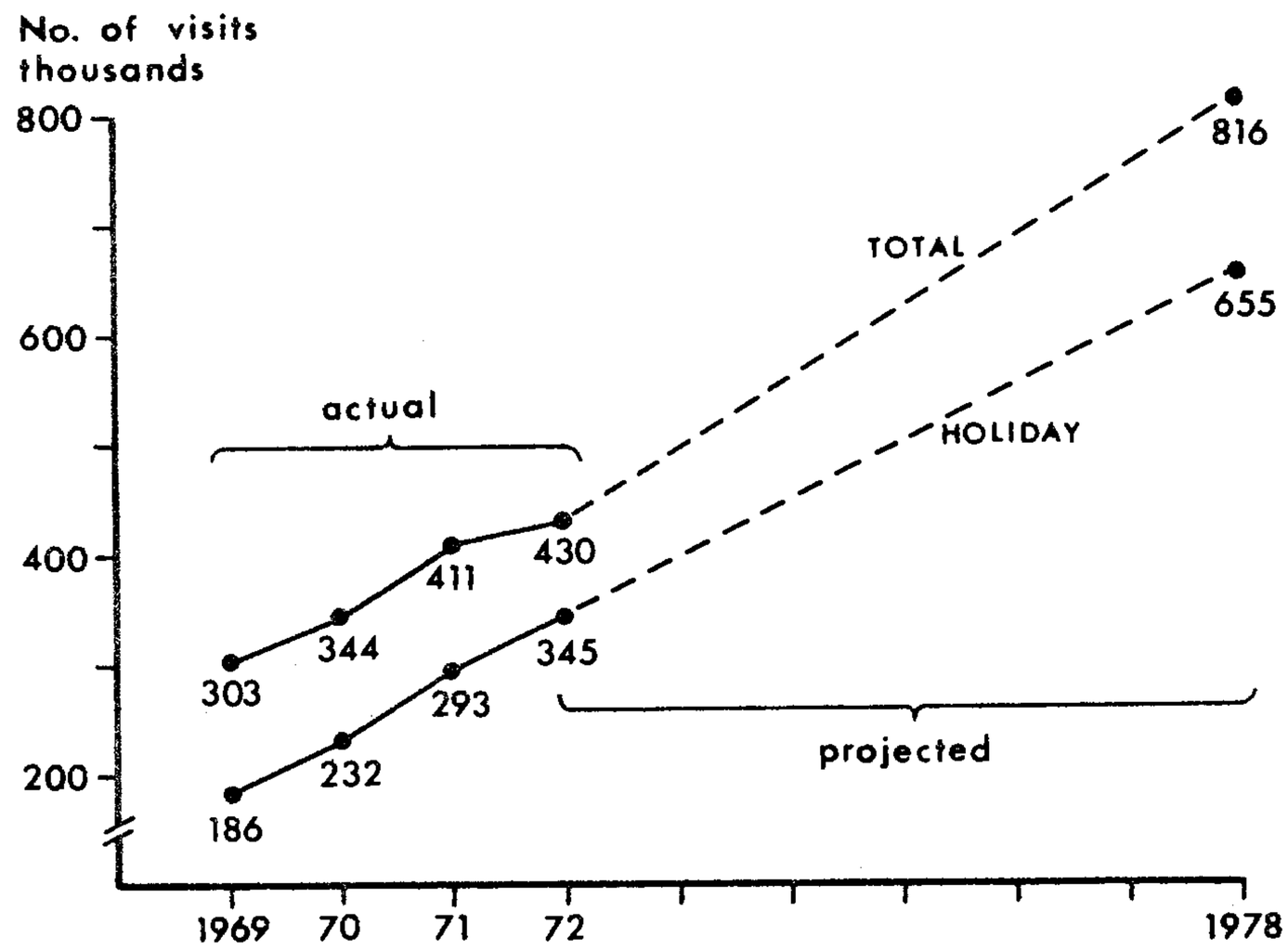
In Kenya, where tourism is more important than in Tanzania, the foreign exchange earned surpasses the income from any single export commodity. Large investments are made in further expansion of the trade. Government investments are concentrated on infrastructure, such as roads, airports and water supplies, and on direct investments in hotel and tour operations through the Kenya Tourist Development Corporation. The establishment of new Parks is another part of the effort (see 4.5.3.). The private sector also plays a major role in the tourist industry.
In figure 20 the actual and projected foreign exchange earnings from tourism, of which 25 % are estimated to go directly to the Government as taxes, are shown.

FIGURE 20. Actual and projected foreign exchange earnings from tourism in Kenya
Sources: Kenya Development Plan 1974-78 and Kenya - an official handbook (1972)



The number of visits to Kenya is shown in figure 21.

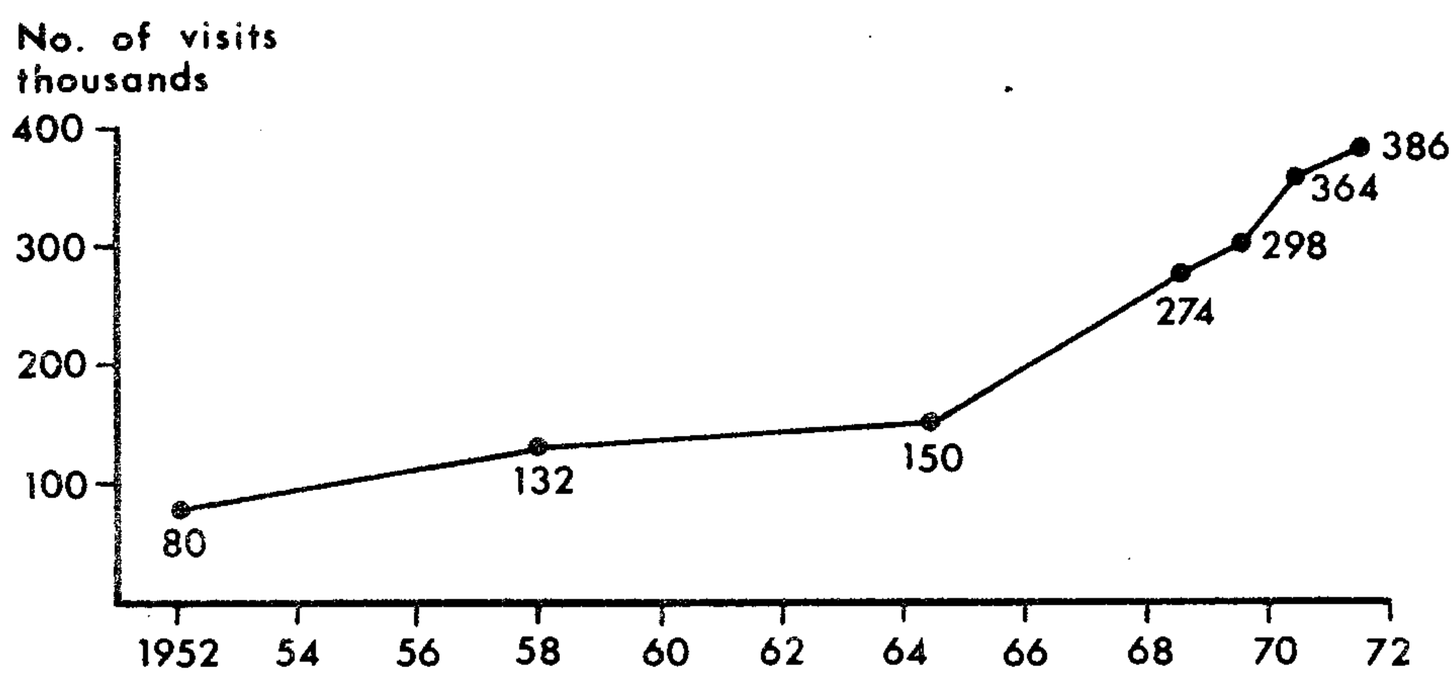
FIGURE 21. Actual and projected number of visits to Kenya, total and holiday
Sources: Kenya Development Plan 1974-78 plus various others (see Reference list)



NOTE: Each visit is counted, i.e. one person may account for more than one visit if he enters the country more than once during a year.

In figure 22 the number of visits to the Kenya National Parks is shown, clearly indicating the close correlation between game viewing and tourism.

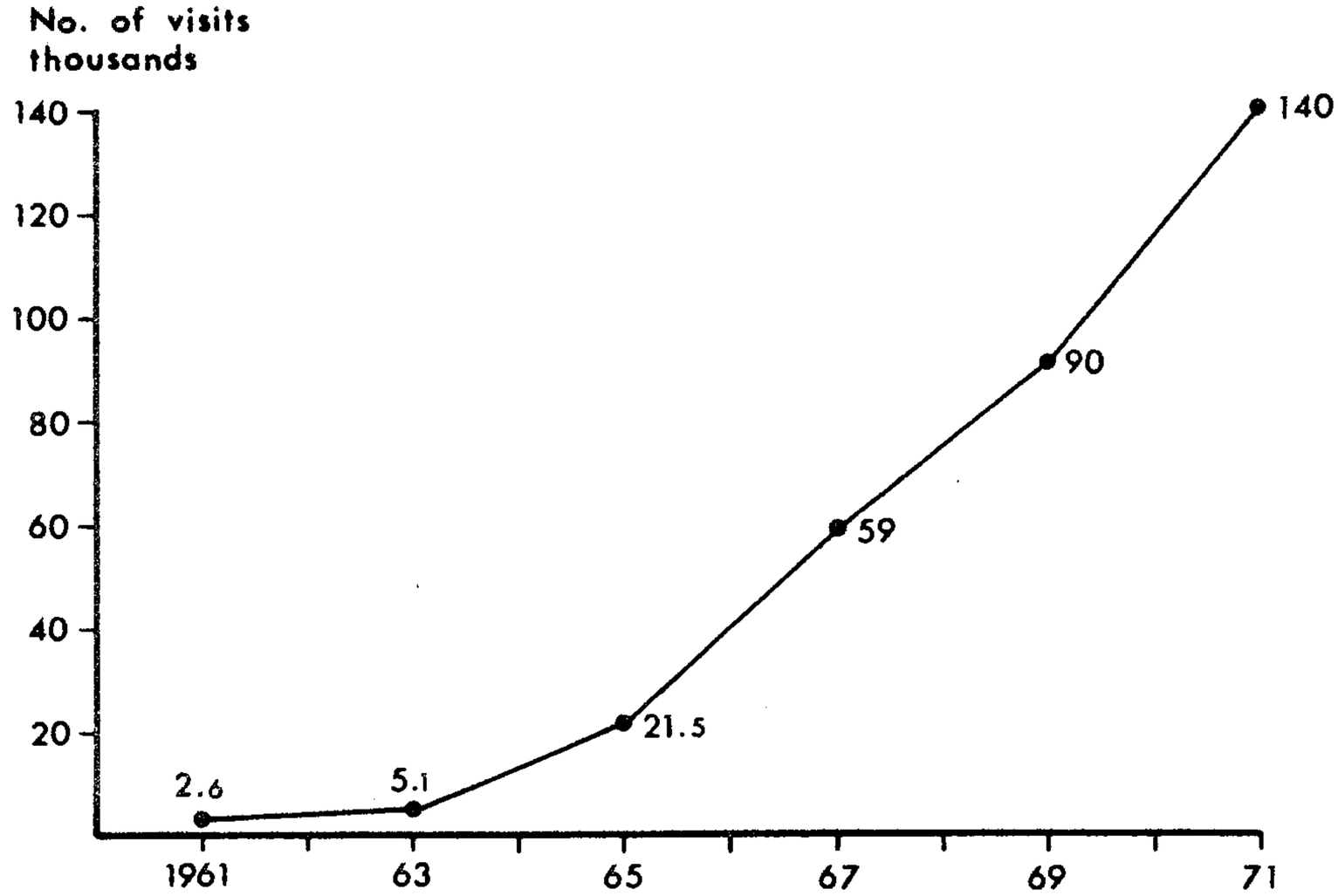
FIGURE 22. Number of visits to the Kenya National Parks and Reserves
Sources: Various (see Reference list)



Sport hunting safaris is an exclusive form of tourism with a long tradition in East Africa. In Kenya the hunting industry brought in gross earnings of 2.4 million pounds in 1972 (of the total of 26.5 mill). The off-take of animals in regulated pleasure hunting, which takes place entirely outside Parks and Reserves in so called "hunting blocks" or "controlled areas" is comparatively small and it is thought that there is a potential for considerably increasing the trade. In 1978, Kenya estimates the income to be 3.3 mill pounds. Much of the expansion will take place on the new private and group ranches under development (see 4.5.4.).

Less recent statistics and projections on tourism are available from Tanzania than from Kenya, but also there tourism is very important economically and highly dependent on the wildlife attractions.
In 1970 the net foreign exchange earnings were 60 million shillings, and the second 5-year plan (ending 1974) envisaged a 20 % per annum growth of visitors, raising the net earnings to somewhere around 120 mill Shs.
The country was visited by 32,000 tourists in 1967/68 and around 100,000 in 1972, showing a strong upward-going trend.
As with Kenya, the corresponding high growth in National Park visits clearly proves the game viewing to be the major attraction. This is shown in figure 23.

FIGURE 23. Number of visits to the Tanzania National Parks
Sources: Various (see Reference list)



NOTE: Until 1961 the only N.P. in Tanzania was the Serengeti, at that time very inaccessible

The further development of the industry has been strongly hampered by inadequate catering service. This partly depends on the fact that most of the tourists to Northern Tanzania, the most important tourist region, have come and still come with Nairobi based package tours, staying in Tanzania for only a few days.
In recent years Tanzania has tried to develop a more independent industry to secure higher shares of the revenues, which now mainly stay in Kenya.

The new airport between Moshi and Arusha, new hotels in Arusha and in the National Parks and development of the Coast and Southern National Parks facilities are parts in this program. Increased restrictions and licensing measures against Kenya tour operators are others.
The tourist industry in Tanzania is almost entirely Government owned and managed by the Tanzania Tourist Corporation.
In 1973 the Tanzanian Government imposed a complete ban on all forms of big game hunting, including tourist hunting. Officially it was done to curb the increased poaching. New rules came into effect 1/1 1975, but the details of these are not known when writing this.

The above summary of the growing economic importance and optimistic projections of tourism must not obscure the problems. There is for example a high degree of sensitivity in the industry to political disturbances, international news media coverage of epidemic disease outbreaks, economic situation in the countries of origin of the tourists and other factors which are more or less impossible to foresee or influence. A recent example of this is the immediate impact of the Uganda crisis in 1972/73 on the number of tourists, which dropped significantly in Kenya and even more in Tanzania.
Another problem that has been much discussed in East Africa is the social and cultural impact of tourism.
Beside these types of problems, which are outside the scope of this report, there are land management problems, some of which are discussed in section 4.5.5.

4.5.4.2. Game cropping. Game cropping normally refers to activities by which wild game animals are cropped on a rational, sustained yield basis and the meat and by-products like skins, horns etc. are commercially marketed. It is thus an economic activity and its profitability as a land use alternative can theoretically be calculated, provided necessary input data are available. This is, however, hardly the case as yet.
A more intensive form of wildlife land use is game ranching, where one or several species of wild animals are kept on fenced ranches.

The debate on game cropping as a form of land use, either exclusively or in combination with domestic cattle, has been very intensive and a large amount of information has been presented in favour of and against it. Misunderstandings,often based on overgeneralisations from single, both negative and positive, experiences and a continued lack of much necessary basic data still makes it impossible to formulate an objective evaluation of the prospects for game cropping. The following is an attempt to present the principal knowledge and arguments.

Two points should be clarified first. Much of the present knowledge on techniques and profitability of game cropping is based on experience from National Park operations, where large numbers of e.g. hippos and elephants have been cropped. Furthermore, many of the figures on wildlife carrying capacities quoted in the debate are from National Parks. This has led to a widespread misunderstanding that game cropping is discussed as a form of using the wildlife in the Parks. It must be emphasised that this is not the intention in the E. A. countries - the cropping that have taken place have been occasional operations considered necessary as a management tool (see 4.5.5.) to prevent large scale habitat destruction by too high populations of certain species.
Game cropping is instead intended as a form of land utilisation in range areas outside Parks and Reserves, on land where permanent subsistence or intensive crop production is climatically impossible. Over much of this

area nomadic or semi-nomadic pastoralism is presently the only form of economic land use, and it has to be shown, if game cropping is going to be accepted on a large scale, that it is either more profitable than, or possible to combine with, domestic cattle. Also in the vast areas where tsetse infection presently makes human inhabitation and cattle raising impossible, wildlife is a possible alternative.
The second point is that game cropping is still of very limited economic significance in East Africa - the intensity of the debate leads many to believe that it is already practised extensively. In 1972 the gross value of game cropping in Kenya was only 175,000 K £ as compared to 2 million £ for sport hunting. A very rapid rate of growth is, however, envisaged and by 1978 the gross value is projected to be 715,000 £.
Among the arguments in favour of wildlife there is an emphasis on its ecological and physiological adaptations, both of individual species and of communities of animals, to the seasonal climate and vegetation of the savannas (see 4.5.2). Thanks to this adaptation high biomasses of wild animals are possible. A number of estimates have been presented, ranging from 35 to 2 tons/km^2, representing a wide variety of grass dominated ecosystems - from fertile, high rainfall, protected National Park systems to low rainfall bush savanna where wildlife is strongly affected by competition from domestic cattle and poaching by man. Compared to biomass figures for domestic cattle, raised in the traditional nomadic way, there is little doubt that wildlife, particularly in drier areas, can sustain a higher biomass under equivalent physical conditions. Furthermore it is unquestionable that the productivity of intact wild animal communities is higher than from domestic cattle in most range areas, due to higher reproduction rates and faster individual growth of animals. The normally higher per centage of meat of the body weight of wild animals compared to cattle further underlines this.
Many, though not all, wild ungulates are better adapted to extreme drought than the local zebu cattle. Oryx, gerenuk and some othergazelles can live for long periods without any free water at all.
Except rinderpest, which is lethal to both wild and domestic animals, a high degree of immunity to most diseases is characteristic for the wild herbivores.

In conclusion, wildlife undoubtedly shows a higher degree of adaptation and productivity in most range areas than domestic stock under traditional management. This is more obvious the drier the conditions are.
A further economic advantage of game cropping land use is that it is well compatible with game viewing and sport hunting.
It has been argued that since domestic stock and game presently co-exist on large areas in East Africa, there is no reason why game cropping and cattle raising could not be supplementary land uses. Many problems do exist, however, some of which are difficult to solve, particularly in range areas where large investments are made on range improvements.

The most serious problem is probably that some wild animals are carriers of diseases which are a threat to domestic stock. The buffalo, giraffe, waterbuck and eland are carriers of East Coast Fever. Wildebeests is a known carrier of malignant catarrhal fever which can be transmitted to cattle. Rinderpest, Foot and Mouth disease and Trypanosomiasis also occur in wildlife.
Direct competition for forage is another problem. Destruction of cattle fences by heavy animals like buffalo and elephant is an important cause of loss to ranchers, predation by lions and other carnivores another. Lions, for example, account for the heaviest losses of the cattle herds on the large Kongwa Ranch in central Tanzania.

In the Kajiado District in Kenya, the Kenya Wildlife Management Project tries to show that joint cattle/wildlife utilisation is economically possible after all. To guarantee that ranchers do not destroy the wildlife in the important wet season dispersal areas around the Nairobi and Amboseli National Parks, the Kenya Government has, however, accepted to pay compensation to ranchers for losses incurred by wildlife, if the incomes from wildlife do not compensate for the losses.

However serious these problems may be, the main obstacles to large scale game cropping are still the technical and marketing problems. Rational killing, butchering, storing and transporting of the products to the market involve large problems which only in exceptional cases have been satisfactorily solved. Large, mobile field abattoirs and cold storage facilities seem necessary, but to make this economic a very efficient cropping technique must be adopted so that the abattoir units are fully utilised. Field veterinary control of meat quality is also a prerequisite. Trials involving all these problems are presently undertaken in Kajiado.
Marketing of skins, horns and other by-products have not posed any problems, but game meat has occasionally been difficult to find a market for, due mainly to traditional feeding habits. The export market is so far closed for unsterilised game meat due to the infection risks.

One way of overcoming many of the above mentioned problems is to raise wild animals in fenced ranches. In Rhodesia and South Africa this has been practised with success for a long time. The species in East Africa that seem most suitable for this form of semi-domestication are eland and oryx, the former well adapted to rather wet savanna, the latter to extremely dry conditions. Little experience is so far available from E. A. At the Galana Game Ranching Scheme in Kenya large scale trials are underway.
Another possible form of game ranching is to raise animals that yield a highly priced product other than meat, e.g. ostriches for skins and feathers.
A final form of wildlife utilisation that deserves to be mentioned is the export of live animals to zoos and for medical experiments (primates). This actually accounted for a higher income than game cropping in Kenya in 1972, or 236,000 £

4.5.5. Problems in wildlife management

When discussing wildlife as a natural resource, it must be remembered that it is built up of individual species, populations of species, communities of many populations and ecosystems in which the animal communities depend on and influence the vegetation in a complex way.
It is a widely held misunderstanding that wildlife, left by itself, establishes a kind of static ecological equilibrium with its environment. The rinderpest epidemics in the 1890's, when large wildlife population were wiped out over some areas, the sometimes catastrophic influence of extreme drought on some species (see below) and the rapid increase of population size of some species, with a consequent drastic influence on the vegetation, that has occured in some National Parks in East Africa, are all clear examples that no such equilibrium exist. Seen on a very long time perspective, a dynamic equilibrium can instead be envisaged, within which sizes of populations and community composition fluctuate between rather wide limits.

Since the current status of wildlife in an area may not be at an optimum from man's economic utilisation point of view - be it game cropping or viewing - <u>management</u> activities may be considered and adopted, by which the wildlife community is changed into a status more compatible with our

aims. Two principal ways are open. One is direct manipulation of population sizes and community composition by cropping a number of animals, the other is manipulation of the vegetation, e.g. through controlled burning, favouring certain species of animals.
However, before the application of intensive wildlife management can be done there are many biological parameters which must be ascertained if large scale mistakes should be avoided. For the wildlife species considered, these include abundance and distribution, habitat requirements, food habits, reproduction and mortality rates, population age and sex structure, migrations and seasonal movements, territorial requirements, inter- and intraspecific behaviour and the impact upon their specific ecological environment. In addition it is important to know the species´ reaction to specific levels of exploitation by man through e.g. cropping.

When managing wildlife for cropping and/or sport hunting all the above knowledge is required to determine the cropping quota, i.e. how many animals can be cropped annually on a sustained yield basis. Basically, the cropping quota in a management unit where the populations of the desired species are considered to be at the carrying capacity levels of their habitats, should equal the recruitment to the species. This is calculated as natality plus immigration minus mortality and emigration. To get all the necessary information to do this, an enormous amount of basic research has to be carried out and a continuous, reliable monitoring program of the populations and habitats has to be designed to detect changes in them. An impressive amount of work, though not enough, on these aspects has been and is conducted in East Africa. For example, a recent bibliography relating to the ecology and energetics of East African large mammals lists 331 articles and publications.

Some possible rates of harvest that have been mentioned are 10 % for buffalo, 20 % for eland, topi and zebra, 25 % for Grant´s gazelle, impala, kongoni and wildebeest and 40 % for Thomson´s gazelle. The figures relate to specific areas where a certain set of biological and physical conditions prevail and can not automatically be generalised for respective species under all conditions. However, seen in relation to the present estimated off-take by legal and illegal hunting of less than 5 % of the game population in Kenya, the figures indicate that there is room for a considerable increase in the harvest.

A type of events that affect all forms of biological production - be it crops, forest plantations, domestic or wild animals - in marginal areas of strongly seasonal climate, are the occasionally occuring extreme droughts or rainfalls. That these events can seriously upset even the most well-founded management plans was shown recently in the Kajiado District in Kenya. Here the rainfall between March 1973 and March 1974 was only half of the long-term average, with consequent drying-up of water holes and failure of fresh grass growth. In a sample area comprising the Nairobi National Park and the Kitengela dispersal area, it was found that around 75 % of the total populations of wildebeest, Coke´s hartebeest and zebra, or 57,000 animals, had died. The three species, which are not particularly drought resistant, made up 90 % of all wild animals found dead. Incidentally, it was estimated that 90 % of the cattle on the Athi-Kapiti plains also died or had to be prematurily slaughtered.

Inside the National Parks, where the aim is to preserve wildlife in as natural a state as possible, no management at all should in principle take place. In many Parks in East Africa however, the populations of some species, notably elephants, have increased to such an extent that they threaten to

destroy the type of vegetation, shrubs and small trees, on which they mainly live. This indicates a possible population crash in a not too distant future. Another negative result of this process is that the diversity of vegetation and of grazing and browsing species, which is one of the main aesthetic attractions of the Parks, is seriously threatened. This situation has been obvious for many years, and it is particularly serious in the Tsavo National Park in Kenya with an estimated elephant population of around 30,000. Also in the Ruaha and parts of the Serengeti National Parks in Tanzania the situation is serious.
Against this background a very hard debate has been, and is still, waged in East Africa whether to try to control the situation by active management, i.e. shooting parts of the populations, or not. In neighbouring Uganda control cropping has been practiced. Two lines of argument, one in favour of population control and one against it, can be distinguished and it may be of some interest to present the main arguments to elucidate the difficulties in National Parks policy making.

Those favouring management say that the elephant, having no other natural enemy than man, given full protection as in the Parks will increase in number well over the carrying capacities of the habitats. This situation is further aggravated by the fact that the elephants, well aware of the protection in the Parks, do not emigrate as they should otherwise have done. Most species of animals increasing too much above the carrying capacity of their habitat will soon reach a stage when the population crashes, but due to the long life-span (around 60 years) of the elephants and their ability to eat almost any plant material when their preference food is depleted, it takes a very long time for the population to crash. During this time irreversible damage to the habitat and other animals have taken place, more or less completely reducing the aesthetic value of the Park. Thus, control cropping saves the Park from destruction and, besides, it is only replacing the assumed natural predation by man.

According to the other line of argument the situation is perfectly natural and just a stage in a long-term cycle involving elephants, other animals, vegetation and fire. Man, admittedly the only predator, can not possibly have been able to keep elephant populations, everywhere and everytime, down to levels much below what is now found in the Parks. Very low human population densities due to tse-tse and other diseases and to inter-tribal warfare must until only recently (say the last 50-75 years) have left large areas comparatively uninfluenced by man.
The presumed natural cycle should in principle involve the following steps. A bushland/thicket community of vegetation, like the one dominating in Tsavo, with little grasses, and consequently few fires, becomes gradually occupied by an elephant population. The elephants, being mainly browsers, find an abundance of food and start to increase in numbers. In doing so they open up the bush, more and more grass enters the ground and these give fuel to an increased number of fires, preventing the bush from reestablishing itself. Shrubs and small trees become more and more scarce and the elephant population decreases, fast or slowly. In the cause of all this, grazing animals have gradually increased in numbers and by keeping the grass short the amount of dead grass for the dry season fires decreases with fewer and less hot fires as a result. Shrubs are then able to establish themselves and the bush vegetation slowly reinvades the area, keeping the grasses down ("bush encroachment") and the cycle is closed. Around 100 years has been suggested as the time of this cycle.
This line of argument may seem far-fetched but there are actually many ecological evidences supporting it. It would be scientifically irresponsible to disturb this cycle by halting it with cropping, it is said by those favouring this view, since, if it is studied for a long enough time, it might

explain much of the vegetation and animal dynamics in Africa that are still not understood.
Another burning issue in National Parks management is to decide what level of disturbances by tourists, hotels, viewing tracks etc. that can be allowed without causing adverse effects on animals, vegetation and soil. Many serious effects have already become evident, e.g. water and wind erosion in car tracks, increased number of accidental fires and disturbances of certain species of animals to the degree that their food intake has been prevented (e.g. for lions). The situation in this respect is particularly serious in the Nairobi National Park, which in 1971 had 44,000 cars entering the area, or an average of 120 per day. Hotels and lodges inside Parks always involve a risk, though small, that careless people get hurt if walking out of the immediate vicinity of the buildings.

Commercial poaching of certain animal species, yielding some highly priced products, such as elephant ivory, horns of rhino, which has got the unfortunate reputation of being a potent aphrodisiac, and skins of the spotted cats, is a very serious problem and large efforts and costs are spent to curb it. "Subsistence" poaching for meat consumption may locally or occasionally be a problem, but on the whole it hardly affects the sizes of the game herds. Much more serious, as stated above, is the decrease in pastures available to the animals and the disturbances of the migratory routes between dry and wet season grazing.

It should finally be emphasised that regardless of the amount of ecological and economical knowledge and arguments in favour of conservation and/or utilisation of the wildlife resource, all ambitious long-term programs are bound to fail if they are not well anchored in a positive public and political opinion. The educational efforts involved in achieving this must be very efficient since they, to a large extent, have to aim at changing deep-rooted traditional hostility towards wild animals.

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4.6. Utilisation and development of water resources

4.6.1. Introduction

Since East Africa as a whole is short of water, it is imperative that its limited water resources should be utilised as efficiently as possible. Much of the rainfall finds its way into storage in the deep porous soils, characteristic of the moister areas of East Africa (see 3.4.) However, only a small proportion of the rain emerges as streamflow as the indigenous vegetation and successful imported species have become well adapted to the exploitation of the soil water reserve. From the point of view of human utilisation of water, the water requirements of crops in East Africa must be considered as a negative natural resource, a natural handicap. Less than 1 per cent of the water used by the plants is fixed as a useful product in plant material, the rest simply passes through the plant and returns to the atmosphere from where it initially came as rain.

The positive water resources in streams, lakes and ground water are what is left of the rainfall after the natural vegetation and crops have taken their toll. Unfortunately, in East Africa the water requirements of crops are very high compared with countries of temperate climate. A water requirement of 2250 mm per annum for the optimum growth of a perennial crop like sugar is not uncommon in East Africa, whereas in Northern Europe a similar perennial crop would transpire no more than 750 mm. Conversely, an annual rainfall of 750 mm in Europe is sufficient to grow practically any crop, whereas in East Africa it would be marginal even for many seasonal crops. Similarly, 1250 mm of rain per annum in Europe would result in a large contribution to surface or sub-surface water resources, whereas in much of East Africa a 1250 mm rainfall would augment the free water resources only if it fell in a relatively short, concentrated rainy season and so percolated well beyond the root range of the vegetation. For an appreciation of why these large differences between regions occur, it is necessary to examine some of the basic plantwater processes involved.

Natural vegetation will, in general, develop root systems that will use all of the rainfall except where the rainfall exceeds potential transpiration or where the seasonal concentration of rain is so great that the water penetrates even beyond the deepest root ranges. At Muguga, where a soil moisture deficit of 500 mm can be expected at the beginning of the rains under perennial grass or forest, a concentration of 700 mm within April-May or November-December is required for any appreciable recharge beyond a depth of 6 metres. Such events have occured twice in the last 16 years, giving an estimated recharge of no more than 380 mm out of 15,875 mm of rain over that period.

4.6.2. Developments in Kenya

Surface water availability. - The total rainfall on the land areas of Kenya is estimated at 289,500 million cubic metres in an average year. This figure is derived from an estimated national average precipitation of 510 mm. The mean annual discharge of all streams and rivers is estimated at 14,836 million cubic metres, the figure made up of 12,364 million cubic metres of measured flows at 361 gauging stations in the principal river basins and 2472 million cubic metres of interpolated flows of minor streams. The distribution of this resource by major drainage areas is as shown in table 34.

TABLE 34. Mean annual precipitation and runoff by major drainage basins in Kenya
Source: Kenya Development Plan, 1974

Drainage Basin	Surface area (sq.km)	Mean annual rainfall (mm)	Mean annual runoff (mill. m^3)
Lake Victoria	49,000	1,245	7,292
Rift Valley	127,000	535	810
Athi-Tsavo-Sabaki area	70,000	585	1,295
Tana River Area	132,000	535	4,700
Ewaso-N'giro Area	205,000	255	739

The portion of the total estimated annual precipitation that can be made available for beneficial use comprises:

a) the portion of surface runoff that can be diverted from streams and rivers; and
b) the portion of surface water that reaches the ground water table and can be recovered.

Total potential water available cannot be estimated accurately until better data on evaporation and transpiration losses are gathered. To provide these data and to prepare a National Water Plan on the basis of a complete analysis of the national water resources, a major survey and study will be undertaken during the current Plan period, 1974-78.

Ground water availability. - In the drier, low potential areas of northern and eastern Kenya, development prospects will depend upon the availability of ground water. Increasingly, in recent years boreholes have been drilled in these areas to supply water along stock routes and to concentrations of population.
In some areas, as along the route of the Nairobi-Addis Ababa Road, ground water is not readily available. In some parts, potential aquifers lie at a considerable depth and, overlain with lava, can only be reached by a very expensive drilling operation. In other parts, potential aquifers or reservoirs have not been identified. Toward the eastern parts of North-Eastern Province the situation is more promising. A number of successful boreholes have been put down in recent years and a limited knowledge of the location and configuration of sub-surface water reservoirs has been acquired.

Earlier fears that current extraction rates would lead to a progressive lowering of the water level in boreholes have not been borne out by experience. Nevertheless, the water table in many districts is at a considerable depth and the possibility does exist that fossil water is being extracted in some places.
The basic difficulty in preparing a development programme for the water deficit regions is that too little is known about ground water availability, its replenishment and appropriate extraction rates. Therefore, a survey to establish these facts about the ground water supply will be undertaken in conjunction with the preparation of a National Water Plan during 1974-78.

The domestic water requirement of the present population is about half a per cent of the average annual precipitation and slightly more than one per cent of the average annual runoff. On the assumption that the average

daily per capita rate of water use will increase from 40 litres to 160 litres by the year 2000, the water required for domestic use by the population living in that year will not exceed 15 per cent of the known mean annual runoff.
A summary of the population served by an organized water supply is provided in table 35. In this table an estimate is made of the population in low potential areas that is within 4 kilometres of an improved water source. A total of 932,500 of the rural population and 1,337,500 of the urban population is presently served by a water supply of one kind or another.

TABLE 35. Population served by a water supply in Kenya, 1974
Source: Kenya Development Plan, 1974

Province	Urban			Rural		
	Major Centre	Urban Centre	Rural Centre	High Poten.	Medium Poten.	Low Poten.
Central (incl. Nairobi)	600,000	105,400	41,000	193,500	18,000	8,000
Nyanza	-	45,700	7,500	15,000	87,500	25,000
Eastern	-	19,000	24,000	38,500	19,500	112,000
North-Eastern	-	-	10,000	-	-	21,000
Rift Valley	-	122,400	32,000	137,000	46,500	43,500
Coast (incl. Mombasa)	286,000	-	30,000	27,500	28,000	36,000
Western	-	12,500	2,000	73,500	2,500	-
Total	886,000	305,000	146,500	485,000	202,000	245,500

Within the framework of a long-term programme for achieving the basic objective of bringing the benefits of a safe and reliable water supply and disposal facilities to the entire population, targets have been established for the 1974-78 period. These are:

I To bring water supply service to 2,000,000 additional people living in rural areas, so that the served rural area population in 1978 will be approximately 3,000,000 people.
II To bring water supply to an additional 500,000 people living in urban areas and rural centres, so that the urban population supplied with water in 1978 will be approximately 2,000,000 people.
III To bring, through an accelerated works programme, the sewage disposal systems of the principal municipalities into an approximate balance with water supply facilities.
IV To establish a continuing National Programme for Water Conservation.
V To complete the National Water Plan.
VI To develop and apply standards and techniques for water quality control.
VII To train in established facilities technical water and sewerage officers for field service in sufficient numbers to meet the demands for supervision generated by the programme and responsibilities of the Water Department.

4.6.3. Developments in Tanzania

The Water Development and Irrigation Division (W. D. & I. D.) was formed in 1946 charged with the responsibility of conserving the natural water resources of the country and the provision of water for domestic consumption,

livestock and irrigation in rural areas. In consequence a very large number of rural water supplies have been constructed in all parts of the country. The supplies are varied in capacity and type and include pumped supplies from deep boreholes, long gravity pipelines from mountain springs and water conservation dams. The centres served include outlying administrative stations, village communities, often in remote areas, isolated institutions, such as prisons, hospitals, schools, leprosaria and research stations, water points for the livestock of nomadic people, and supplies to tourist centres.

Unreliable rainfall conditions have made the development of irrigation a matter of major importance. The practice of irrigation on a large scale in Tanzania is, however, a completely new departure, all traditional irrigation having been confined to mountain areas where permanent streams abound, such as Kilimanjaro, the Pare and Usambara Mountains, or to planting after recession of flood waters. A number of pilot irrigation schemes have been established to pave the way for large scale developments and the systematic planning of the major river basins is currently being undertaken, aimed at the exploitation of all resources, including irrigation development, hydro-electric power generation, flood control, promotion of fishing industries and the opening up of tourist areas. This planning is most advanced in the Pangani River Basin where 1110 mill m^3 of water is stored by the recently constructed Nyumba ya Mungu Dam on the Pangani River, which makes water available for irrigation and hydro-electric power generation.

The aim of providing clean water supply to all inhabitants of Tanzania is a development goal of consequence. In general, water supply projects may be classified into piped and non-piped categories. The piped schemes involve taking water either by pumping or gravity from rivers, lakes, reservoirs, etc. The non-piped schemes involve dams, wells, springs and boreholes, that have no facilities for distribution of water to other locations. The design figure used is 45 litres per person per day in all rural schemes utilizing communal standpipes. For livestock the value is about 25 litres per day for cattle and 5 for sheep and goats. During 1946-68 the W.D. & I.D. built 300 earth dams and catchment tanks, 600 gravity and pumped water supplies and about 500 boreholes. The W.D. & I.D. has recently undertaken the construction of much larger water supply schemes.

4.6.4. Existing and planned water development schemes

For a better understanding of the status of water utilization and development endeavours in East Africa, a summarized compilation has been made of existing and planned projects. The information has been gathered through literature studies. A classification has been made between schemes for hydro-electric power, for domestic water supply and for irrigation purposes. The location of the various schemes has been marked on map 18 with symbols referring to table 36 below.

Hydroelectric power schemes (H) are concentrated in Kenya mainly to the Tana River and in Tanzania especially to the Pangani and Ruaha rivers.

Dams for domestic water supply (D) have developed rapidly in recent years especially in Tanzania, where they are an integrated part of the programme for rural development.

Pipelines (P) imply schemes of more prominent character, such as the "mains" which run from Kilimanjaro.

Irrigation schemes (I) are developed throughout East Africa where water resources so permit. However, due to financial difficulties many projects remain at the planning stage. The area now (1973) under irrigation in Kenya is about 70,000 ha and in Tanzania about 40,000 ha.

TABLE 36. List of major water projects in Kenya and Tanzania
Sources: See Literature ref. column

Symbol	Location	Size, capacity	Literature ref.
Kenya			
H1	Wanji in upper Tana R.	2 MW	Morgan (1972)
H2	Upper Tana River	6 MW	"
H3	Kindaruma at Seven Forks, Tana R.	90 MW (1968)	"
H4	Kamburu at Seven Forks, Tana R.	50 MW (1974) 75 MW (1976)	Kenya Dev. Plan 1974-78
H5	Near Mesco, Maragua R., Upper Tana R.	0.38 MW	Morgan (1972)
H6	Sagan Falls in Sagana R., Upper Tana R.	1.5 MW	"
H7	Ndula in Thika R., Upper Tana R.	2.25 MW	"
H8	Nanyuki in Liki R., Upper Ewaso Ngiro R.	0.1 MW	"
H9	Selby Falls, near Eldoret in the Sosiani R., Upper Nzoia	0.36 MW	"
H10	Macalder-Nyanza Mines in Migori (Kuja) R.	0.9 MW	"
Tanzania			
H1	Nyumba ya Mungu in Pangani River	1.16 MW	"
H2	Hale in lower Pangani R.	21 MW (1964)	"
H3	Pangani Falls, lower Pangani R.	17.5 MW	"
H4	Tosamaganga, Iringa, Little Ruaha R.	1.22 MW	"
H5	Mbeya, Nzovwe R.	0.34 MW	"
H6	Kidatu, Great Ruaha R.	100 MW (1974) 200 MW (1981)	Temple, P. & Sundborg, Å., (1972)

Continued

TABLE 36. Continued

Symbol	Location	Size, capacity	Literature
Kenya			
D1	Sasumua dam, S. Kinangop.	~5000 m^3 per day 1974-78 to Nairobi	Kenya Dev. Plan 1974-78
D2	Materas Reservoir	For Mombasa	"
Tanzania			
D1	Imagi, Dodoma Region	136,000 m^3 volume	Rapp et al., (1972)
D2	Msalatu, Dodoma	300,000 m^3 (1944)	"
D3	Ikowa, Dodoma	2,300,000 m^3 (1957)	"
D4	Matumbulu, Dodoma	250,000 m^3 (1960)	"
D5	Hombolo, Dodoma	30,000,000 m^3 (1958)	Awadh, (1971)
D6	Kisongo, Arusha Region	70,000 m^3 (1960)	Rapp, et al., (1972)
D7	Bulenya Hills, Nzega District	2,800,000 m^3 (1960)	Warner, (1970)
	Mwamapuli, Nzega District	Larger (1970)	Berry, (1970)
D8	Mang'onyi, Singida Region	8,600,000 (1951)	Berry & Kates, (1970)
D9	Mgori, Singida Region	1,900,000 (1959)	"
D10	Nondwa, Dodoma Region	5,800,000	Awadh, (1971)
D11	Dabolo, Dodoma Region	6,400,000 (1961)	"
D12	Mindu, Morogoro Region		Berry, (1970)
D13	Mbuyuni, Arusha Region		Rapp, (1972)
D14	Kalimawe, Kilimanjaro		Berry, (1970)
Kenya			
P1	Sasumua dam to Nairobi	55 km	Survey of Kenya, (1970)
P2	Shimba Hills to Mombasa	30 km (1916-30)	Carruthers, (1973)
P3	Ol Turesh Springs to Sultan Hamud and Simba	125 km (1965) 2000 m^3/day	" Morgan, (1972)

Continued

TABLE 36. Continued

Symbol	Location	Size, capacity	Literature
P4	Mzima Springs to Mombasa	225 km	Morgan, (1972)
P5	Kiserian R. to Magadi	160 km	Survey of Kenya,(1970)
P6	Sabati R. to Mazeras Reservoir, Mombasa	(1974-78)	Kenya Dev. plan 1974-78
P7	Naivasha to Suswa	(1974-78)	"
Tanzania			
P1	Ismani, Iringa Region	70 km 1135 m^3/day	Warner, (1970)
P2	Bulenya Hills, Nzega District	26 km (1967) 655 m^3/day	"
P3	Misungwi, Mwanza Region		"
P4	Ruvu R. to Dar es Salaam	60 km 28,000 m^3/day	"
P5	Mgigili R. to Kwakoa village	3.2 km	Berry, (1970)
P6	Wona, Wasi and Manjo Rivers to Mkuu	16 km 1000 m^3/day	"
P7	Rubeho-Kisitwe, Morogoro Region		Ministry of Water Dev. & Power(1971)
P8	Heru Juu, Kigoma Region		"
P9	Mbuyuni, Kilimanjaro Region	(1962)	Warner, (1969)
Kenya			
I1	Mwea-Tabere near Embu	50,000 ha (1956-72). Rice, coffee, tea, maize	Chambers & Moris,(1973)
I2	Perkerra, Rift Valley	500 ha (1954-73) Red onion, flowers, maize	Kenya Dev. plan 1974-78
I3	Ahero-Kano Plains, near Kisumu	1000 ha (1969-74) Rice, cotton, sugar cane, 700 ha + 5000 ha (1974-78)	"
I4	Yalo Swamp	300 ha (1971) Rice, cotton	"

Continued

TABLE 36. Continued

Symbol	Location	Size, capacity	Literature
I5	Hola/Galole, Tana R.	1000 ha (1957-73)	Mansell Prothers, (1969)
I6	Bura, Tana R.		Kenya Dev. plan 1974-78
I7	Garissa, Tana R.		"
I8	Garsen, Tana R.		Ominde, (1971)
I9	Chakama, Lower Athi R.		Survey of Kenya,(1970)
I10	Taita Hills		"
I11	Taveta	600 ha	Ruthenberg, (1966)
I12	Chai, Athi R.		Survey of Kenya,(1970)
I13	Yatta, Machakos District		Ruthenberg, (1966)
I14	Ishiara, Thuchi R.		Survey of Kenya,(1970)
I15	Nguruma, Lake Magadi		"
I16	Kerio Valley, Rift Valley		"
I17	Wei Wei, West Pokot District	800 ha	Kenya Dev. plan 1974-78
I18	Kerio-Kangetet	5000 ha	Fallon, (1963)
I19	Lodwar, Turkana District	1000 ha	"
I20	Turkwell, Turkana District		Survey of Kenya,(1970)
I21	Isiolo		"
I22	Mandera		"
Tanzania			
I1	Mbarali, Rujewa, Mbeya Region	2500 ha (1969) Rice, wheat	Ominde, (1971)
I2	Kahe, Pangani Valley	5000 ha	United Rep. of Tanzania. (1969)
I3	TPC sugar estate, Moshi	5000 ha (1971)	Dep. Agr. Eng. & Land Planning, (1972)
I4	Kilombero sugar estate, Kidatu	4000 ha (1963)	"

Continued

TABLE 36. Continued

Symbol	Location	Size, capacity	Literature
I5	Kilangali, Morogoro	Rice (1969)	Dep. Agr. Eng. & Land Planning, (1972)
I6	Mombo, Tanga Region	1000 ha (1963)	Berry, (1970)
I7	Kalenga, Iringa Region	160 ha (1969) Paddy rice	Dep. Agr. Eng. & Land Planning (1972)
I8	Bhagwant Sugar estate, West Lake District	800 ha	"
I9	Ikowa, Dodoma region	800 ha (1957)	Berry, (1971)
I10	Gonja, Kilimanjaro Region		"
I11	Mwakijembe, Lushoto district		"
I12	Ruvu State Farm Arusha Region		Dep. Agr. Eng. & Land planning (1972)
I 13	Puma, Singida Region		Berry & Kates, (1970)
I14	Mgori, Singida Region		"
I15	Mangonyi, Singida Region	250 ha (1958)	"
I16	Kigwe, Dodoma Region	50 ha grapes, tomatoes	Awadh, (1971)
I17	Upper Wami, Morogoro District		Berry, (1970)
I18	Mbeya, Mbeya Region	5000 ha (1969)	Rimer, et al. (1970)
I19	Kalimave, Kilimanjaro Region		Berry, (1970)
I20	Usambara Mts, Lushoto District	Small projects	Atlas of Tanzania, (1967)
I21	Uluguru Mts, Morogoro District	Small projects	"

NOTES: H = hydro-electric power station, D = dam, P = pipeline and I = irrigation. For location of the various projects see map 18.

Map 18 UTILIZATION OF WATER RESOURCES

(Sources: see Reference list table 36)

● I Irrigation scheme

■ H Hydro-electric power stations

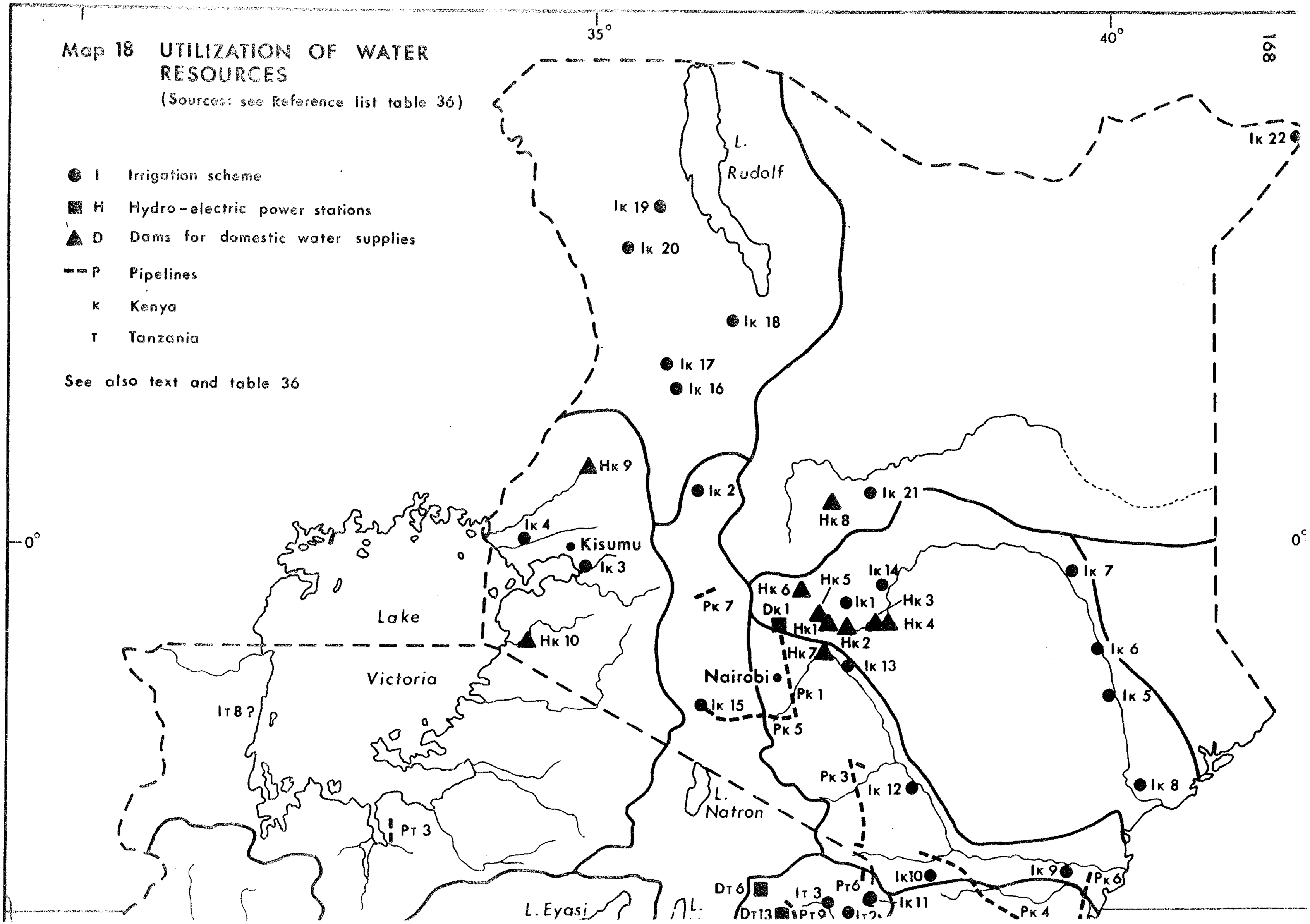
▲ D Dams for domestic water supplies

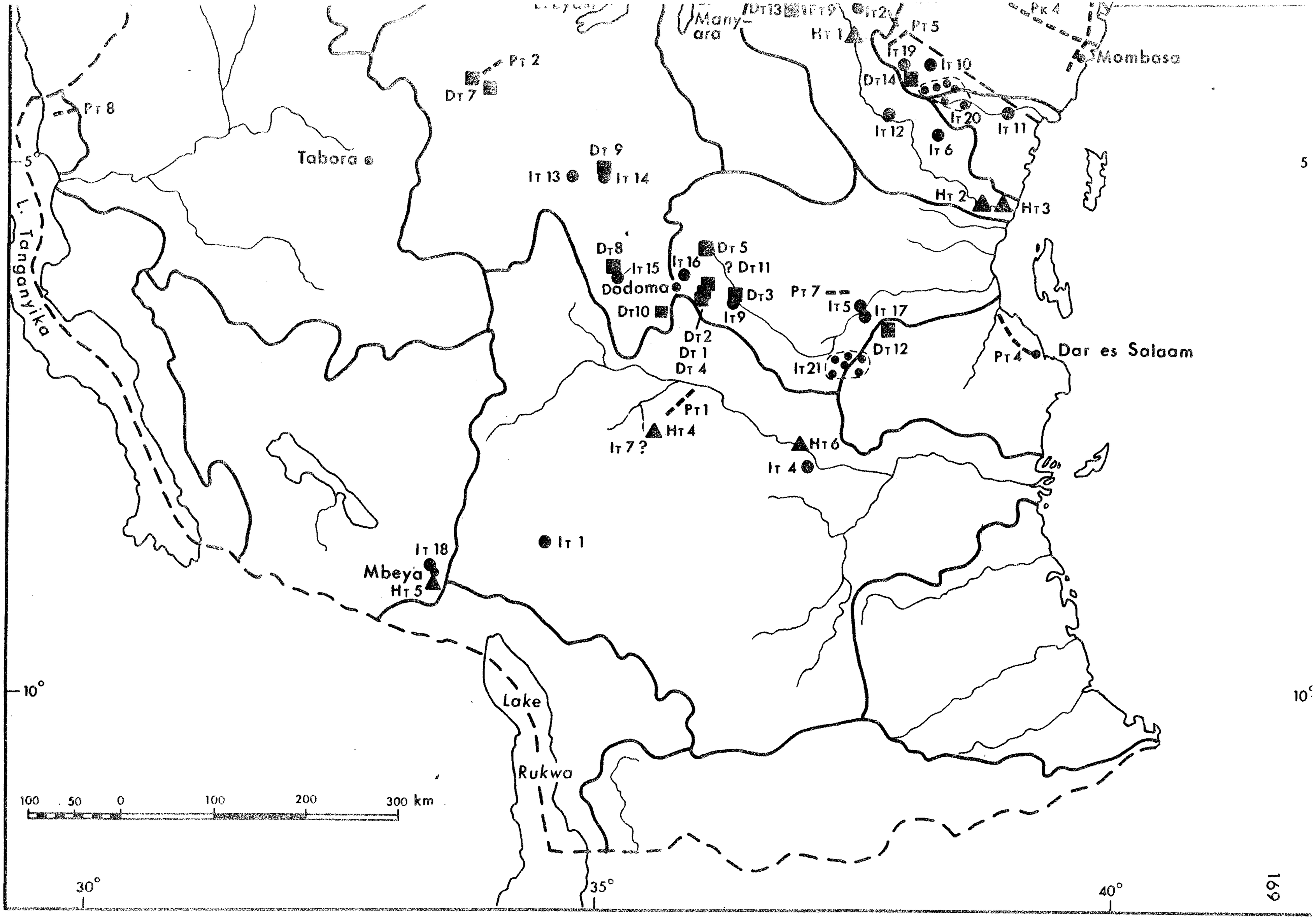
P Pipelines

K Kenya

T Tanzania

See also text and table 36

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Tabora
Dodoma
Dar es Salaam
Mbeya
Lake
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It 12
It 6
It 11
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Ht 3
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5°
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30°
35°
40°
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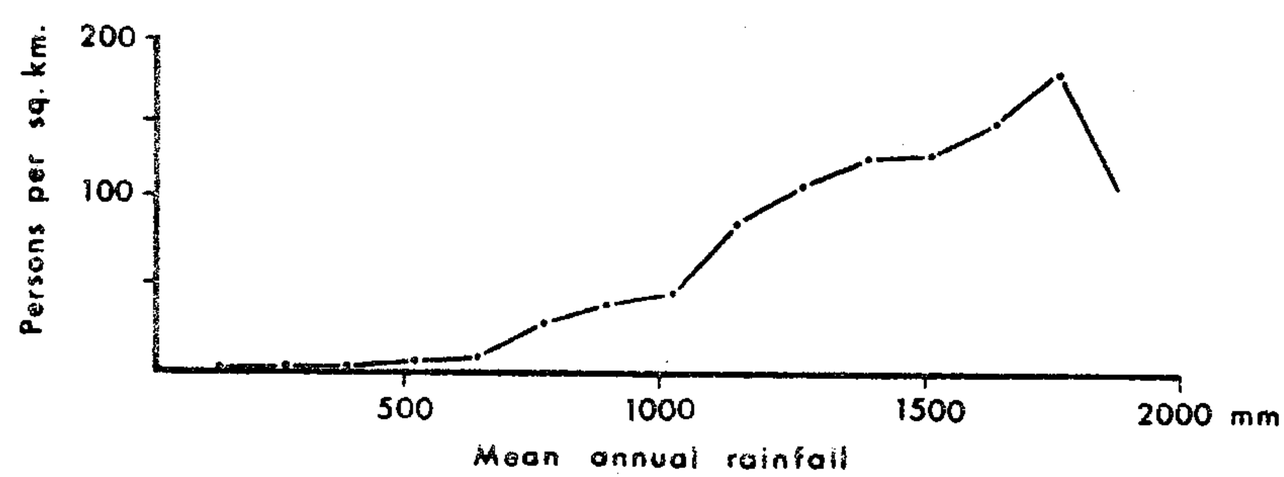
5. PROBLEMS AND CONFLICTS IN PRESENT LAND UTILIZATION

5.1. Population increase and land availability

Tanzania's total population was estimated at 14.12 million in 1973. On past trends the rural population of 13 million is expected to grow by 2.5 % annually while the small urban population (1 million) will probably expand over twice as fast. Presently there is 0.34 ha of cultivated land per capita of rural population, but, if no new land is brought into production, this average will fall to 0.21 ha by 1992. In view of soil erosion and fertility problems, and since new land on average can be expected to have lower productivity, the area expansion requirements would probably have to be even larger than 64 % - from 0.21 to 0.34 ha per capita by 1992 - to maintain the same production base.
The opportunity exists for the opening up of new areas for settlement and this must be an important part of any future agricultural policy. The expansion of beef production will largely require that potential grazing land be freed from tse-tse infestation.

Kenya shows the greatest concentration of population. About 75 % of the population is contained on only 10 % of the total area (see figure 4). A primary cause for this is the distribution of rainfall (see figure 24 below). There is a marked imbalance in the distribution of land among the people as well as great variations in the efficiency of the land use. Nearly half of the population of all East Africa is clustered in one zone around Lake Victoria and one in the Kenya highlands (see map 2). The population of Kenya totals about 13 million (1974) and are overwhelmingly rural. At the 1969 census over 90 % lived outside the towns (see 2.2.).

FIGURE 24. Relation between population density and annual rainfall in Kenya
Source: Morgan (1973)



In the future, it is critical that a comprehensive effort is made to compile more detailed information on the production potential of the different zones. Thus, increased efforts in land use planning and research should be designed to:

(a) Identify possibilities for the expansion of cultivated areas and grazing land as well as priorities for required investments in roads, water, social facilities and tse-tse control.
(b) Establish optimal farming systems.
(c) Identify yield improvement opportunities.

To this list of required efforts in land use planning and research we suggest that the contributions of forestry, fisheries and wildlife management to support human needs and income, should be assessed and integrated.

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5.2. Changes in land use

5.2.1. Agricultural areas

Both in the agricultural areas and the range areas population increase is the most serious problem, not only socially, but particularly in regard to the use and conservation of the land. In the agricultural areas population increase has in the past and is at present changing actual land tenure and land use practices, the former of which are gradually legally recognized or attempts are made to replace them with other systems.
Pressure on the land leads to fragmentation and more intensive use of the land. Intensive use of the land require new techniques (anti-erosion measures, new seeds, fertilizers, new crop rotation systems etc.) not always easily accepted by the african small scale farmer. It has to be stressed though that the "acceptance problem" may not be bigger than the "extension problem", i.e. the agricultural teaching, distribution of agricultural inputs plus - on the national level - price policies with regard to agricultural inputs and outputs. The latter are influencing the small farmers decisions on how to use the land as much as what the tradition tells him to do.

Pressure on the land also forces the population to look for new agricultural land and there is a danger of increased forest encroachment. Forest, bushes and trees are removed not only to create new agricultural land but also in order to provide firewood for the increasing population. Whereas the movement towards the forest is an "upward-movement", observable in Kenya on the slopes of the Nyambene, Mount Kenya and the Mau Escarpment (although the law is against it) another movement is towards the low-lying marginal areas, where agriculture still is possible, although connected with great hazards. Apart from the political problem (clashes between the rights of agricultural groups and nomadic groups) the increased use of marginal areas is socially dangerous. With more and more people moving to these areas famines become more extensive during bad years. A still bigger problem is that little is known on how to use the marginal areas properly and the danger is great that these areas will be destroyed sooner or later through the use of agricultural practices not adapted to them.

In addition to removing cultural prejudices the following measures will have to be given priority:
- improved and extended extension advice
- price policies
- research on the use of marginal areas

5.2.2. Range areas

In the range (pastoral) areas population increase is not as big as in the agricultural areas. No exact figure can be given, but it can be assumed that the natural increase in these areas is appr. 1 % less. A number of facts contribute to this, i.a. a higher sterility rate amongst nomadic women, higher infancy death rates, less access to health facilities etc. Nevertheless population has increased considerably even in these areas during the last decades and it has been possible to keep this increased population alive with increased herds (eradication of rinderpest and other diseases). Overstocking has often been the result and led to serious problems in e.g. Sukumaland in Tanzania and the Machakos District in Kenya. During droughts the herds are diminished, starvation and losses of human life follows, albeit efforts are made to give famine relief. After the

disaster, herds are quickly built up again with the result of increased exploitation of the land leading to still bigger disasters for people and cattle during the next drought.

Again - improvement of the situation is dependent on a change of cultural attitudes (dietary habits, value systems regarding the use of cattle as a status-symbol and in ceremonial transactions) and a change of technical (economic etc.) preconditions. Attempts to introduce rational ranching (in the western sense) with scientifically determined stocking rates, rotational grazing with fencing and proper spacing of water boreholes and improved marketing mechanisms have been made. It is still too early to judge the success of these programmes. Although the cultural resistance may have been stressed too much in the past (by the way not always exclusively by anthropologists) it would be dangerous to assume that the removing of technical problems only will bring about a change in attitudes amongst the people concerned.

Overexploitation of the soil with resulting deterioration of the environment due to population increase is happening and will increase in the future (see 5.4.). Measures to prevent this development are wideranging and include the introduction of new techniques, laws and economics policies in regard to the agricultural and related sectors. These measures will only succeed, however, if they are well coordinated and, first of all, are taking into consideration the social environment which they attempt to affect. This will have to be done in a spirit which may be called "participant intervention", to borrow a term from the social anthropologists, who are meticulous in their insistence on the use of participant observation as the main tool to understand society.

5.3. Disturbances in the hydrological cycle

5.3.1. Need for data collection

Much of the international aid for developing countries takes the form of technical survey missions, whose reports normally have to draw attention to the lack of hydrological and meteorological records. The history of development in many countries in Africa shows a tendency for the offer of further aid to be in the form of yet more surveys, rather than in the systematic correction of the data deficiencies already reported. In logical development, installation of measuring structures and organisation of the staff and supervision to operate the routines and to tabulate and report the data, should all follow without delay on the recommendation of a competent technical reconnaissance.
Practical examples of such timely action in Africa are the long-standing cooperative readings of water levels of Lake Victoria and flows of the Upper Nile, agreed between the British and Egyptian governments, which prepared the way for the highly successful development of the Jinja Dam at the lake outlet; the lake level was raised to generate electric power for both Uganda and Kenya. In contrast, lack of, among else, adequate rainfall records, combined with lack of attention to the scanty data available, led to the costly failure of the British Groundnut Scheme in Tanganyika.

5.3.2. The importance of forested catchments

East Africa has many sad examples of the degeneration of perennial water flows from naturally forested hills which have been unskilfully stripped of their forest cover. Torrential rain-season spates replace infiltration and storage, so that streams dwindle or vanish in the long dry season. The safe answer for the community is undoubtedly to protect the streamsource areas by Forest Reservations. These, however, cost money for fire protection and for policing, especially when the surrounding countryside is overpopulated and overstocked with cattle, sheep and goats.

In spite of much forest research, commercial non-destructive harvesting of the natural forests has given yields too low to pay for this protection. When capital became available for investment in plantation enterprises, the unspoilt soils of the forests offered the best prospects of success. There was then anxious debate as to whether it is necessary to lock up valuable land exclusively to collect water, or whether modern scientific development on planned soil conservation principles can be undertaken without detriment to water supplies. The attractions, for developing countries, are the tax yield and employment opportunity of plantation enterprise in contrast to the cost of forest protection. In the more distant future, when storage dams are built, the question of total water yield will become more important. Until then, water quality and regulation of flow are most needed.

5.3.3. EAAFRO's catchment studies

The large scale changes of land use experienced in East Africa as a result of population growth combined with population spread into previously uninhabited areas is endangering the quality of soils and water. In this context watershed studies offer valuable opportunities to obtain evidence in advance of proper decisions on land use policy. In this respect East Africa may be said to be unique in the developing world in making use of experiments directed towards immediate practical problems, making use of interdisciplinary and interdepartmental cooperation and organizing the work through the energies of full-time specialists that make the most of the small resources at hand.

Fifteen departments from three governments took part in the initial planning meeting in 1956. Targets were agreed upon and responsibilities were accepted by the Water Development, Agricultural, Forestry, Geology and Administrative services of Kenya, Uganda and Tanzania. Cooperation from a major international tea plantation company and from the East African Meteorological Department was also assured. EAAFRO supplied a full-time research team. Two studies were set up in Kenya to study replacement of indigenous forest by tea plantation and pine forest and two were set up to study improvement of eroded pastures (in Uganda) and to ascertain the effects of primitive cultivation (in Tanzania). Three of these will be described in the following.

5.3.3.1. Tea plantations versus tall rain forest. The densely forested hills NE of Lake Victoria receive a consistently heavy rainfall from 1500 to 2500 mm. From this tall evergreen forest, perennial streams supply large human and livestock populations in the lower and drier country of the lake littoral. Much of the forest has already been cleared and planted to tea, one of Kenya's main export crops and an important source of employment. Capital investment, of the order of half a million pounds sterling per plantation unit, is very well protected by soil conservation work, but no prediction could be made with confidence about the effects on the seasonal pattern of the streamflow or on the total water yield. With no storage reservoirs and no early prospects of building any, the critical test was the effect on dry-season flow. Peak flows from the heaviest rains were also important since all road bridges were designed for the flows controlled by the forested headwaters.

Two parallell forested valleys were selected, after study from the air and from the ground. One of these, the 700-ha watershed of the Sambret stream, was excised from the Forest Reserve and leased to the Brooke Bond (East Africa) Company. The 540-ha completely forested Lagan Valley was studied as a control. The valleys selected were at a mean altitude of 2200 m with a slope of about 4 %. A larger valley on which only streamflow was gauged was proposed for long-term comparisons.

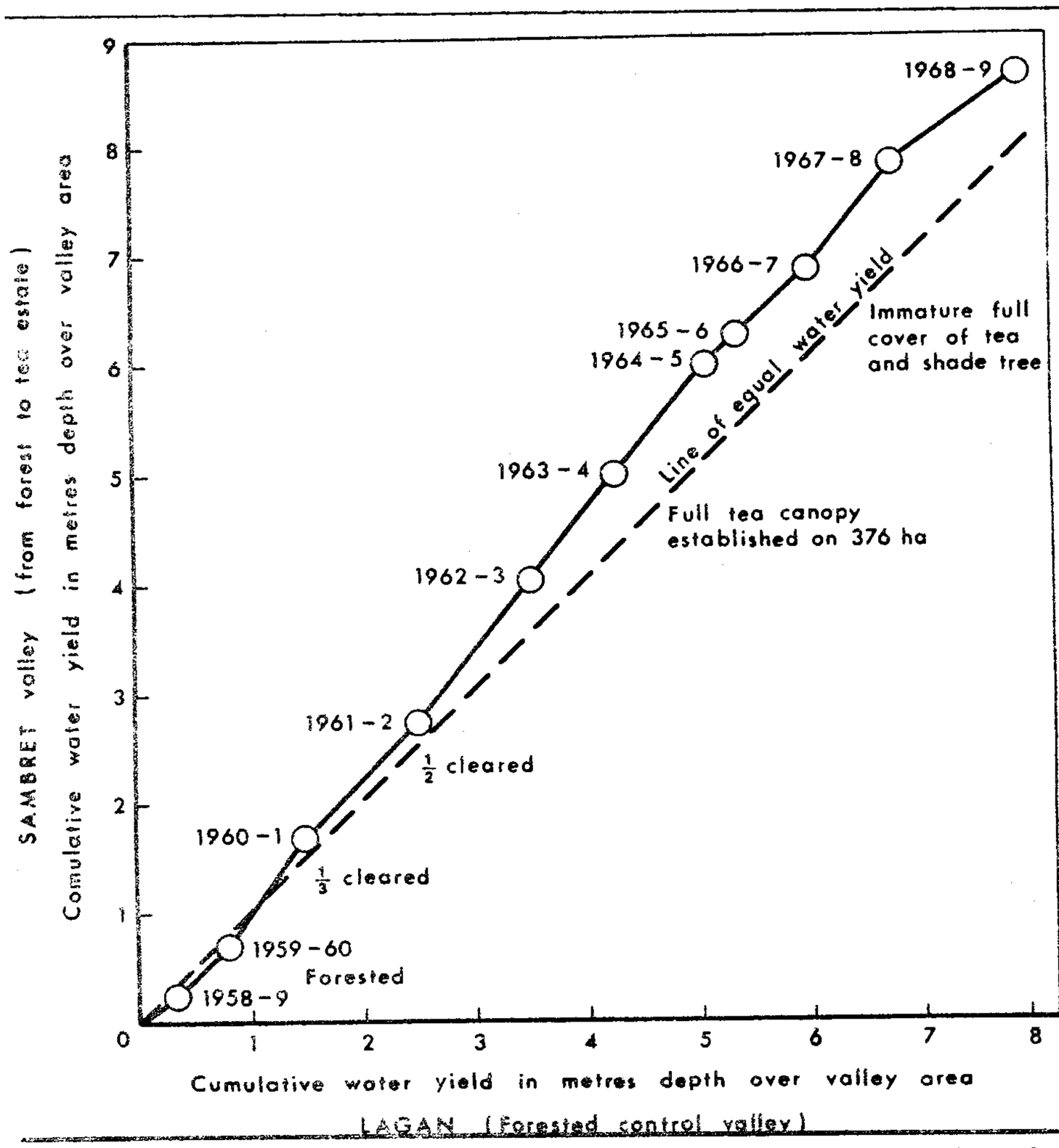
After a preliminary year of comparison of the water balance of the two valleys, development of the Sambret began. Clearing and planting were planned and carried through to a timetable drawn up by the research group, the land use change being carried out as rapidly as possible. One hundred and twenty hectares were cleared in the first year and planted in the second, and the whole area suitable for tea, comprising 350 ha, or about half of the valley, was planted in four years with full development of roads, housing, factory and a small water-supply dam. Most of the remaining area lay within a subcatchment in the upper part of the valley, which was gauged separately and remained under natural forest.

Blackie (1972) showed that over the first eleven years the mean annual water consumption was the same for both forms of land use. Approximately 1300 mm (51 in) per annum were evaporated both from the tall rain forest and from the continuous canopy of tea and shade trees which replaced it. Both valleys gave an average E_t/E_0 ratio of 0.8.
The initial clearing gave an 11 % reduction in water use. This was rather less than had been expected but only 30 % of the valley was under bare soil at any one time. At Kericho the very favourable climate for tea growing is produced by rapid alternation between hot sunshine and rain (average of 6.5 hours of bright sunshine a day with 240 rain days per year). Van Bavel, Fritzchen and Reginato (1963) have shown by accurate experiments that while the soil surface is wet it behaves similarly to an open-water surface

and the rate of evaporation is about the same. Blackie estimated the evaporation rate from bare soil to have been about 0.45 E_0 to account for the 11 % reduction in water use by the whole valley.

Two exceptionally dry years, 1965-6 and 1966-7, had the unexpected effect of reducing the water use of the rain forest more than that of the tea plantations, so that over the eleven years, a period long enough to minimise the effects of annual storage changes, the mean water-yields of the two valleys were effectively equal (figure 25).

FIGURE 25. Ten-year cumulative water yields from forest and from tea plantation
Source: Pereira (1973)



NOTE: Eight years after clearing began, the resulting increase in water yield totalled 1 m depth over the valley area, or about 2 m depth over the area converted.

5.3.3.2. Pine plantations versus bamboo forest. By means of a continuous water budget record based on rainfall, pan-evaporation measurements and occasional soil samplings, it was possible to compare the water use of softwoods with that of indigenous bamboo forest.
Adjacent plantations on a level, uniform site, free from surface runoff, were compared with the surrounding bamboo forest. These plantations, 1.5 km inside the forest, were presumed free from edge effects. The altitude was

2650 m; the long-term average annual rainfall was 1250 mm, with two dry seasons, and the annual open-water evaporation was approximately 1500 mm. In uniform plantations of Radiata pine (Pinus radiata), 37 m high, and Monterey cypress (Cupressus macrocarpa), 16 m high, and in the bamboo (Arundinaria alpina) thicket, 13 m high, pits were dug and roots were washed with firefighting equipment to observe their depth and distribution. The main root development was within the first 3 m depth of porous, stone-free volcanic soil, with negligible development beyond this depth. The horizons were sampled volumetrically and wilting-point and field-capacity measurements were made.

Well-replicated profile sets of simple "gypsum block" electrical resistance gauges for soil moisture tension were installed and resistances were measured on a robust portable meter with a hand-wound dynamo and an open logarithmic scale. From the drainage tension pattern thus observed it was possible to greatly reduce soil sampling occasions. Three four-man crews, in one day, were able to complete well-replicated patterns of soil-moisture samples to 3.2 m depth and to establish the soil moisture storage totals with acceptable accuracy.

The three forest types each drew water in most years from the full 3.2 m depth, while the resistance gauges showed drainage from the root range to have ceased. When the rains resumed, the deep soil took several weeks to refill to the point of through-drainage. Soil sampling under these conditions gave soil moisture changes free from drainage losses. Water use by trees was thus computed from the sum of rainfall and soil-moisture change.
Comparison of water use with open-water evaporation for the periods free of drainage beyond the 3.2 m depth gave the E_t/E_0 ratios shown in table 37.

TABLE 37. Water use of trees by soil sampling
Source: Pereira (1973)

	Height	Age	Et/E_0
Natural bamboo thicket	12 m	-	0.86
Radiata pine plantation	37 m	25 yrs	0.85
Monterey cypress	16 m	16 yrs	0.86

NOTE: All three mature tree canopies used water at a similar rate, as shown by comparison with evaporation from open water.

The ratios for all three vegetation types were remarkably uniform. Little change would therefore be expected in the water use of the vegetation when bamboo forest is replaced by softwood plantations. However, in one long spell of dry weather the tensiometers indicated a more thorough drying of the soil profile under the tall Radiata pines, then thirty years old, than had occurred under the cypress and bamboo; soil sampling confirmed the difference to about 75 mm in the 3.2 m root range.

The measurements were continued while the cypress area was felled and replanted with Patula pine (Pinus patula). This was done by the "taungya" system by which forest workers cultivate the soil and grow vegetable crops between the young pine trees (see 5.6.2.). For the first three years the whole profile remained wet enough for frequent free drainage to occur

beyond the root range. Cultivation then ceased. Tall woody weeds (Sambucus spp.) rapidly filled the gaps in the pine canopy and created soil-moisture deficits slightly greater than those caused by the pines or cypresses.

From these simple studies it was thus possible to conclude that a short-term rotation of softwoods could be expected to use about the same amount of water as the undisturbed bamboo forest, with an expected increase of water yield during the first three years of clean weeding under vegetable crops, and an indication that an increase in the length of the forest rotation might lead to greater water use in drought years (Pereira and Hosegood, 1962).
The samplings were continued to compare age-groups of plantations and annual water balances were calculated. Table 38 shows that for this site at the warmer and drier extreme of the watershed protection forest, there was effective recharge of deep groundwater in only four years out of eight. The danger of assuming groundwater recharge to be a constant proportion of the rainfall is evident.

TABLE 38. Water balance near the lower edge of a mountain watershed protection forest of bamboo thicket
Source: Pereira of Hosegood (1962)

	1953	1954	1955	1956	1957	1958	1959	1960
Rainfall (mm)	787	1295	940	1143	1372	1448	940	813
Water use ($0.85E_0$) (mm)	965	839	940	839	864	864	889	965
Balance available for recharge (mm)	-178	+456	0	+304	+508	+584	+ 51	-152

NOTE: The balance available for recharge is that calculated to have drained beyond 3.2 m depth.

5.3.3.3. Grazing. A study of restoration of overgrazed savanna country has been carried out in the Karamoja district of Northern Uganda, at the top of the head-water catchments of the Nile near to their boundary with the watershed of Lake Rudolf. The annual rainfall of 500-750 mm, although far less than the open-water evaporation of some 1800 mm, is adequate to maintain open woodland with a rich flora of grasses underneath a well developed tree stratum of many species, of which Commiphora, Acacia, Terminalia, Balanites and Tamarindus dominate.
This country can be productive as ranchland, but persistent misuse by overgrazing has reduced many hundreds of square km to thornscrub with desert grasses. Runoff from the bare and trampled soil is so great that men and their livestock depend precariously on seasonally declining waterholes dug in dry sandy watercourses. Hydrologically, the results are embarrassing to the road authorities, since bridges over the drainage lines are repeatedly damaged by torrent flowes.

The local pastoral tribes have not begun to understand their own predicament. They attribute their troubles to "poor rains" while their increasing numbers of livestock relentlessly reduce their habitat to desert. Rainfall records for thirty years at Moroto give no indication of decline. Construction of extra watering points by building of earth dams and drilling of boreholes was attempted by the administration in order to spread the grazing over

wider areas, but cattle populations grew rapidly around the new water sources and merely extended the area of destruction. The development of further water points was therefore stopped pending the achievement of grazing control.

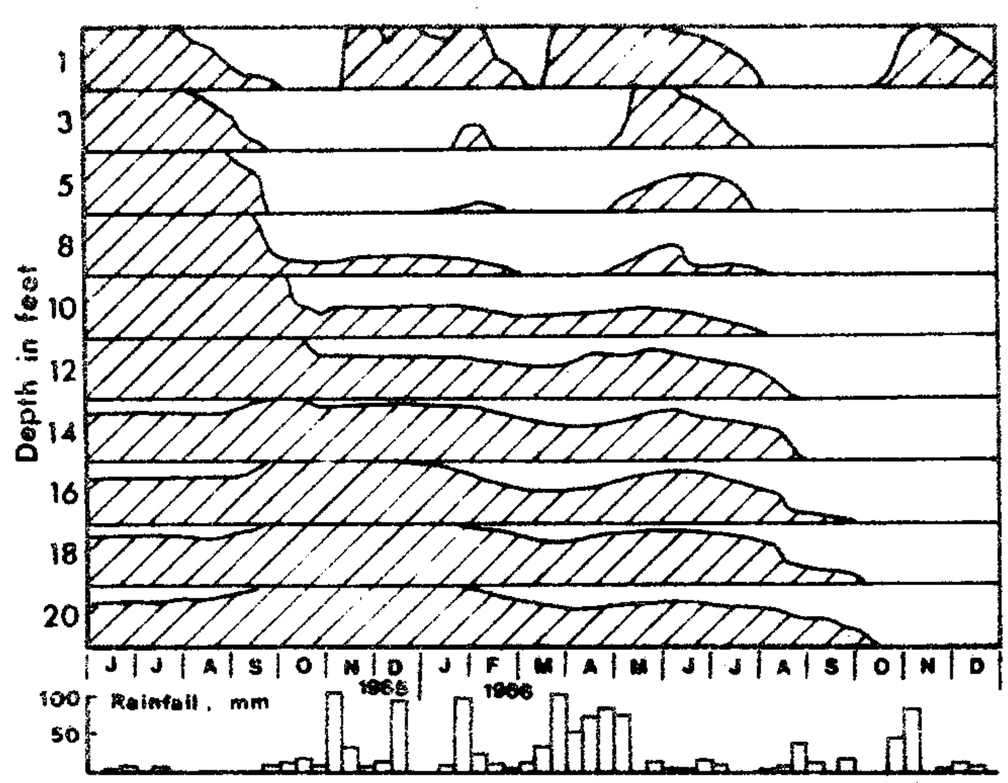
Two opposing hydrological factors can be accepted as established by evidence: firstly, that control of grazing to preserve a grass cover and to prevent excessive soil exposure and trampling is an essential precaution against accelerated soil erosion and flood flow; secondly, that improving the density and productivity of grassland decreases total water yield. As with forest cover, the protection of soil, preservation of water quality and moderation of flow patterns are obtained only at a substantial price in extra water use by the vegetation. In the case of deep-rooted perennial grasses this price can be very high indeed in climates with long dry seasons where total annual evaporation exceeds annual rainfall. At Muguga in Kenya, analysis of the water balance under well-managed "star grass" Bermuda grass), Cynodon dactylon, in grazing experiments where rainfall, runoff and soil moisture changes to 3 m depth were measured for six years, showed how serious the hydrological results could be. Even on 10 % slopes these pastures gave negligible runoff and used all of the 990 mm (39 in) of annual rainfall. Star grass newly planted on a deep soil at field capacity was shown by soil-moisture tension indicators (gypsum blocks) and by soil sampling to be extracting water down to 3 m depth within the first year and to maintain continued subsoil moisture deficits which effectively prevented drainage to recharge groundwater.
In the absence of such drainage, soil sampling permitted a detailed water balance; comparison with open-water evaporation (Penman estimate) gave annual E_t/E_0 ratios for this closely-grazed pasture of 0.4 in the first year and 0.5 in the second. When fully supplied with water the ratio, from a nearby lysimeter, was 0.75 (Pereira, Hosegood and Dagg 1967).

In comparison of grass species at greater depth, the vigorous Buffalo grass (Cenchrus ciliaris) depleted the soil profile from field capacity to wilting point to a depth of 6 m, creating a deficit of 610 mm eighteen months after planting (figure 26). Several common perennial grasses in East Africa have similar rooting characteristics and the creation of deficits of 500 mm or more in very deep porous tropical soils is of substantial hydrological importance. Before recharge of groundwater can occur, the following rains must refill this deficit while meeting current transpiration demands; this requires a total of about 700 mm. For these experiments at Muguga in Kenya, detailed records showed that such conditions had been satisfied only twice in the past sixteen years. Of the total 16 m of rainfall received in these years, only 400 mm would have been transmitted to groundwater by these vigorous perennial pastures (Dagg, Hosegood and McQueen 1967).

5.3.4. The effects of irrigation and drainage

Irrigation systemsconvert dry soil surfaces into transpiring crop canopies over considerable areas, where they become developed and will therefore constitute a noticeable hydrological influence. The main problem as far as water use is concerned is the control of drainage and salinity. Only a decade ago it is probable that a larger area was lost to world cultivation every year from salinity than was gained by new irrigation schemes. In East Africa irrigation enterprises have been slow to develop and been limited to small schemes close to the major lakes. In many areas the incidence of bilharzia (parasitic worm which spends half of its life cycle in a water snail and half in the human body) limits the attractiveness of irrigation practices.

FIGURE 26. Water use by an African pasture grass
Source: Dagg et al. (1967)



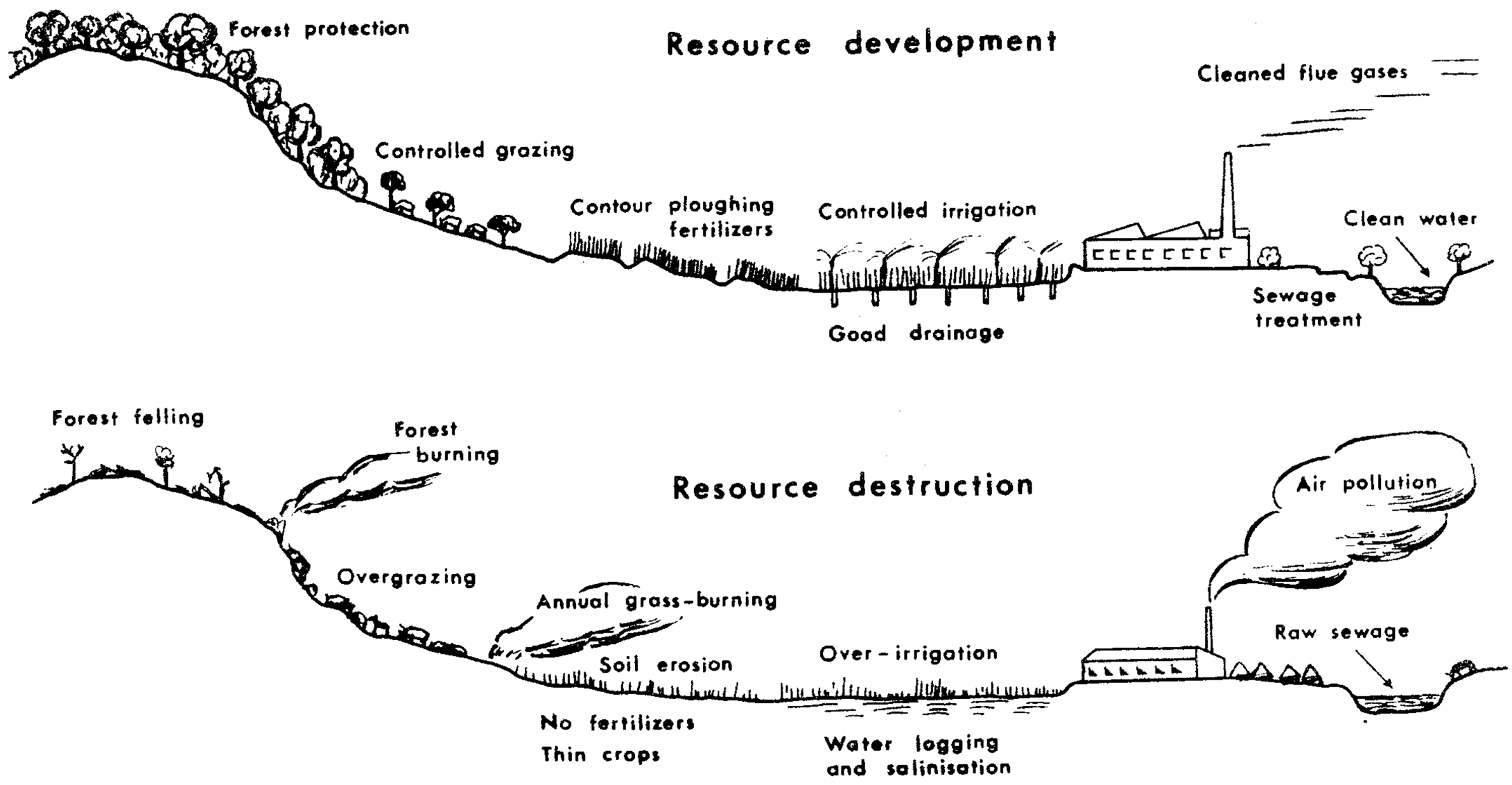
NOTE: The shaded areas represent available water at each depth. Depletion is from field capacity to wilting-point throughout a 6 m depth of soil, creating a soil-moisture deficit of 610 mm (24 inches) in 18 months after planting Cenchrus ciliaris.

Three developments in irrigation techniques, which are under research and may benefit irrigation outcomes, are improved means of preventing leakage from irrigation channels, better plant adaption and soil and water management techniques to permit extended use of brackish water and, finally, optimize water application abilities to minimize water usage.

5.3.5. Improved watershed management understanding

In developing countries in tropical climates, where the penalties of land misuse strike earlier and harder than in temperate regions, there is a great danger that the rates of human increase will outrun both the powers of local governments and the help of friendly nations to restore deteriorated resources. The deterioration comes from the destruction of the protective vegetation by the spread of unorganised and unskilled subsistence agriculture in ever steeper and drier country, see figure 27. All mankind must be alerted to realise that if we are to remain in any tolerable balance with our soil and water resources then human numbers cannot continue the present mindless rate of increase. In fact, it may well prove that it is the medical scientist rather than the soil and water conservation engineer whose progress will eventually determine the condition of our watersheds.

FIGURE 27. Generalised pictures of resource development and resource destruction in a watershed
Source: Pereira (1973)



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5.4. Soil erosion

5.4.1. Introduction

Soil erosion is a very serious threat to the limited resources of productive soil, water and vegetation, and hence to the well-being of present and future generations of people, particularly in developing countries. The present food crisis in the world is also generating increasing soil erosion, due to increased overgrazing or overcultivation of marginal lands in many countries. Drought, starvation, increased pressure on marginal lands and soil erosion are factors which tend to be linked together in a vicious circle.

Soil erosion can be caused by water or by wind. Both kinds of erosion are facilitated by lack of vegetation. A cover of forests, grass or other vegetation prevents the raindrops from beating the soil surface, increases the water infiltration and thus decreases the amount of surface runoff.

The eroding capacity of water and wind is proportional to the flow velocity close to the ground surface. Both wind and water velocity near the ground is much reduced by vegetation, which thus protects the soil particles from being carried away by water or wind.

Destruction of vegetation cover, leading to ecological degradation, culminating in soil erosion, are processes threatening under different types of land use, e.g. crop production, range management and forestry. In all these types of land use the long-term productivity can be maintained by proper soil conservation measures, based on ecological adaption to the local conditions of soils, climate, slopes and vegetation.

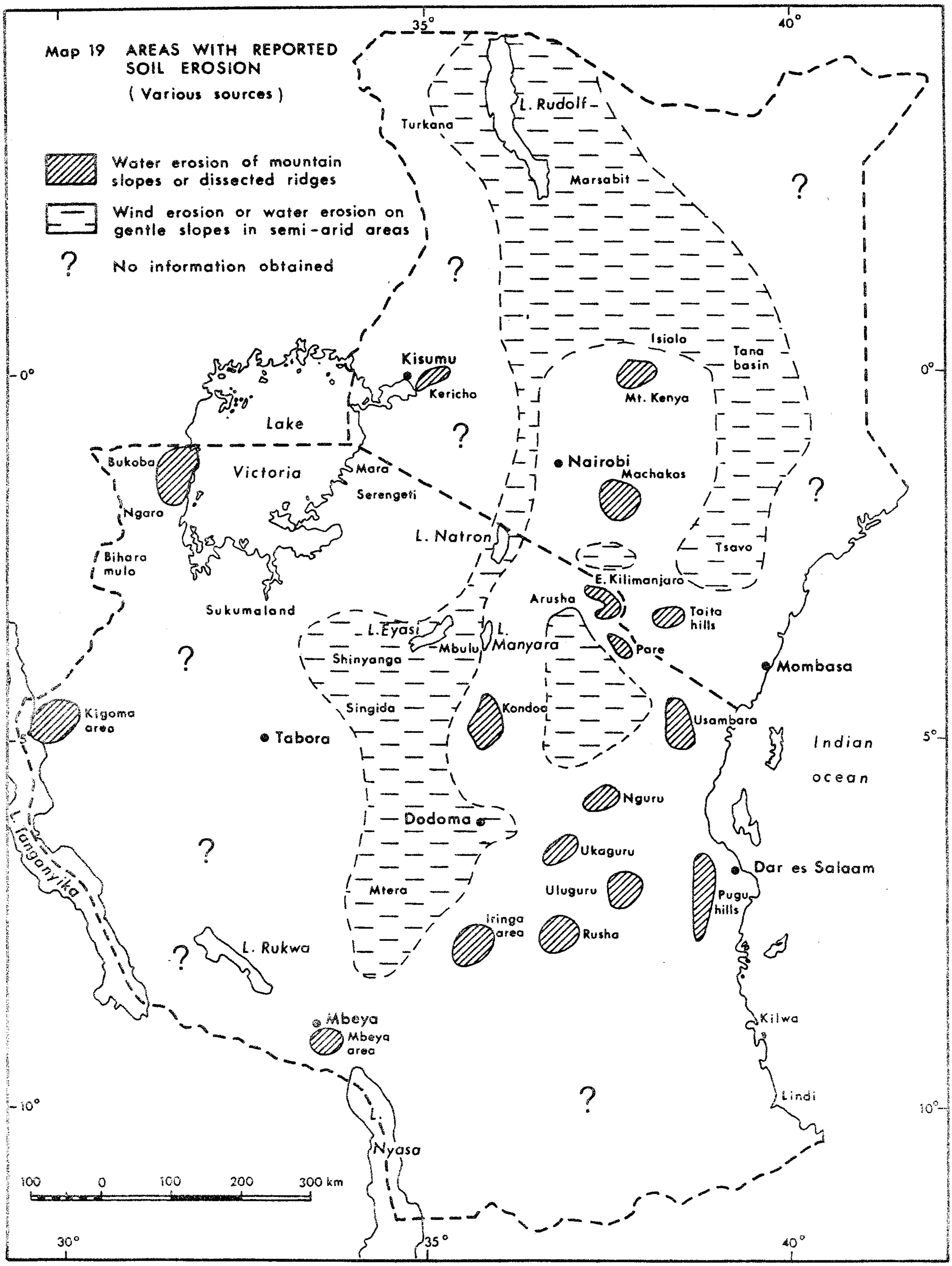
There are two types of areas in East Africa, which are very susceptible to erosion:

a) the semi-arid savanna lands and other drylands with sparse vegetation cover at the end of the dry season
b) the deforested mountains with cultivation of steep slopes.

In these two critical types of environment the main reasons for human overexploitation, leading to soil erosion and loss of productivity are generally summarized under the four following practices:

1) overgrazing
2) overcultivation
3) excessive collection of firewood or charcoal burning
4) excessive burning of grassland, woodland or forest.

These four factors have been recognised as the main causes of degradation of lands into desert along the southern fringe of the Sahara. In Kenya and Tanzania both drylands and highlands are in many cases exploited until severe degradation due to increasing concentration of people and cattle, without efficient measures for resource conservation.
No systematic regional inventories of the types, extent and rates of soil erosion processes have been made in Kenya or Tanzania. In the latter country an attempt of an assessment was made by Baker (1970), based mainly on air photo interpretation. As appendix to this section, we enclose a list from Baker's assessment.
On map 19 areas with reported soil erosion are shown.


Map 19 AREAS WITH REPORTED SOIL EROSION
(Various sources)
Water erosion of mountain slopes or dissected ridges
Wind erosion or water erosion on gentle slopes in semi-arid areas
No information obtained
35°
40°
0°
5°
10°
30°
L. Rudolf
Turkana
Marsabit
Isiolo
Tana basin
Mt. Kenya
Kisumu
Kericho
Lake
Victoria
Bukoba
Mara
Serengeti
Nairobi
Machakos
Ngaro
Bihara mulo
L. Natron
Tsavo
E. Kilimanjaro
Arusha
Toita hills
Sukumaland
L. Eyasi
Mbulu
L. Manyara
Pare
Shinyanga
Mombasa
Singida
Kondoa
Usambara
Kigoma area
Tabora
Indian ocean
Nguru
Dodoma
L. Tanganyika
Ukaguru
Dar es Salaam
Uluguru
Pugu hills
Mtera
Iringa area
Rusha
L. Rukwa
Mbeya
Mbeya area
Kilwa
Lindi
L. Nyasa
100 0 100 200 300 km

5.4.2. Some basic definitions

The forms of water erosion are generally classified in the following slope sequence from hill-crest to valley-bottom:

Splash erosion is "the shattering of small soil particles caused by the impact of raindrops on soils".

Sheet erosion is "the removal of a fairly uniform layer of soil from the land surface by runoff water".

Rill erosion is "a soil erosion process in which many small channels s few inches deep are formed".

Gully erosion "is channel erosion that cuts so deeply into the soil that the ground cannot be smoothed out by ordinary tillage tools. It often follows sheet and rill erosion". To the negative effects of gullies we will add that they speed up losses of topsoil and water from intergully areas by functioning as drainage ditches during rainfall.

River erosion is mainly geological erosion, scouring the banks or river beds. Rivers can, however, in many cases cause loss of farm land or crops by lateral erosion or overbank scour during flooding. The main damage to farm land is probably brought about by excessive river flooding and sediment deposition.

Soil erosion by mass movements: Sliding or flowing mass movements of soil and regolith on slopes are causing much damage to land under cultivation and grazing in developing countries. The movements (e.g. debris slides, debris flows, or mudflows) are generally initiated by rainstorms of high intensity, although the driving force is gravity.

Wind erosion is causing loss of topsoil by blowing off fine particles as dust clouds high up in the air, and driving sand particles along the ground surface, creating mobile sand dunes.

5.4.3. Erosion in Tanzania

The following is an extract from Rapp, Berry and Temple (1972).
Since the 1920s soil erosion has been an issue of growing concern in Tanzania. In 1931 a special committee was set up to study soil erosion and its relation with crop production, animal husbandry, afforestation, tsetse fly, irrigation, water supplies, roads, railways and public welfare. The authorities decided to rely on persuading the people to adopt improved land use methods rather than to carry out extensive schemes to prevent erosion or check deterioration. This was then the policy and practice of the 1930s and early 1940s.
After the Second World War a change of Government and policy in Britain brought new pressures on the colonial administration in Tanganyika. Remedial and ameliorative measures became possible and were given an impetus by the establishment of the ill-fated Groundnut Scheme set up in 1947. A soil conservation service was set up in Tanganyika in 1945 and an official review of the soil erosion problem attempted in 1951-52.

By this time there was clear evidence of resource wastage in particular areas. In other areas however the data were much less definite. As land conservation schemes were firmly associated with the colonial government and their agricultural policy it was not surprising that policies changed

after independence, when direct action was abandoned as a policy, though it had been abandoned in fact some years before.
The TANU party programme published in 1972 emphasizes that one of the causes of the decline in agricultural efficiency in Tanzania is soil erosion, which is said to be "very serious in many places and getting worse". Soil conservation measures are placed among the first-essentials of an improved agriculture.
Later on, the Forest Division has officially been charged with the task to plan, coordinate and supervise a national programme of soil conservation in Tanzania.

5.4.3.1. Mountain areas. The studies of soil erosion in the Ulugurus show that small landslides and mudflows triggered by extremely intense rainstorms are important processes affecting steep cultivated slopes in the western Ulugurus. Erosion by landslides and mudflows is also active under forest and woodland, but is greatly accelerated on deforested slopes. The recurrence interval of such events on deforested slopes in the Ulugurus is probably one to a few decades, judging from analyses of records of rainfall intensity (see figure 35).
The "normal" annual erosion from splash and sheet wash in the Morogoro catchment corresponds to a general denudation of 0.26 mm. A tenfold higher intensity of denudation by slopewash is likely on the 10 % of area that is under cultivation within the catchment. This conclusion is supported by erosion plot records from Mfumbwe in the Ulugurus. Further information concerning the erosion and runoff on slopes in areas of high rainfall is provided from soil erosion tests in plots at Lyamungu and Tengeru in northern Tanzania (see figure 28).

The most feasible means of controlling landslide erosion on such mountain slopes would be shelter belts of forest planted below ridge crests, along road cuts and along stream sides, to stabilize the soil and regolith with tree roots. Slopewash can be considerably diminished by use of cover plants, mulching, reduced burning, and change to perennial instead of annual crops.

5.4.3.2. Semi-arid areas. The rate of soil erosion and reservoir sedimentation is very high in four catchments investigated near Dodoma and one near Arusha. Reservoir sedimentation rates in the cases investigated correspond to annual sediment yields of 200-730 m^3/km^2 averaged over the longest periods of available records.
The most important process of erosion in the Dodoma and Arush catchments is sheet wash from overgrazed land and unprotected cultivations. Gully erosion is spectacular in some areas. Gully cutting is probably connected with rare and extremely intense rainstorms.
Improved grass management in the semi-arid catchments is the best general method of decreasing soil erosion and increasing the life of the reservoirs.

Severe wind erosion and dust storms have been reported from Singida, from easterly winds in June to August. Other areas in Tanzania with reports of strong wind erosion are the Mbulu and Arusha districts.

5.4.4. Erosion in Kenya

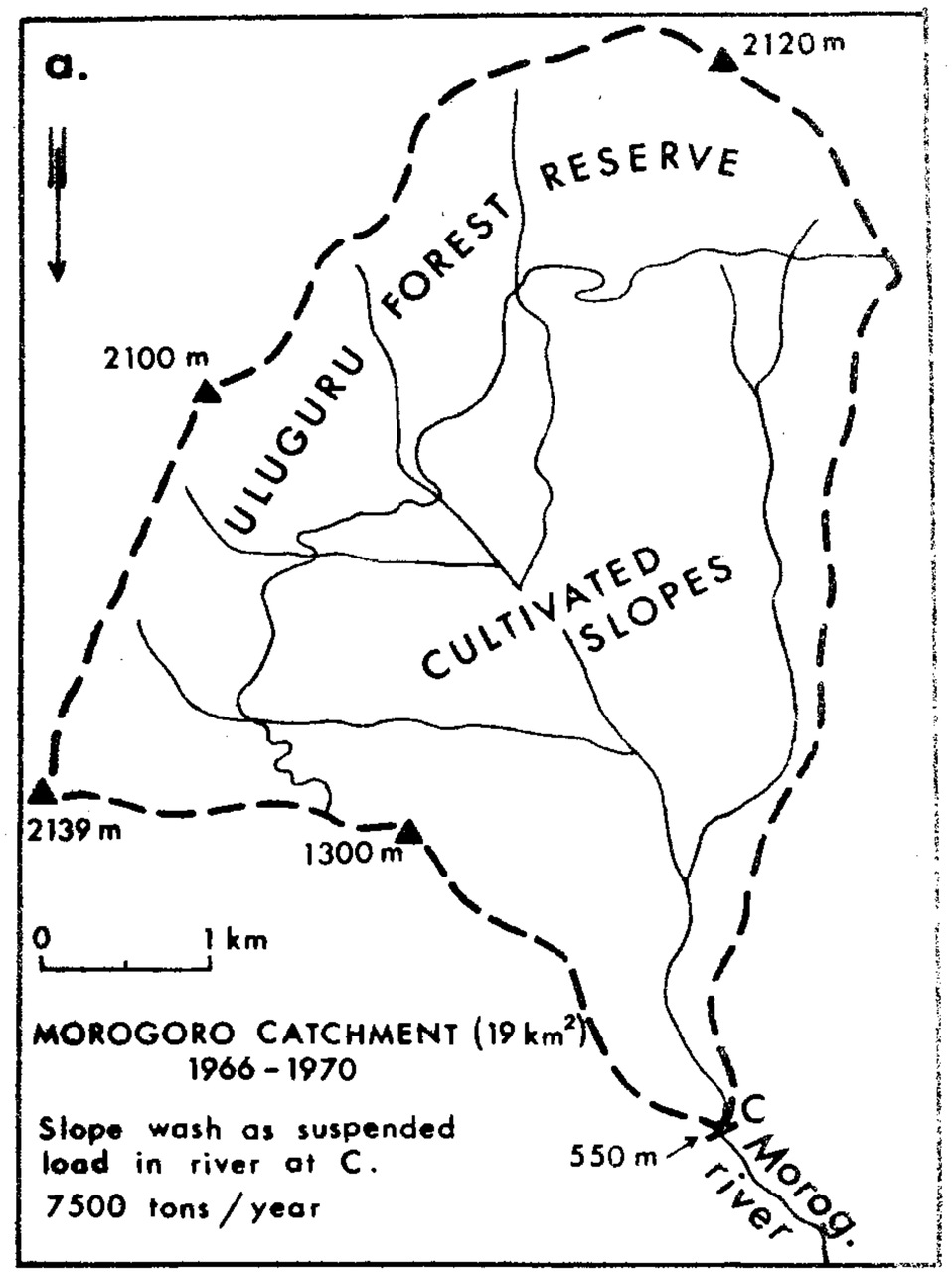
The third development plan of Kenya (1974) has a chapter devoted to "The environment and its conservation". It states that the concept of conservation is not new in Kenya, and characterizes the actual situation as fol-

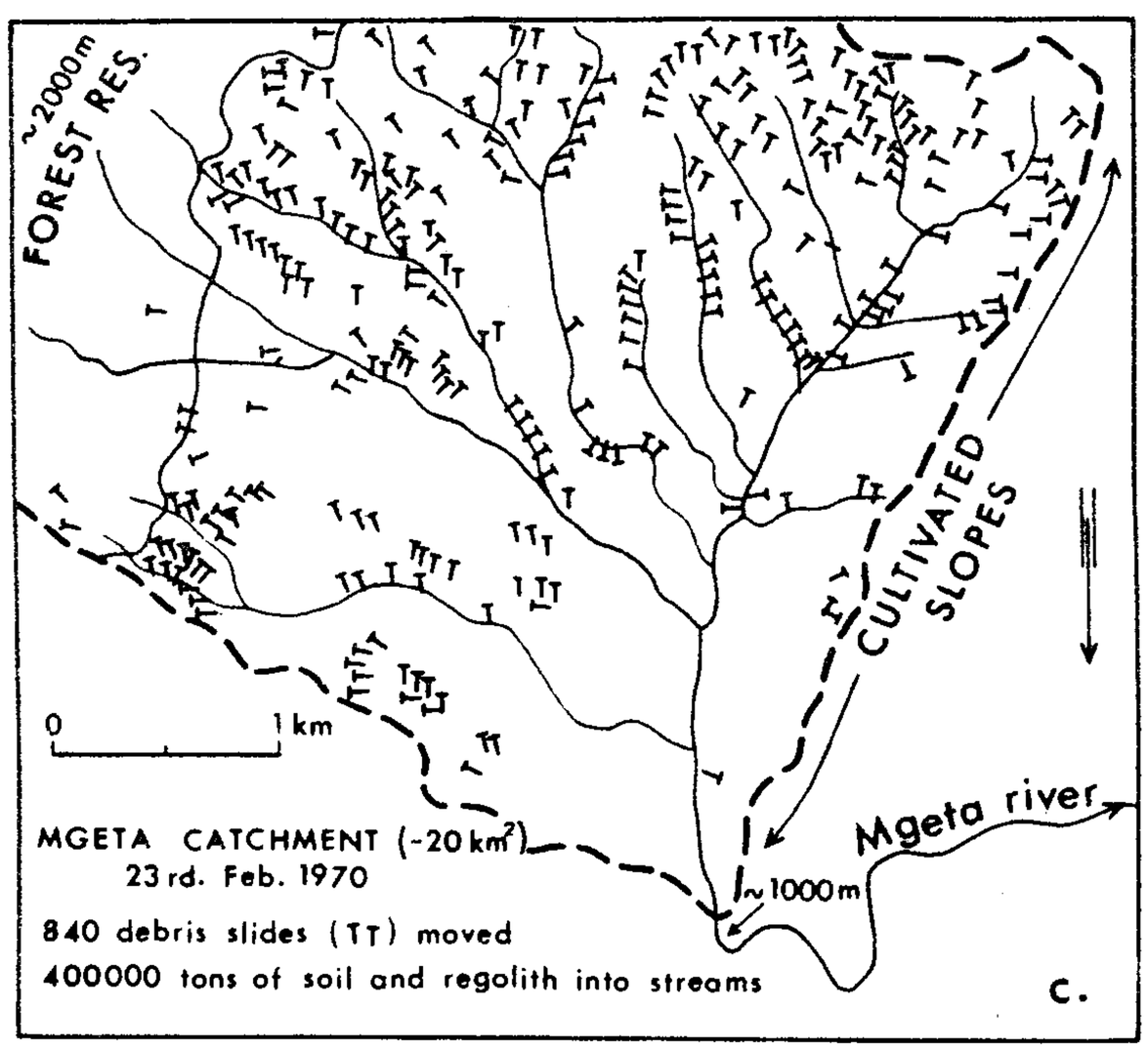
FIGURE 28 a-c. Three maps showing three major types of erosion on deforested and cultivated slopes in the Uluguru Mts
Sources: a, c - Rapp et al. (1972), b - Lundgren & Rapp (1974)

a. Annual "average" slopewash 1966-1970 from cultivated slopes caused a soil loss of 7500 tons/year, measured as suspended load in the Morogoro River.

b. Large landslide within same watershed area as on a, in April 1973. It blocked the water intake of Morogoro town, silted up the water pipes and damaged the water supply for weeks.

c. A large number of small landslides triggered by a heavy rainstorm of 100 mm on 23 Feb. 1970. A few landslides occurred in the forest reserve, more than 800 on deforested slopes below the forest reserve boundary.





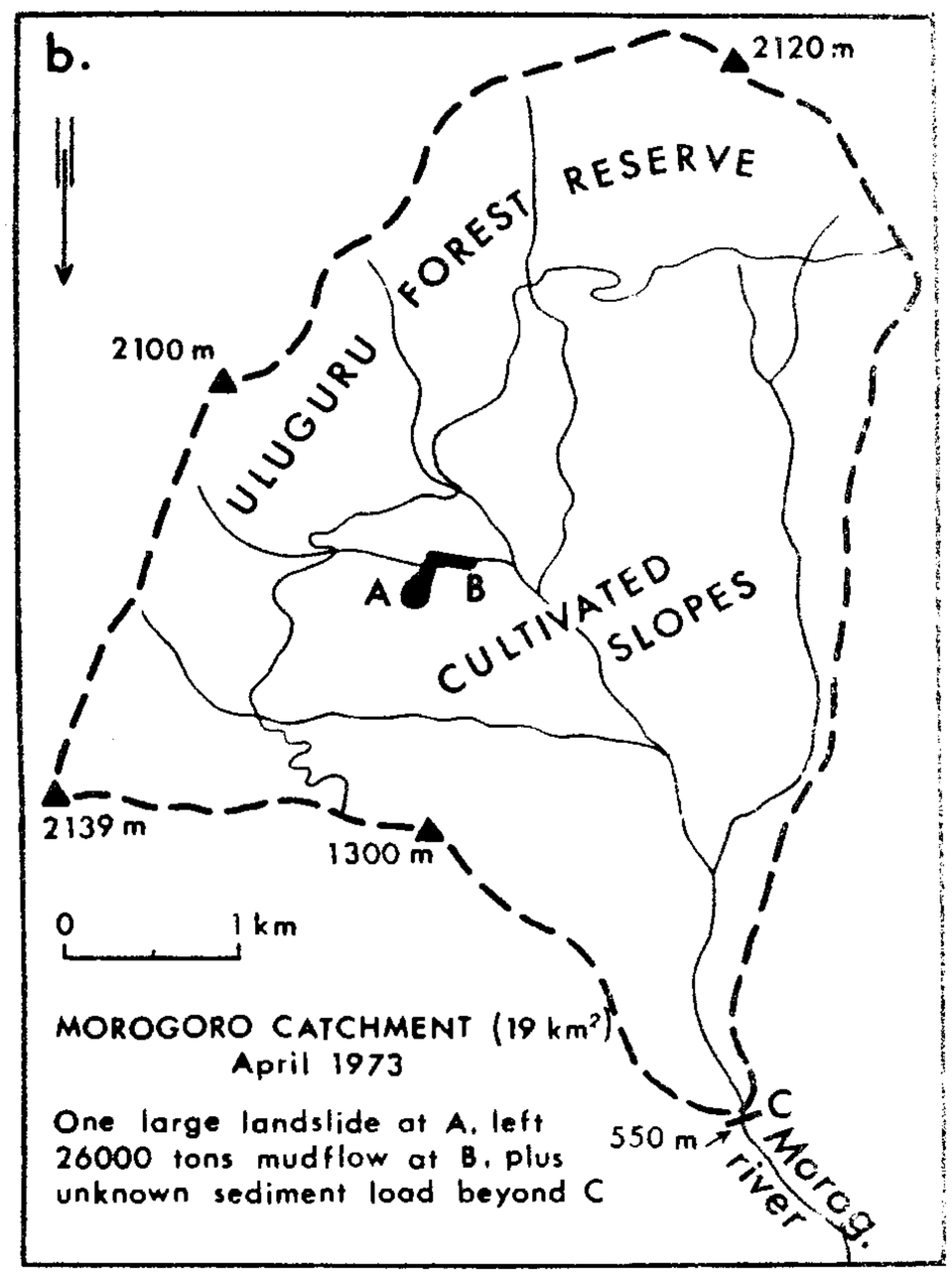
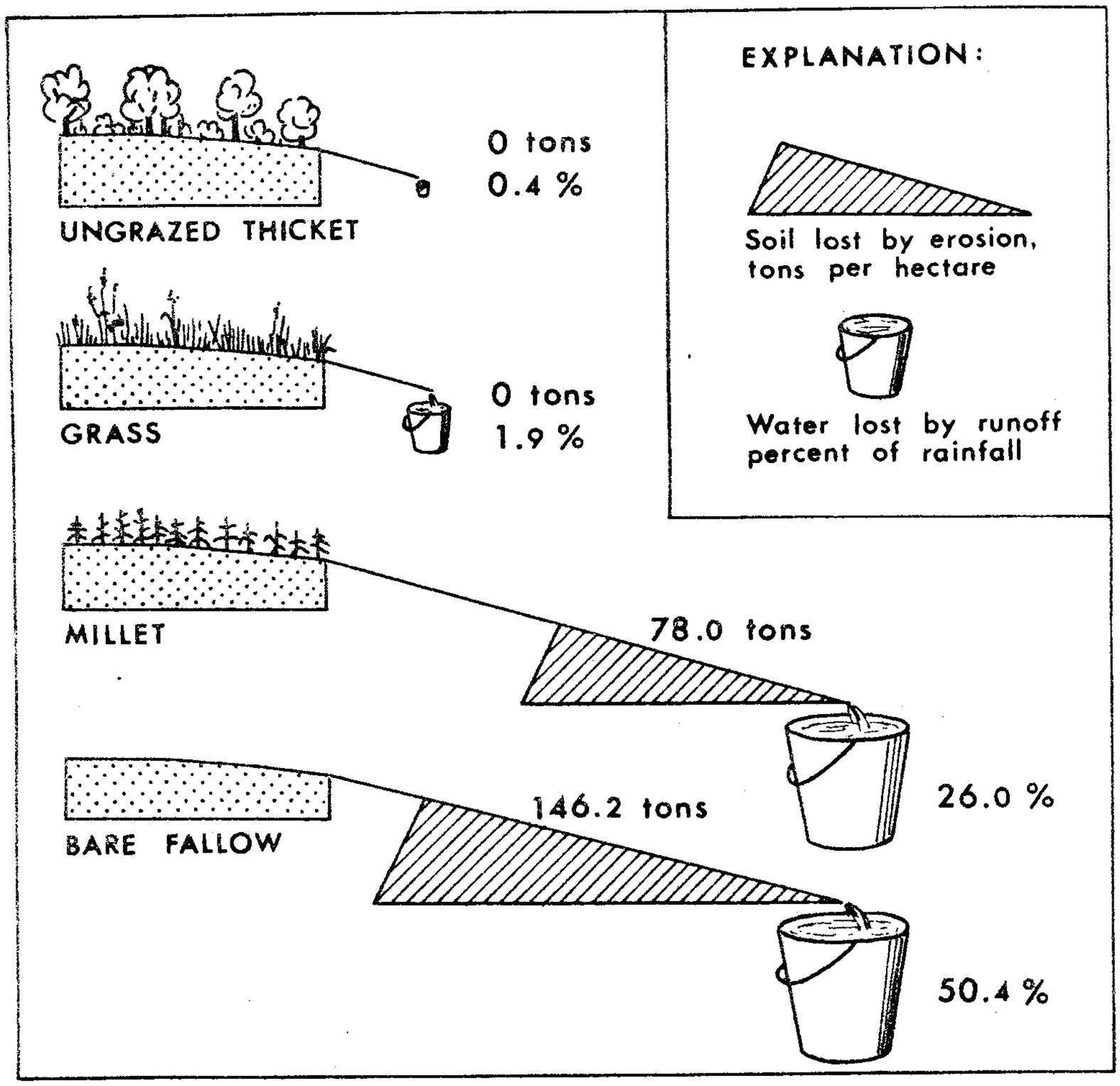


FIGURE 29. Results of soil erosion tests on ground with different vegetation covers at Mpwapwa, Tanzania
Source: Staples (1938)



NOTE: Annual average of two years records in erosion plots of 50 m^2 area of red sandy loam soil on a pediment slope of 3.5^o gradient.

The Government recognizes that the conservation of the environment is becoming increasingly important as the growth of population and the impact of development and technology bear on the capacity of the environment to sustain the use being made of it. The Government will, therefore, increase its conservation activities and, whenever possible, restore damaged environments.

The following paragraphs are condensed from a paper by T. Dunne (1973): Studies of soil erosion in Kenya.
There is a tremendous variation of erosion between the regions of Kenya. In areas of undisturbed forest, even where the topography is steep (e.g. the Sagana and Sirimon drainages), rates of soil erosion are very low indeed. The rate increases under agricultural conditions, and is much greater under grazing in semi-arid regions of the country. The highest rates of soil loss are measured in an area of very steep topography on the eastern side of Mount Kenya, where cultivation is being practised on the steep valley sides in the upper part of the basin, and cultivation and grazing are occurring in the gentler, but drier hillslopes in the lower part.

This information can be compared with sediment yields from other parts of the world. In arid regions, as effective rainfall and runoff increase, so does the mean rate of erosion - simply because there is more rainfall and runoff to cause soil detachment and removal. As rainfall continues to increase, however, vegetation becomes more dense, shielding the soil from raindrop energy and sheetwash. When there is sufficient vegetation to completely shield the ground, the rate of soil loss levels off and remains approximately constant through most humid regions.
In catchments that retain a forest cover, rates of sediment production are less than those indicated by Douglas for untouched areas in Australia.
In grazing lands of Kenya, however, the sediment yields are very high compared with those indicated by even the curve for the United States, where soil erosion is acknowledged to be a major problem in managing semi-arid rangelands. The rates of sediment production for two semi-arid basins (above Garissa and Archers Post) are 2.5 times those from catchments in similar climates in the United States and 6 times those from ungrazed semi-arid basins. Given the already poor status of the soils in these areas, this acceleration of soil erosion is of great importance for land productivity.

An even more striking example of accelerated soil erosion occurs in the steep catchments draining the eastern slopes of Mount Kenya to the Tana River. The rate of soil loss from these basins is more than 12 times that indicated for basins of similar runoff in the United States. It is a response to agricultural activity on very steep slopes, and to grazing in the semi-arid zone. Such rates of soil loss are an obvious threat to soil fertility, and to the economic life of dams planned for the Tana River.

Extreme soil disturbances are brought about by large floods. In a six-months period in 1961-62, the Uaso Nyiro drainage basin lost as much sediment as it had lost in the preceding 19 years. More than 1,000,000 tonnes of sediment per day were passing Archers Post and Garissa at the height of those floods.

Gully formation is another important soil erosion process being studied in Kenya. Rough estimates of the amount of sediment released by gullies in the Maralal area yield figures of approximately 100 tonnes/sq.km/year for the past 12-15 years. Although this figure is small compared with the yields of sheet erosion from the hillsides, gully formation is an important process of soil erosion because it damages roads and reduces the trafficability of some areas so that the effective grazing range is diminished.

Wind erosion is probably important in the western and eastern drylands of Kenya, although systematical observations are missing. One locality with frequent dust storms in June-August is Isiolo (oral inf. A. Hjort).

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Appendix to 5.4.

Location of units with erosion in Tanzania. After Baker (1970). See map 19.

Area between Serengeti and Angata Salei Plains, Masailand
Area around Kondoa
Area of Dodoma
Mbulu plateau
Pare and Usambara Mountains
Nguru and Rubeho Mountains
Hills north-west of Dar es Salaam
Escarpments bordering Newala Plateau and parts of Kilwa/Lindi
Area of Kilwa/Rufiji border
Valley of Great Ruaha, around juncture with Little Ruaha
Poroto, Livingstone and Rungwe Mountains
S. E. Shinyanga and N. E. Nzega
Eastern Shinyanga and Maswa
S. W. Maswa
Parts of northern Geita; Ukerewe
Western Serengeti
Area bordering Tarime Highlands, N. Mara
Much of western part of Mara Region and area S. W. of Shinyanga
Tarime Highlands, N. Mara
Kasulu Highlands
Kibondo area
North-west Ngara and west Biharamulo
Southern Kigoma
Numerous small, rounded hilly areas of banded ironstone in Sukumaland
Karagwe District, central Biharamulo and western Bukoba
Eastern Bukoba and Biharamulo
South-central and northern Kigoma
North-western Kigoma

5.5. Conflicts between different forms of land use

5.5.1. Crop production and animals

The conflicts between crop production and animals can be split up in two types: Conflicts with domestic and with wild animals. Of these the conflict with domestic animals cannot be considered a very serious one. Accidental or illegal grazing by cattle are, however, likely to damage different kinds of crops, especially when the availability of grazing is poor. Normally the advantages with close cooperation between animal husbandry and crop production outweigh the disadvantages. E. g. in areas where both crop and animal production are possible it is often advantageous with mixed farming, which also occurs in some areas of East Africa (see 4.2.3.1.). Crop residues can be used in animal production, and monocultures of cereals can be alternated with pastures and fodder crops.

The conflict between crop production and wildlife is a much more serious one. The mere presence of certain animals, e.g. elephants, permanently or just during a certain part of the year, may make cultivation of many crops nearly impossible. As elephants are moving over large areas in their search for food, control measures must be taken to such a degree that the future of the elephants outside the protected areas is threatened.
The protective shooting of elephants is controlled as only the people of the Game Departments are allowed to do it.

Other animals, e.g. bush pigs, baboons and most smaller monkeys, are declared as vermin and may be killed by anybody. The destroying of the crops by these animals is also the root to another habit causing certain disturbances. As their protection usually is the forest, it is a temptation for the farmers to remove the forest in order to facilitate the fighting of these pests. By doing that, soil erosion increases and it may result in larger losses in productivity than the animals caused themselves. Great losses in the harvest of e.g. sorghum may be caused by birds. Generally, with a high percentage of the children attending school the problem of crop damage by wild animals and birds is likely to increase as, by tradition, the watching of the crops is carried out by the children in school age.

The conflict crop production - wildlife is of course most serious near game protected areas (National Parks, Game Reserves), from which the animals temporarily are migrating. By an extensive protection shooting just outside these areas, the mere reason for establishing the Reserves, the wealth of animals, may be threatened. This is a problem which will grow more serious during the coming years as the population pressure on the areas not yet fully utilized by agriculture will rise considerably.

5.5.2. Domestic animals and game

As stated earlier (4.5.4.2.) keeping of domestic stock in arid and semi-arid areas may not be competitive with game animals, although the zebu cattle are very well adapted to shortage of water, even better than eland, wildebeest and buffalo. On the other hand, Thomson's and Grant's gazelles have a better ability to use metabolic water. Their greatest advantage is however their better resistance to trypanosomiasis, rinderpest, tickborne diseases etc.
The production under arid conditions (500 mm annual rainfall) has been stated about 1.5 times better from game than from domestic animals (3.7 and 2.0 kg carcass yield per ha for game and zebu respectively).

A great obstacle to game utilization (game farming, game ranching or game cropping) are the problems related to collection, handling, butchering, inspection and marketing of the meat (see also 4.5.4.2.).

Direct conflicts will arise when disease-carrying game mix with domestic stock and cause losses among non-resistant animals (trypanosomiasis, rinderpest, foot- and mouth disease). Killing of all game has been tried with questionable results. In Ankole district of Uganda 60,000 game animals were killed to make cattle raising possible but the area was constantly reinfected by migrating game. Similar experiences have been gained from Rhodesia.
In some areas lions can cause serious trouble in commercial ranches and other big game can destroy fences.

5.5.3. Forestry and agriculture

Characteristic for forestry is the need of a certain area for fulfilling its goals, whatever they are. This, in turn, leads to certain conflicts with either vested interests in agriculture or proposed extensions. Common to those purposes mentioned in chapter 4.3.5. is that they, although of utmost importance, do not have any immediate benefit for the people, like e.g. improvements in agriculture, where fast and easily comprehensible benefits can be gained.

The permanent conflicts with the agriculture has led to that the role of the forester in the eyes of the common people is mostly fiscal, meaning that he is watching his FR (Forest Reserve), punishing anybody who enters without permission. This attitude also make people in many areas suspicious about e.g. planting projects, and they look upon the projects as means of restricting their freedom. Contrary to this, most politicians at the national level seem to be aware of the necessity of forestry but, when it comes to action, they often have to yield to the local people.

The most common conflict is with the peasants outside the reserved forests. They are usually growing crop after crop, mainly with maize. Because of inadequate or non-existing fertilization, soil erosion and a rapid population growth, the lack of food increases. Knowing that by clearing the forest, fertile land will be available for at least 5-10 years, there is a very strong temptation to enter the FR. If the general administration of the country doesn't give the Forest Departments a strong support, large areas of the protective forests in high rainfall mountainous areas will be lost. Because of increasing soil erosion the effect for the whole region may be devastating. Because of such pressure, some areas with young, established softwood plantations have been given to the people for cultivation and the young plants removed.
Nearly as unfavourable effects may be caused by excessive number of grazing cattle in forests. By destroying the vegetation cover through grazing and trampling the area will be open for soil erosion and regeneration made more difficult. Without a proper control of the number of cattle most activities in forestry, be they for protection or production, are made meaningless.

In the neighbourhoods of the large miombo FR's near Tabora in central Tanzania, an increasing production of flue-cured tobacco is taking place. Large amounts of firewood for curing the tobacco is needed and, since no plantations are established, the tobacco growers have to move deeper and deeper into the FR's in search for firewood.

In certain areas, like the East Usambaras in Tanzania, the cultivation of highly profitable crops like cardamom and tea have caused rapid clearing of large areas of high forests. The problem here is mainly that unique ecotypes are destroyed (see 3.6.4.). It is likely that no violent increases in soil erosion etc. will be caused as these crops are perennial and thus the soil has a vegetation cover when the rains start.
As shown in 5.3.3.1. at least the change in water outflow is only modestly affected when transforming a high forest into a tea plantation. A somewhat opposite problem is when forest plantations are established in areas where a scattered cultivation has taken place. Much trouble has had to be taken and large sums of compensation to be paid in order to make large, manageable plantations possible.

5.5.4. Forestry and wildlife

The conflicts between forestry and wildlife are normally not as significant as between forestry and agriculture. Locally, however, the problem can be acute, as recently has been the case at the Usa project in Tanzania, near Arusha National Park, where Olea welwitschii (Loliondo), an indigenous species, had been planted together with some exotics. Because of permanent damage from mainly buffaloes and elephants, all planting has ceased. Such violent confrontations between wildlife and forestry are not so common, although experience from some National Parks indicates that a high population of elephants cannot be combined with any kind of forestry, as the trees are exterminated and only grass remains.

For Kenyan conditions, Logie & Jones (1968) describe a division of Forest Reserves and some National Parks into zones with regard to game control. Some of the zones are as follows:

1. Indigenous forests under extensive management and bamboo. In this zone animal numbers have to be controlled at a level that allows for the natural regeneration of the forests. The early signs of overpopulation consist of scarcity of undergrowth including young trees and the lack of pole stage trees. It is particularly in this zone that much more work requires to be done on the assessment of animal numbers and on the definition of acceptable levels. In this zone hunting takes place under control of the Game Department.

2. Older plantations and intensively worked forest. Here large animals need to be excluded. Where necessary, this is done by game ditches combined with a limited amount of shooting. These game ditches are expensive considered as a cost per km, but where sufficiently large areas are enclosed the cost per ha is not prohibitive. Where heavy game is present, small isolated areas suitable for plantations cannot be economically afforested at present.

3. Young plantations. Where the populations of buck and wild pig are high, these areas have to be fenced and animals excluded until the trees are sufficiently high.

The method with game ditches is further described by Clark (1968) and seems to be effective against big game if properly managed. According to Procter (1968), animals which damage the trees must be excluded from the plantations, at least when the trees are young and vulnerable. As the intensively managed plantations must be sited near markets and sources of manpower and these places mostly lie outside the game areas, conflicts are rare.
In forest reserves with natural forests, the game can be accepted but the

population must be kept under control.

Damage by Sykes monkey, which feeds on the young bark of especially cypress, is considered very serious. In no stage in the growing cycle are the trees immune from attack (Clark, 1968). The problem seems to have several causes, partly destruction of the natural habitat which has forced the monkeys to enter the plantation and also the fact that their main predator, the leopard, does not have a hunting technique that permits him to follow the monkeys in the plantations. Current control measures consist of shooting and trapping, none of them giving more than temporary relief.

Problems can also be caused by rodents, which, when present in high populations, are eating the bark of young softwood plants. The cause of high populations is probably that the ground vegetation after the planting usually is high for some years, giving good protection against predators. Among recommended control measures are to keep the undergrowth and grass short, attracting buzzards by simple bird perches, poisoning etc. The problem is that the rodent threat is not permanent and that the control measures are expensive to carry out as a routine in all plantations. The risk is evident, many control measures are not carried out until the damage is a fact, and large replanting will thus be necessary.

To sum it up, some control of the wildlife is necessary for most kinds of forestry. In plantations, especially in game areas, extensive protective measures have to be taken.

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5.6. Multiple use of land, problems and benefits

Multiple use of land has been very much in favour in e.g. USA, where mainly the combination forestry-tourism has been much used. Many ways for implementing multiple land use have been suggested for East Africa, unfortunately the out-turn has usually not been as good as expected. In this chapter a brief survey of the possibilities of various forms of multiple use and their potentials is given.

5.6.1. Combination forestry - animals

Forest and Game Reserves coincide over large areas in East Africa, and these dually reserved areas can thus be regarded as being under multiple use. The interests here are somewhat diverging since from the forestry side, the interest is to keep closed stands with a high timber production, which by no means is an optimal biotope for most wildlife. And in certain forest types, e.g. plantations, very little wildlife can be accepted. The feasible multiple use between forestry and wildlife seems to be limited to forests suited to serve as a shelter during daytime, e.g. for buffaloes, which during the dark hours are grazing on nearby open areas. The forest types suitable for serving this purpose are natural forests under extensive management and thus a fairly low output of timber.

Within most forest reserves, also the more intensively managed, there are areas where at least cows can be grazing without making any harm to the forestry activities. There is e.g. grass at the roadsides, in firebreaks and on areas under regeneration. Cows usually don't eat softwood plants, which sheep and goats do, and therefore a limited grazing could even be of benefit for the operations. But the intensity of grazing must be kept under very strict control, otherwise it will end in overgrazing, resulting in failed regeneration and/or soil erosion. For a great number of forest reserves the number of cattle per day which can be allowed to graze is actually mentioned in the management plans. In some forest reserves this cooperation between pastoralists and forestry people runs smoothly, in others the number of cattle has run out of control with discouraging results.
To sum it up, cattle grazing in forest reserves is a feasible multiple use, but very strict control is necessary.
Grazing of cattle under coconut plantations in the coastal areas has proved successful in many cases.

5.6.2. Shifting cultivation

The traditional land use in many forested areas in Kenya and Tanzania is shifting cultivation, where a certain area is cleared from the forest, the waste material burnt and the area used for agriculture crops during some years. Usually the soil is fertile during the first years after clearing because of the litter from the previous forest and the ash from the felled and burnt trees. After some 2-5 years the harvest decreases as the soil structure is deteriorating and the nutrient content diminishes as no fertilizers are added. Then the cultivators clear a new plot and start cultivating again, leaving the first area to be reinvaded by the forest, a process which is very rapid as the clearings usually are small and tightly surrounded by forest. After some 40-50 years there is again a high forest cover, the deep tree roots have brought nutrients to the crowns, which by the falling litter finally will reach the forest floor and enrich the upper soil layers. The area is now ready for a new clearing and cultivation.

As long as the population is limited this is a working model which has been in operation for several hundred years in many areas. Today, however, we are experiencing a very rapid increase in population, resulting in reduction of the forested "fallow-time". According to FAO (1974) it is now 2-30 years in Tanzania, the length mainly depending on population pressure. Subsequently, the desired fertility of the soil will not be reached by the time of the clearing, as a result larger areas need to be under cultivation, this will result in poorer water balance and soil erosion and the whole system is rapidly entering an evil circle resulting in a treeless area with low fertility.

In fact, shifting cultivation is a very inoptimal way of utilizing the forest products, as most of them are wasted. It is also a system which cannot provide food for a great many people per unit of area. It seems likely that concentration on forestry in certain areas and on agriculture in others will give the highest benefit. In most areas it will be necessary to introduce new methods in agriculture in order to avoid serious deterioration of the soils when cultivated continuously.

A specialized form of shifting cultivation in connection with forest plantations is the "taungya" system. The idea is to provide cheap clearing of land and tending of the young stands. It is carried out as follows:
A number of families obtain permission to clear plots for cultivation in the forest. After one or two years trees are planted by the forest department. The cultivators (squatters) have the duty of tending these plants by weeding etc. After approximately three years the trees are too tall to permit further growing of other crops. The squatters are then given new plots for clearing and the process starts all over again.
In Kenya this system has been very much favoured and is practiced also in connection with the final harvest and subsequent replanting of the forest plantation.

In Tanzania, the system has in many places come to a crisis when the extension of a plantation area is finished and thus there is no more land for clearing by the squatters. After some incidents with squatters refusing to leave the plantations although their contracts had expired and the tree plants were tall, the Forest Department has decided to cease this habit completely and henceforth clear with the help of employed labourers.

5.6.3. Combination livestock - wildlife

Traditionally, there has been the view among the settlers that cattle and wild herbivores cannot live together as the latter are transferring the trypanosomiasis (nagana) to the domestic animals (see 4.5.4.). This has lead to attempts of massive extinction of all wildlife in large areas of Africa, e.g. in Rhodesia (see 5.5.2.). The campaigns have not proved totally successful and the value of the method is now very much in doubt. It is likely, however, that within areas with a potential risk of trypanosomiasis infection a high population of wild herbivores, which themselves are not attacked by the disease but which can carry the contagion, will make raising of livestock impossible. As it is proved that the vectors of the disease, the tse-tse-flies, are very much attached to certain game species, it is possible that a selective exterminating of these species will prove effective (Karlsson et.al. 1973).

In other areas, where trypanosomiasis is not present, cattle and wildlife have since long been living together. This is the case in most of Masailand in both Kenya and Tanzania. The masais are hunting only to a very

limited extent and the wild animals have just been left in peace. By no doubt, certain browsers, e.g. elephants, rhinos and impala, increase the amount of grass by reducing the competition from trees and shrubs. Others, like zebras, are just competing with the cattle.
According to Enderlein (1973) the government in Tanzania has prepared a Masailand development plan, where areas have been reserved for the game in certain "Ultimate reserves" where the cattle are supposed to enter only under very adverse conditions.

In order to get the wildlife accepted by the government, some economical output will be necessary. Here the problem is that the pastoralists by tradition are not hunters, and also that the tendency up to now has been that the cattle herds are increasing in number to an extent where the environment is destroyed for both cattle and wildlife. Large changes in the fundamental thinking of the pastoralists are necessary to make such an attempt a success, changes which are not likely to occur without very strong external pressure.

Within certain fenced farms, e.g. in Kenya (Hvidberg-Hansen, 1971), attempts with keeping Thomson's gazelles together with cattle have been carried out. Biologically there seem to be no problems. These are met with in organizing an efficient cropping of the game population and an economic marketing of the products, where especially the meat handling necessitate heavy investments in mobile cooling equipment etc.

5.6.4. Combination tourism - game cropping

There are very strong regulations against shooting in the National Parks and Game Reserves in Kenya and Tanzania. It has, however, been suggested that part of the game population could be cropped either within or immediately outside the reserves (Procter 1968).
Although there are strong principal objections to such an action, this could e.g. be a solution to the present overpopulation of elephants in the East African National Parks and at the same time provide the human population with meat. Successful attempts in this way are e.g. cropping of the hippopotamus population in Queen Elizabeth National Park in Uganda (Bere, 1959). In 4.5.5. the problems and various views on control measures for too high wildlife populations are discussed.
Such steps need to be carefully considered before being implemented. There is an obvious risk that they will affect the frequency of tourists in the National Parks and thus reduce one of the larger sources of foreign exchange.

By tradition, revenues are obtained from sport-hunters in game-rich areas. This is still the case in Kenya, while Tanzania until 1 July, 1975, has abandoned all kinds of hunting. The future of this activity is difficult to foresee.

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6. LAND POTENTIAL SURVEYS AND LAND USE PLANNING

6.1. Introduction

This chapter is devoted to an analysis and discussion of the data requirements and methods of rational planning of the utilisation of land resources. Geographically, the focus is still on Kenya and Tanzania, but many of the points and recommendations put forward are applicable also to other developing countries with similar physical background.
Throughout the text, the integrated approach to land use planning is stressed. When doing so, we are also fully aware of the bias in the report towards the physical and biological aspects of land potential assessment and land use planning. This should not be conceived as a rating of importance of different aspects to be considered in land development planning - it is merely a reflection of the fields of competence of the members comprising the group. In convening a group of this professional constitution, we have interpreted it to be SIDA's intention that an emphasis should be laid on elucidating the physical and biological aspects in the analysis.

Our general aims have been:

- to indicate and explain the information needs in land potential assessment for land use planning, both at the national and at the project levels, with particular reference to Kenya and Tanzania, and

- to present an idealised framework for integrated land use planning operations at the local development project level.

The aim has thus not been to make a concrete land evaluation or to recommend any specific land use alternatives for the two countries or for any physically defined sub-division of them.

In the preparation of this discussion and analysis our points of departure may be summarised by the following quotations:

- "Political enthusiasm is indeed necessary to generate legislation and to raise funds, but decisions for action must depend on knowledge of causes and effects."(Pereira, 1973)

- "A major hazard of development is the propagation of unwise plans. These plans are an aspect of political opportunism used as a response to the restless dissatisfaction of the people and the personal insecurities or ambitions of politicians." (Caldwell, 1972.)

- "These rapid changes (in physical characteristics) both immensely increase the potential variety of crops that can be grown in East Africa and at the same time greatly intensify the difficulties associated with proper land use planning." (Brown & Cocheme, 1969.)

- "The time has come to call a halt to accepting advice based purely on speculation and to concentrate on aquiring the basic data without which no land use can be introduced with safety." (Eggeling, 1962.)

- "It is this interdisciplinary point of view that has particular relevance to development planning. It will always involve bringing together the appropriate range of expertise to enable a full environmental evaluation of any proposed way for using land and water or otherwise modifying the human environment." (Dasmann, 1973.)

These quotations are expressive enough and need no further elucidation. It is our hope that the severe critisism implied in them will gradually loose

its relevance by the incorporation of the "appropriate range of expertise" in the planning and execution of development projects involving utilisation of natural resources, including land. We are not in the position to convey this recommendation to the governments of the countries under discussion, but have to restrict the address to SIDA, which has a particular responsibility as an aid giving donour.

Although, at a first glance, the need for land use planning may seem evident, it is still appropriate in a context like this to try to identify the rationales for its adoption as an instrument and aid in development.

Man, being inseparably dependent on the natural resources, has used and misused land for as long as he has existed as a biological and social being. Failures and successes of cultures, societies and nations have more often than not been closely related to the use of the land. Deforestation and erosion contributed to the weakening of the Hellenic and Roman cultures, salinization by irrigation did the same to the old Mesopotamian cultures, and man-made desertisation has put a time limit to the flourishing of many historical cultures in North Africa and the Middle East.

This gloomy list of man-created land degradation can certainly be extended into the present time, when large scale, accelerated destruction of soil, forests and water resources over vast areas of the world points towards an inevitable decrease in the carrying capacity of land for man and for his domestic animals and crops. Due to the time-scale involved in the process, the regional seriousness of the situation is often not realised by the people affected or by politicians and others responsible for legislation and planning. It is first when acute catastrophies occur like the recent drought and starvation in the Sahelian and Ethiopian regions of Africa, that the true extent of the effects of land misuse becomes apparent.

Of course, it can be argued that land use planning could have prevented these catastrophies, as well as it can be argued that it was the unplanned use of land that lead to the historical land degradations mentioned above. But these arguments would be no more than speculations. Many spectacular examples can also be mentioned where equally "unplanned", and gradually intensified, utilisation of land has supported increasing numbers of people without any degradation of the resource base - e.g. the old, and still highly productive, irrigated paddy cultures of South and East Asia or the successful agriculture of the North European and North American temperate zones, with the notable regional exception of the "Dust bowl" catastrophy. Similarly, an endless number of past and present, successful and devastating, examples of local, unplanned land utilisation ventures could be pointed at. And further, there is a rapidly growing number of examples where planned land development, in the modern systematic sense of the word, has led to costly failures.

Land use planning as such is thus no guarantee for successful development, as well as lack of planning will not automatically lead to land destruction. More important than planning itself is the particular combination in the area concerned of physical and socio-economic conditions, the technological level, the know-how and experience of the people affected, as well as their motivation and initiative to adopt changes. Indeed, the implementation of large scale, centralised land use plans, aiming at introducing new, intensive technologies in land utilisation, may lead to a much quicker and more thorough destruction of land resources than does unplanned, traditional land misuse, if the land use plan is based on insufficnet knowledge about the limitations of the physical environment and about the effects of manipulating the land resources. Similarly, land use plans disregarding the

socio-economic context in which they are to be implemented are likely to fail.

Obvious as the above points may seem, it is still appropriate to issue a strong warning against an uncritical adoption of land use planning in development work. Calls for increasing any type of planning, including land use planning, have a strong inherent appeal to most politicians and other decision-makers, as evidenced, for example, by the rapidly growing number of international resolutions on the need for a planned utilisation of natural resources. It is, however, equally, or even more, important to make the same administrators realising the information needs and requirements for proper and rational land use planning, and to accept the implications of this by allocating enough resources to the collection and evaluation of this information, before implementing any plans.

Apart from the direct risk of failures of land use plans based on inadequate information, there is also a risk of "overplanning" the land resource utilisation. This risk is particularly pronounced in centrally planned developing countries with the ambition of quickly achieving a more efficient use of the land resources.
Criteria and aims of land use planning (see below) are, quite naturally, expressed in terms of the socio-economic and technological conditions prevailing at the time of plan formulation. These may change rather quickly, but new types of land use, once implemented and established, tend to be difficult or costly to change. The situation therefore often occurs that a land development project, although successful in relation to the original aims and criteria, after some time will be sub-optimal in light of the general social, economic, scientific and technological development of the country or region. A wise general rule, therefore, ought to be to leave as many resource use options as possible to the future and restrict the implementation of land use plans to cases where it is deemed necessary or where the potential gains are obvious.
An equally good advice to politicians is to give high priority to increase the foundation of knowledge about the physical resource base, which is not liable to rapid changes, so that when the need arises, land use planning can be based on firm knowledge about the limitations and potential of the environment.

This brings us back to the starting point of the discussion, namely to identify the rationales for adopting land use planning as an instrument and aid in development.
Why and when is land use planning desireable?
Is there anything particular in the present situation that justifies the increasing demands for land use planning?

The answer to the last question is well known and there is no reason to elaborate on it. In summary, there is a general, global need to increase the planning of natural resource utilisation for the following reasons:
- the present, unprecedented population growth in developing countries,
- the aspiration of the developing countries not only to feed their growing population from the natural resources, but also to create a surplus for economic growth and increased standards of living.

These facts and aspirations have created a situation where land, over rapidly growing areas in the developing world, has become a limiting resource to development - the traditional low-yielding, and often destructive, use of land simply is not enough to feed the growing numbers of people. As in the case with all limited resources there is therefore a strong logical justification for the rational planning of optimal land utilisation. Still, of course, with the above discussed restrictions in mind.

As a mental exercise and as a field for international rhetorics, it has become very common to study and discuss these questions in a global context. Resolutions have been passed and speeches given on the necessity to plan resources utilisation on a global basis to bridge the gap between rich and poor nations. Appealing as this may seem, it is at present, and for the foreseeable future, an entirely unrealistic approach. The concrete decisions, responsibilities and risks of land use planning - i.e. answering the first question above on why, when and how land use should be planned - will for a long time to come have to be taken at national, or even lower, levels. Looking at individual developing countries, like Kenya and Tanzania in this case, the problems of land use and its planning become exceedingly complex in light of the local variations in physical, social, economic and cultural realities. The sweeping generalisations of international resolutions are of little guidance to national and project leaders when concrete land development decisions have to be taken.

When analysing the national needs for land use planning many factors have to be considered. An analysis of the geographical extent of demands on the land for various uses may be a first help in clarifying these needs. The land can, for example, be divided according to a simple stratigraphy of demand situations thus:

- Demand is absent, for physical or other reasons - deserts; afro-alpine areas; bare rocks etc.

- Demand is singular - e.g. agriculture in fertile, already cultivated areas; forest reserves; national parks; urban areas, etc.

- Demand is multiple, either not conflicting - e.g. protection forests and wildlife, or conflicting - e.g. marginal areas suitable for both agriculture and pastoralism; unreserved forests suitable for agriculture; degraded range and agricultural lands, etc.

For the first group of land, there is no immediate need for land use planning, although deserts in a future may be interesting areas for development.

In the second group the land use type as such is predetermined and land planning, when considered relevant, will concentrate on intensifying existing land use by diversifying it or by introduction of new technologies and improved management systems. It is in this group of land that the highest population concentrations are found today and it is by far the economically most important areas, e.g. the Kenya Highlands.

The need for land use planning in the traditional sense, i.e. to determine the optimum types of land utilisation for various tracts of land, is in principle greatest in the last group, where conflicting demands on the land are present. In East Africa, this type of land is by far the most extensive in area, including most of the semi-arid bushland, savanna and woodland, where shifting agriculture, local permanent agriculture, pastoralism, wildlife utilisation and forestry presently are the main land uses, often carried out on a very extensive basis. These areas represent a theoretical potential land reserve for absorbing the growing population of the densely populated lake, highland and coastal areas.

At the same time, however, the present extensive land use, although supporting only small numbers of people, show signs of leading to land degradation by erosion, loss of fertility, impoverishment of vegetation and, ultimately, desertisation. A clear need for land use planning thus exists, if these last reserves of land shall not be degraded beyond repair by un-

controlled utilisation. Priority areas in need of immediate planning must be identified.

Apart from such a reconnaissance survey of national areal needs for land use planning, an analysis of present land use ought to be carried out. Even if most of the areas concerned can support alternative patterns of land use, it is often, for social and cultural reasons, difficult to change an established pattern of land use. Besides, in areas where the physical base is poor, the number of alternatives is generally low and the present land use, except in cases where it is obviously destructive, may be better adapted to the physical conditions than is often realised by administrators and planners.

Present land use is the result of different causes, many of which are directly related to the nature and quantity of land resources, others of which have their origin in cultural, social and economic conditions of the past and their developments within the context of history. As a result it is obvious that present land use is seldom in accordance with the interplay of today's resources and human society. Often, it is even less adapted to the requirements of tomorrow as these can be estimated by a projection of today' s ideas and needs. Present land use, therefore, must always be, if not continually, at least periodically, tested against other possible methods of land use.

Although the ideal situation in land use planning is to be able to deal with large undeveloped areas, with ample funds available for development and no pressing time schedule, this combination is hardly ever encountered in practice. In Kenya and Tanzania, certainly, there are relatively few areas that are not already under some form of use. There is never enough money and, for political and social reasons, there is always a pressing time schedule. These facts implies the need for national priorities for determination of when and where land use planning should be carried out, and it is when establishing these priorities that the above discussed analysis of demands on land, and of present land use are relevant and desirable.

An equally important consideration when establishing land development policies is the identification of national criteria for land use planning, to serve as a frame, within which objectives for regional or project land use plans shall be formulated. There are three major sets of factors - social, economic and ecological - that must evenually be considered in the course of developing stable successful patterns of land use. Since the interplay of these three aspects is always involved, either in the development of new forms of use or in the maintenance of existing forms, it follows that criteria in land use planning should include social, economic and ecological criteria.

At the highest level - national criteria for land development as such - these criteria will have to be expressed in rather generalised terms; e.g. efficient allocation of resources, economic growth defined in terms of per capita income, high and stable employment, equitable distribution of income and conservation of natural resources. Any nation's planning activity will serve some mixture of these goals. The relative importance attached to each of them will differ among nations and also in time, but these differences should not obscure the point that the role of all land use planning is to serve some high level set of national goals. To derive appropriate and faithful working criteria from those goals is indeed a major problem in local land use planning.

However, in land use planning at local or regional levels, it is not enough to be guided by these generalised criteria. Decisions about developing various forms of land use - e.g. crop production, forestry, animal husbandry, wildlife utilisation, nature reserves, etc. - must also be based on specific criteria laid down for each of these land uses. Such criteria will theoretically play a major role in land evaluation (see below), which is the basis for land use planning. In practice, in countries like Kenya and Tanzania, large difficulties will arise when integrating these criteria in the land evaluation and planning processes, due to lack of knowledge about the physical requirements of the different land uses. A simple, theoretical example may clarify the point:
The national criteria for forestry with regard to timber production is to make each region selfsupplying. A demand analysis shows that, say, 1 mill. m^3 will be required at a certain time. For the land use planner the problem is to find land to fill this requirement. But, to evaluate a tract of land in relation to this aim, he must quantify the potential of the land in terms of how many m^3 it can produce. This, however, can only rarely be done with the present level of knowledge about land resources and the physical requirements of the land use in question.

A final, introductory elaboration should be made on this important issue of land evaluation.
Throughout this report we have analysed and identified the physical information needs for land potential assessment and the feasibility aspects to be considered in land use planning. Furthermore, we have stressed that land evaluation, which forms the direct basis for decisions on land use, must be based on a synthesis and integration of the physical potential and various feasibility aspects, and related to specified land utilisation types. What is not discussed and analysed in detail, however, is how the actual evaluation process shall be tackled, i.e. how to quantify the social, economic and ecological values of various anticipated land uses from a defined piece of land, with certain physical characteristics, so that a direct comparison can be made between different land use alternatives. This is a crucial problem that eventually will be encountered in practically all concrete land use planning operations.

In many developed countries with a large foundation of knowledge about the physical resource base, detailed insights in the physical requirements of different land uses and a well developed and sufficiently staffed land research and planning organisation, much effort is laid down in developing land evaluation systems suited for computer analysis. It was, for example, recently stated at the FAO Consultation on Land Evaluation (Brinkman & Smyth, 1973):
"A systematic approach by linear and non-linear programming techniques of land evaluation systems for alternative land uses in rural areas must be one of the main goals of further development in this field. As agricultural production takes place in an integrated process, land evaluation systems will have to be based upon techniques which simulate this process as closely to reality as possible."

The level of knowledge about even basic aspects of land resources and land use requirements is far too low in Kenya and Tanzania to make such sophisticated evaluation systems feasible at the present. For a long time to come, land evaluation will have to rely upon rather crude approximations of the local information on land use requirements, that happens to be available and relevant in each area.

However, even if the quantitative data requirements for computer modelling is not available in Kenya and Tanzania, there is one, potentially very

beneficial, application of a systematic programming approach to the complex of interactions between physical parameters and land utilisation types. By creating a two dimensional matrix in which the physical and other relevant land characteristics are broken down into their relevant components in one dimension and the commodities and services produced by various land uses in the other, it will be possible to schematically indicate qualitative relationships between the two dimensions. Experience, even if limited, and common sense will also enable a crude quantification of these relations, e.g. it is possible to say if soil texture is very important, just relevant or non-significant for irrigated crop production etc. By relating such a matrix to present knowledge, it will be possible to make a systematic identification of important gaps in knowledge and to establish priorities concerning surveying and research work necessary for continued land evaluation work.

This systematic approach has been developed and discussed by Singh and Nilsson (1974) with special reference to different forest based land uses. Their system is, however, in principle generally applicable and with some further refining and local adaptations it could be of great help in concrete planning situations in East Africa.

With this conclusion we terminate this introductory discussion about the general context and problems of land use planning and return to the contents and aim of this chapter - to indicate and explain the information needs in land potential assessment and to present a framework for land use planning at the local level.
In summary the contents of the sections in this chapter are:

Definitions and concepts (6.2.) gives a general frame for the use of the key words of this report in general and chapter 6 in particular. Various concepts of "land" are presented and definitions of "land use", "land resources", "land evaluation" and "land suitability" are presented and discussed.

National land potential surveys (6.3.) discusses the aims of preparing country-covering small-scale reconnaissance surveys. Further, the present status and desired development of the various national surveys and mapping of the basic land resources determining physical land potential - topography, geology, climate, hydrology, soil and vegetation - are discussed. The two different approaches used by the two countries in preparing national land potential maps are described and their limitations are analysed. A third approach, "evapotranspiration ratio", is tentatively presented and its applicability to Kenya and Tanzania is discussed. Finally, the general social considerations, against which physical land potential has to be tested before defining national land development policies, are treated.

Local, integrated land potential surveys (6.4.) is dealing with the basic problem of physical information needs for land potential classification at a local (project) level. Methods and problems of basic resources surveying are discussed in some detail and an approach to delineating physically uniform land management units is presented. Finally, the USDA land capability classification is described to show one possible method of rating land units with reference to a particular use.

Special surveys (6.5.) discusses the information needs for the planning of five different land uses. The examples are taken from the fields of specialisation of the members comprising the group preparing this report.

Feasibility aspects (6.6.) should be read as a continuation of 6.4. The various sets of factors - national and project goals, social and economic

considerations and ecological considerations - are discussed, which are necessary to superimpose on the physical land potential before a realistic, feasible land evaluation, which can serve as a basis for land use decisions, can be achieved.

Developing a land use plan (6.7.) describes, as an example, an actual land use planning operation in the Sudan, including how the type of surveys and pre-feasibility aspects discussed in 6.4. and 6.6. have been carried out and considered in the plan formulation.

Implementation (6.8.) discusses briefly some important aspects and potential bottle-necks in the implementation phase of a land development project.

Evaluation of impact (6.9.) emphasises the importance of an efficient continuous evaluation of the socio-economic, technical and ecological impacts of a land development project to ensure that corrective feed-back mechanisms are available.

Summary and conclusions (6.10.) stresses again, in a summarised form the main points and recommendations emphasised in this analysis, and presents an attempt to a systematic approach in land use planning for local development projects by summarising into a diagram how the contents in the various sections are connected to each other. This diagram may serve as a basis for developing a practical system of land use planning.

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6.2. Definitions and concepts

Throughout the previous chapters, the key words of this report - "land", "land use", "land potential", etc - have been used without formally defining them. Among most persons dealing actively with various aspects of land utilization there is a general consensus about the practical meaning and implications of the terms "land" and "land use". No doubt, however, even subtle differences in opinions about the meaning would create disagreements when it comes to accepting a precise, unifying definition of the words. These difficulties are even more pronounced when trying to find generally acceptable definitions on compound terms like "land suitability", "land potential", "land development", etc., where the second words - suitability, potential, development - imply the need for defining a reference base - e.g. suitability for what and under what conditions?

We have not considered it relevant, or desirable, to agree upon detailed definitions of these terms or to use them in a strictly consistent sense throughout this report. Where the use of the words does not conform with the conventional meanings, this is quite obvious from the text.

In the following some definitions are discussed, mainly with the aim of presenting the approximate conceptual frames within which the terms are used. Most of the quotations are taken from the recently published book: "Land Use in Advancing Agriculture" (Vink, 1975). This is the first comprehensive text-book on land use questions published, and it contains a number of interesting view-points and systematic approaches to land use problems which regrettably were not available when preparing the major parts of this report.

As a starting point, however, it may be appropriate to quote two definitions of the basic work "land", taken from other sources, and showing two principally different concepts of "land".

"The term land refers to all these physical and biological characteristics of the land surface which affect the possibility of land use, in other words the whole combination of factors which constitute the agro-environment. In practice, it refers more particularly to the obvious, inherent features of the land surface, namely to topography, soils, vegetation and climate." (Christian, 1959).

"Land is the total natural and cultural environment within which production takes place. In addition to soil, its attributes include other physical conditions, such as mineral deposits, climate, and water supply; location in relation to centers of commerce, populations, and other land; the size of the individual tracts or holdings; and existing plant cover, works of improvement, and the like." (Soil Conservation Society of America, 1970.)

The first definition is more narrow, restricting the term land to physical and biological characteristics, whereas the second includes the total natural and cultural environment. The elaborate discussion in Vink (1975) on the basic terms "land" and "land use" is quoted in a slightly shortened version below to elucidate how complicated it is to actually separate these two concepts.

"Land use is any kind of permanent or cyclic human intervention to satisfy human needs, either material or spiritual or both, from the complex of natural and artifactial resources which together are called "land". Land carries ecosystems; land use is the application of human controls, in a relatively systematic manner, to the key elements within any ecosystem, in

order to derive benefit from it. Man, although an inherent part of the ecosystem in which he lives, places himself to some extent outside the system and tries to manipulate it. He may do this in a very intensive manner, as is seen in the paddy cultures of Asia or in the horticultural cultures of Western Europe, or in a very extensive manner, e.g. the semi-nomadic peoples of Africa.

Land, being the carrier of those ecosystems which provide the most benefits to mankind, is the over-all natural resource. A resource is there to be used, and use takes place in specific areas and at specific localities. Although land may be viewed from a broad, holistic concept in natural science, its use always involves specific surface areas; land is therefore a truly geographical concept. The land as we see it today is in many areas the result of a combination of both its natural genesis and the human influences which have been brought to bear on it in the past and of those which are still active in the present.

Land is a dynamic concept; it carries ecosystems, but is itself also a part of these ecosystems. One of its main components, the soil, is itself a complex ecosystem containing animals and plants of different sizes and activities. Natural processes occurring in the land derive energy from the sun as well as from mineral and biological sources. Relief, which is one source of energy, i.e., the energy provided by differences in height, is a specific attribute of the land surface. Land, although tending towards a steady state, is therefore never truly stable. The land, viewed as landscape, as observed today by both visual and other methods of perception, may achieve near stability from certain points of view, but this stability is the result of complex interactions of a multitude of phenomena and processes. We try to use this for our own ends and hope to induce those kinds of near-stability which will benefit us most on a long-term basis.

The best definition of land therefore is one which involves the geographical aspects of "a tract of land" and reads: A tract of land is defined geographically as a specific area of the earth's surface; its characteristics embrace all reasonably stable, or predictably cyclic attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying rocks, the topography, the water, the plant and animal populations and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

This definition obviously includes all land resources, both natural and man-made, of a clearly permanent or cyclic nature. Vegetation and animal populations, both natural and man-induced, are definitely included. Permanent artificial structures such as dikes, canals, metalled roads or stable terraces are also considered a part of the land. Several institutional factors, however, are not included. Thus, a distinction must here be made. The concept of land as a natural resource does not include the institutional aspects; scientists adhering mainly to this conceptual approach prefer to include institutional aspects with the "land utilization type". Land as a "tract", i.e. as a geographically defined specific area, does include the permanent or cyclic institutional attributes. Thus, the general field pattern and the system of ownership of a particular tract of land are attributes of the land itself, because they are relatively permanent. Whether a particular individual is at a certain moment the owner of a tract, which may be a subdivision of the above-mentioned one, is not an attribute of the land, because in many social systems ownership may be changed by a simple deed. National and administrative boundaries, also relatively permanent, are attributes of the land as well. In some cases they may even have

a marked influence on the resources of the land. In land development planning as well as in environmental management, these attributes often are highly significant; they offer both resources and limitations which may have to be adapted by rural reconstruction, in order to use the land to its best advantage." (Vink, 1975.)

In the initial definition of "land use" given above it was stated that land use is an intervention of the complex of natural and artifactial resources making up "land". What these resources included was somewhat elaborated in the definition of "land". Before proceeding to Vink's definition and discussion of "land evaluation", a further elaboration on the term "land resources" will be quoted.

"Land resources include all those features and processes of the land, which can, in some way, be used to fulfill certain human needs. As can be seen from the definition of "land" given above, these resources are numerous and complex.
For agriculture, the most important land resources may be indicated in broad groups:

a) climate,
b) relief and geological formations,
c) soils (including soil hydrology),
d) water (including geohydrology),
e) artifactial elements of a stable nature,
f) vegetation and related biological features.

The land resources may be divided into three groups: (1) very stable resources (climate, relief, geological formations), (2) moderately stable resources (soils and water, some artifactial elements of the land), and (3) relatively unstable resources (vegetation and related biological features). The stability of a particular resource is seen in relation to its period of formation as well as to the ease with which human activities can influence it, causing either degradation or improvement." (Vink, 1975.)

The "land resources" thus defined by Vink, approximately equals the "basic resources" treated in sub-section 6.4.1. in this report.

One of the key problems in land use planning is the evaluation of the suitability of the land to sustain different forms of land use. Since this problem is the main concern in this chapter 6, it is motivated to include the following lengthy discussion from Vink on land evaluation, the ideas of which closely coincide with our concepts.

"Land resources as such are phenomena of nature which are described in strictly scientific terms; they give no indication themselves of how they could or should be used. Land qualities, or ecological land conditions, are used as a means for indicating the direct relations between the land as an ecological complex and the biological and technological activities of land use. A land quality is a complex attribute of land which acts in a manner clearly distinct from the actions of most other land qualities in its influence on the suitability of land for a specific kind of land use. The land qualities may therefore be used as diagnostic criteria for land suitability, but they do not themselves indicate a suitability. Land qualities are extremely useful in indicating how a land, with given natural (resources) characteristics, could be used in a given land utilization type. They do not, however, indicate whether one land utilization type would be better suited to a particular kind of land than another. Land qualities are

also essential for indicating improvement needs of lands, but they do not indicate whether a particular improvement would be suitable for execution within any relevant and foreseeable land utilization types.

For the purpose of judging land suitability, both for land use and for land improvement, a systematic land evaluation is necessary. Land evaluation is the process of collating and interpreting basic inventories of soil, vegetation, climate and other aspects of land in order to identify and make a first comparison of promising land use alternatives in simple socio-economic terms. Land evaluation therefore bridges the gap between the physical, biological and technological means of land use and its social and economic purposes. Land evaluation is not economics, but neither is it a purely physical discipline; it is the utilization of social and economic parameters in evaluating physical data. The actual characteristics and behaviour patterns exhibited by the social and economic data used for this purpose lie within the sphere of the investigations carried out by the social scientists and economists; likewise, the physical data are, or at least should be, used as parameters for social and economic evaluations.

Land suitability is the fitness of a given tract of land for a defined use; differences in the degree of suitability are determined by the relationship, actual or anticipated, between benefits and required inputs associated with the use on the tract in question. In its most quantitative form, land suitability is expressed in economic terms of inputs and outputs, or in its results as net income or, especially in developing regions, as standard of living of the farming population.

Land evaluation is, however, often carried out in relative terms, partly because insufficient quantitative information is available, and partly as a first approximation in a complicated iterative procedure. This is often called "land suitability classification" of which the definition reads: Land suitability classification is an appraisal and grouping (or the process of appraisal and grouping) of specific tracts of land in terms of their relative land suitability for a defined use.

Land suitability is the expression of the physical and ecological potential of a land based upon certain social and economic assumptions. The assumptions used in land evaluation are concerned with the nature and processes of the relevant and foreseeable land utilization types. The nature of the assumptions has to do with the economic and social conditions in their widest sense and with the level of technical know-how of the farmers. These assumptions, and the kinds of land utilization types, must be clearly indicated in any land suitability classification.

Land evaluation, using sets of assumptions which are of value only during a specific period, is always relatively ephemeral. Changing social and economic conditions, or technological developments, including the introduction of new varieties of crops, may lead to different suitabilities of the land. The basic land resources are much more permanent. These can only be changed by large projects of major land improvements or by catastrophic natural processes: volcanic eruptions, earthquakes or floods. In general, therefore, land resources data and land resources maps are the only reliable bases for predictions and interpretations of land qualities and land suitabilities. Basic land resources maps can always be reinterpreted for practical use with new assumptions or under new conditions.
Land suitability can be interpreted from land resources maps using two main sets of assumptions about land conditions:

a) Actual land suitability, i.e. the suitability of land units for the use in question in their present condition without major land improvements.
b) Potential land suitability, i.e. the suitability of land units for the use in question at some future date after major land improvements have been effected where necessary.

Land evaluation is an essential tool in land use planning. It is assigned the indispensable task of translating the data on land resources into terms and categories which can be understood and used by all those concerned with land management, land improvement and land development. The process of integrating land evaluation and land use planning is, however, much more complicated than is often realized." (Vink, 1975.)

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6.3. National land potential surveys

6.3.1. Objectives

A national land potential survey may be regarded as an instrument for defining, classifying and ranking the use and management of land resources. It must be undertaken in conformity with the specific requirements of different types of land use. As a national instrument it must necessarily be expressed on a small scale reconnaissance type level of the order of 1:1 million or so. Here the central government may express its political goals in more practical terms, giving guidelines for local government bodies to regulate developments on a larger, more detailed scale.

Particular emphasis must be placed on land resources and ecosystems which are currently subject to heavy development pressure, for example forests, savannas, high mountains and coastal areas. By way of leading into future studies, various problems associated with dams, irrigation and major river basin development, forestry, livestock and agricultural projects as well as the rather specialized case of tourism development, must also receive due attention.
Land potential surveys must be made through close liaison between development agencies and experts on ecological evaluation and environmental assessment. The goal should be to achieve both conservation and economic development or, in other words, a framework for the rational use of land resources to provide the highest possible quality of living for the citizens of the country.

Conflicts will undoubtedly arise between ecological, political, social and economic forces, but each must be conditioned for compromise. From an ecological point of view three principles should be borne in mind (Dasman et al., 1973): firstly, the need to keep a range of resource use options available to future generations,
secondly, the fact that, for reasons based on their history and evolution, more intense agricultural and pastoral development of lands of proved productivity is likely to give a better return than attempts to develop marginal areas,
and thirdly, the fact that conservation of species and natural communities is a logical first step in development, for the reason that the resources of such communities are irreplaceable both from the point of view of satisfying human aspirations and also because of their long-term contribution to the stability and productivity of the planet.

Conflicts between development and conservation can be minimized if there is a well developed understanding and partnership between those involved on either side. This is particularly so during the process of selection of options for land use planning of new development areas. A physical land use plan is generally evolved which includes the best possible balance between development and conservation aspirations. It is based on surveys indicating permissive land use policies for various types of utilization such as agriculture, forestry, settlement, recreation, etc, and restrictive policies for the protection and management of limited and fragile resources, such as unique geologic formations, wild life, water catchments, cultural values, etc.

At present, few nations have carried out comprehensive land potential surveys based on adequate resource inventories and mapping, and, as a conse-

quence, even fewer countries have produced any land use plans or formulated more than very general policies on land development priorities. For the most part there exists piece-meal type plans that lack expression of goals and mechanisms of effective steering and control. In Kenya, a Land Capability Survey has been commenced to incorporate relevant knowledge of land potentialities for different types of usage and conservation.
What we need to stress here is that national surveys must strive towards integrating both ecological potentialities and socio-economic ambitions, so that an appropriate balance between conservation and development may be set up as a planning and control instrument.

6.3.2. Physical information handling

The aim of a national land potential survey should be to provide politicians, administrators and other resource managers with an instrument with which small-scale geographic priorities concerning development of various land uses can be established.

Since land potential is a function of the interaction of the basic physical and biological land resources of climate, topography, soil, geology, hydrology, vegetation and fauna, it follows that no land potential can be assessed without adequate knowledge of the geographic pattern of these resources.

In East Africa, resource inventories and mapping have been going on for a considerable time and small-scale national maps (1:1 milj-1:5 milj) have been presented, e.g. in the National Atlases of Kenya and Tanzania. Many of these maps are shown in chapter 3 of this report.

The very fact that these maps have been published might give the impression that the basic resources surveys have reached an advanced stage and that there is enough background material to safely predict land potential for different parts of the countries. This is however far from the case - most national resource maps can merely be regarded as preliminary reconnaissance maps, based on inadequate factual information. There are too many unfortunate examples where these maps have been used far beyond their respective permissive limits of use, sometimes with very negative results (e.g. the Groundnut scheme).
Thus the use, for land potential assessment, of the physical information presented in the various national maps requires a knowledge of the inventory and survey techniques and intensities used as a background when compiling the maps. The following points may be useful to keep in mind (they should be seen as supplements to the text and maps in chapter 3 and Appendix 1).

- The surveys underlying the different resource maps have been carried out by various national government departments and ministries and by East African Community departments. Methods of data collection, sampling intensities and, consequently, reliability vary considerably. There are also large regional differences in coverage and quality. Little or no co-ordination between the different resource inventories has been carried out.

- Topographic mapping is well underway in both countries, with good, although not complete, coverage of 1:50,000 and 1:250,000 maps based on aerial photographs. It should be noted that these topographic surveys and maps are the only exact resource inventories carried out in the countries, all other inventories relying more or less pronounced on extrapolations and approximations from topographic maps and aerial photos. One can therefore

safely assume that the soil and vegetation maps, for example, are much more reliable for those parts of the countries where good, contoured topographic maps exist.

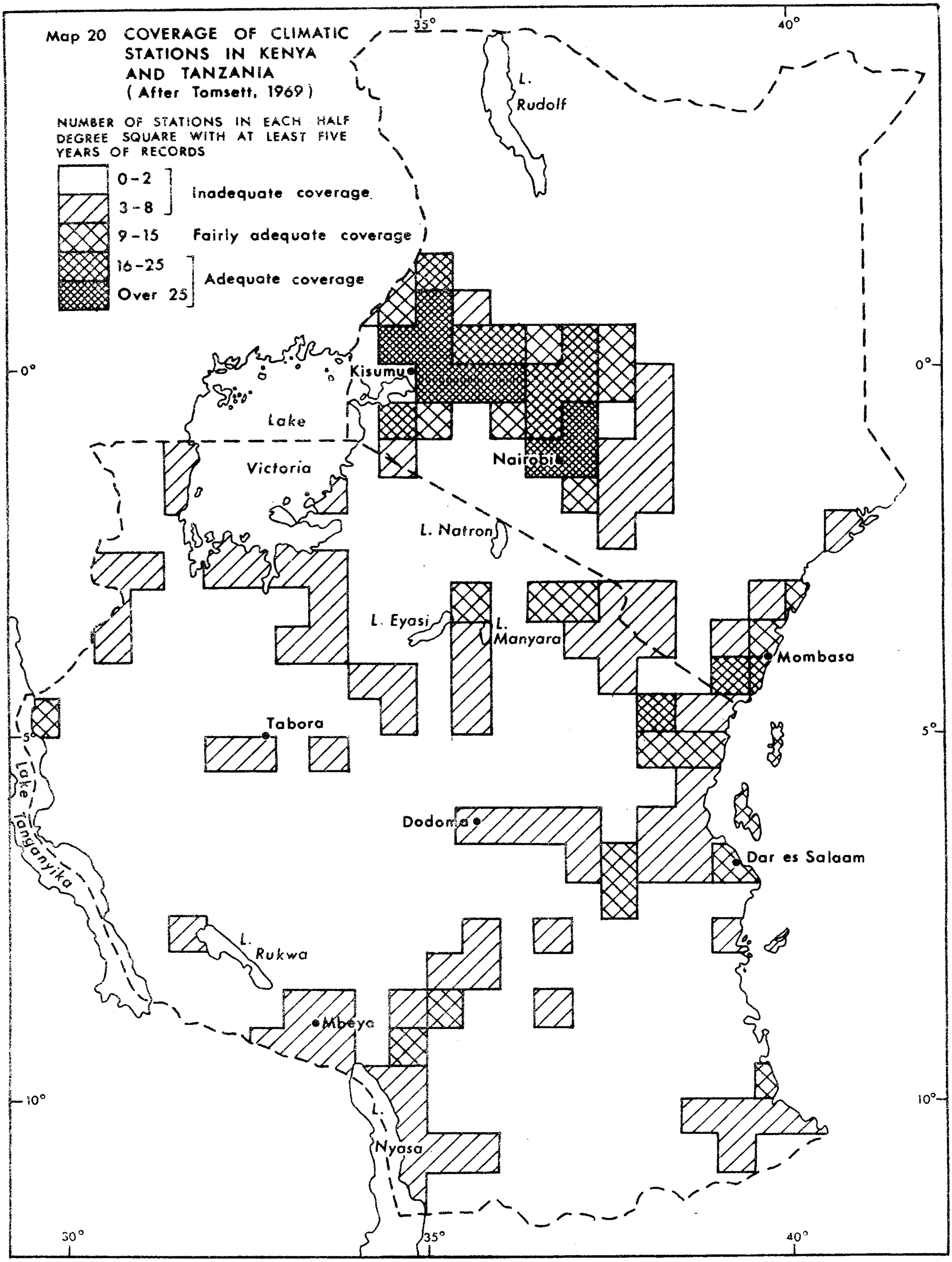
- The systematic geological surveying, covering about half of Tanzania and Kenya with maps in scale 1:125,000, is the second most reliable inventory. Field sampling intensity is very high, and also for those areas not yet covered by large scale geological maps there is normally quite sufficient information available. Geological surveys and studies started very early and intensively, in both Kenya and Tanzania, the reason being to prospect the countries' mineral resources.

- Climatic data are compiled by the E. A. Meteorological Department. Numerous climatic maps on scales ranging from 1:1 mill. to 1:5 mill. have been published (see 3.1.). In East Africa climate is by far the most important limiting factor for most land uses, both via its direct and indirect influences.
  All other land resources have their impact on land use within the general context of the given climate. It is therefore of fundamental importance to realise, for those responsible for land potential assessments and for decisions on regional land development priorities, that the coverage of meteorological stations is sufficient only for limited areas. Practically all of the vast semi-arid regions of East Africa have an inadequate coverage for compilation of reliable climatic maps. In map 20 this is clearly shown. Not only are there too few stations, but the number of years of records is often too short to allow statistical treatment, readings are often carried out by unqualified personnel, broken instruments take long time to replace (giving discontinuous series of readings) etc.

- The intensities of hydrological measurements, e.g. lake level measurements and stream flow gauging, shows a clear regional imbalance. Northeastern and eastern Tanzania is fairly well covered by hydrological stations whereas western Tanzania almost entirely lack hydrological measurements.
  The close interrelation between climate and hydrology would have made a coordinated network of stations logical, but it is only recently, when installing new measuring stations, that this has been achieved.

- The small scale soil maps published for Kenya and Tanzania are probably the most insufficient of all basic resource maps. They are based on very little field observations of the soils, and boundaries between soil groups are almost entirely drawn with the help of topographical, geological and climatic (see above) maps. In Kenya, for example, only 2.5% of the country has been actually soil surveyed in various degrees of detail since 1945. The coverage in Tanzania is probably even less.

- Also the actual coverage of field surveys of the vegatation is small in the two countries, though the use of aerial photo interpretation in combination with a low degree field sampling would allow a fairly sufficient method. There are however no government departments directly responsible for vegetation surveying and most of the data used for the national vegetation maps are based on a large number of local, unrelated surveys and indirect delineations based on topography. The knowledge of the vegetation distribution is nevertheless quite good in Kenya, where the range survey work by the Range Management Division has considerably increased the knowledge of the vegetation of the semi-arid regions. A systematic vegetation survey of south western Kenya has also been published in maps


Map 20 COVERAGE OF CLIMATIC STATIONS IN KENYA AND TANZANIA
(After Tomsett, 1969)
NUMBER OF STATIONS IN EACH HALF DEGREE SQUARE WITH AT LEAST FIVE YEARS OF RECORDS
0-2
3-8
Inadequate coverage
9-15
Fairly adequate coverage
16-25
Over 25
Adequate coverage
35°
40°
L. Rudolf
0°
Kisumu
Lake Victoria
Nairobi
L. Natron
L. Eyasi
L. Manyara
Mombasa
Tabora
5°
Lake Tanganyika
Dodoma
Dar es Salaam
L. Rukwa
Mbeya
10°
L. Nyasa
30°

in scale 1:250,000. In Tanzania the amount of systematic information is much less, and the vegetation map is based entirely on old, very approximate sketch maps.
Considering the rapid, man-induced changes of the vegetation, it is important to be aware of the age of the background material (e.g. aerial photos) when using the published vegetation maps for any type of land potential assessments.

From the above points it should be clear that the present status of basic land resources surveying is quite insufficient for making a reliable land potential evaluation over large parts of East Africa. This fact has also been realised by the governments in the two countries. It is, for example, stated in the Kenya Development Plan 1974-1978:

"Land is Kenya's most important natural resource. It is therefore important to establish the actual and potential capability of the land. Over the years, considerable knowledge about land forms, soils, precipitation, run-off, land use and erosion has been acquired. Much of this information has never been published, although it has been used in the design of various government programmes.
It is proposed that, during the current Plan, this accumulated knowledge will be updated and collated for planning purposes. The basic topographical survey of the country will be accelerated, the stream run-off monitoring programme will be extended and programmes for surveying and analysing soil types will be expanded. In addition, it is proposed to start publishing a series of agricultural land use surveys in graphic and cartographic form.
The Land Capability Survey will be co-ordinated by the Natural Environment Advisory Research Committee and a number of different Government agencies will be involved in the programme."

As a part of this programme an agreement has been signed under which the Netherlands will provide financial and technical assistance for five years for a Soil Survey Project. The project will deal with four types of survey:

- country-wide exploratory survey
- reconnaissance survey
- semi-detailed survey
- detailed survey

Most effort will be devoted to the reconnaissance survey because it provides the basic inventory of soil and land resources from which to plan agricultural development.

Another recent project of integrated surveying is the Land System Atlas of Western Kenya, described in section 6.4.2.

In Tanzania, the Bureau of Resources Assessment and Land Use Planning (BRALUP) was established in 1967 at the University of Dar el Salaam. It deals, as the name implies, with compilations and analysis of resources, both human and physical, for land use planning purposes. A great deal of very useful work has been published already, but BRALUP is presently understaffed to take on the enormous task of carrying out a systematic, small-scale land potential inventory (say on a scale of 1:250,000).
A new edition of the Atlas of Tanzania, incorporating much of the new information on basic resources that BRALUP has produced, is ready and awaiting publication.

The need for a systematic activity in Land Use Planning was recently emphasized by IBRD in their report on Tanzania:

"Critical among present constraints is the dearth of reliable detailed data on the production potential of the different agro-economic zones, 46 of which have been identified (Conyers, 1973). Information is particularly needed for each zone on such matters as soil conditions, present yields, farming systems and erosion problems. With this information in hand, it will be possible to identify area expansion possibilities and establish optimal farming systems. A real improvement in land use planning and applied research is thus not only a high priority, but must necessarily precede the more intensive agriculture programmes which Tanzania needs to develop over the next 20 years."

The conclusion and recommendations by IBRD were:

"Thus, increased efforts in land use planning and research should be designed to:

a) Provide an expanded data base for the various agro-economic zones with particular emphasis on soil conditions, climate, present yields and farming systems, erosion and fertility problems.

b) Identify possibilities for the expansion of cultivated areas and grazing land as well as priorities for required investments in roads, water, social facilities, and tsetse control.

c) Establish optimal farming systems (crops, rotations, soil converva-tion measures, integrated farming).

d) Identify yield improvement opportunities for different crops.

Such planning will require a joint effort by the BRALUP, the Ministry of Communications and Works, regional and district administrations, and the Ministry of Agriculture (Research Division, National Soil Service). The Ministry of Agriculture should assume overall responsibility for the coordination of these efforts, and a special land use planning unit needs to be established for this purpose."

Another project that will help in filling important gaps in the knowledge required for land potential analysis in the little surveyed western parts of Tanzania is the NORAD-assisted establishment of a network of hydrometeorological stations in these regions.

An agro-meteorological section has recently been established within the East African Met. Dept. The aim of this section is to expand the network of stations throughout the marginal potential areas in East Africa where much new agricultural development takes place and where the present network of stations is insufficient (cf. map 20).

In conclusion it can be said that the most urgent needs in the handling of physical information for land potential assessments in Kenya and Tanzania are:

1. A comprehensive, systematic compilation and treatment of all relevant data existing on physical resources today in order to clearly identify the gaps in knowledge. There is an enormous amount of information "hidden" in old and recent surveys and investigations, relating to special projects or limited geographic areas, known only to the departments,

organisations or even persons who have been responsible for them.

2. A speeding up, or initiation of systematic basic resources surveys, e.g. soil, hydrology, climate and vegetation and, at the same time, establishing a closer co-ordination between these surveys.

3. The establishment of national land potential surveys, aiming at integrating the information from the basic resource surveys into a form which can serve as an instrument for decisions on land use developments (e.g. land potential maps in scales 1:100,000 - 1:250,000).

It is quite natural, however, that the development of agriculture, animal husbandry, irrigation projects, forestry and other land uses, cannot await the completion of an integrated small-scale land potential survey. Indirect and approximate methods to assess regional differencies in land potential have to be relied upon in the meantime, using the relevant physical information that is available. Two methods, from Tanzania and Kenya respectively, will be discussed in the following sections, as well as a method not yet applied in East Africa.

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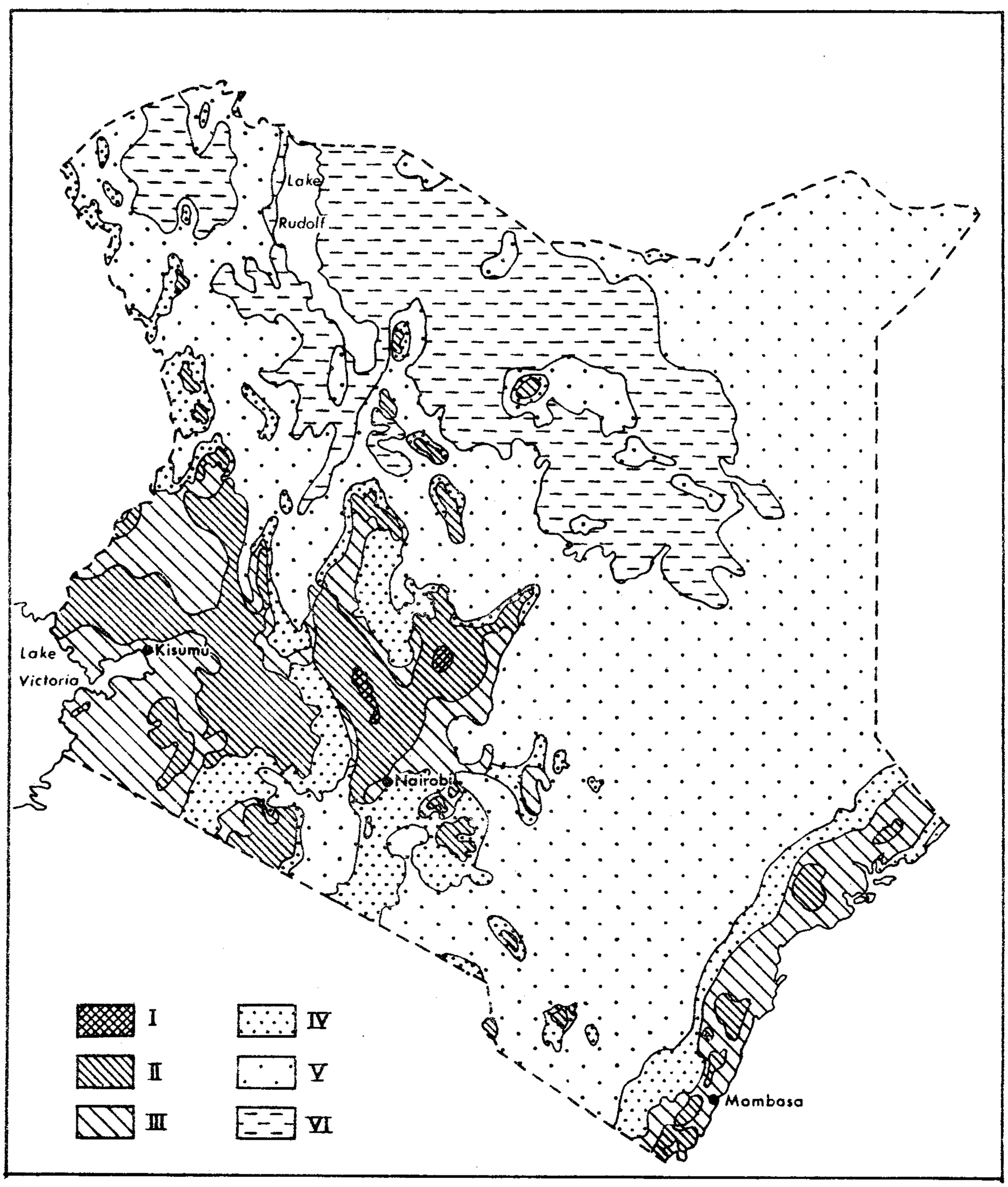
6.3.3. Examples

6.3.3.1. Ecological potential map of Kenya. In the National Atlas of Kenya an Ecological potential map is presented, dividing the country into different zones according to their ecological land use potential. The map, redrawn here as figure 30, has been extensively used for statistical calculations of crop and animal production potentials as well as for proposals on land use development priorities. Much recent literature on Kenya's land development problems, some of which has been quoted previously in this report (see e.g. 4.2.2. and 4.2.4.2.), also use the ecological zones as a basis for discussions.

FIGURE 30. Ecological potential map of Kenya
Source: National Atlas of Kenya (1970)



The following description of how the map has been prepared and discussion on its advantages and limitations are quoted directly from the Atlas. Some important points have been underlined and references made to other relevant sections in this report.

"The ecological approach to land classification and utilization has now won general acceptance, but its value is accentuated in Kenya by the wide range of conditions that occur - from glacial peaks to semi-desert.
The factors determining the inherent potential of a unit of land are its climate, topography and soil. The basic ecological land unit - the working basis for detailed planning and management - is therefore a unit of land which is differentiated by reference to each of these three factors. However, because mapping on this basis has started only recently in Kenya and requires for accurate presentation a scale of at least 1:250,000, it is possible here to illustrate only six broad ecological zones.

In exact terms, these are eco-climatic zones, defined in terms of climate but described by reference to their vegetation and land-use. Climate, and especially rainfall, is the primary factor which determines land potential in Kenya and it is climate which must therefore be given first consideration in planning land-use. Furthermore, there exists a close relationship between rainfall and altitude which is reflected in the vegetation, as a result of which it is possible to use the occurence of certain plant species and vegetation types as indicators of certain climatic régimes and so delineate climatic boundaries more accurately than is possible by relying solely on data from the relatively sparse scatter of meteorological recording stations (see map 20). It is by this method that the present map has been prepared."
(The climatic range of some individual indicator species is shown in figure 39 in section 6.4.1.5.)

"This map follows that presented by Pratt et al. (1966). Climate is defined according to Thornthwaite except that the estimate of evaporation follows Penman. This combination gives an expression of climate that is derived from monthly rainfall and evaporation data, with the estimate of evaporation based on measures of radiation, temperature, saturation deficit and wind speed and weighted for altitude and latitude (cf. 3.1.).
The descriptions of vegetation that are given refer to characteristic climatic types and do not cover edaphic variants, while the livestock carrying capacities (based on stock units of one 450 kg steer) are average which do not apply to denuded land and areas under thicket or to extended periods of drought (cf. 4.2.4.).

It is anticipated that, ultimately, in the process of refinement, the present zones II and III will be separated into their humid, sub-humid and dry sub-humid components, and that it will be possible to differentiate the coastal forms of zone II to IV as separate sub-types.
When this system of classification is applied to detailed work it is intended that the eco-climatic zones should be sub-divided according to topography and soil to give the desired ecological land units (cf. 6.4.1.2., 6.4.1.4. and 6.6.3.). It is possible to apply a relatively broad sub-division into sites of impeded and free drainage, but it is likely that for most work a relatively complex series of land-forms will be required as the basis of sub-division. In recent range surveys, eco-climatic zones have been sub-divided into geomorphological divisions (landscapes, cf. 6.4.2.); the ecological land units then represent individual sites within the landscape, described by reference to position and soil type."

TABLE 39. Ecological zones in Kenya
Source: National Atlas of Kenya (1970)

Climatic zone	Vegetation and land use
I Afro-alpine climate (Climate governed by altitude not moisture)	Moorland and grassland or barren land, at high altitude above the forest line; of limited use and potential, except as water catchment and for tourism.
II Equatorial climate Humid to dry sub-humid (moisture index not less than -10)	Forests and derived grasslands and bushlands, with or without natural glades. The potential is for forestry (with local wildlife and tourist development) or intensive agriculture, including pyrethrum, coffee and tea at the higher altitudes. The natural grassland, under intensive management for optimum production, supports one stock unit per 1-1 1/2 ha dependent on grassland type. (Ground water forests occur under climates drier than dry sub-humid.)
III Dry sub-humid to semi-arid (Moisture index -10 to -30)	Land not of forest potential, carrying a variable vegetation cover (moist woodland, bushland or "savanna"), the trees characteristically broad-leaved (e.g. Combretum) and the larger shrubs mostly evergreen. The agricultural potential is high, soil and topography permitting, with emphasis on ley farming. Areas under range-use are still extensive and under close management their stock-carrying capacity is high, at less than 2 ha per stock unit.
IV Semi-arid (Moisture index -30 to -42)	Land of marginal agricultural potential, carrying as natural vegetation dry forms of woodland and "savanna" (often an Acacia-Themeda association) or derived semi-evergreen or deciduous bushland. This is potentially productive rangeland - usually less than 4 ha per stock unit - limited mainly by the encroachment of woody species. The more open country with a high density of wildlife constitutes a valuable tourist asset.
V Arid (moisture index -42 to -51)	Land only very locally suited to agriculture, the woody vegetation being dominated by Commiphora, Acacia and allied genera, mostly of shrubby habit. Perennial grasses such as Cenchrus ciliaris and Chloris roxburghiana can dominate, but succumb readily to harsh management; more than 4 ha is required per stock unit. Wildlife is important, particularly where dry thorn-bushland predominates. Burning requires great caution but can be highly effective in bush control.
VI Very arid (Moisture index -51 to -57)	Rangeland of low potential, the vegetation being dwarf shrub grassland, or a very dry form of bushed grassland with Acacia reficiens subsp. misera, often confined to water courses and depressions with barren land between. Perennial grasses (e.g. Chrysopogon aucheri) are localized within a predominantly annual grassland; productivity is confined largely to unreliable seasonal flushes and grazing systems must be based on nomadism. The populations of both wild and domestic stock are restricted severely by the environment.

From the above it is quite clear that the authors are fully aware of the limitations of the map and they stress that it cannot be directly used for such detailed planning as it actually already has been used for. Four main points must be considered when using the map:

a) Soil differences are not included in the classification. The sandy soils of the coast, with very bad water-holding properties, are, for example, entirely different from the deep volcanic loams of the highlands from a crop or tree production point of view, although they are grouped in the same zone on the map.

b) At different altitudes temperatures are different and even if the moisture indexes are the same (that is the relation between rainfall and evaporation) the temperature is largely deciding the kind of crops or trees that can be grown or the type of animals that can be raised (see e.g. figure 15).

c) The classification does not consider the very important influence of climatic extremes which, particularly in drier areas, severely restricts long term land use alternatives. In Kajiado District e.g., mainly in zone IV ("potentially productive rangeland"), extreme droughts have twice during the last 20 years (1960/61 and 1973/74) reduced the cattle stock by 70-90% (see figure 34 and 4.5.5.).

d) Indicator plants and communities have been used to delineate climatic boundaries, and although climate is the main factor governing vegetation distribution, the impacts of man, fire and animals have certainly changed the vegetation over vast areas, making it exceedingly difficult to delineate "natural" vegetation boundaries (cf. 3.6.1., 4.5.5. and 6.4.1.5.).

REFERENCES (6.3.3.1.):

Kenya, Survey of - 1970 - National Atlas of Kenya, Nairobi.

Pratt, D. J., Greenway, P.J. & Gwynne, M. E. - 1966 - A classification of East African rangeland. J. appl. Ecol. 3.

6.3.3.2. Land use potential map of Tanzania. The map of "Potential Land Use" of the Atlas of Tanzania, redrawn here as figure 31, is an example of a land capability map based on soils. It is an attempt to group the soils of the whole country into eight potential land use categories. As stated in the text to the map, each category covers a considerable range of soils and the statements about them are therefore inevitably very general, e.g. a crop which is listed for a particular group may not be capable of growing on all the soils comprising that group.

It should be emphasized that the potential land use categories of this map are too large and the scale too small to permit a detailed description of each group. The available soil map gives much more information, but also that is based on a very limited number of field observations and soil analyses (cf. 3.4. and 6.4.1.2.).
Furthermore, the map of land use potential does not include such important capability factors as rainfall, evaporation, topography, natural vegetation or occurrence of tsetse flies. Therefore, it gives only a very general and at the same time oversimplified view of land use potential.

FIGURE 31. Potential land use map of Tanzania
Source: Atlas of Tanzania (1967)

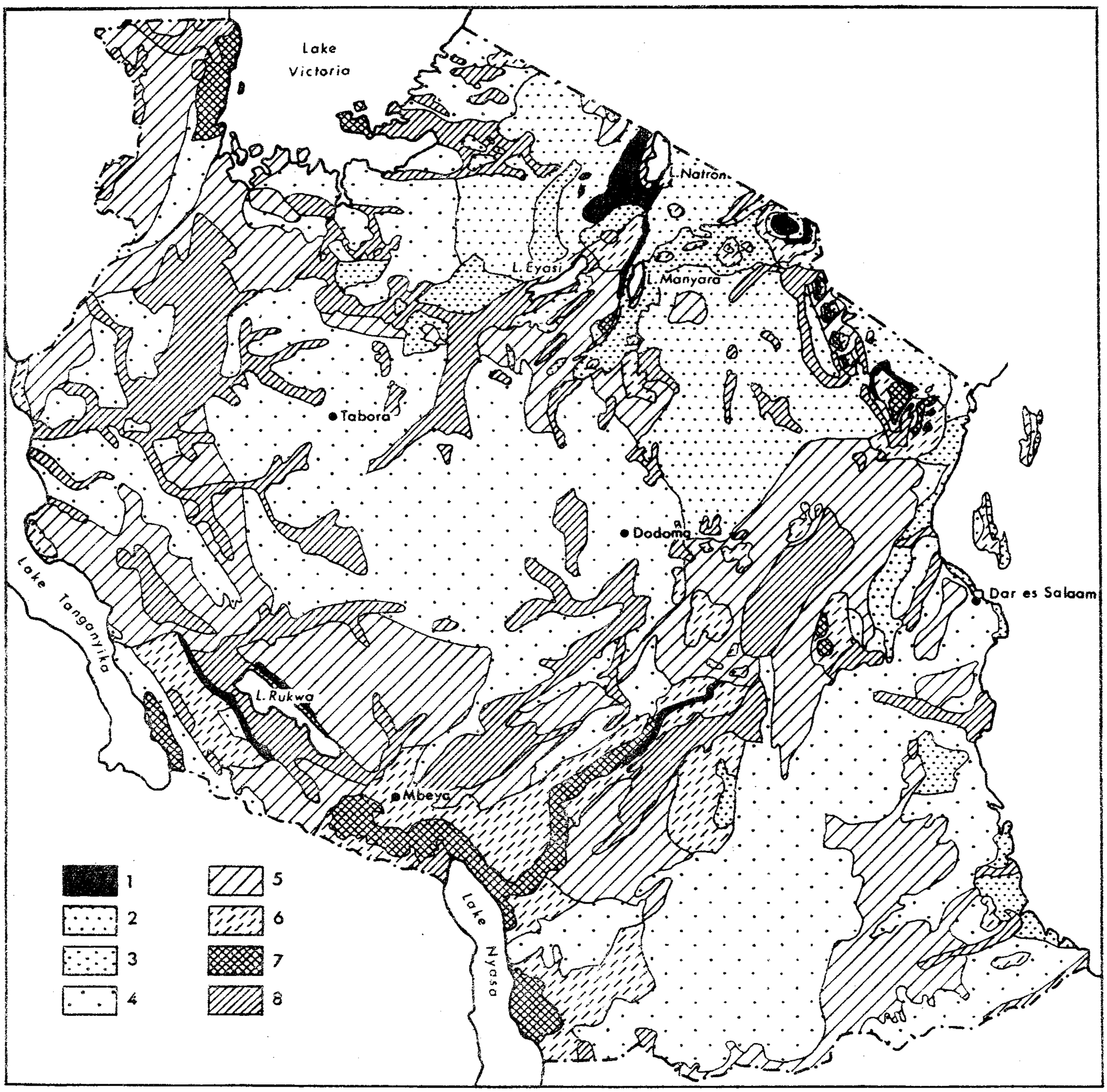


TABLE 40. Potential land use classes in Tanzania
Source: Atlas of Tanzania (1967)

Potential land use class	Description
1	Soils unsuitable for cropping. (Game, limited grazing for cattle, possibly forestry in humid areas.)
2	Soils where little cropping is possible. (Ranching, game, sometimes limited cropping with sorghum, millet, castor, groundnuts.)
3	Fertile soils where low rainfall or shallow rooting depth limits crop yields. (Sisal, sorghum, cotton, beans with maize, wheat, pastures and sometimes irrigated coffee at high altitudes.)
4	Soils of very low fertility with moderate potential. (Sorghum, cassava, cashew, castor, coconuts, simsim, tobacco, groundnuts, cotton, pastures, softwoods.)
5	Soils of low to medium fertility with moderate potential. (Sisal, groundnuts, sorghum, maize, soya, cashew, castor, cotton, cassava, beans, pastures.)
6	Soils of medium to high fertility with high potential. (Arabica coffee, wheat, pyrethrum, bananas, timber, potatoes, onions, vegetables, temperate fruits, grass, legume pastures at high altitudes, sisal, citrus, cocoa, robusta coffee, pastures, coconuts, spices at low altitudes.)
7	Soils of low fertility in areas of high rainfall. (Tea, robusta coffee, bananas, timber.)
8	Various alluvial or colluvial soils of considerable potential, but often requiring flood control, drainage or special management. (Sugarcane, castor, cashew, cotton, rice, pasture, legumes, bananas, onions.)

The neglect of the rainfall factor has led to such consequences as putting Dar es Salaam (1041 mm rainfall/year), Dodoma (573 mm) and Mwanza (999 m) in the same category of potential land use, viz. category 4. It is described as follows in the key: "Soils of very low fertility with moderate potential (sorghum, cassava, cashew, castor, coconuts, simsim, tobacco, groundnuts, cotton, pastures, softwoods)." For description of the eight different land potential classes, see table 40.

The map should not be used for practical planning purposes beyond a simplified overall picture of the soil regions in the whole country. For example, the map has been used for calculations of area percentages of different land use potential units on the level of different administrative regions in Tanzania. This is not advisable.

REFERENCES (6.3.3.2.):

Tanzania, Surveys and Mapping Division - 1967 - Atlas of Tanzania. Dar es Salaam.

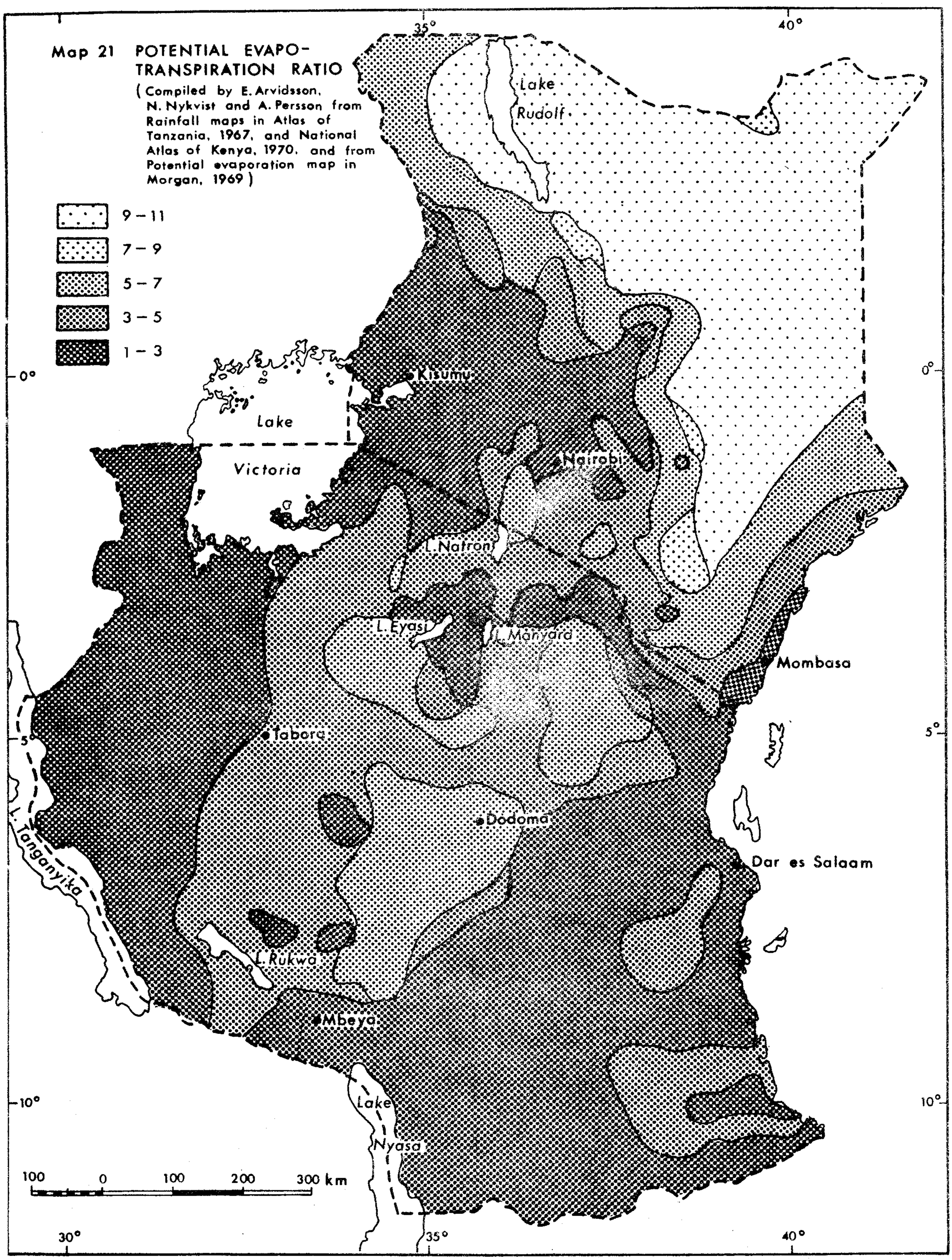
6.3.3.3. Water balance approach. Many attempts have been made on making ecological classifications of natural environments on a climatological basis. Among older systems more widely known mention can be made of the Köppen system (Köppen & Geiger, 1930) and the two Thornthwaite systems (Thornthwaite, 1931 and 1948). The two earlier systems are based on combined studies of climate and vegetation, while the 1948 Thornthwaite system is based entirely on climatic data. The climatic parameters used are three: temperature, precipitation and evaporation.
Among the most well-known and thoroughly worked out classification systems in recent years is the Holdridge Life Zone classification system (Holdridge et al. 1971). It would lead too far to go into details regarding this system here, but it is of universal character and is applicable to all climatic conditions between the poles and the equator.

One of the classification bases used in the Holdridge system is the biotemperature, which is defined as the mean of unit-period air temperatures with the substitution of zero for all unit-period values below 0°C and above 30°C. The upper limit, 30°C, is still tentative.
The other main classification base is the ratio between the mean annual potential evapotranspiration and the average total annual precipitation, called the evapotranspiration ratio. A ratio of 1.00 indicates that the precipitated moisture is just equal to potential evapotranspiration for the long-term average year. A higher ratio indicates more arid conditions and a lower ratio more humid conditions.

Holdridge has devised a three-dimensional model which divides the world into over 100 Life Zones, arranged according to latitudinal regions, altitudinal belts and humidity provinces. Normally, however, the Life Zones are shown on a two-dimensional diagram, the boundaries of each being defined by the total annual precipitation and the mean annual biotemperature.
As the Life Zones are closely correlated to natural vegetation communities, it may serve as a base for assessing the potential yield or carrying capacity of a certain locality. The Life Zone system does not take soils and geology into consideration.

Within Tanzania and Kenya, rainfall in combination with high evapotranspiration is usually the single most limiting factor to crop production, although soil properties are often locally important (see 3.4. and 6.4.1.2.). The Land use potential map of Tanzania, discussed in 6.3.3.2., is for example mainly built up on soil factors. This leads to overestimation of the carrying capacity in certain cases, since the real limiting factor, the evapotranspiration ratio, has not been taken into consideration. The Ecological potential map of Kenya (see 6.3.3.1.), however, is based mainly on vegetation classification. In areas which are not too densely populated the vegetation may give a good estimate of the carrying capacity of the land. However, in large parts of Kenya and Tanzania, the "natural" vegetation has been destroyed by over-grazing and frequent burning, in which case the carrying capacity may be higher than indicated by the vegetation.

When working entirely under East African conditions, a combination of a map of annual rainfall with a soil map would probably make it possible to draw approximate limits for cultivation potential of defined crops. Also knowledge of rainfall periods is important, e.g. the length of the pronounced dry season, whether there is "summer-rain" or "winter-rain", or if the rainfall distribution during the year has one or two peaks.


Map 21 POTENTIAL EVAPO-TRANSPIRATION RATIO
(Compiled by E. Arvidsson, N. Nykvist and A. Persson from Rainfall maps in Atlas of Tanzania, 1967, and National Atlas of Kenya, 1970, and from Potential evaporation map in Morgan, 1969)
9 – 11
7 – 9
5 – 7
3 – 5
1 – 3
35°
40°
Lake Rudolf
0°
Kisumu
Lake Victoria
Nairobi
L. Natron
L. Eyasi
L. Manyara
Mombasa
5°
Tabora
Dodoma
Dar es Salaam
L. Tanganyika
L. Rukwa
Mbeya
10°
Lake Nyasa
100 0 100 200 300 km
30°

The reason why annual rainfall is considered to be sufficient in this case is that within East Africa there is a fairly regular pattern of increasing rainfall with increasing altitude. This covariation obscures the real effect of the evapotranspiration ratio when restricting the study to East Africa. Maps over evapotranspiration ratio have their value, however, when comparing the potential of regions with entirely different covariation between altitude and rainfall. In such cases there will be clearer indications of which areas there is identity between as concerns the growing of certain crops. Thus, the use of evapotranspiration ratio will give the maps a more universal value than if they were based on rainfall only.

In order to show what can be done by fairly simple utilization of Holdridge's ideas map 21 has been prepared on the basis of the potential evaporation map published by Morgan (1969) and the rainfall probability maps from the National Atlas of Kenya and the Atlas of Tanzania. The potential evaporation map in Morgan (1969) is based on the methods devised by Penman (1948) and data published by Woodhead (1968 a and 1968 b).
If sufficient data is available, the principles used in preparing this map can be used also in the local planning.

Generally, a map over evapotranspiration ratio, like map 21, will not satisfy all requirements on the national level. It may, however, in combination with a soil map, serve as a better base for small scale land use planning than the Ecological potential map of Kenya and the Land use potential map of Tanzania. Restricting the comparison to Tanzanian conditions the potential evapotranspiration ratio map is found to correspond better with the results of forest growth trials than does the Land use potential map of Tanzania.

Further work along these lines is subsequently desirable. A drawback in elaborating the system in Kenya and Tanzania is the sparse network of climatological stations that exist there as seen on map 20.

REFERENCES (6.3.3.3.):

Holdridge, L. R. et al., - 1971 - Forest environments in tropical life zones. Pergamon Press. Oxford.

Köppen, W. and Geiger, R., - 1930 - Handbuch der Climatologie, Teil I D. Borntraeger, Berlin.

Morgan, W. T. W.,- 1969 - East Africa: its people and resources. Oxford Univ. Press. Nairobi.

Penman, H. L., - 1948 - Natural evaporation from open water, bare soil and grass. Proc. Roy. Soc., A., 193.

Thornthwaite, C. W., - 1931 - The climates of North America according to a new classification. Geogr. Review 21 (4).

Thornthwaite, C. W., - 1948 - An approach to a rational classification of climate. Geogr. Review 38 (1).

Woodhead, T., - 1968a - Studies of potential evaporation in Kenya. Ministry of natural resources Nairobi.

Woodhead, T., - 1968 b - Studies of potential evaporation in Tanzania. Ministry of Lands, Settlement and Water Development Dar es Salaam.

6.3.4. Social considerations

When starting to analyze land use, the resources can be treated as a system made up of basically three components: "land", "technology" and "man". These components interact at various levels and various degrees. In 6.6.2., for example, a common relationship between "land" and "man" is presented, which can drastically be summarized as "land owns people rather than people own land".

The disposition of the present chapter 6 is to use land potential surveys as a starting-point for discussion, then considering all complicating factors and, finally, to present a land use plan. Among such complicating factors one finds unreliable rainfall as well as cultures and know-how. Using the three components above this means that the focus is on "land" with "technology" and "man" as limiting factors or parameters.
This approach may sometimes create difficulties. If an area with a homogeneous land potential is demarkated for a certain land use planning programme, it might well include several disparate social systems and cultures which may need entirely different adjustments. In this case the normal approach would be to focus on "man" and make necessary adjustments with regard to the limiting factors "land" and "technology".
In areas with a relatively homogeneous population the first approach may be most fruitful, whereas in areas with a heterogeneous population the second may be best. The choice must be based on a situational analysis.

Whatever approach is chosen the implementation must have a local backing, even if this means a slowed down implementation process, so that the discrepancy between introduced technology and well known technology does not become over-whelming and so that the suggested land use can be considered in light of the traditional land use.

Social and cultural limitations on the land development potential may thus vary greatly from area to area. The focus here is on a number of crucial factors at a national level. One of these is administration which is an instrument when implementing projects. Another is the context into which this implementation shall take place. Here the present land use system must be taken into account so that the plans can be organized in relation to this. Education and innovation are so called development factors, which constitute a necessary ingredient in a change situation. In many areas population pressure is high and may be one crucial factor that should be calculated with before and during an implementation. Certain infra-structures are a necessary prerequisite especially with regard to economic growth.

At a general level an administration shall ideally implement politically defined changes in present land use systems. Hydén, Jackson and Okuma have analyzed this aspect of the administration in Kenya. A similar analysis has been made for Tanzania by Meyns. The difficulties in Kenya can be summarized in a few points: (1) the colonial inheritance which still has implications for the bureaucratic structure, (2) political-administrative conflicts, (3) legislative difficulties to control the aims of private organizations and (4) scarce resources.
For Tanzania Meyns hints at (1) difficulties in communications between decentralized planning units, (2) lack of man-power at the administrative level (3) scarce resources and (4) a failure in the service for peasants, especially credit facilities and agricultural extension workers.

Before implementing changes in land use, the present land use pattern must be analyzed at relevant levels in order to make the efforts effective. Such issues that need looking into may be physical and institutional limitations, the patterns of rotation schemes and what shortterm and longterm effects a suggested land use may have. It is particularly necessary to isolate local implications of a development policy.

Education programmes are necessary when introducing new land use policies. In this context they are ideally supplemented by administrative efforts; see above. The complex situation of a farmer is pointed out by Morris who distinguishes some 200 different options for activity combination including a series of expenses, social activities and arrangements for livestock grazing adjusted to (in the average) three or more food crops, two or more kinds of livestock and three or more cash crops per farm. He sees a correlation between more education and interests in e.g. land consolidation, soil erosion, irrigation, more active cash crop farming and saving. Also, more educated farmers are more likely to make systematic use of agricultural field staff.
Both education and innovative efforts are components in the process of mobilizing the mass of the people. Kenya and Tanzania have different programmes towards this goal, both aiming, however, at programmes on a decentralized basis.

The Harambee Self Help Movement in Kenya is based on local initiatives combined with various Government involvements. Mbithi points out that the programme, at its best, activates people who were before considered "conservative", "uncooperative", "lazy" or "apathetic". The reason for this should be the different point of initiative.
The Ujamaa Policy of Tanzania implies an active ideological commitment to African Socialism. One effect is the creation of Ujamaa villages intended to provide the inhabitants with basic services and with an economy at a fairly self-reliant level and on a cooperative basis; see for example Mohiddin.

The population distribution is uneven, especially in Kenya but also in Tanzania as map 2 and figure 4 indicate. The number of people in an area in relation to its productivity may be an indication on the area's population pressure. As pointed out in 4.2.2.2. this may constitute an indication on overpopulation, though it must be emphasized that such an indicator is ill-defined and of poor quality when analyzing implications of the size of a population in an area. The notion of population pressure is sufficient, however, to identify problems related to the population size. It is insufficient as a basis for decisions regarding, say, family planning.

To begin with one must look into reasons why present situations exist, e.g. that households have many children, as people normally act logically from their own situational perspectives. If the planners do not achieve an understanding of the society, they will not realize implications of responses from the local population. Often one finds that this is necessary to secure a safe old age. In such a case another means of security must first be established.
Another cause of high population pressure may be that old redistribution systems have failed to function, thus generating an uneven distribution of, mostly, land or cattle. This means an increased stratification, an increased pressure in the lower strata and an amplified need for people of these strata to have many children; the possible economic sub-goals that they can acheive become reduced while the average economic level in the area may well increase.

There are often traditional, but insufficient, ways of coping with local overpopulation, e.g. a ritually sanctioned abstinence when it comes to limiting the number of people, or ritually sanctioned redistribution systems when it comes to land or cattle.
It should be obvious that such efforts be taken into account when dealing with population pressure at a micro level as well as land distribution at a national level.

The economic and social infrastructure includes irrigation and water supplies, communications, education and health services. Roads are a necessary prerequisite for the marketing of farm products in order to facilitate delivery from the producer to the consumer. It is important that roads are all-weather, so that no delivery problems occur in a new market-system. The road network is presented in map 1.

REFERENCES (6.3.4.):

Hydén, G., Jackson & Okumu (eds.) - 1970 - Development Administration. The Kenyan Experience. Oxford Univ. Press. Nairobi & London.

Mbithi, P. - 1971 - The intervention and explication models: their application as strategies for rural development. In Kempe & Smith (eds.): Strategies for improving rural welfare. Inst. for Dev. Stud., Univ. of Nairobi.

Meyns, P. - 1973 - Some aspects of planning and socialism in Tanzania. In Cliffe & Saul (eds.): Socialism in Tanzania. Vol. 2. E. A. Publ. House. Dar es Salaam.

Mohiddin, A. - 1973 - Ujamaa na Kujitegemea. In Cliffe & Saul (eds.): ibid. Vol. 1.

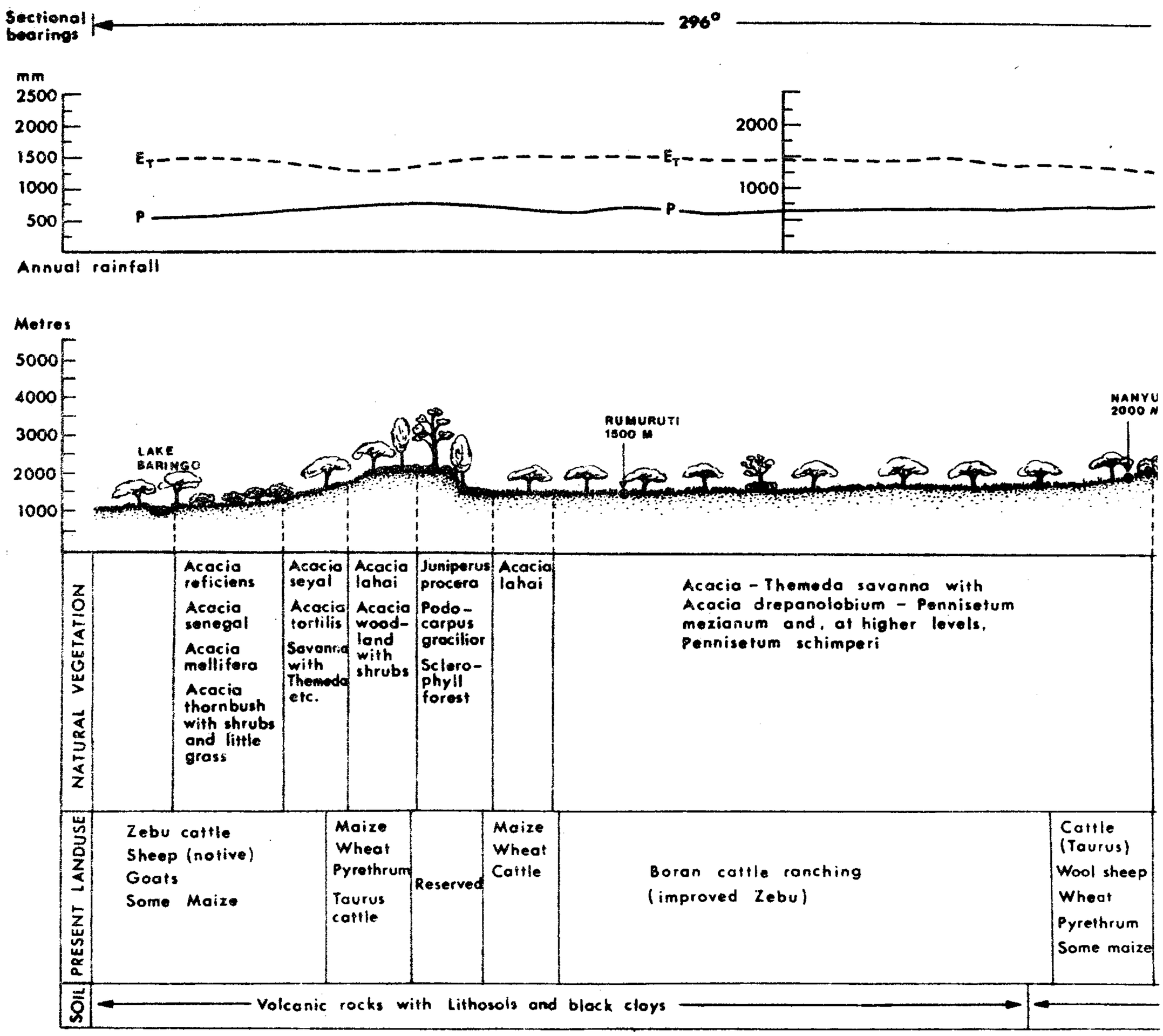
Morris, J. - 1967 - Farmer training as a strategy of rural development. In Sheffield (ed.): Education, Employment and Rural Development. E.A. Publ. House. Nairobi.

6.4. Local, integrated land potential surveys

This section deals with methods and problems of collecting, synthetising and evaluating physical data for land potential assessment in connection with local land development projects. Considerable importance has been attached to this section for three reasons:

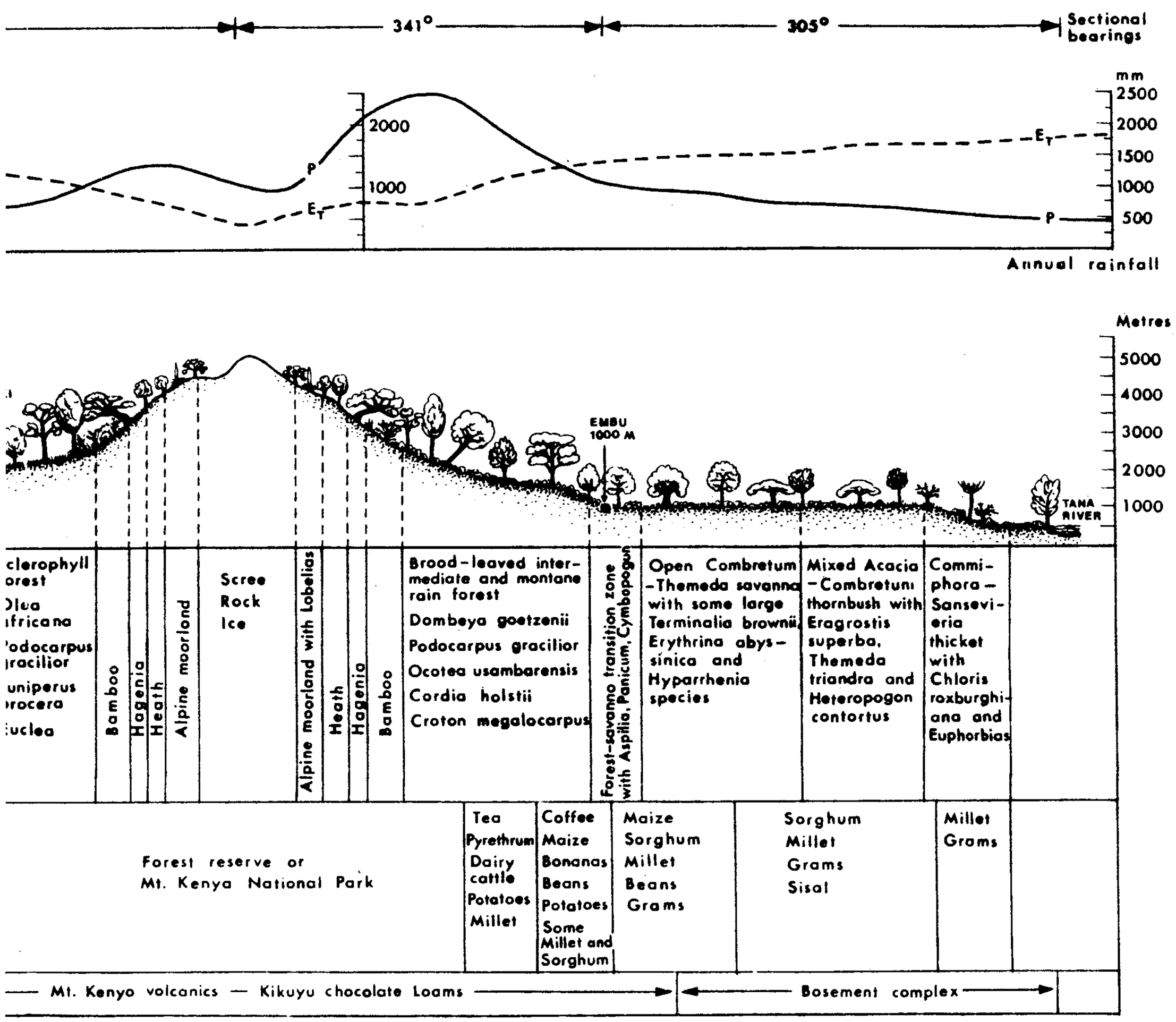
a) it is normally within the context of local development projects that international aid organisations and technical personnel (i.e. the group of people for which this report is prepared) are working with land use problems,

FIGURE 32. Transect Lake Baringo - Mt. Kenya - Embu - Tana River showing the co-variation between climate, macro-relief, vegetation, geology, soils and present land use
Source: Brown & Cocheme (1969)



b) the data available on physical resources at a national level in Kenya and Tanzania (see 6.3.) are not enough for establishing land potential variations in relation to local land development planning needs, and there is therefore always a need for natural resource surveys and interpretation for local land use planning,

c) lack of understanding the interplay between the combined influence of the physical resources on the one hand and the potential for various land uses on the other is a common cause of failure in development projects.



When talking about local surveys, the implication is not only one of limited geographical extent but, more important, it is a question of detail in surveying and map scale requirements. This may be elucidated by looking at figure 32. In this, the interaction between physical conditions and present land use is presented in a scale and detail that can be expected to be brought out in a national land potential survey. The corresponding map scale is from 1:250,000 to 1:500,000.

In a local development project (say of the area between Rumuruti and Nanyuki), where the aim of a land potential survey is to delineate and rate land management units for particular, well-defined land uses, the detail is not enough. It is, for example, not sufficient to know that the soil groups found in the area are lithosols and black clays (vertisols) - their actual location, extent and characteristics have to be mapped. As a very schematic rule it can be said that a land potential survey should be presented on maps of a scale of 1:20,000-1:100,000 for local development projects.

Local development projects may be of many different kinds, varying in size, criteria in delimitation, aims of development etc. The following are the main types of geographic project delimitations:

a) administrative boundaries (e.g. regions, districts, provinces, divisions),
b) hydrological boundaries (e.g. Tana River Basin),
c) tribal or ethnic boundaries (e.g. Masailand),
d) physiographic boundaries (e.g. the Usambara Mts.),
e) phytogeographical boundaries (e.g. miombo woodland),
f) climatic boundaries (e.g. rangeland, $<$750 mm rain),
g) present land use boundaries (e.g. pastoral areas).

The type of delimitation is normally closely linked to the over-all social and political aims of the project and as such will influence the whole planning process, including the land potential surveying. There is no room for separate discussions on the particular implications on land potential surveying of the various types of geographical projects, but it should be borne in mind when a concrete project is considered.

A land development project may aim at the introduction or improvement of one particular form of land use, e.g. crop production of forestry, or it may aim at multiple land use development, including some or all possible land uses, e.g. food and cash crop production, animal husbandry, forestry, soil and water protection and conservation, wildlife, tourism etc. The type of land use envisaged must be known, since land potential must always be referred to a particular form of land use and, hence, the whole lay-out of the surveys depend on this.
In this section land potential surveying is discussed more general, without any particular land use in mind, even if reference, where appropriate, is often made to different forms of land use. In section 6.5., some problems in connection with sectorial projects are discussed.

This section is divided into three sub-sections. In 6.4.1., methods and relevance of surveys of basic land resources of climate, soil, hydrology, topography and vegetation are described and discussed. In 6.4.2., a method of integrating the basic physical data into a mapping system with units suited for land use management purposes is described. Finally, in 6.4.5., a land capability (or potential) classification system is presented in which land units, delineated on basis of uniformity in physical characteristics, are rated in relation to their potential to sustain a particular form of land use.

The survey of the basic physical land resources includes the mapping and characterization of the kinds and quantities of land attributes as well as laboratory analyses to quantify specific characteristics. The rationale for carrying out these surveys is obvious and very fundamental - the survival and growth of a given organism, plant or animal, depends on the quantities and qualities of foods, nutrients, water and energy which are available at a given place and time. The extent to which these key variables should be surveyed depend on the kind of land and on the kinds of land uses which are relevant and foreseeable within the area in question. Climate, topography, water and soil are always important ecological factors for any type of biological production, and factors such as geology, vegetation and artifactial elements may also be of considerable ecological importance for particular land uses.

In these basic resources surveys, each of the factors which contribute to the environmental complex may to a certain extent be examined in isolation. For reasons of clarity this has been done in 6.4.1. In reality, however, physical land potential depends on the total interaction of all physical factors and the crucial problem of land potential surveying is how to synthetize these factors into some form of land unit classification, in which each unit of land can be assigned a potential capacity to support a particular form of land use. Due to the complex interaction of the physical characteristics and its bearing on land potential, this is not simply a matter of adding up the results from different surveys by interpreting each individual factor in terms of its isolated influence on the land use under consideration. It is therefore fundamental that an integrated approach is adopted in basic resource surveying, i.e. the design and methods of the individual surveys should be closely co-ordinated with an aim of obtaining a holistic land potential classification. This is simple to say, but substantial problems will arise in a real planning situation when designing and interpreting an integrated resource survey. The basic problem in East Africa is that there are large gaps in knowledge about the physical requirements of various land uses. This is particularly true for new forms of land uses, e.g. recently introduced crops, irrigation agriculture, crop production in marginal areas etc.

It can therefore justly be argued that there is little use in developing very detailed physical classifications in cases where there is no or little knowledge on their relationship with the actual requirements of various land uses. Some form of land potential classification is, however, always justified, and even necessary. Broad classes can be defined based on general ecological requirements of all forms of organic production. The system can then be progressively refined as research and experience increase the knowledge of land use requirements.

Whatever degree of sophistication and detail used in the land potential survey the fundamental aim remains the same, i.e. to identify and map sufficiently uniform classes of land and to evaluate them with regard to their suitability for various land use types and, finally, if possible, to rate the units with regard to particular land uses. Somewhat simplified, it can be said that the land potential survey and classification seek an answer to the question: "What kind of land use can theoretically be carried out in this tract of land under the given physical conditions?"
At this stage, it is, in theory, relatively unimportant to consider the present land use, socio-economic and technical conditions of the area. These feasibility aspects will be considered in the formulation of the land use plan, where answers are sought to the questions: "Why and how should this kind of land use be implemented?" This is dealt with in sections 6.6., 6.7, and 6.8.

6.4.1. Basic resources surveys

6.4.1.1. Climate. Climate is undoubtedly a crucial factor influencing development opportunities in East Africa. It closely governs the status of water resources, crops, pastures, livestock, disease etc. Perhaps the major problem of physical planning is to gain maximum benefit of the limited water resources that climate affords. Unfortunately, research is lacking as regards the relationships that exist between the climatic factors on the one hand and the cultural development and economy afforded by human settlement on the other.

Considering the importance of various climatic parameters it is quite natural that high priority is given to describe as accurately as possible the climate of an area for which the land use potential shall be evaluated. The first step will then be to analyze the records from existing meteorological stations, if any, in the area. In East Africa, the distribution of meteorological stations, both official EAMD stations and various others, reflects to some extent the pattern of settlement, and since settlements are concentrated in high rainfall areas it follows that met. stations are scarse, or even non-existing, over vast areas of semi-arid land as well as on land sparsely populated for other reasons, e.g. the miombo in Tanzania. As a consequence, many land development projects in marginal areas in East Africa lack sufficient climatic data for a land potential evaluation. In such cases indirect information on the climate has to be obtained via detailed studies of the natural vegetation (see 6.3.3.1. and 6.4.1.5.) and traditional land use, combined with oral information from local people. Establishment of a network of met. stations must naturally be a very high priority in such areas.

Even if met. stations are available in an area, great caution has to be exercised when interpreting the records and use them to characterise the climate of the whole area. The rainfall, for example, is usually very localized, occurring in scattered convective storms. Thus analysis of rainfall records for a particular gauge does not necessarily reflect conditions in the neighbouring area except over a long period of time. What is more, the frequency distribution of rainfall is more often than not a skewed distribution function which does not lend itself to probability analysis, a difficulty also relevant to dry seasons in wet areas. Studies need to be valid for areas and not just for isolated rain gauge sites, but a sufficiently dense network of rain gauges is often difficult to establish. The development of synoptic meteorology in tropical areas is still in its infancy.

Average annual rainfall alone is not enough to describe the climate of an area from a land use potential point of view. Since the actual factor deciding the potential of land is the amount of water available to plants during their growing season, it is of even greater importance to know the year to year variation (rainfall reliability) and seasonal distribution of rainfall as well as potential evaporation. Over most of East Africa the year to year and seasonal variation in rainfall is large indeed, and it is a too often repeated mistake in land development plans not to consider this.
Dodoma in Central Tanzania is a good example of a station in a semi-arid area. In figure 33, annual rainfall in Dodoma for a 40-year period is shown. It should be quite obvious that land use planning, including e.g. recommendations on human and cattle carrying capacities, based only on the average annual rainfall figure of 564 mm is bound to cause serious problems.
Figure 34 illustrates the hazard of climatic extremes, in this case the effect of an exceptionally dry period on the cattle population in Kajiado District in Kenya. The same type of cattle and wildlife population crashes took place in 1973/74 in the same area (cf. 4.5.5.).
These extreme droughts, occurring about once in ten years, are seriously limiting the number of land use alternatives in semi-arid East Africa, particularly growing of perennial crops.

FIGURE 33. Annual rainfall in Dodoma 1931-1971.
Source: Redrawn from Rapp et al. (1972)

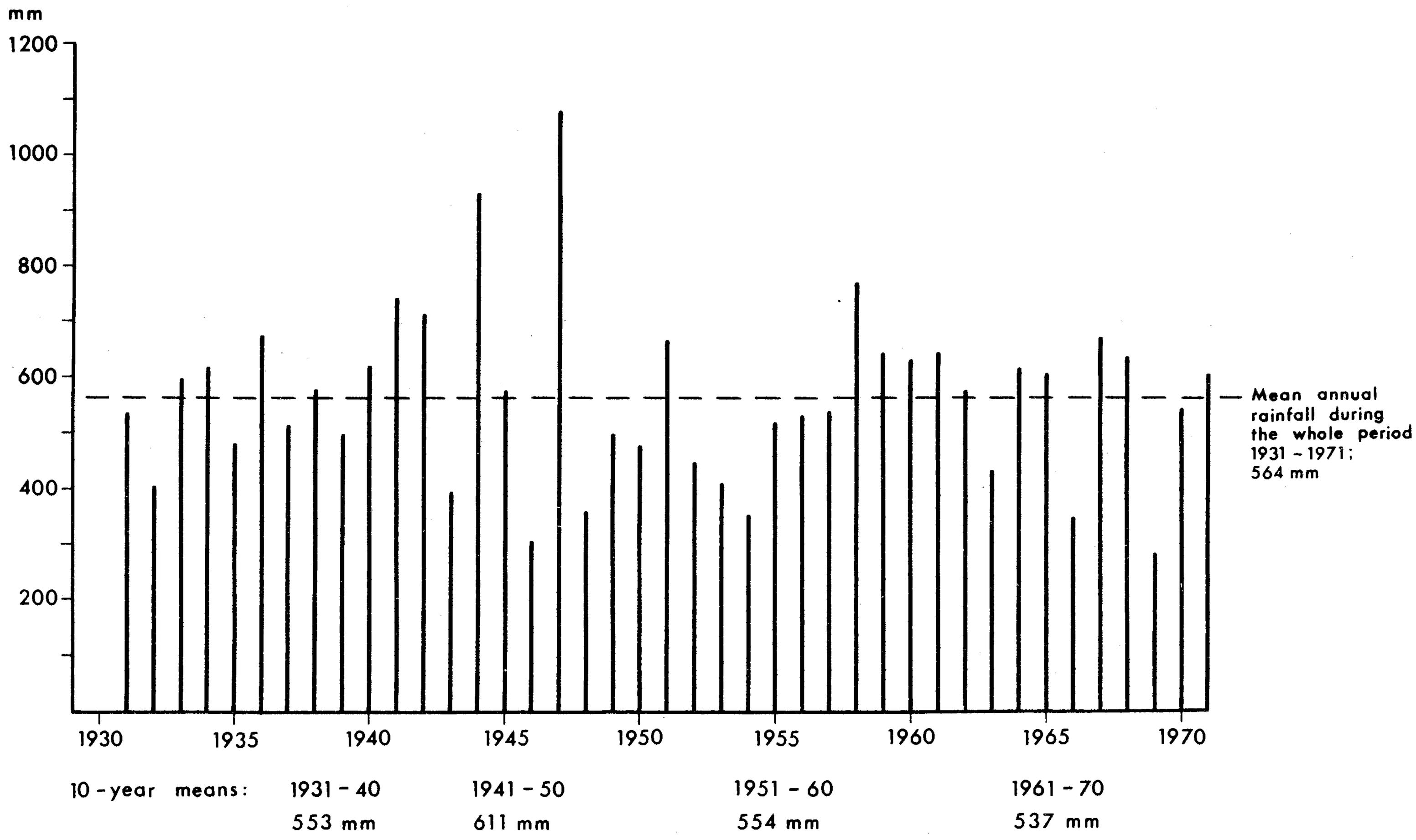
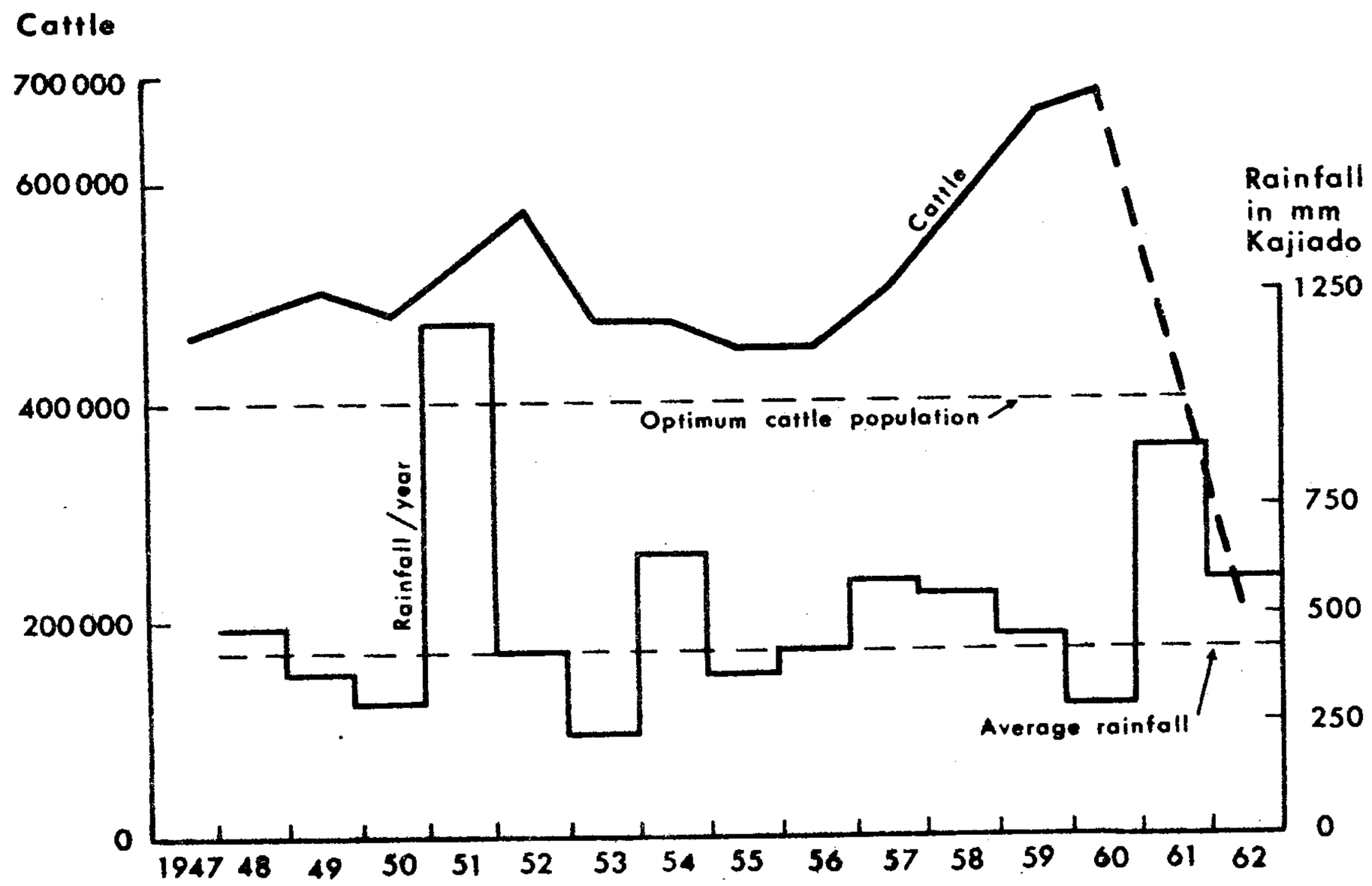


FIGURE 34. Rainfall and cattle population 1947-1962 in Kajiado District, Kenya
Source: Prole (1967)

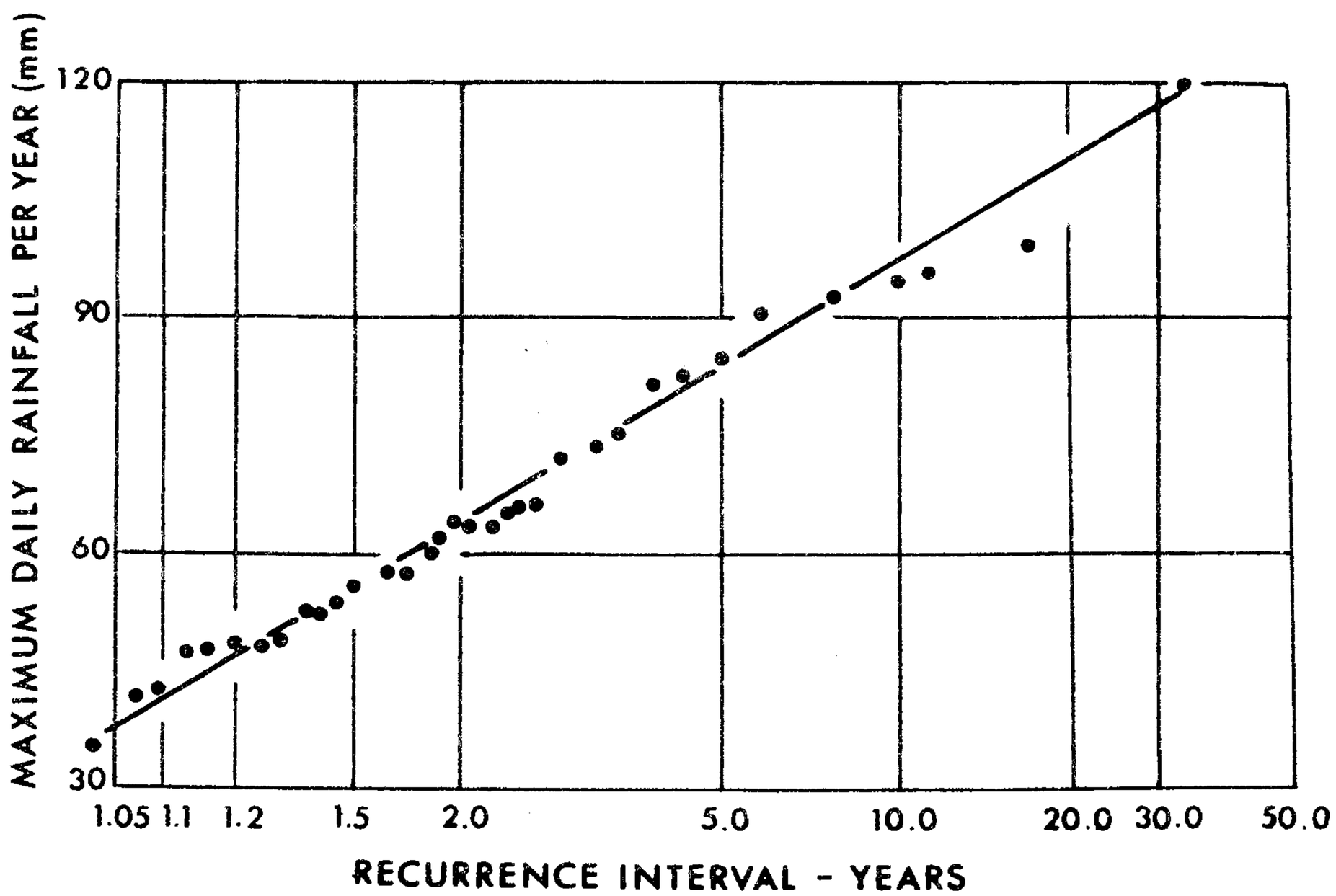


It is not, however, only the occurrence of extreme droughts that sets limits to land potential, but also the opposite case, namely high intensity rainfalls. In areas of dissected topography, they often cause serious erosion and flooding problems. The most devastating forms of erosion - gullies and landslides - are normally the result of extremely heavy rainstorms of a few hours duration (cf. 5.4.2. and 5.4.3.1.). In figure 35 the recurrence intervals of heavy storms in Dodoma have been analysed and plotted on a graph. It can be seen that there is a day of 100 mm of rainfall once every ten year.

As concerns temperature, altitude gives a reasonable guide throughout East Africa. However, there are marked local variations in the rate of change of temperature with altitude. Still more complex are the diurnal temperature regimes which vary from place to place and with season and are very much dependent on cloudiness and dew-point temperatures. Such variations can be important for crops and there is still a great deal to be done in the recognition of critical temperatures for particular crops and the analysis of their likely occurrence.

Precipitation and evaporation are antagonistic processes. Abundant rainfall is associated with a high content of water vapour in the air, cloudy skies, which reduce solar radiation, and low temperatures. The evaporation rate is enhanced by the opposite conditions, that is, by low air humidity, high solar radiation and high air temperature.
Various methods have been devised for combining precipitation and evaporation data into integrated indices that can characterize different types of climates. Thornthwaite 1948 and Köppen 1936 have proposed such indices that

FIGURE 35. Graph showing return periods of maximum daily rainfall per year, for Dodoma Met. Station, 1937-1970.
Source: Rapp et al. (1972)



have been used to classify and map world climates into a large number of precisely defined categories. However, most of the boundaries are set rather arbitrarily, and consequently the information provided is qualitative only and of little help for detailed land use planning (selection of crops, estimation of irrigation requirements, etc.). In 6.3.3.3. and map 21 another such system is presented.

To determine suitable crop production and irrigation requirements more precise knowledge is required about the actual evaporation losses that occur from the crop surface. To obtain such knowledge Penman (1948) has devised a formula that can be applied using standard climatological data. Dagg (1965) has applied Penman's formula for East Africa whereby an estimate of potential evaporation has been obtained. This has been compared by Woodhead (1970) with rainfall distribution and taking into account water storage in the soil to develop an index which expresses exploitable rainfall in terms that can be related to potential or actual vegetation. Woodhead believes that a more detailed mapping of this index will make possible a refinement of the ecological classification of land areas. Woodhead's approach seems very promising since it integrates in a sensible manner the characteristics of climate, soil and plant factors, and it ought to be a standard procedure in land potential evaluations in connection with development projects.

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6.4.1.2. Soil survey. The need of knowledge about soil conditions when planning all types of land use based on production of plants (crops, trees and animal fodder) is obvious. Chemical soil conditions determine the amounts of nutrients available and physical soil conditions determine, within limits set by the climate, the amount of water available. Erodibility, stoniness, workability and many other properties of the soil also strongly influence the productive potential of a site.

In section 3.4. the distribution (map 11) and characteristics of the major soil groups and their relation to soil forming factors and processes were described. Like in most descriptions of soils at a national or international level, the approach in 3.4. is a pedo-genetical one. These small-scale soil maps seldom serve direct practical purposes, except for selecting regions of high priority for development and for teaching and research. For the purpose of soil surveying of a limited area, to establish potential for various land uses, a more practical approach has to be used, taking into account those soil characteristics directly influencing productivity.

It is of overriding importance, in countries like Kenya and Tanzania with vast areas of land of low production potential due to climatic conditions, that optimum use is made of the soil resources. To this end, it is necessary to survey the resource systematically. In Kenya, the Soil Survey of the Ministry of Agriculture has launched an ambitious program of mapping the soils of the country at a 1:50-100,000 scale, and similar plans are underway in Tanzania. Still, however, the coverage of these types of surveys is very limited and mainly confined to certain development projects, like irrigation schemes, larger estates or agricultural research stations and farms. For a long time to come it will therefore be necessary for most new land use development projects to carry out soil surveys as a part of a natural resources survey, aiming at delineating areas of different capability.

There are numerous examples from the tropics, including Kenya and Tanzania, where soil surveys have preceeded and served as a basis for land use plans. Practically every FAO, UNDP and IBRD project concerning land development is,

for example, based on a soil survey. However, despite the increasing use of soil surveys and the general realization of their necessity, there are many misconceptions about the purposes they can and cannot serve. Below, some important considerations in connection with planning, implementing and evaluating a soil survey are listed and breifly commented upon.

1. The logical first step when planning a soil survey will be to make an inventory of existing information and aids. These may include:

a) Previous soil investigations, fertiliser trials and other direct, documented information about general and particular soil conditions in the area. Soil surveys from areas with similar conditions may also yield much valuable information.

b) Investigate to what extent present land uses are correlated to soil conditions. Traditional knowledge of soils, often borne out of generations of trial and error cultivation and manifested in various agricultural practices, is too often neglected by foreign soil surveyors.

c) Existing topographical map and aerial photo material. If such maps and photos are available, as they are for quite large areas of Kenya and Tanzania (cf. 6.4.1.4.), they will provide a very valuable basis for the survey work.

d) The close correlation between vegetation and soil conditions makes all possible vegetation maps or inventories extremely useful (see 6.4.1.5.).

2. Determine design and type of soil survey. Apart from the above mentioned existing direct and indirect information on the soils of the area, the actual design and type of the soil survey will be influenced by the following factors:

a) General and specific aims of the development project for which the soil survey is done. As a general rule it can be said that the more intensive land use alternatives that are considered (e.g. growing of particular cash crops, irrigation etc.), the higher will the requirements be on the soil survey with regard to amount of information and accuracy.

b) Resources available in terms of qualified personnel, money, equipment, laboratories and time.

c) Nature of the area to be surveyed - whether forest, savanna or land already under cultivation; topography; whether provided with roads or not etc.

d) Co-ordination with other surveys. The soil survey is one among other natural resources base-line surveys made in preparation of the final land use plan, and it cannot be isolated from these, since they will all form integral parts of an eventual land capability classification (see 6.4.3.).

Considering all these factors and others that may be relevant, the design and type of soil survey should be determined with regard to:
- Scale and accuracy of resulting map.
- Mapping units (see point 4 below).
- To what extent maps and aerial photos can be used to map the soils.
- Which soil factors are relevant in the survey (see point 3 below).
- Intensity of field sampling and what this will involve as well as possible laboratory analysis.

Normally, a reconnaissance soil survey is made of the whole plan area using as much as possible of existing maps and aerial photos with supplementing field sampling at an extensive basis. Detailed surveys may then be made of those areas that have been identified as having high potential, or that have been considered for intensive use.

3. To decide what kind of information that is relevant to delineate soil units which subsequently can be used for classification of soil capability for various uses, is one of the most difficult tasks of the soil surveyor. Which characteristics can be satisfactorily described in the field and which require laboratory analysis is another question that must be answered.

In a general purpose soil survey in East Africa the following characteristics ought to be investigated:

a) Properties affecting water infiltration, water holding and drainage characteristics of the soil. These include texture, structure, porosity and bulk density, possible rooting depth over rock or impermeable layers (like lateritic crusts) and depth to groundwater.

b) Properties affecting the erodibility of the soil. Erosion is caused by the interaction of climatic, topographic, soil and land use factors and to understand the mechanisms in any particular case, all these factors must be surveyed in an integrated fashion. Existing erosion in the area should also be mapped (cf. 6.5.5.).

c) Properties affecting the workability of the soil. Apart from topography, which is dealt with in 6.4.1.4., the degree of difficulty of working the soil is determined by load capacity, stoniness, presence of rock outcrops and presence of hardpans near or at the soil surface.

d) Properties affecting the chemical fertility of the soil. The most important of these are organic matter content, nitrogen, pH and exchangeable cations. Under certain circumstances, e.g. when crops with particular fertility requirements are to be grown or where deficiencies of micronutrients are suspected, the amount of information collected must be increased.

Many of the above properties can be satisfactorily described or measured in the field or by very simple analysis equipment. Some, however, particularly the chemical properties mentioned under d), require more sophisticated laboratory analysis. It must then be remembered that the interpretive value of laboratory analysis depend as much on the sampling methods as on the laboratory work itself.
Furthermore, it must be borne in mind that topsoil fertility relations depend to a very high degree on land use and vegetation at the time of, or immediately prior to, the sampling. This variation makes it dangerous to use chemical properties for delineation of permanent soil units.

4. In order to prepare a soil map it is necessary to define as clearly as possible soil units at different levels which are to be used as mapping units. These are based on the field observations and laboratory analysis of the soils, topographic conditions and general observations on the soil profile.

There are countless different ways of classifying soils. As with all classification, the type used will depend on the purpose for which the soils are being classified. A very simple classification could be made on the basis of soil texture, separating soils into clays, light clays, loams, sands and so on. The soils can also be separated into drainage classes, according to soil

depth, fertility status etc. A general purpose soil survey ought to delineate soil units which may serve as suitable management units for a variety of different land use alternatives and, at the same time, the information on the soils must allow a classification of their capability for these different uses. Normally, the basic units are called soil series. Topographical sequences of soil series ("catenas") are also mapped as soil associations, particularly when land systems (see 6.4.2.) are used for over all land capability zoning.

5. The soil survey and mapping are thus not aims in themselves. They are instead means of compiling, in an objective and systematic way, the information needed for the final stage - identifying and mapping soil suitability classes. These suitability classifications must be referred to a particular form of land use. It may be a fairly wide classification for crop production or forestry in general or it may be a narrow classification for particular purposes, like irrigation or certain crops with specific requirements.

In section 6.4.3. one such suitability classification system is presented in more detail. It is the USDA land capability classification, which is primarily based on a soil suitability rating but it has also integrated topographical and other physical factors.

It should also be stressed that any system of soil capability classification must have an arbitrary element built into it, as there can be no strictly objective quantitative criteria which can be used for deciding into which class any particular piece of land should be placed.

6. A complete soil survey and suitability classification should not only contain the above mentioned descriptions and ratings of the soils at the time of the survey but also recommendations on how to develop and improve the soils in the best way according to their individual properties. This may include ways of improving structure, increasing organic matter and nutrient contents, improving drainage, decreasing salinity etc. A very important aspect are recommendations on soil conservation measures against erosion(cf. 6.5.5.)
Furthermore, the soil report ought to include enough information so that if need arises, an evaluation can be made of soil suitability for road construction, community and urban planning etc.

As an example of a soil survey and capability rating an extract from "Soil and land use survey of the Kano Plan, Nyanza Province, Kenya" is shown below (figure 36).

"Description of Soil Unit 9 - Kano clay

This is a very dark grey or black clay often with a very shallow surface cover of very dark brown or greyish recent origin. Although no textural distinction exists between the topsoil and subsoil, the later is generally slightly heavier with mean content of silt 18% and clay 70%; the clay fraction being composed of 60% montmorrillonite with remainder illite and kaolinite in equal proportions. When dry, the soil has loose surface mulch consisting of discrete very hard granular or blocky aggregates dominantly less than 5 mm in diameter; accounting for good surface tilth. The subsoil is distinctly blotched in deeper layers. When dry the soil is also characterised by deep

vertical cracks about 2-5 cm wide and having rust mottling as high in the profile as the surface horizon, often taking the shape of root channel rusting; whilst most sub-surface horizons have strong blocky structures with dense fabric and hard to extremely hard consistence when dry. The profile permeability is slow to negligible and once the cracks close, water losses due to percolation are very slight. Topsoils tend to be acid to neutral in reaction but the subsoil is generally alkaline with mean exchangeable sodium of 13%; the highly significant level of alkali is encountered around 70 cm depth. A noteworthy feature of the subsurface horizons is the invariable presence of root galleries, comprising of a profusion of mats of broken fine dead roots. This may be considered a horizon of root frustration as rarely do any healthy roots appear below this layer, presumably due to alkali and montmorillonitic clay content. Within the modal profile carbonate concretions appear about 100 cm depth; free lime and gypsum clusters were encountered at depth in some profiles. There are adequate levels of nutrients including P, K and S but nitrogen content is marginal. The Table 12 (Profile 44) gives analytical data of a typical Kano clay.

Description: Profile 44: Depth 150 cm.

A 11, 0 - 9 cm. Very dark greyish brown, 10 YR 3/2 clay; common distinct yellowish brown (10 YR 5/4) rusting in root channel; weak fine and medium blocky, and strong fine granular and blocky micro-structure; hard, firm sticky and plastic; vertical cracks 3 cm wide; mats of abundant fine roots; upper 2 cm (dry) distinct hard fine aggregates forming spongy surface; clear smooth boundary.

A 12, 9 - 65 cm. Very dark grey, 10 YR 3/1 clay; strong medium and coarse blocky; very hard; very firm; common 2 cm wide cracks continuing from above with shiny pressure peds (slickensides); common fine roots; gradual smooth boundary.

AC, 65 - 114 cm. Very dark grey to very dark greyish brown 10 YR 3/1 - 3/2, clay; common fine brownish streaks; moderate medium and coarse blocky compounded into weak prisms with shiny pressure peds; extremely hard, very firm; common fine carbonate concretions; abundant root galleries (broken down fine roots on ped faces); few fine roots; gradual smooth boundary.

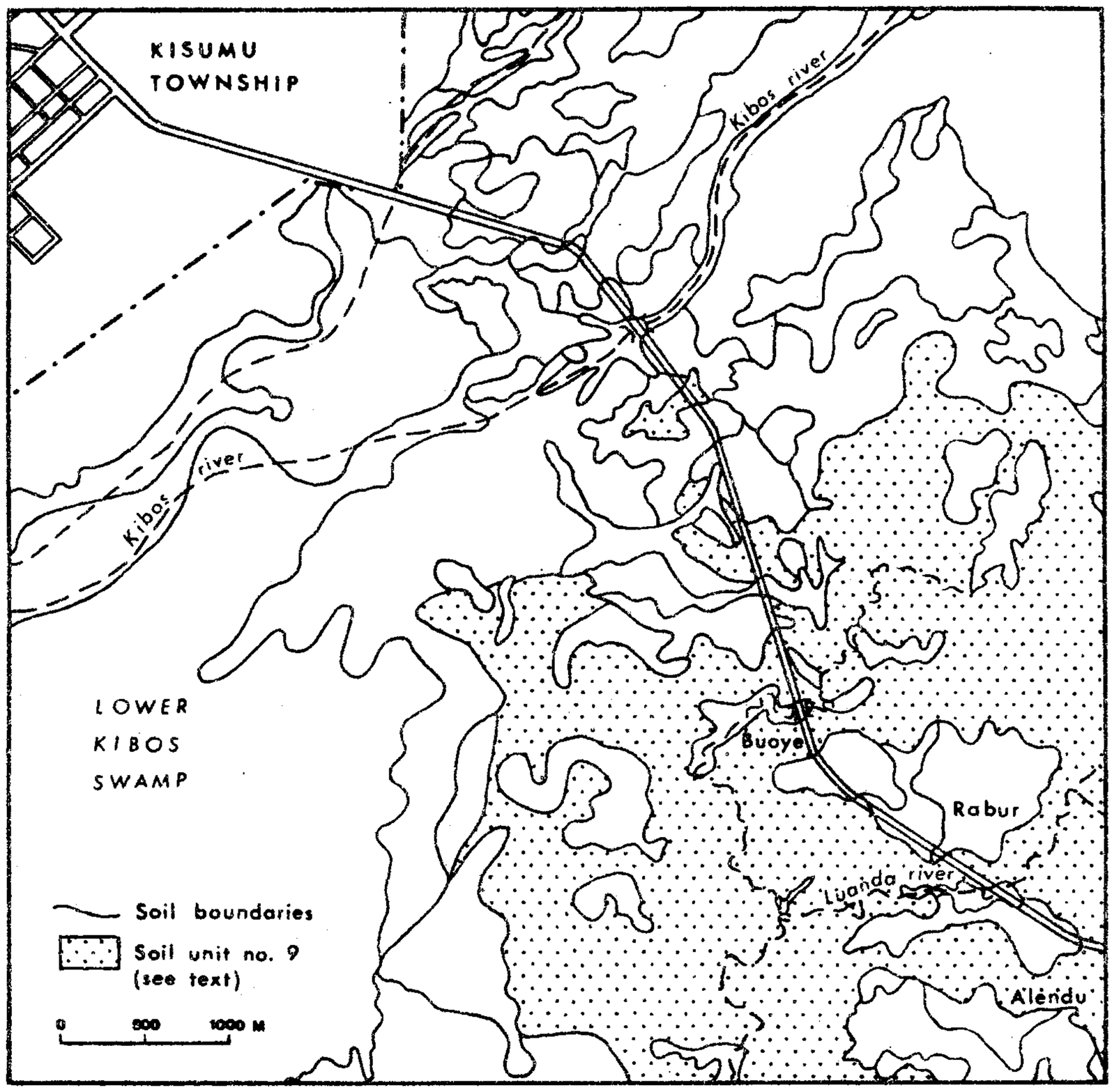
C, 114 - 150 cm. Dark grey 10 YR 4/1 blotched very dark and dark greyish brown 10 YR 4/2, 3/2; moderate medium subangular blocky; firm to slightly friable; abundant fine and medium calcium concretions; few soft segregations of lime and gypsum; no roots.

The Kano clay is the dominant soil of the Plain, occupying wide level to slightly sloping situations; the total extent is about 16,000 ha.

Classification: This soil falls in the "Typic Pellustert" subgroup of Vertisols sometimes intergrading towards "Chromic Pellustert".

Suitability: The Kano clay, owing to the wide nearly flat stretches it occupies and because of the poor drainage and slow permeability status, is considered ideally suited for irrigation of paddy. Periodic checks would be necessary to ensure that no toxic levels of sodium are built up in the subsoil; deep rooting crops such as sugar cane would necessitate soil amelioration methods, such as ripping, ridging and application of gypsum. Response to nitrogen fertilizers could be expected."

FIGURE 36. Detail from soil map of the Kano Plain, Kenya
Source: D'Costa & Ominde (1973)



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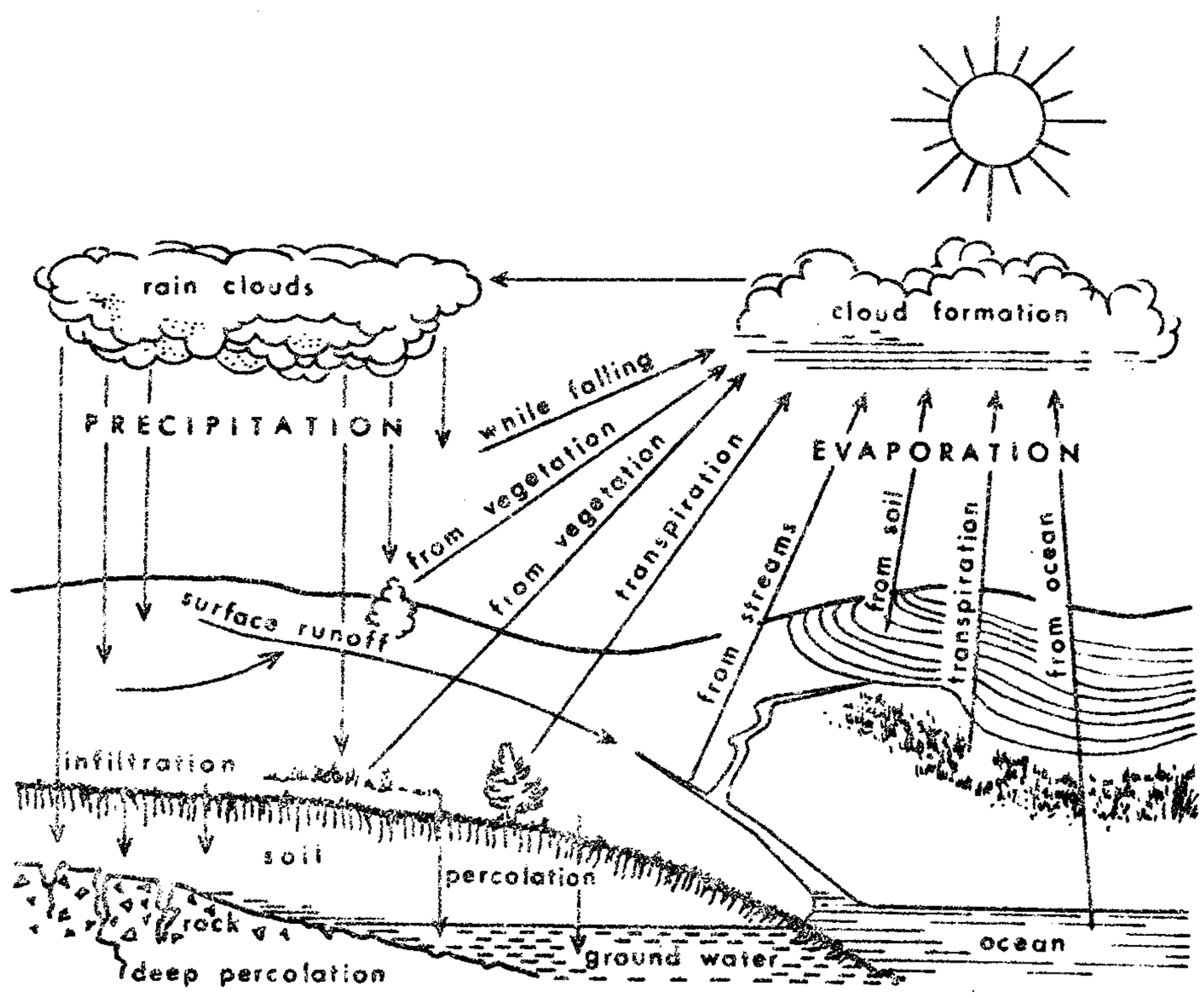
6.4.1.3. Hydrological survey. The over-all hydrological characteristics of Kenya and Tanzania and the present degree and types of utilisation of the water resources in the two countries are described in sections 3.5. resp. 4.6. In 5.3., some effects of disturbances in the hydrological cycle (see below) due to population increase and changes in land use are discussed, mainly by reference to current research in different catchments in East Africa. The present section will briefly summarise the need of hydrological data collection in connection with land potential surveying.

All forms of land use depend ultimately on the availability of water. Development of the land resources is thus intimately and inseparably linked to the development and management of the water resources.
The range of water-based biological and social requirements is very broad. Apart from the basic physiological need of water of all organic life on earth, including e.g. in the photosynthesis, water is needed for domestic and industrial use, energy, fisheries, transportation and recreation. The geological effects of water - erosion, transportation and deposition of solid material - are also of great significance in assessing its role in land development.

One of the major prerequisites in successful land development is consequently that sufficient water of acceptable quality is available in the right place at the right time. The higher and better distributed the rainfall is the less is the likelihood that water is a limiting factor to development (though, of course, water management problems also may exist in areas with a water surplus, e.g. erosion, sedimentation, floodcontrol etc.). Over most of East Africa, however, there is a water deficit, i.e. potential evapotranspiration is much higher than precipitation (see map 21), and in those areas lack of water is the most important limitation to land use. The potential for intensifying land utilisation in the semi-arid regions is therefore dependent on a rational conservation and management of the limited water resources. To achieve this a detailed survey of the hydrological characteristics of the plan area must be carried out, along with other basic resource surveys.

A hydrological survey should be designed with the basic fact in mind that water, seen from the standpoint of a defined area of land, is a cyclic resource that can be described in terms of input, storage, flow and output. This "hydrological cycle" has been touched upon in section 5.3. In figure 37 a generalised hydrological cycle is shown.
The precipitation and inflowing surface and ground water represent input; evaporation, transpiration and outflowing water are the outputs; increases or decreases in lake and groundwater levels and in soil moisture represent changes in water storage; and all movements of water within the area, including percolation, surface run-off, streamflow and groundwater movement, are flows.

FIGURE 37. The hydrological cycle
Source: Vink (1975)



All measurements and assessments of the components of the hydrological cycle are greatly facilitated if they are referred to natural hydrological land units. Depending on the scale of the survey, hydrological units may be anything from major drainage basins - e.g. the Lake Victoria drainage basin - via larger river basins - e.g. the Tana and Pangani River basins (see map 12) - to small mountain valley catchment areas - e.g. the ones described in section 5.3.3.

In principle, the hydrological land unit is geographically defined by a single point in a river or a stream. Thus, the lake Victoria basin is defined by the point where the Nile leaves the lake, the Tana and Pangani River basins by the points where the rivers fall into the Indian Ocean and minor catchments by any conveniently chosen point in the stream draining them. The delineation of the drainage area then emanates from this point by following, on a topographical map or stereo photos, the water divide until the whole area is encompassed from which all precipitation water theoretically would flow as surface water by gravity forces to eventually reach the starting point. A substantial part of the precipitation will naturally be lost by evaporation and transpiration before reaching the outflow point and some, although normally negligible amounts in semi-arid land, may be lost by deep groundwater flows, which may not at all coincide with the drainage area as defined by surface topographical features.

Since the primary aims of the hydrological survey are to identify and quantify the various components of the hydrological cycle, the advantages of basing the survey on drainage areas are obvious: the only incoming water is the precipitation over the area and the total surface discharge from the

area passes through a single point.
So important is in fact the possibility of being able to integrate an accurate water balance in the total land use planning that many development schemes, both of integrated and sectorial type, are delineated by hydrological boundaries.

The detailed design and accuracy required of the hydrological survey will naturally depend on the aims of the particular project (whether, for example, irrigation and dam constructions are considered), on climatic conditions, and on time and resources available for the survey.

The following points ought to be considered and, if feasible and relevant, measured or evaluated:

1. Identification and mapping of the drainage pattern of the plan area, including permanent and seasonal streams and rivers, lakes and swamps, and delineation of suitable drainage areas for quantitative measurements. Where the plan area does not coincide with hydrological boundaries it is important to clearly map the areas outside the plan area which influence its hydrology.
If good topographical maps and/or aerial photos exist, this initial work can be done as a desk study.

2. Climatic information collection is dealt with in section 6.4.1.1. Total rainfall over the drainage areas, seasonal distribution, rainfall intensities and actual and potential evapotranspiration are the most important climatic parameters needed for the hydrological survey. To increase future accuracy in water balance calculations, it is important that hydrologists and climatologists in cooperation establish a network of rain-gauges over the project area.

3. Soil physical parameters, described in section 6.4.1.2., must be evaluated in terms of their hydrological significance. The most important are infiltration capacity and soil moisture storage capacity.

4. Water flow in streams and rivers is probably the most important hydrological parameter to measure, since this represent the surplus, or yield, of water from the drainage area after evapotranspiration and deep percolation have taken their parts of the precipitation. The streamflow is thus what is available of surface water for development of irrigation, dams, energy and other water-based activities.
Accurate measurements require installation of streamflow gauges which should be read frequently, preferably automatic gauges giving continuous readings. The graphical representation of these readings is called a hydrograph for that particular point, and it is a necessary tool in planning water utilisation. Important river discharge features which can be read from hydrographs are, apart from total annual streamflow, maximum and minimum discharge over any time unit, seasonal variation, peak discharges in relation to specific intensities of rainfall over the catchment, and the time-lag between rainfall and peak discharge. The latter two parameters are important indications of the relative importance of evapotranspiration, surface run-off and infiltration under the specific land use practised in the area.

In East Africa, characterised by unreliable rainfall and large annual variations, it is quite obvious that streamflow measurements have to be carried out for a number of years to be statistically reliable.

5. The quality of the water is of decisive importance in determining its value for various uses. Irrigation water must not have too high concentra-

tions of dissolved, harmful salts; drinking water should not contain human or animal disease carriers; water that will be used in mechanical constructions, like hydro-electric power stations or pumping stations, must be reasonably free from suspended sediment particles, etc. Whatever the use and quality requirements, it should be remembered that water quality varies a lot in time and space and, consequently, must be assessed frequently and in different places.

6. An evaluation of the effect of different forms of land use on the hydrological characteristics should also be made. Such an evaluation must be made with a multi-disciplinary approach, including experts in fields like hydrology, soil science, climatology, general ecology and agriculture. Some aspects that might need attention are e.g. rainfall interception and water use by different crops and types of natural vegetation, erosion under various agricultural systems and crop combinations, relation between vegetation and land use on the one side and soil infiltration capacity on the other. The role of catchment protection forests should be elucidated in this type of evaluation.

7. Location of possible groundwater aquifers should be done where surface water is either not available in adequate quantity or where its quality is not sufficient for the use in question. The extent of groundwater in semi-arid East Africa is not well known, but it is thought that considerable amounts are available for exploitation. Expert knowledge in hydrogeology is normally required to assess groundwater conditions.

The seven points discussed above are just very brief summaries of the most important major components in a hydrological survey. In an actual plan situation these have to be elaborated. An example of a possible further breakdown of points 7 and 4 respectively, is shown in table 41 below, which is taken from a recent book on land evaluation.

TABLE 41. Hydrologic data required for land development projects
Source: Vink (1975)

1.	Geo-hydrology
1.1	Qualitative appraisals of safe yield, safe seepage
1.1.1	Geological information
1.1.2	Qualitative appraisals of seepage:
1.1.2.1	Water-saturation phenomena as reflected by the soil profile
1.1.2.2	Water-saturation phenomena as reflected by the soil vegetation
1.2	Quantitative appraisals of safe yields, safe input, seepage
1.2.1	Isohypses and seasonal fluctuations
1.2.2	Equipotentials and seasonal fluctuations
1.2.3	Depth to and thickness of aquifers
1.2.4	Aquifer characteristics such as:
1.2.4.1	Transmissibility
1.2.4.2	Piezometric gradient
1.2.4.3	Non-capillary porosity
1.2.4.4	Hydraulic resistance of aquicludes or overlying strata
1.2.4.5	Storage coefficient
1.2.4.6	Water quality

continued on next page

2.	Hydrology
2.1	Runoff characteristics
2.1.1	Approximate discharge determinations
2.1.1.1	with the aid of the dimensions and shape of water courses and their stage marks
2.1.1.2	by means of rainfall-runoff relationships
2.1.1.2.1	following the curve-number method (Handbook of Hydrology, S.C.S., U.S.D.A.)
2.1.1.2.2	following the method of Krayenhoff van de Leur
2.1.1.2.3	following the unit hydrograph method
2.1.1.2.4	following the rational method
2.1.2	Discharge measurement data
2.1.2.1	Location of gauging stations
2.1.2.2	River stage data
2.1.2.3	River cross-section data and stage-discharge relation
2.1.2.4	Other discharge-measurement data
2.1.3	Sediment load
2.1.4	Water quality
2.2	Tidal characteristics
2.2.1	Approximate determinations
2.2.2	Location of gauging stations and tidal-fluctuation data
2.3	Location and capacity of existing natural or man-made drainage outfalls

From what has been said above, three main objects of a hydrological survey can be distinguished, namely:

a) A basic resource survey, which, together with other resource surveys described in this section (6.4.1.), will be synthetised into a land potential evaluation.

b) A collection of data needed for specific water development projects and water resources management, including irrigation, dam constructions for various purposes, canal building, digging or drilling for groundwater etc.

c) A base-line description of the hydrological relations in the plan area, and how these are influenced by factors like land use and vegetation (i.e. the ecological role of water) before land and water development plans are implemented. This is one of the prerequisites for future evaluation of the project.

There has been an unfortunate tendency in East Africa, as in most developing countries, to plan and implement water development projects from a rather narrow, sectorial point of view, more so than for many other types of single purpose development projects. The engineering problems of quickly making water available for a particular use have often resulted in that less attention has been paid to an assessment of the overall ecological role of water in the area, and how that is affected by the changes in the hydrology brought about by the implementation of the particular water development project. Numerous examples can be quoted where interferences in the hydrological cycle have led to unexpected side-effects normally negative, but occasionally also positive.
It is therefore appropriate to stress here, as has been done many times in this report, that land as well as water use planning must be based on integrated pre-feasibility surveys and evaluations.

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6.4.1.4. Topography. A good topographic map is an important tool for land surveys and planning. The topography or "relief" of the land has a strong influence on drainage, soils and vegetation. The difference between dry sites such as ridges or hill slopes and floodplains or other areas liable to flooding are particularly important in the tropics with drought in the dry season and floods during the rainy season. To make optimum choices of location for roads, railways, villages, towns and farming areas requires consideration of the hazard of flooding, for instance. Another important aspect of topography in the tropics is the influence of elevation above sea level on climate - temperature, evaporation, wind and rainfall.

For these and several other reasons much effort has been spent on topographical mapping in both Kenya and Tanzania. The published map sheets cover about half of the countries and the mapping work continues. Since about 1950 the topographic maps have been based on aerial photographs.

The following types of maps are now available for use in the two countries:
topographic maps in 1:50,000, most of them with contour lines for altitude;
maps in 1:250,000, with generalized relief;
town maps in scales up to 1:5000 for built-up areas and their close surroundings.

Air photographs are a very important source of information on topography, drainage, vegetation, land use and other factors. They are in standard scales from 1:20,000 to 1:40,000 and the coverage is almost complete over the two countries, however from different years of photography. The air photographs can be used with great advantage for steroscopic examination under a mirror stereoscope, which gives a magnified, three-dimensional view of the photographed land. They can also be obtained as so-called air-photo mosaics, combined into sheets of scale 1:50,000 or as less detailed "print laydowns" in scale 1:125,000 (see figure 38 and table 42).

For detailed planning purposes in connection with development projects it is however often necessary to prepare new, high quality, large scale maps of the project area. This may be because existing maps are too old, too small-scaled, lacking contour lines or are of bad quality for some other reason. In actual fact, taking of new aerial photos, permitting the preparation of high quality topographical maps at scales of 1:5000-1:15,000, ought to be a

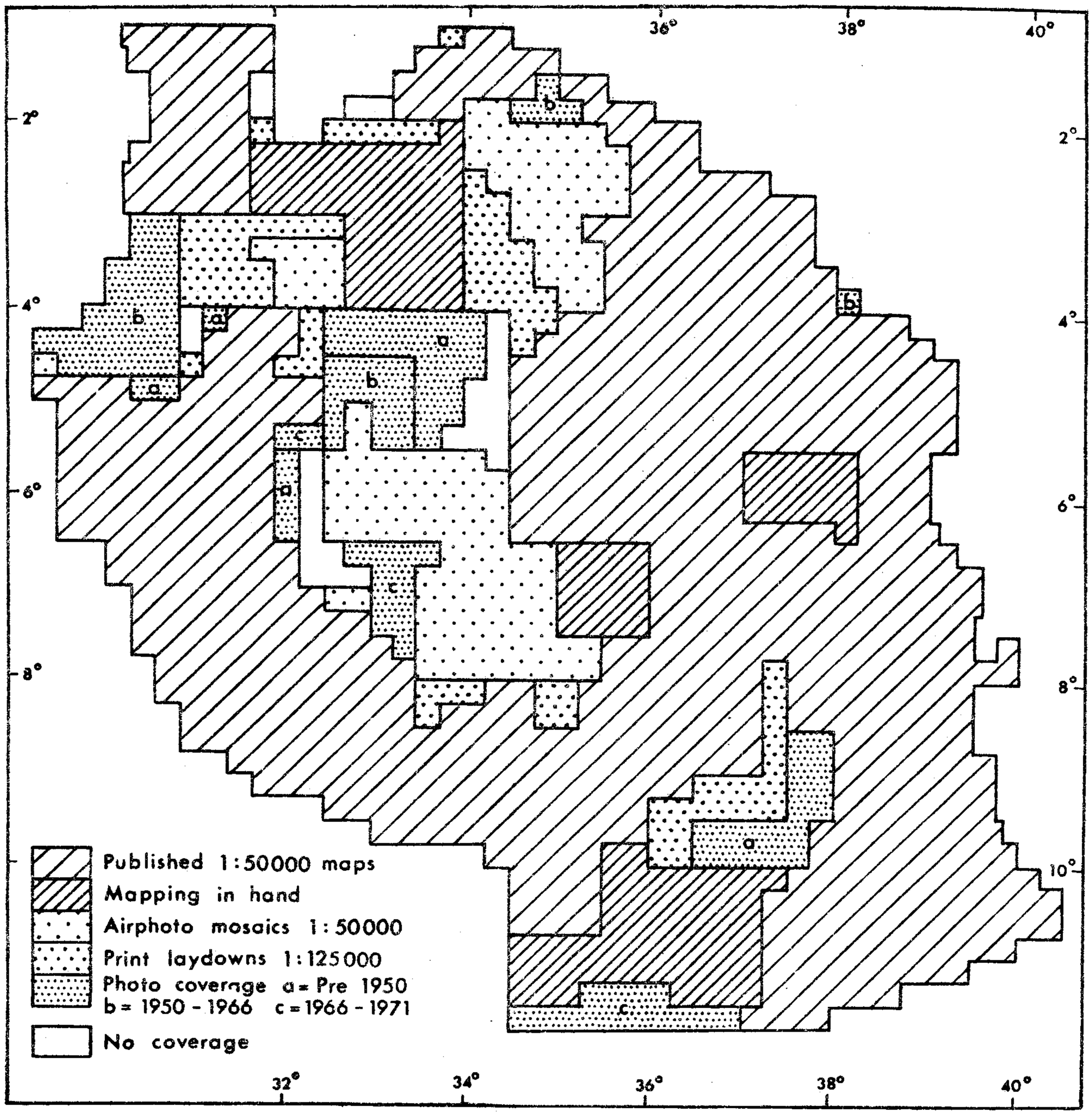
standard procedure in land potential surveys and land use planning operations, even if fairly good, but somewhat outdated, maps already exist. There are three main reasons for this:
Firstly, the surveying of natural resources like soil, vegetation and hydrology can be much easier and more accurately done if large-scale maps are available.
Secondly, surveying of present land use (and vegetation) can only be done reliably from recent aerial photos.
Thirdly, it is extremely useful in connection with later project evaluation work - social, technical and ecological - to have a set of aerial photos taken just prior to the commencement of a land development project.

For planning purposes at a regional or national level a very useful new tool is the photographic images from the satellite ERTS-1 (Earth Resources Technology Satellite). Each ERTS image covers a land area of 160 x 160 km and complete coverages are available taken at 18-day intervals during a year from July 1972. Contact prints or diapositives can be ordered from a distribution center in the U.S.A., and the images can be magnified by standard photo magnification up to scales of 1:250,000 and in favourable cases even more. Ground objects of a minimum size of 80 x 80 m are visible in the satellite images. They are particularly useful for areas which lack good maps or aerial photographs and also to update older maps or photographs. It is necessary to check possible occurrence of cloud cover on air photographs and satellite images, as the clouds hide the ground areas in both kinds of material. The usefulness of satellite pictures is somewhat limited for topography, as they do not give a three-dimensional stereoscopic view.

TABLE 42. Summary of map and air photo coverage of Tanzania
Source: Porter (1973)

Data as of Jan. 1972	Number of 15′by 15′maps	Percent
Topographic maps 1:50,000	787	63
Mapping in hand (dyeline) 1:50,000	132	11
Sub-total	919	74
Print laydown (mosaic)	120	10-
Print laydown 1:125,000 (some poorly rectified)	72	5+
Cumulative sub-total	1,111	89
Air photo coverage (uncontrolled and unrectified):		
Pre-1950	47	4-
1950-1966	44	3+
1966-1971	27	2
Cumulative sub-total	1,229	98
No coverage	26	2
Total	1,255	100

FIGURE 38. Status of mapping and air photo mosaic and print lay-down coverage of Tanzania as of 1 January 1972.
Source: Porter (1972)



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6.4.1.5. Vegetation survey. In section 3.6. the overall pattern of vegetation distribution and descriptions of the major physiognomic vegetation types were presented. As with the small scale soil map and description in 3.4., the vegetation map (13) can not be used for any detailed planning purposes on larger scales, but merely as an indicator of regional climatic zonation.
In most land potential studies some form of vegetation survey and mapping are dutyfully carried out as a part of a natural resources survey, though unfortunately the great usefulness of a competently conducted and interpreted vegetation survey is seldom realised by development planners and decision-makers. Actually, in areas where reliable climatic information or soil maps are scarce or non-existing, as they are over most of Kenya and Tanzania, a vegetation survey ought to precede other types of natural resources surveys since the field sampling intensity and methods used for these other surveys may be greatly influenced and modified if an accurate and professionally interpreted vegetation survey exists.

Below, a brief account of reasons, methods and contents, and some examples of possible uses of vegetation surveys in connection with land potential studies are given.

1. Apart from purely botanical studies, where the aim is to increase our knowledge about the flora and vegetation as such, one may, somewhat simplified, talk about three main groups of reasons why vegetation surveys are carried out.

a) The most obvious case is where the natural vegetation, or parts of it, will form the primary production basis of a particular type of land use, and where active management of the vegetation consequently has to be planned. In East Africa, the most common examples are range management for animal production, National Park management and utilization of natural forests and woodlands for timber, fire-wood or charcoal production.

b) Where certain types of natural vegetation or specific plants exert a significant indirect influence on land potential. The most important cases are where animal or human disease vectors are associated with particular plants or communities of plants, like tsetse flies carrying trypanosomiasis, ticks carrying e.g. East Coast Fever and others. Many wild plants may also serve as alternate hosts for important insect or other pest organisms affecting economically important agricultural or forestry crops, in which case their distribution and frequency must be surveyed.

c) In a general purpose survey in connection with land use planning, it is the value of the vegetation and plants as indicators of land potential that is the primary matter of interest. This stems from two basic facts:

- Individual plants and communities of plants are growing on a site as the result of the specific interaction of environmental factors on that particular site. Knowledge about the requirements and tolerance limits of the plants and vegetation will thus, to the experienced observer, give valuable information about climate, soil and hydrology on the site as well as possibilities to evaluate general ecological conditions, e.g. with regard to human and animal influences.

- Vegetation is much easier and quicker to survey, both from maps and aerial photos, and in the field, than are e.g. soil, hydrology and climate.

A base-line vegetation survey is also one of the main components both in an ecological pre-feasibility study and in later evaluations of the ecological success or failure of a land development project. It is therefore important

that the vegetational conditions in the area are well documented before any changes in land use are introduced.

2. Like with soil and other capability and pre-feasibility surveys, the methods employed in a vegetation survey will largely depend on:
- the aims of the specific plans under consideration
- resources available with regard to qualified personnel, time, money, maps, aerial photos, herbaria and floras for plant identification etc.
- nature of the area to be surveyed
- type and degree of co-ordination with other surveys.

A complete vegetation survey ought to include the following information and evaluations:

a) A map of the vegetation types and plant communities in the survey area and a description of them with regard to physiognomy and species composition.

b) An evaluation of the extent to which the vegetation is "natural" or "modified", and whether it is in a stable or dynamic phase (i.e. the successional relations).

c) An evaluation of the degree and type of correlation between the vegetation on one side and the natural environment (soil, topography, wild animals) and or antropogenic influences (fire, cultivation, grazing of domestic animals, vegetation clearing) on the other side.

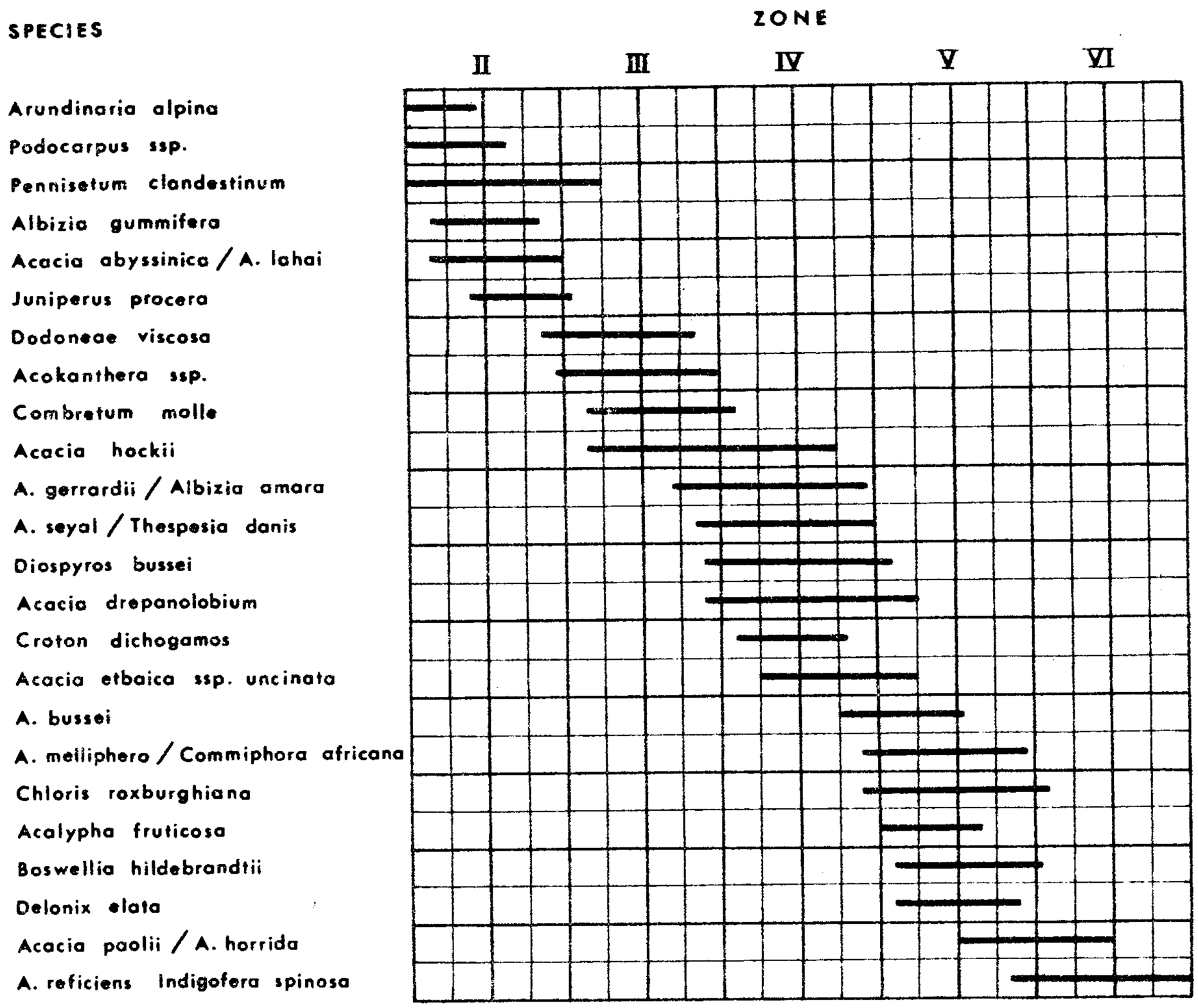
d) A rating of the vegetation from a conservation point of view, e.g. if any vegetation type is scientifically unique as such or if it forms an integrate part of a unique ecosystem.

e) Information about distribution of economically or otherwise valuable plant species. These may e.g. include fodder plants for animals (e.g. Acacia albida for dry season food), medical plants, timber trees, woody species used for carvings or other specialised purposes etc. A compilation like this must be based on knowledge about local and traditional uses of plants.

3. A few examples of how the knowledge about plants and vegetation can be used to obtain information about factors deciding land potential will be given below.

- All plant species are physiologically adapted to grow under certain climatic conditions, e.g. with regard to total effective rainfall, particular sequences of dry and wet seasons, temperature ranges, humidity etc. The problem when using plants as indicators of climatic conditions is to identify their climatic range and how this range is affected by other factors.
If plants are used to delineate climatic boundaries it is an advantage to use several species with partially overlapping climatic ranges. This has been done when preparing the Ecological Potential Map of Kenya (see 6.3.3.1.). In figure 39 below is shown how the occurence of 30 indicator species used when preparing this map are correlated to "moisture index", which is the factor used as a basis for delineating Ecological zones.

FIGURE 39. The ecological range of some important indicator species used in delineating eco-climatic zone boundaries in Kenya. Source: National Atlas of Kenya (1970)



- Within the climatic ranges of individual plants and plant communities there is often a more or less marked vegetational separation or zonation related to soil conditions. This is particularly pronounced where soil conditions are extreme in one way or another, e.g. on seasonally waterlogged soils, on very heavy or very light soils, on thin soils, or on soils with high salt concentrations etc., in which cases the vegetation has got a very good indicator value. Edaphic (controlled by soil conditions) plant communities are quite common in East Africa, the best example probably being the grasslands with scattered Acacia drepanolobium dwarf trees associated with the dark, cracking, montmorillinitic clays in flat valley bottoms ("mbuga" sites). Likewise Acacia seyal-communities are found on seasonally waterlogged or flooded soils. The close correlation between soil and vegetation is also seen along slopes and this fact is used when studying topographical soil associations ("catenas") from aerial photos.

There are also many examples of individual plants indicating particular soil conditions, e.g. high salinity (halomorphic plants) or extreme concentrations of aluminium or other substances which may be toxic to other plants. Sometimes this type of correlation can be used when prospecting mineral deposits, which is the case e.g. with copper in Rhodesia, Zambia and Katanga, where the plant Becium homblei is associated with soils derived from rocks rich in copper.

- Fire and/or grazing by domestic and wild animals modify the vegetation by favouring plants with certain features, e.g. fire-resistance - thick bark, vigorous coppicing, hard seeds, deciduousness, geophytic forms etc. - or grazing-resistance - thorny and spiky bushes or trees, grasses with high silica content or generally untasty plants. The resulting vegetation depends very much on the intensity and frequency of the acting agencies. In areas where burning and/or grazing have acted for a prolonged period without significant fluctuations in intensity, a kind of subclimax vegetation in equilibrium with these factors is developed. More often, however, the intensity of these factors is increasing due to increased human pressure and the vegetation is continuously changing. Whatever the case, an experienced botanist and ecologist will be able to interpret these influences by examining the vegetation.

- In some cases certain soil conditions will give rise to local physiognomic adaptations in plants. On slopes with marked soil creep, trees will tend to grow bended, stiltroots may develop in seasonally waterlogged areas etc.

4. The situation in Kenya and Tanzania with regard to large-scale vegetation mapping is almost as bad as with soil mapping. Only part of SW Kenya has been systematically surveyed in detail and mapped on a 1:250 000 map. Local surveys for specialised purposes, e.g. in National Parks or range development projects, have also been carried out, but many of these are difficult to obtain.
The general knowledge about the flora and vegetation is, however, fairly satisfactory, particularly in Kenya. Good field floras exist for woody plants and grasses, but not for other groups of plants. The large "Flora of Tropical East Africa" is being published family-wise since 1952 and at present around 65 families of plants have been treated. Among existing herbaria, the East African Herbarium in Nairobi has by far the largest collection of plants in East Africa.

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6.4.1.6. Information from existing agriculture. A very important source of information about physical land potential which is often overlooked in land use planning in developing countries is the study of how traditional agriculture has developed in response to the physical environment. Technocrats, agriculturalists and planners educated in developed countries often consider traditional agriculture as being a priori sub-optimal, primitive and directly destructive to the environment. "Wrong" crops, low yields, erosion problems, overgrazing etc., which certainly are widespread problems, are the visible evidences to support this option.
What is forgotten then is that the present situation almost invariably is the result of recent population increase far above the carrying capacity levels of the environment (i.e. with traditional practices). Additional reasons may be the partial introduction of new techniques (e.g. increased water supply in semi-arid areas and highyielding crop varieties without additional fertilisers) without full understanding of their overall implications or moving people from overpopulated, but fertile, regions to drier areas without teaching them how to cope with the new environment (e.g. the Ujamaa and "planned" villages in Tanzania).

All this must not, however, conceal the fact that traditional agricultural practices have evolved in response to environmental factors and that, under "normal" conditions, they are well adapted to these factors. Different peoples in East Africa are thus growing different crops with different techniques mainly because they live in different environments. In a land potential survey much valuable information about the physical environment may therefore be obtained by a study of traditional agriculture in relation to physical factors.
Below follows a very generalised discussion of some types of factors that ought to be studied and interpreted in terms of land potential.

1. Agricultural systems - whether shifting, permanent or intermediate forms of agriculture are practiced. Shifting cultivation is almost invariably a response to infertile, easily exhausted soils. A study of the use of fire should also be included.

2. Cropping systems. The extent of perennial respectively annual crops, whether crop rotations, double cropping, mixed cropping and intercropping are used, will all reveal something about soil and climatic conditions in an area. Perennial crops are grown mainly where high and reliable rainfall occur or where groundwater is close to the surface. The more fertile and

well watered an area is the more sophisticated cropping systems have developed. All this may seem quite obvious and normally of course it is not necessary to look at the cropping system to identify a fertile, high rainfall area. The reverse condition, however, is not seldom met with in East Africa. In other words, there is reason to be cautious when planning the development of a seemingly high potential area if traditional agriculturalists have not developed rather sophisticated cropping systems. A closer study of soil conditions and climatic statistics will then often reveal serious limitations in land potential.

3. Crops grown and their yield. Make an inventory of different crops and identify the factors limiting their yield - whether primitive agricultural practices, soil, climate, pests etc. It is often less hazardous to try to improve the yield of crops that have proved to be adapted to the climatic conditions of an area than to introduce entirely new crops. A number of other factors will of course also influence the choice of crops in a development scheme, e.g. nutritional and economic aspects, but the above mentioned advantage of established crops should not be forgotten.

4. Topographical location of crop fields - whether on top of hills and ridges, on slopes or in valley bottoms. This is often governed by soil and hydrological conditions and an experienced observer may get a good first hand impression of the physical conditions by studying this on aerial photos. It should be a natural question in feasibility surveys to ask why fields are situated at a particular place or why they are not situated on other places, which to a casual observer may seem suitable (e.g. "mbuga" sites). There is always a rational answer to these questions that may help the planner to avoid unnecessary mistakes.

5. Time of sowing or planting. In areas where climatic data are scarce the traditionally used indications to determine time of sowing or planting ought to be studied, since they may give information about rainfall reliability and seasonality.

6. Animal husbandry practices in semi-arid areas are strictly governed by environmental conditions. The interpretation of factors like species and races of animals used by traditional pastoralists; animal food preferences during different seasons; movements of herds to obtain water, fresh grazing and to avoid tsetse infested areas; sizes of herds in relation to range carrying capacities and possible land degradation trends etc. will give very valuable, or rather absolutely necessary, information to planners.

These are just a few of many examples of how a careful study and interpretation of existing, traditional agriculture may help the land use planner to establish land potential. Some of these factors can be satisfactorily studied on aerial photos, others must be investigated by asking the local population and studying their activities in the field.

6.4.2. The land systems approach in land potential mapping

In chapter 3 a number of small-scale maps were presented showing physical features, such as climate, soil, geology, landforms etc., of the whole of Kenya and Tanzania. As pointed out in the accompanying text, the boundaries between different mapping units in these maps represent large generalisations and simplifications. This means, among else, that, when making a land potential survey for a limited area - say a District or a river basin - it is normally not possible to enlarge the area in question from the small-scale maps to get a reliable assessment of the variation of physical features within the plan area. The demand for accuracy in connection with detailed land use planning is higher and we have to rely upon special surveys

and inventories of the relevant physical features in the area under consideration. These surveys have been discussed in the previous section (6.4.1.).

Problems arise when the results of these various basic resource surveys shall be synthetized into one or several maps on which the continued land use planning can be based. Ideally, the mapping units of such a map should meet the following requirements:

a) there should be a natural correlation between the various physical factors, i.e. soil, topography, drainage, vegetation, hydrology etc., and the mapping units,
b) the mapping units should be uniform enough to form suitable management units for the types of land use considered,
c) the definitions and descriptions of the physical characteristics of the units should enable a rating of them with regard to their potential for most types of land use.

One approach to land resource mapping that has won wide international acceptance is the land system method.
Land systems mapping was developed by the Commonwealth Scientific and Industrial Research Organization in Australia (CSIRO) as a rapid method of reconnaissance survey from aerial photos of otherwise unmapped or poorly mapped areas. The primary aim was to establish a classification of the suitability of land for agricultural purposes. The first area was mapped in 1946. Since then many more areas have been mapped as this method of reconnaissance survey continues to prove its value.

The method has been adopted by the Land Resources Division (LRD) of the Overseas Development Administration, Foreign and Commonwealth Office (formerly the Ministry of Overseas Development) in Britain. Reports have been produced for parts or all of countries like Nigeria, Lesotho, Botswana and Gambia (Ministry of Overseas Development, 1970). "A Land System Atlas of Western Kenya", (by R. M. Scott, R. Webster, and C. J. Lawrance) was published in 1970.

The basic unit of the classification is the land facet. This is a recognisable part of the landscape, usually with simple form, and with particular rock, soil and water regime that are either uniform over the whole of the facet or, if not, vary in a simple and predictable way.
Each land facet is sufficiently homogeneous over its extent to be managed uniformly for all but the most intensive kinds of land use. Land facets are of such a size that they can be mapped at scales in the range 1:10,000 - 1:50,000, and they are recognisable on air photographs at scales in this range.

Land facets are the units of land in terms of which we should hope to organise and collate information on the natural resources of an area like western Kenya. But for mapping the whole of such an area at any convenient scale individual occurrences of land facets are too small. (Also there are very many of them so that it may often be difficult to recognise them.) Some means of grouping land facets is needed to make the classification manageable.

It is common experience that as the area of interest increases from that of a single facet the number of different kinds of land, that is land facets, does not increase in proportion. Instead the same few, and only a few, land facets are found to recur. And they recur repeatedly with the same interrelations to form a pattern. It is the recurrence of a particular set of land facets that gives a landscape its character. Different landscapes are recog-

FIGURE 40. Detail from "Land system atlas of western Kenya"
Source: Scott et al. (1970)

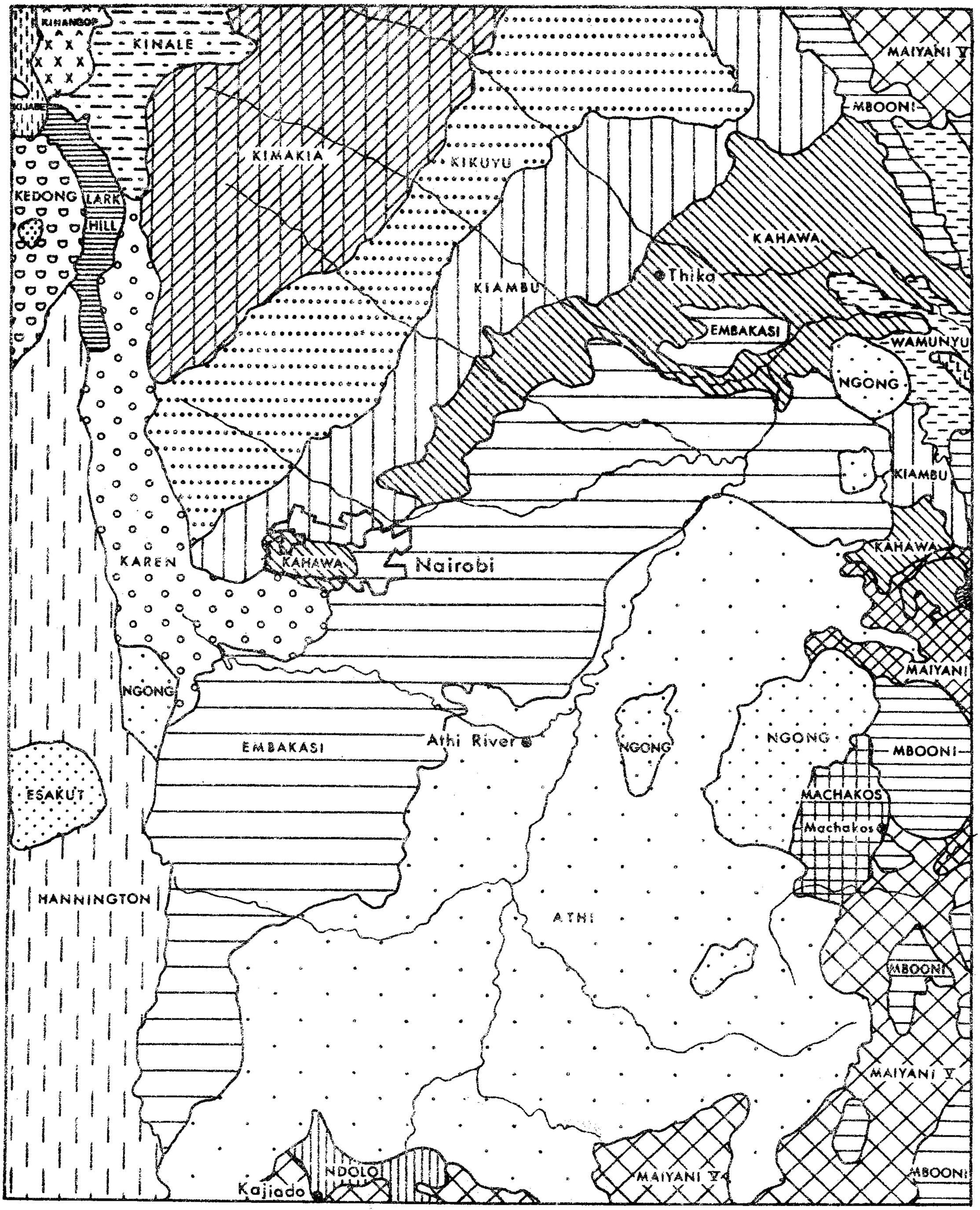
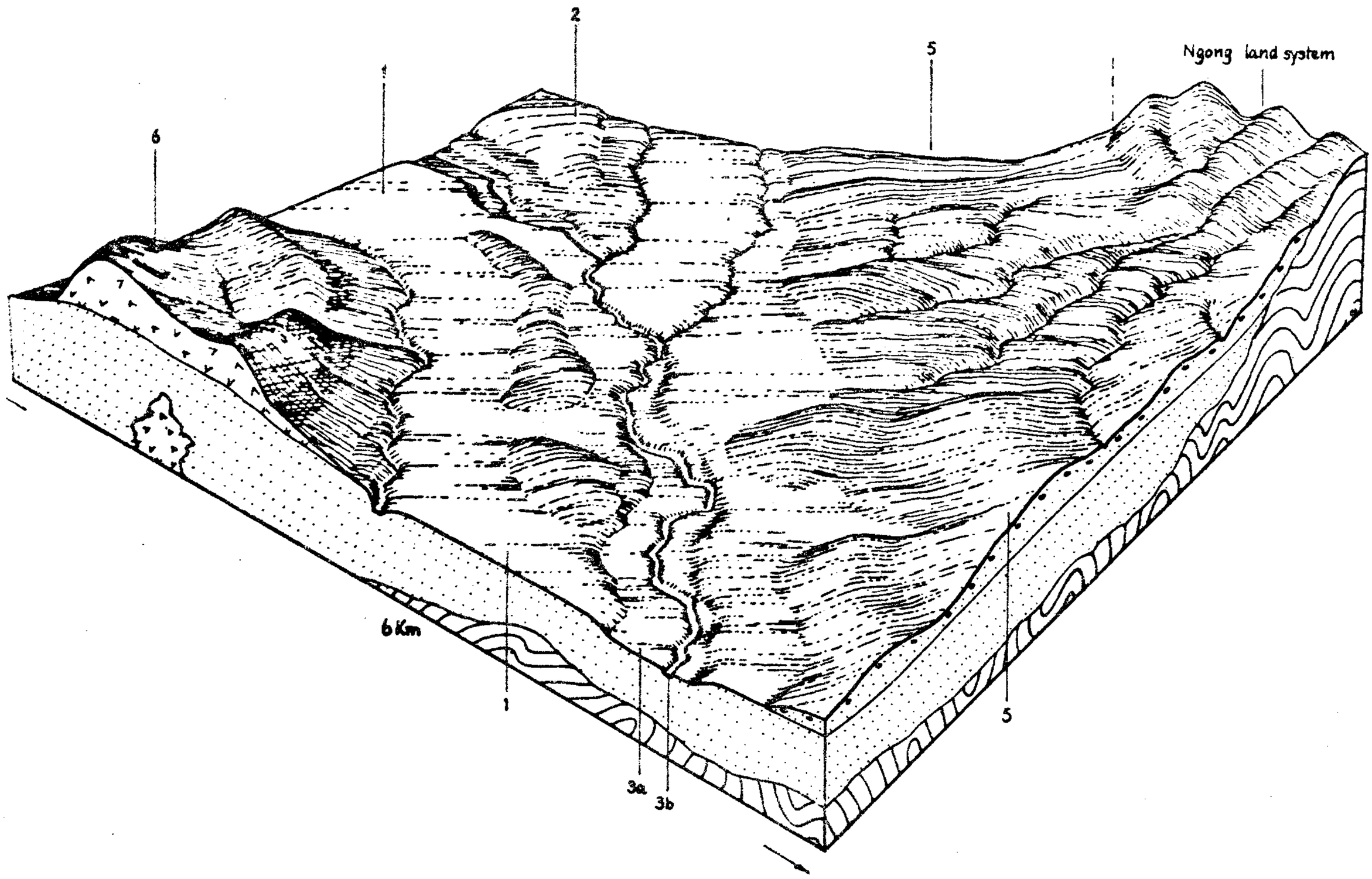


FIGURE 41. Idealised block diagram and description of the Machakos Land System (KE 91)
Source: Scott et al. (1970)



Climate: Rainfall 500-1000 mm. November-December, March-May.

Geology: A variety of waterlaid sediments of Tertiary to Recent age including lacustrine river deposited and fan materials derived from volcanic and basement rocks. Also outcrops of olivine basalt.

Landscape: Two broad valley areas between high hills. Broad, flat or gently sloping terraces are more or less deeply dissected by streams and are surmounted by rounded remnants of earlier terraces. In the Southern occurrence (Machakos variant) there are two upstanding volcanic cones.

Soil: Texture contrast soil.

Vegetation: Not recorded.

Relief: 10-30 m excluding cones. Cones up to 100 m.

Altidude: 1600-1825 m.

TABLE 43. Descriptions of the different land facets found in the Machakos Land System
Source: Scott et al. (1970)

Facet No	Form	Soils, materials and hydrology	Land cover
1	Main terrace. Level or very gently sloping; even; lower margins characteristically convex and slopes up to moderate; up to 2 km across.	Grey compact loamy sand to ca. 20 cm, grey compact more or less mottled plastic sandy clay loam to ca. 1 m. (Texture contrast soil). Lake sediments occur at depth; waterlogged periodically during wet season.	Not recorded
2	Low ridge. Gently sloping; convex or weakly undulating; 300-600 m wide and up to 2 km long.	Dark reddish brown over red clay with quartz and/or iron gravel to ca. 1 m over massive laterite. Basement Complex gneisses at depth. Freely drained.	Not recorded
3	Main valley floor. Level or very gently sloping; 200-400 m wide including (a) Flood plain. (b) Channel: winding; 5-30 m wide.	Not known	Not recorded
4	Minor streams. Up to 5 m wide often; entrenched to 2-6 m between very steep gully sides; more or less straight. Occur within facet 5 and to a lesser extent facet 1.	Not known	Not recorded
5	Fans. Gently sloping; slightly irregular; broken by minor streams (facet 4); extend from foot of adjacent hills (Mbooni and Ngong land systems) 2-3 km wide.	Dark grey sandy topsoil to ca. 20 cm over brown sandy clay loam to ca. 1 m over massive laterite.	Not recorded
6	Volcano. (Restricted to Machakos variant). 200 m high and 1 km across; roughly circular in plan; with steep to moderate sides. (Not shown on air photos.)	Not known	Not recorded

nised either where there are different sets of land facets or where the patterns of relationships between the constituent land facets differ.

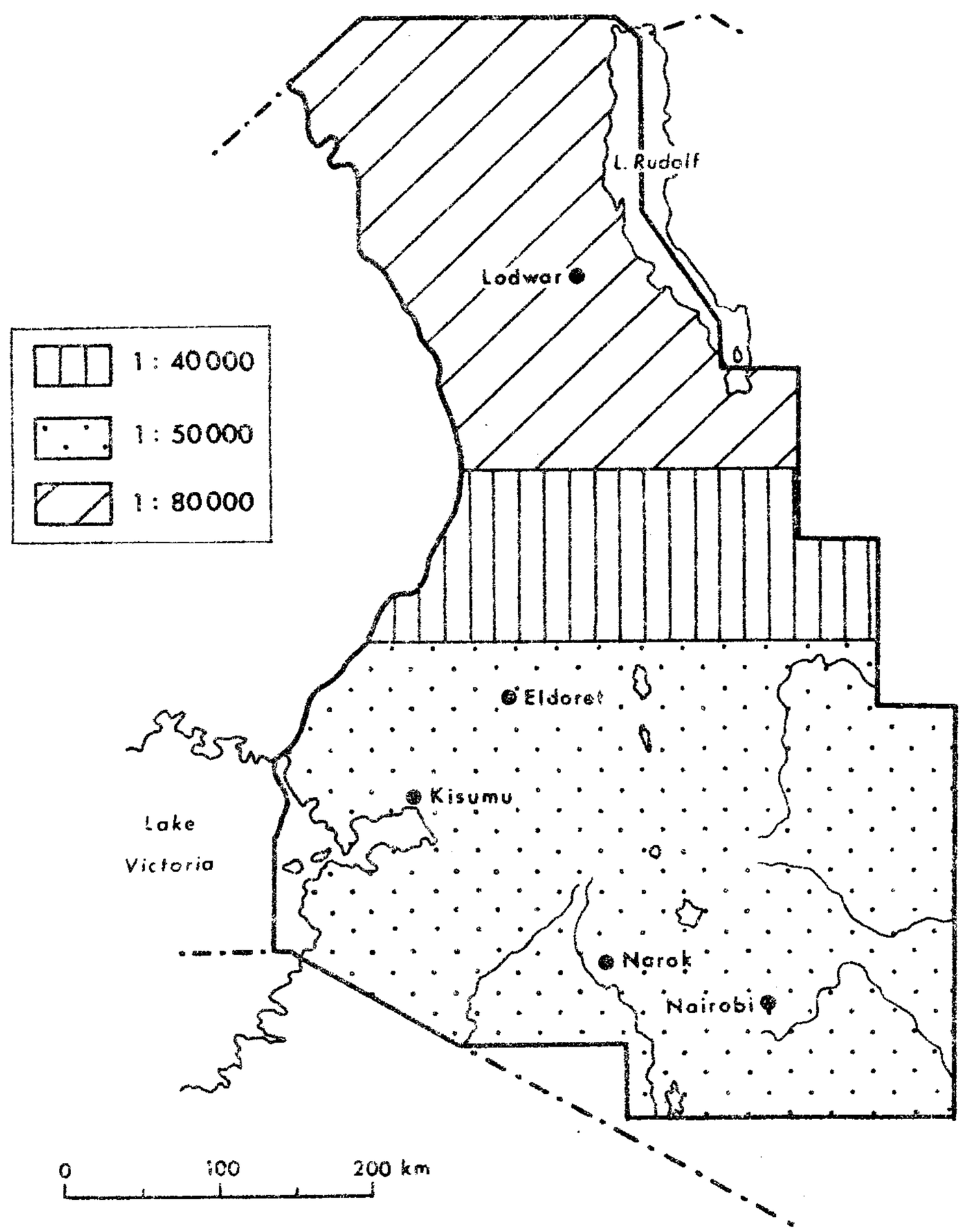
The recurrent patterns of landscape are called Land Systems. They are convenient groupings of land facets for mapping land at scales of 1:250,000 to 1:1,000,000. In Western Kenya they have been mapped at 1:500,000 (extract from the map in figure 40). Thus the land systems are the legend to the map and at the same time the key and framework for their constituent land facets. They are therefore described both as units and in terms that guide the user of the atlas to the correct identification of the land facet at any point of interest.

So in the main part of the atlas, each land system is described separately. For each one there is a more or less idealised block diagram representing a few square kilometres of country (see example figure 41). The diagram portrays all the land facets present in the land system and the characteristic relations between them. In the simplest cases the diagrams show actual blocks of country that contain all the facets to be portrayed, though for pictorial purposes there may have been minor modifications. For each land system there is also a verbal description of the land system as a whole, stating its climate, geology, relief and altitude, its geomorphology and its dominant vegetation and soil type. Its component land facets are then described individually as fully as the available information allows (see table 43). These descriptions of the land facets record the land form, surface materials (including both soil and rock or superficial deposits), water regime, and land cover, i.e. natural vegetation or land use. Each land facet has a name which is usually some aspect of its form, but may include any terms that enable it to be remembered. The names are underlined in the "form" column of the descriptions. Air photographs are included for every land system to illustrate typical, and in many instances additional, less typical, examples of the land systems.

Through land-systems mapping the general physical characteristics of a territory can be rapidly determined, and even at this general reconnaissance level it is frequently apparent that for a specific purpose some parts of the territory are of no value and need no further investigation. Land-unit mapping can then be carried out in the remaining areas if, for the purpose in hand, more detailed information is required about specific sites. In this way the mapping programme can be user-orientated in terms of the scale of map production. It is vital, of course, that if it is to be of any practical value the information listed in the land-unit table should be of the kind required by the user. Thus, although the classification system is general, the land-unit information may need to be very specific.

The basic method used to identify separate land systems is by analysing relief as portrayed on aerial photographs. Initially these photographs are laid out as a large mosaic upon which boundaries are drawn between areas having distinct but different photographic images. These are predominantly related either to the relief character of the ground or to its vegetation, but in essence it is an integrated expression of the geological, geomorphological, soil, vegetation, and land-use properties of the region. As such it is a particularly useful approach at the reconnaissance stage of a survey when an over-all view of the area is required. The validity of the boundaries drawn in this way are tested by examining selected pairs of photographs under a stereoscope. A boundary is usually accepted on the basis of there being a distinct difference in the landform assemblages on either side of the line. Once the boundaries have been established then each area is examined, by means of aerial photographs, in order to assess the character of the land-units it contains. The best photo scale for identifying land units is between

FIGURE 42. Scale of aerial photographic coverage in the "Land system atlas of western Kenya".
Source: Scott et al. (1970)



1:20,000 and 1:30,000, though sometimes a scale of 1:40,000 is used, while photo mosaics reproduced at a scale of 1:125,000 are generally the most useful for identifying land-system boundaries. In figure 42 the scales of the aerial photos used to prepare the Land System Map of Western Kenya are shown.

The character of land units can very largely be determined from good stereopairs of photographs, with an optimum scale of about 1:20,000 depending upon the complexity of the terrain. Field work is necessary, however, in order to sample soils and identify bedrock characteristics and plant types.

Many of the CSIRO and LRD mapping projects were undertaken to assess the suitability of land for agricultural development. In the United States the Soil Conservation Service of the Department of Agriculture formalized a land-capability classification for agriculture which resembles the land-systems method. The United States system recognizes a threefold hierarchy from smaller to larger groupings of (i) capability units, (ii) capability subclasses, and (iii) capability classes (see 6.4.3.).

REFERENCES (6.4.2.):

Cooke, R. U., & Doornkamp, J. C., - 1974 - Geomorphology in environmental management. An introduction. Clarendon Press. Oxford.

Scott, R. M., Webster, R., & Lawrance, C. J., - 1970 - A land system atlas of western Kenya. MEXE/MVEE. Christchurch, Hampshire, England.

6.4.3. The USDA land capability classification

The mapping of a region into Land Systems and Land Facets, described in the previous section, is an objective method of delimiting and describing units of land which are uniform enough to serve as land management units. It is not, however, in itself a rating of these land units in terms of capability to sustain a particular form of land use. Such a capability rating can be regarded as the final step in an integrated physical land potential survey, the individual components of which have been discussed in 6.4.1. Ideally, a landcapability classification is thus a synthesis of climatic, edaphic, hydrological, topographical, vegetation and present land use data within a geomorphologically uniform land unit compared to, and rated in relation to, other land units.

A capability classification must refer to a clearly defined form of land use since different forms of land use have more or less different physical requirements. Most classification systems have been developed for general agricultural (crop production) purposes and they are often based mainly on soil characteristics with other physical factors, like climate and topography, exerting an up- or down-grading influence on the basic soil capability.

The fundamental principle underlying land capability classification is to identify the factors that are preventing crops from giving high yields, or are complicating the problems, or increasing the costs of production compared with productive, easy-working soils. Thus, the basic problem is to define a class of soil from which high yields can be expected without there being any particular difficult management problems to be solved. Other soils are then down-graded to a greater or less extent depending on the severity of the limitations on cropping, yield or management imposed by the soil and

other physical conditions.

One such land capability classification system is described in more detail below. It is the United States Department of Agriculture (USDA) system, which is an interpretative system based upon limitations to agricultural use. It is not a rating of productivity in terms of yield.
The USDA system has been adopted in more or less modified form by many countries throughout the world. It is described here merely to show how it is built up - if it is to be used in East Africa, as has recently been suggested by Hathout (1973) for Tanzania, it has to be modified since the original system assumes a fairly high level of mechanisation (see below).

The system is made up of eight capability classes (I-VIII), each comprising land units that have the same relative degree of hazard or limitation. The agricultural limitations or risks of soil damage become progressively greater from class I to class VIII. The capability subclass denotes the kind of limitation to agriculture (see table 44).

The U. S. D. A. land capability classification makes several assumptions which are important to bear in mind:
(1) The classification is interpretative and it is based upon the effects of combinations of climate and permanent soil and land characteristics.
(2) Soils within a class are similar only with respect to degree of limitations in soil use for agricultural purposes.
(3) A moderately high level of management is assumed.
(4) Where limiting factors such as presence of stones, soluble salts, or hazard of overflow are removable, then they are not considered to be permanent limitations.
(5) Soils suited to cultivation are also suited to other uses such as pasture, rough grazing, forest and wildlife.

Class I Land
Land in this class has few limitations restricting use. A wide range of crop plants may be used safely for cultivated crops, pasture, range, woodland and wildlife. The land is nearly level and erosion hazards (wind or water) is low. The soils are deep, well drained, and easily worked. They hold water well and are either fairly well supplied with plant nutrients or are highly responsive to inputs of fertilizer. The local climate must be favourable for growing many of the common field crops.

Class II Land
Land in class II has some limitations that reduce the choice of plants or require moderate conservation practices. Limitations include gentle slopes, moderate susceptibility to wind or water erosion or moderate adverse effects of past erosion, less than ideal soil depth, somewhat unfavourable soil structure and workability, slight or moderate salinity or alkalinity, easily corrected but likely to recur, occasional damaging overflow, wetness correctable by drainage but existing permanently as a moderate limitation, and slight climatic limitations on soil use and management.

Class III Land
Land in class III have moderate limitations that restrict the amount of clean cultivation, the period of planting, tillage and harvesting, the choice of crops, or some combination of these. The number of practical crop alternatives is lower than for lands in class II. There is less choice of plants grown, or special conservation practices are necessary, or both. Physical protection from erosion may be required where erosion is the limiting factor.

Class IV Land
Class IV lands have very severe limitations that restrict the choice of plants, require very intensive conservation practices, or both. As a result these lands are suitable for occasional but not regular cultivation. It is primarily grazing land.

Class V Land
This is nearly level land with little or no erosion hazard even if cultivated, but it has other limitations (usually wetness or frequent overflow from streams) that are not practical to remove and that prevent the normal production of cultivated crops. This land may be used for pasture or forestry with few or no limitations.

Class VI Land
These lands are generally unsuited to cultivation and are used mainly for pasture (range) and woodland. The soils have continuing limitations that cannot be corrected, such as steep slope, severe erosion hazard, effects of past erosion, stoniness, shallow rooting zone, or severe climate. It is still practical to use tractors and machinery for improvements on this land.

Class VII Land
Lands in class VII have very severe limitations that make them unsuited to cultivation and restrict their use to grazing and woodland. Practices that require the use of tractors and machinery are impracticable.

Class VIII Land
Lands in class VIII have such severe limitations that their use is restricted to reserves for wildlife and recreation and to watershed protection.

The subclasses, together with the kind and degree of limitations in the various classes, are given in table 44.

In Tanzania a land capability system, modified from the USDA system has been proposed, dividing the soils into seven potential classes based on one or more of the following limitations:

a) topography
b) drainage
c) erosion
d) stoniness
e) fertility
f) water requirements
g) soil depth
h) water-holding capacity

Classes 1-3 in this system are suitable for sustaining production of common field crops, class 4 is marginal for arable agriculture, classes 5 and 6 are suitable for use as permanent pasture and, finally, class 7 is unsuitable for crop production or permanent pasture.

Land capability classifications have also been developed for forestry. An example is the Canadian forest land capability classification (McCormack 1967) which rates lands according to seven classes with increasing limitations to the growth of commercial forests. Class I lands are best for pine; class VII lands are poorest. The classification is based on detailed growth data from forest plantations in or adjoining the survey area (i.e. according to site indexing).

TABLE 44. Subclasses in the USDA land capability classification; kind and degree of limitation
Source: Klingebiel & Montgomery (1961)

Limitation	Degree of Limitation	Class	Subclass
Susceptibility to wind and water erosion, including previous erosion	Slope<1% or up to 2% on slopes less than 1000 ft long	I	–
	Slope 1-3%	II	e_2
	Slope 3-8%	III	e_3
	Slope 8-15%	IV	e_4
Topography-limitation to the use of machinery	Slope 15-20% and moderate gullying	VI	t6
	Slope >20% and extreme gullying	VII-VIII	t_{7-8}
Stoniness in soil	Tillage interfered with but not impractical	III	r_3
	Tillage difficult	IV-V	r_{4-5}
	All use of machinery impractical	VI	r_6
	Stoniness such that there is some value for poor pasture and forestry	VII	r_7
	Stoniness>90% of the surface	VIII	r_8
Rock outcrop	<2% - no interference to tillage	II	o_2
	2-10% - intertillage is practicable	III	o_3
	10-25% - intertillage is impracticable. Suitable for hay and improved pasture	IV-V	o_{4-5}
	25-50% - all use of machinery impracticable. Suitable for natural pasture and forest	VI	o_6
	50-90% - suitable for poor pasture and forestry	VII	o_7
	>90% exposed bed-rock	VIII	o_8
Physical properties affecting plant growth, e.g. massive subsoil, hard-setting surface horizons	Slight restriction	II	p_2
	Moderate restriction	III	p_3
	Severe restriction	IV	p_4
Wetness, e.g. poor drainage, overflow, seepage	Overflow 1 in 5 years	III	w_3
	Overflow >1 in 5 years	IV	w_4
	Overflow seasonally (1 in a year) or poorly drained	V	w_5
Salinity and alkalinity	Crops moderately affected (pH 9·0 or less, total salts<0·5% exchangeable sodium<10%)	III	s_3
	Crops seriously affected (pH 9·0 or less, total salts may slightly exceed 0·5% under conditions that permit periodic leaching, exchangeable sodium<15%)	IV-VI	s_{4-6}
	Non-arable-pH>9·0, total salts>0·5% exchangeable sodium>15%	VI	s6

Continued

TABLE 44. Continued

Limitation	Degree of Limitation	Class	Subclass
Soil depth	36-48 in.	II	d_2
	24-36 in.	III	d_3
	12-24 in.	IV	d_4
	<12 in.	V-VI	d_{5-6}
Available water capacity (in. of water in profile up to 36 in. in depth)	6 in. or more - high	II	m_2
	3-6 in. - medium	III	m_3
	<3 in. - low	IV	m_4
Land unit size, shape, distribution	Slight limitation	II	x_2
	Moderate limitation	III	x_3
	Severe limitation	IV	x_4
Soil nutrient status	Low - 6-12 m-equiv./100 g; 20-40% base saturation	III	n_3
	Very low -<6m-equiv./100 g;<20% base saturation	IV	n_4

Finally, mention should be made of the new international system of land evaluation, developed by FAO and the International Institute for Land Reclamation and Improvement in 1972 (Brinkman & Smyth, 1973). This system also includes a proposal for a new land suitability classification, built up in a very logical and systematic way, which certainly will be much used in the future.

REFERENCES (6.4.3.):

Brinkman, R. & Smyth, A. J. (eds.) - 1973 - Land evaluation for rural purposes. Intern. Inst. Land Reclam. and Improvement (ILRI). Publ. 17. Wageningen.

Hathout, S. A. - 1973 - A new approach to soil mapping in Tanzania. BRALUP Research Paper No. 22. Univ. of Dar es Salaam.

Klingebiel, A. A., and Montgomery, P. H. - 1961 - Land Capability classification. U. S. D. A. Agric. Handb. No. 210.

McCormack, R.J. - 1967 - Land capability for forestry. Outline and guidelines for mapping. Canada Dep. Forestry and Rural Development, Ottawa.

6.5. Special surveys

In the previous sections of this chapter, as well as in the ones following 6.5., land potential surveying and land use planning as such are treated in a logical sequence.

Many readers of this report, being experts within specialised fields of land utilisation, such as crop production, animal husbandry, forestry, irrigation, soil reclamation etc., will normally not be involved in the whole planning process in connection with a development project. Most technical aid personnel involved in land development projects will instead work within a fairly narrow field, corresponding to their competence as specialists.

The overall land use planning is, however, substantially influencing the sectorial development as well as it is influenced by the requirements and benefits of component sectors of development. It is therefore important for the individual expert to know how land use planning affects his field. In monodisciplinary development projects this is often quite simple, since possible land potential surveying and land use planning are exclusively aiming at finding and rating the land suitable and available for the particular use (e.g. tea growing, pine plantation, irrigation of cotton etc.), and then plan its detailed utilisation.

A number of complications and problems, related to the special technology of the particular development sector, exist, which influence the land planning. A good example is the large water requirements of a pulp industry, which, although unrelated to land potential for forest plantations as such, will influence the location of the raw-material plantations for the industry. Many similar considerations, impossible to go into detail with in this report, will affect actual land use planning. Therefore, this section (6.5.) has been included in the report to show a few examples of what the planning of specific sectors may involve in terms of land potential surveying and how technical and other aspects may affect the planning.

For obvious reasons, the ambition has not been to make a complete list of possible sectorial projects, but just to show some examples from the fields of experience of some of the members of the group preparing this report. It includes crop production (6.5.1.), cattle production (6.5.2.), forest plantations (6.5.3.), irrigation schemes (6.5.4.) and reclamation of eroded land (6.5.5.). It has been left entirely to the discretion of the authors of each sub-section to decide what to include and how to dispose of the space. From the editorial and logical points of view the section lies outside the other sections, which are loosely edited according to an imagined time sequence.

6.5.1. Crop production

Agriculture, including crop production and animal husbandry, has to be considered as an integrated, often the most important, part in regional rural development projects. For that reason, when planning and implementing a project in a country where the majority of the population is occupied with traditional agriculture, it is of great importance to be well aquainted with all environmental, social, technological, and political conditions and factors affecting the agriculture. It should, however, also be stressed that agriculture is not only a livelihood for the rural people, it is also a way of life - a social life developed during centuries - which can not easily and rapidly be converted. Therefore, before starting an agricultural development project - including for instance introduction of improved farming practices and production means - the present conditions have to be carefully studied and evaluated. It is also necessary to follow a well elaborated procedure which will be discussed in the following.

I. Formulate the goal of the project. Mostly the government, and sometimes an aid giving donour has formulated the goal concerning a particular project before it is started.
An overall target may be to achieve economic and social development among the majority of the population in a selected area. The subgoals of the specific field of crop production may be to improve the yield of present food crops or to develop some cash crops in high demand by starting agricultural research and extension activities in the area concerned.

II. Investigation of the present conditions. In order to get an overall view of the area proposed for development, reliable data about the area is needed. These data include the environment, the infrastructure, agriculture, (including animal husbandry), social structure and beliefs, traditions and customs of various people, the stage of technology, marketing and economy. The most important data will be in accordance with the following description.

A. Political and infrastructural conditions. A topographical map including the administrative boundaries and infrastructural conditions like roads, towns and villages, will be the base for the agricultural survey to be carried out in the area.

B. Land use pattern. Generalised land use maps are normally available in the countries. These maps give a rough view of different categories of land use according to the following:

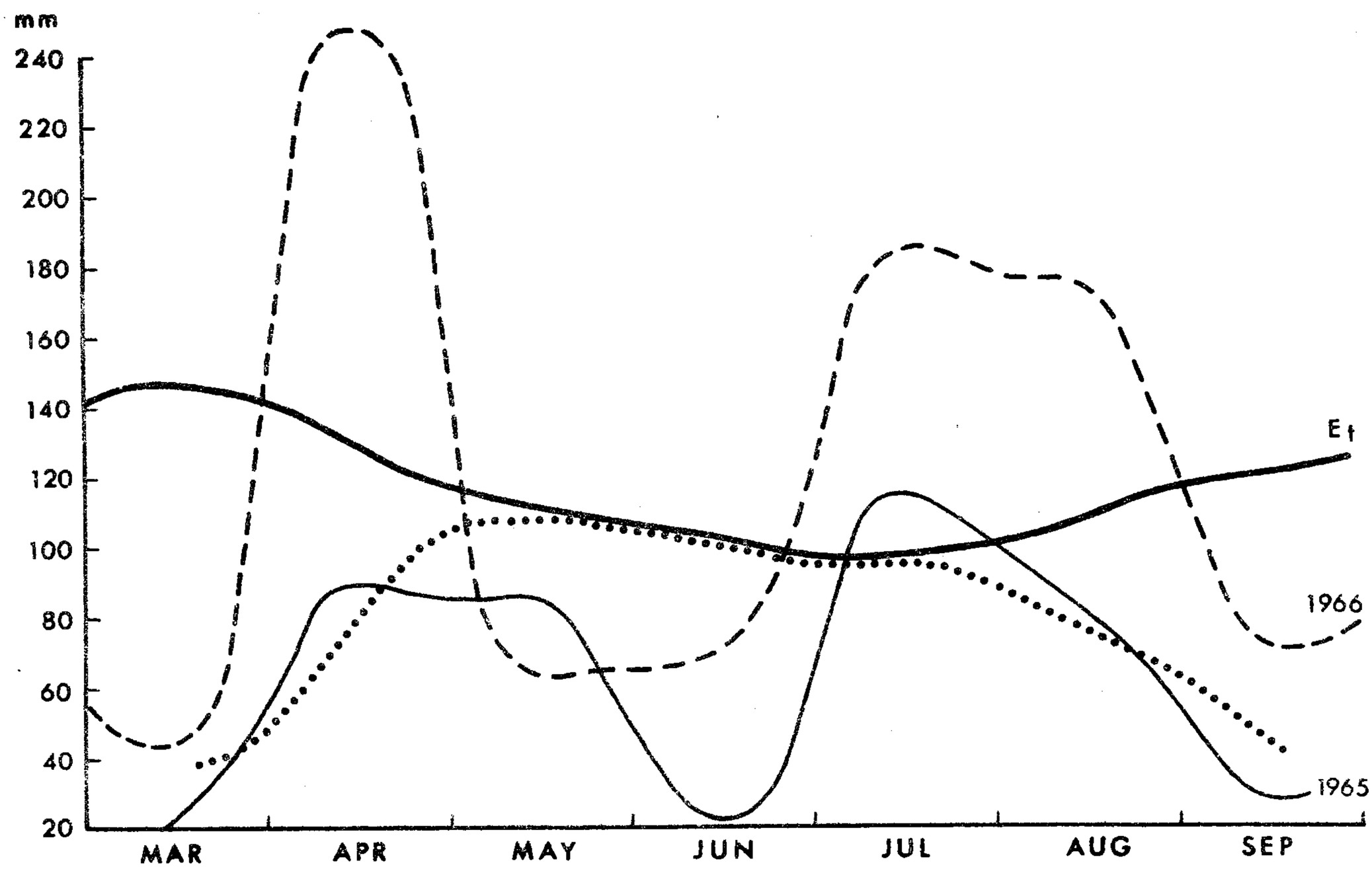
1. Cultivated land, including all land which has been used for cropping, both of annual and permanent crops.
2. Permanent pasture, including open grassland, bush-covered land, and other types of land where cattle, sheep or goats can graze.
3. Forest.
4. Desert areas (from the agricultural point of view). Non-agricultural land, including areas occupied by towns, villages and houses, roads, tracks, rivers, swamps and severely eroded areas.

C. Environmental conditions. Information about environmental factors influencing the cultivation of various crops is essential. The main factor is the climate. The choice of crops to be grown and of dates suitable of planting them are effected by the availability of water in the soil during the growing cycle. Data about rainfall distribution, intensity and reliability, and potential evapotransporation indicate further the crop potential and the necessity and advantage of drainage or irrigation. Records about temperature,

particularly below the freezing point, indicate limitation for growing frost susceptible crops. The meteorological maps of rainfall (map 4) and evaporation (map 7) in Kenya and Tanzania only give very rough descriptions of the whole countries and they do normally not tell anything about the conditions in a specific area. For that reason meteorological stations must be established in an area.

Water availability, either as groundwater or in rivers, streams and lakes, is very important to know when preparing crop development. The pastoralist can move with his livestock to perennial water sources but the cultivator must remain by his fields to work and protect them. The provision of water sources, e.g. by the creation of a dam, a well or a bore hole, can bring an otherwise unusable area into productive use.
Figure 43 shows the importance of sufficient rain at time of planting and during the flowering period of maize. The yields of maize for the two years were 13 quintals/ha (1965) and 34 quintals/ha (1966) on the experimental field, which is situated in Kenya. It is seen that in 1965 rainfall was insufficient and there was no possibility of ground storage at a time when the need was greatest, especially in June.

FIGURE 43. Mean potential evapotranspiration (E_T), estimated maximum water requirement (dotted line) and rainfall during the years 1965 and 1966 (Strong's Farm, Kenya).
Source: Brown & Cocheme (1969)



The soil maps of the two countries only give a very rough description of the soil conditions, and no detailed information about a limited area. For that reason it is necessary to take representative soil samples in the area, and to analyse them regarding physical and chemical conditions. The contents of clay, organic matter and mineral nutrients like phosphorus, potassium and some trace elements, indicate together with the meteorological data the potential for growing crops and give indications about what production means should be tried and introduced.

D. Farming conditions. Data about present agriculture are essential for further planning. Type of farming (e.g. small scale subsistence peasant farming or commercial mechanized farming), farm size, land ownership relations, food and cash crops grown and their yields, crop systems (shifting cultivation or permanent cropping, intercropping, double cropping etc.) crop pattern and farm technology used among the farmers (labour intensive or extensive farming) and animal husbandry (numbers, management and yields), are all data of importance to be collected.

E. Population and human food consumption. Since the aim is to improve the standard of living among the rural people, data about population size, structure and growth are necessary. Also consumption patterns, expressed as calorie and protein intake per person per day, should be available to enable an assessment of the need of diversifying food crop production.

F. Market conditions. The total amount of crops produced and marketed in the area give valuable information about surplus and deficiency of various crops. The possibilities for expansion of growing crops for export or for cannery should be known.

G. Social conditions. As has been mentioned above, information about social structure, traditions, beliefs and customs of the people in the area should also be recorded for a better understanding of the people. To bring about a change in people's attitude towards agricultural practices is a slow process and the social pattern must be considered when planning a development project in a region.

REFERENCES (6.5.1.):

Brown, L. H. & Cocheme, J. - 1969 - A Study of the Agroclimatology of the Highlands of Eastern Africa. FAO/UNESCO/WMO.

6.5.2. Cattle production

Commercial milk production should as a rule only be considered in high potential areas or under irrigation in the vicinity of densely populated areas. The brief comments below will thus be limited to ranching for beef. The following points should be taken into consideration in connection with planning of a cattle ranch:

1. The carrying capacity of the land. Estimation of maximum and optimum stocking rates. Assess the influence of climatic extremes on carrying capacity. Consider risks for soil erosion and how to control them. Methods of improving carrying capacity should be investigated.

2. The prevailing diseases and the possibilities to control them. Special attention should be paid to occurrence of trypanosomiasis and tick-borne diseases, and the need for dipping net-works and other routines and methods

of controlling the diseases should be considered.

3. The availability of water and salt. The need for extra bore-holes and the proper spacing of watering points in relation to vegetative food availability.

4. The need for roads, fencing, enclosures, crushes, machineries etc. for proper running of the unit.

5. The availability of cattle of different breeds. Decide if improvement or up-grading programmes should be launched. Recruitment plan.

6. The probable forage competition from wild game and disturbances by predators.

7. Different technical parameters under given conditions like herd composition, death rate, calving rate, culling rate, sales and purchases of stock etc.

8. The availability of skilled and trained staff. Need of expatriate staff. Housing of staff.

9. The marketing facilities and channels and how they fit into the proper running of the unit. Pricing of different types of stock. Needs for improvements and adjustments.

10. The present status and tradition of resident population and how this can affect the implementation of the planned unit.

These investigations should end in a feasability study of the project which should form the basis for the decision-making.

6.5.3. Forest plantations

The following check-list is directed towards establishing a fairly large plantation, serving as a raw material basis for an industry - in this example we assume it is a medium sized pulp mill in combination with a sawmill.

1. Economical consideration on a national scale. The planning must start with an inventory of the national balance for the products from the industry. An assessment must be made of the future supply from neighbouring countries and it must be decided if the industry is to be built mainly for domestic use or if a large part of the production has to be sold on the world market. One of the probable results from such an assessment will be that in order to keep a certain degree of flexibility for the future, the localization should be such that export to the world market will be possible.
Generally, it cannot be expected that ecological considerations will affect the planning at this stage; the decisions will probably be based mainly on national economy and political considerations.
If the resulting decision will be that an industry of a certain capacity need to be established within the country, the following points should be considered.

2. Possible localization. According to the prerequisites, the industry should include a pulp mill. With present technology such a mill has a fairly high water consumption. Although the technical development may diminish the need for fresh water, a responsible decision must be to erect the mill only where the water supply is adequate.

Another condition for the location of an industry not entirely based on the domestic market is cheap transport to an export harbour. This means either short distance by road or proximity to a railway with sufficient carrying capacity.

An inventory will show that the number of possible industrial sites is limited. The next step, selection of possible planting sites need only be extended over areas with cheap transport to the possible industrial sites.

3. Biological considerations. In a first reconnaissance survey, some sites can probably be ruled out immediately because of inadequate rainfall, which will make tree growing impossible or at least uncertain. Because of lack of sufficient experience of growing exotic trees in East Africa, the areas of uncertainty will probably be fairly large.
When selecting from the remaining sites, one factor will be of particular importance. It is the presence of already successfully established plantations, even on a fairly limited scale.
The existence of older plantations on a potential site will be advantageous for two reasons:

Firstly, the presence of older plantations of fast-growing trees will reveal in a much faster and cheaper way than any trials if cultivation of that species is possible. It will also make possible a rough prediction of future yields, as well as providing material for testing of pulp quality.

Secondly, the presence of certain areas of already established plantations can shorten the time between starting the plantation and reaching a continuous wood production sufficient to cover the need of the industry. In the beginning, raw material can then be obtained from the older plantations.

4. Technical considerations.When comparing possible plantation sites several factors on a more technical level have to be considered, e.g.:
How are the roadbuilding conditions?
Will connection roads have to be constructed, or is it possible to rely on already existing roads?
How are the labour recruitment conditions?
Will a completely new infrastructure have to be built up, including dwellings for the labourers?
Will alternative raw material sources be available not too far away, e.g. waste material from sugar cane processing (bagasse), wood from wattle plantation after extracting the tannin from the bark etc.?

A list of these types of questions can be fairly long, and those mentioned above are just some examples. They have in common that one single factor will probably not be prohibitive for establishing the project, but combined effects of several factors may add up to a considerable difference in feasibility between different localizations.

5. Alternative land use. When comparing possible sites for the plantation, alternative land use must be seriously considered.
Most of the tree species suited as raw material for a pulp mill have a low demand on soil fertility. Where soil fertility is low the potential for agriculture is also low and, thus the competition between agriculture and forestry for the land is less.

These decisions ought to be taken on the basis of a national land use plan, stating the priorities. If possible, areas with low agricultural production potential should be preferred, provided other factors, like rainfall, are

favourable. Depending on national priorities, however, also areas of high agricultural potential may be used for forest plantations. This is due to the fact that most well-managed forest plantations, although not as resistant against soil erosion as a natural forest, usually protect the soil much better than any agriculture crop or intensive grazing. In East Africa, most existing forest plantations are in fact situated in high potential areas for this reason.

6. Research program. Either the plantation is to be established in areas with or without older plantations, the research program will principally be the same. The difference will be the extent of research necessary and the time factor. In the case where older plantations have been successfully established, full scale plantations, using the species and provenances already tested in the area, may be started parallel with the research programme. The provenance problems can be overcome by collecting seed in the established plantations.

In this way, by using known material and known methods, possible risks and probable yields can be predicted.

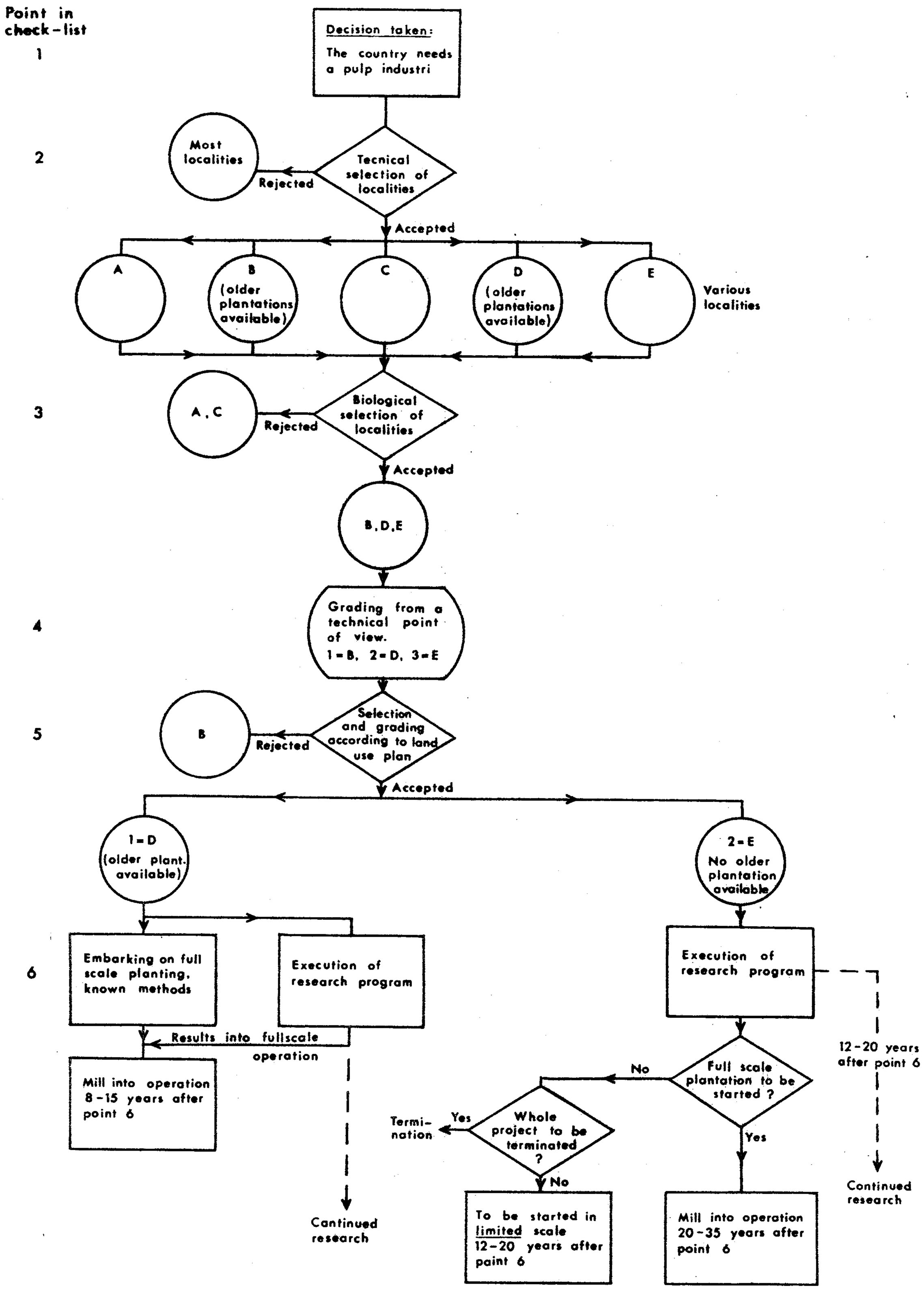
There are no guarantees, however, that the material and the methods used are optimal. Therefore, an extensive testing programme should be started, based on smaller trial plots in the area, where both species and provenances should be tested. The testing of provenances within a species should be more exhaustive for species expected to be suitable. Selected provenances should, as a parallel operation, also be planted in so called field trials, totalling about 10 ha per species and distributed in at least two or three vegetation types.

It is usually recommended that the species trial comes first, then the provenance trial, then the field trial and, finally, full scale plantation. Even if selections from the steps in this sequence are carried out at early ages, it will take many decades before a final, safe decision of suitable species for large scale planting can be taken. Decisions about large scale plantations are therefore normally taken at an early stage in this idealised experimental sequence, often already on the basis of the initial species trials, where the species were planted in small plots only. Since the costs of a failed large scale plantation can be tremendous, no efforts must be spared in order to avoid future failures. Thus, establishing of provenance and field scale trials already when initially testing if a locality is suitable may prove to be both time-saving and a guarantee against failures.

In connection with these experiments research about nursery and planting techniques must also be started, as well as investigations into suitable soil preparation techniques etc.

The really difficult and dangerous decisions are those which have to be made in cases where experience is only available from similar, but not exactly equivalent, areas. Will it be possible in such a case to start the large-scale plantation at once or should the outcome of the research programme, which may take 15 years, be awaited? It is a most delicate task for a forester to give the proper advice which, in such a case, must be based on long experience and a sound judgement.

7. Principles for choice of species. When finally deciding the species for the plantation, this must be based on cooperation with pulp technicians and marketing experts. If they have found that the only saleable product is long-fibred softwood pulp, the choice of species is mainly restricted to pines. Under East African conditions most pines will need a rotation period


Point in check-list
1
Decision taken:
The country needs a pulp industri
2
Most localities
Rejected
Tecnical selection of localities
Accepted
A
B (older plantations available)
C
D (older plantations available)
E
Various localities
3
A, C
Rejected
Biological selection of localities
Accepted
B, D, E
4
Grading from a technical point of view.
1 = B, 2 = D, 3 = E
5
B
Rejected
Selection and grading according to land use plan
Accepted
1 = D (older plant. available)
2 = E No older plantation available
6
Embarking on full scale planting, known methods
Execution of research program
Execution of research program
Results into fullscale operation
Mill into operation 8-15 years after point 6
Cantinued research
12-20 years after point 6
Continued research
No
Full scale plantation to be started ?
Yes
Termination
Yes
Whole project to be terminated ?
No
To be started in limited scale 12-20 years after paint 6
Mill into operation 20-35 years after point 6

of around 15 years in plantations managed for pulpwood production only.

If a short-fibred hardwood pulp will be accepted then several eucalyptus species are possible to use, whereby rotations down to 7-8 years would be feasible.
It is also important to consider that eucalyptus plantations most likely will produce a poor sawtimber, and that the pine plantations will need about twenty years to produce sawtimber of fair quality.

Taking all these factors into consideration, a combination of species would probably be suitable in most cases.

From the biological viewpoint, the risk of catastrophic pest outbreaks may be diminished by using more than one or two species. It could also be worth trying crop rotations, which may prevent or diminish possible decreases in yield in the second rotation, mentioned in section 4.3.6.

From the economical viewpoint, the factory could start operating already 7-8 years after establishing the first eucalyptus plantations. Later on, pulp of a higher quality could be prepared by mixing pines into it, planted at the same time but with a growth period of 15-20 years. If properly managed, parts of the pine plantations will also give sawtimber at the final felling.

8. The above list is by no means complete, neither will it guarantee success, but it may serve as a guideline to avoid at least some of the common pitfalls in connection with forest plantation planning and implementation. In figure 44 the points are presented as a flow-chart.

6.5.4. Irrigation schemes

Irrigation planning and management necessitates advance knowledge of the soil to be irrigated and therefore a soil survey is a natural first step in the studies undertaken to obtain information on irrigation reguirements. The soil survey encompasses both information on the nature of the soil and the general features of the landscape and groundwater conditions.
Attention must also be directed towards the quality of the water to be used for irrigation. It must be evaluated according to both plant tolerance and soil properties. In an irrigated area the degree of interdependence between the soil as a natural body and the water as a fertility and soil-forming factor is much higher than in non-irrigated areas. The soil survey in many arid to sub-humid regions will include data on soil salinity and the salinity of shallow ground water to a depth of less than 2 m below the ground surface.

The soil map scale and, in accordance with this, the survey intensity and the details required of the maps, depend on the various stages of irrigation, planning, and management. These include:
(1) a reconnaissance soil survey during the "preinvestment" stage.
(2) a semidetailed soil survey for the "feasibility" studies, and
(3) a detailed soil survey for the "design and execution" of the project (se Yaron & Vink, 1974).

FIGURE 44. Diagram showing a suggested model for planning forest plantations for a pulpmill.
(Opposite page)

TABLE 45. General indications on the detail required of soil surveys for irrigation
Source: Yaron & Vink (1974)

Level	Scale	Type of Survey	Type of Mapping Unit
Preinvestment	1:250,000 to 1:100,000	Reconnaissance	Physiographic units including associations of great soil groups and of soil families; individual soil families; phases of associations and families
Feasibility	1:50,000 to 1:10,000	Semidetailed	Associations of soil series: physiographic units (including identified soil series); soil series; soil complexes; soil types; phases of associations
Design and execution	1:20,000 to 1:2,000	Detailed	Soil series; soil types; phases of soil series and of soil types

Table 45 gives general guidelines on the detail required for soil surveys in the various stages. The cost of surveys, if executed by competent personnel, never exceeds 1 or 2% of the total costs of the project for which they are made, particularly if systematic interpretation of aerial photographs precedes or accompanies the essential field observations. The use of airphoto interpretation is particularly useful for the first two stages, when relatively large areas have to be surveyed within limited periods of time. In the detailed surveys required in the third stage, many field observations and laboratory analyses have to be made. However, more time is available for this purpose; it must be done in advance of, but not more quickly than, the execution of the various parts of the project ("irrigation blocks").

To be complete, any analysis of the irrigability of a particular tract of land must take into consideration the cost of structures to be built for irrigation purposes and related activities, as well as how the land will be utilized after the project is completed. The nonrecurrent and recurrent inputs for a project can then be taken into account and the future payment capacity of the project can be used to calculate the land's payment capacity. To a large extent, this capacity depends on the productivity of the various soils under an appropriate irrigation system, and on the landscape, which largely determines the nonrecurrent inputs (capital investments) to be made.

In recent years, the land classifications developed by the U.S. Bureau of Reclamation have often been used for this purpose. In this system, on the basis of soil surveys and other investigations, six land classes are recognized:
Class 1 has the highest level of irrigation suitability, and hence the highest payment capacity.
Class 2 has intermediate suitability and payment capacity.
Class 3 has the lowest suitability and payment capacity.
Class 4 designates land with strong limitations, that is irrigable only under special technical and economic conditions.
Class 5 is a temporary designation due to incomplete knowledge of the land.
Class 6 includes all soils that are unsuitable for irrigation (see also Maletic and Hutchings, 1967).

For practical purposes it can be said that the following main properties of land and soil must always be considered in the selection of irrigable land (modified after Storie, 1964):

1. Topography and microrelief.
2. Depth and quality of groundwater.
3. Quantity, quality and seasonal periodicity of available irrigation water.
4. Permeability and water-retention capacity of the soil profile and soil drainage conditions.
5. Salinity, alkalinity and other toxic conditions.
6. Depth of soil to hardpan, bedrock or cobble.
7. Texture, mineralogical and chemico-physical characteristics of the soil profile.

The interrelationships between these factors must be carefully considered within the scope of each project.

Modern technology as used in irrigation modifies the effects of all factors of soil formation. Its intensity may even lead to a considerable change in the rate of soil formation, often resulting in substantial and quantitative changes in the characteristics of a soil. Ultimately, these changes may bring about the development of a soil profile that differs even in its main taxonomic classification from the original soil. Prior to the introduction of irrigation, there exists in every soil a natural water balance between the rainfall on the one hand, and stream flow, ground water, evaporation and transpiration on the other. Irrigated agriculture disturbs the relatively steady state of soils by acting as a new and continuous soilforming factor. This man-induced process is called metapedogenesis. Whereas in the natural process of soil formation the pedogenic factors in general act slowly and over prolonged periods of time, the metapedogenic factors tend to have a strong, and often rapid, effect on the soil properties.

In order to study the kind and rates of soil changes that occur in irrigated agriculture, periodic field and laboratory investigations have to be carried out. These have to start as soon as the project has been partly implemented, particularly for those soil characteristics that are subject to rapid changes: salinization-desalinization, formation of gypsum-accumulation horizons, and hydraulic conductivity. The scheduling of the frequency and intensity of these periodic observations is not rigid, although to check on salinity it may be necessary to carry out yearly samplings of some representative fields for the first five to ten years. Also, specific control sample areas often can be selected in advance on the basis of the original soil map, and the data from these "control surveys" are then presented on very detailed maps, e.g. a scale of 1:2000.

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6.5.5. Reclamation of eroded land

Soil erosion and other kinds of land degradation can be regarded as a disease of the ecosystems, and should be treated and counteracted as such. Diagnosis, prescription and execution of cure, and repeated health controls are three steps in the handling of human diseases. Cases of ecosystem degradation should be treated with a similar approach. In other words, land reclamation work begins with a survey to define and analyze the actual type of degradation, its intensity and distribution. Secondly, a plan of reclamation is worked out, including techniques to be used and organizations for its implementation. Thirdly, a plan for repeated evaluations of the socio-economic and ecologic effects of the reclamation programme has to be made. The evaluation requires reference data for comparisons of the situation before treatment and at annual intervals during and after implementation of reclamation projects.

Four common reasons of land degradation in the tropics are a) overgrazing, b) overcropping, c) excessive field burning and d) excessive wood cutting. Since prevention is always better than cure, methods to prevent these four activities from developing into serious problems will be discussed below.

Overgrazing. Le Houérou (1973) has suggested a number of measures that may help to control or check the process of degradation in dry grazing lands in Africa. The following list is based on his recommendations, with some viewpoints added to Nos. 7 and 8.

1. Plantations of xerophytic forage species (e.g. *Acacia*)
2. Controlled grazing management. This means control of animal numbers, preferably by water control, and reliable cattle counts, e.g. by aerial surveys or other techniques
3. Control of the use of fires
4. Conservation of seasonal surpluses (e.g. hay making) and provision of dry season reserves
5. Integration of range management with agricultural systems
6. Establishment of woodlots for firewood, poles and charcoal
7. Water conservation. Particular emphasis on the rational spacing of watering points for cattle, to avoid large-scale overgrazing around watering points

8. Ecological research on, for instance, effects of reseeding of grasses, controlled burning for bush control

In summary, it is necessary to aim at restoring both grass and tree vegetation in the overgrazed savannas. The ecological importance of trees should not be forgotten. The destruction of deep rooted trees in the savannas has an adverse effect on the soil hydrological cycle and on the nutrient cycle. Trees are a very important protein source for browsing animals and are necessary for firewood, fencing, and building poles. The protective effect of trees against wind erosion of topsoil is evident also in woodland or savanna with only scattered trees.

Overcropping. By overcropping we mean cultivation with destructive effects on the cultivated plots, for instance, soil erosion or water losses and resulting low crop yields. Overcropping can occur both in traditional and in mechanized farming. Traditionally the most widespread small-scale farming system in tropical Africa is shifting cultivation, with long periods of fallow under grass, bush or trees, to restore soil fertility. With the increasing pressure on land as a consequence of a rapidly growing rural population, the periods of fallow have become shorter and land degradation is increasing.

Many simple cultivation practices can be used to combat this negative trend. Some practices which can be recommended are: increased use of mulching, green manuring, tied ridging for water conservation, grass barriers, terracing of fields, reduced stubble grazing.

"Mulch prevents the formation of a surface crust, or compaction. It also prevents erosion, modifies soil temperatures, conserves soil moisture and enhances earthworm activity. It is suggested that mulch tillage, using weeds and grasses, should be tried." (Lawton, 1975).

Marginal lands on steep slopes or in dry savannas should be withdrawn from cropping and reserved for other land use, such as forestry, controlled grazing or wildlife, according to a land capability classification (table 46, cf. also 6.4.3.).

TABLE 46. A comparison of some land capability systems
Source: Hudson (1971)

	United States Department of Agriculture	Federation of Rhodesia and Nyasaland	Israel	Philippines
Arable	I II III IV	I II III IV	I II III IV	A B C D
Non-arable	V (special problems) VI grazing VII forestry	V (wet) VI grazing VII forestry	 V VI	L M N
Non-agricultural	VIII	VIII	VII	X (water) Y (dry land)

Fires. Burning of grass, bush and trees is a general practice in Africa. According to an investigation made by Deshler (1974), using ERTS satellite pictures, the coverage of burnt areas was 40% to 60% of all land in a zone of 5-12°N latitude from Nigeria to the Red Sea during the drought season of 1972-73. The reasons for the burning of grazing areas are several: to promote the growth of new grass, to prevent bush encroachment, to kill ticks, etc. In the dry savannas many fires seem to be accidental. Burning is also a regular practice in preparing land for cultivation in different ecological zones, including wooded savanna and forest.

Opinions differ considerably concerning the negative or positive ecological effects of burning. Fire plays an important role in the ecology of miombo woodland, that covers large areas of central Africa. The dynamic ecology of miombo woodland can be described in terms of the successional development of tree canopies that suppress the ground flora, mainly grasses, and so control the intensity of dry season fires. The time of burning is important; a fire during the early part of the dry season will do little damage to the miombo tree species, but a fire towards the end of the dry season will destroy the woodland or maintain it as coppice re-growth (Lawton, 1975).

Methods to fight the accidental and destructive grass fires of the late dry season include the establishing of fire lines and fire guard patrols, as well as promoting a change from late season to early season burning. In the Sudan, the rangelands in dry savanna will be protected by a network of 85 m wide fire lines, established by ploughing at the sides and early burning in the middle of the lines.

Excessive wood cutting. The trend towards increasing exploitation of firewood is very marked all over Africa. Lawton (1975) gives the following examples from West Africa:

> "The increase in human population has lead to the destruction of the woodlands. Large areas have been cleared for cultivation and trees have been felled for firewood and charcoal. The town of Mopti, in Mali, on the Niger, requires 130,000 tons of wood to smoke fish. The effects of deforestation around Mopti covers a radius of 100 km (FAO/SIDA mission, 1974). Kano, in Nigeria, has an annual firewood consumption of 75,000 tons, and there is no firewood within 64 km of Ouagadougou in the Upper Volta. Trees are also lopped to provide fodder for livestock, particularly when grazing is short."

In an editorial of the newspaper "East African Standard" (Feb. 5, 1970) the problem of charcoal burning in Kenya is highlighted:

> "Publication of a report concerning the booming market for Kenya charcoal in Arabian Gulf countries has attracted criticism amounting to hostility . . . seven ships will have loaded a total of more than 20,000 tons of Kenya charcoal at Mombasa for delivery to ports in the Arabian Gulf . . . Mr. P. Odingo, Director of the National Parks, has condemned what he termed "the apparent permissive attitude being allowed to develop towards destruction of some of the best rangelands in Kenya through uncontrolled cutting of trees and burning of charcoal by a few individuals. The subject can be widened to embrace all the forces at work in Kenya, destroying the fertility of the land and leading to soil erosion."

Dr. J. O. Kokwaro (1974) suggests the following measures for Kenya to counteract the overexploitation of wood for charcoal and other purposes:

1. Afforestation must be implemented all over the country.
2. Plant fast growing trees such as Eucalyptus species which will yield wood material quickly.

3. Cut material from those plants which are capable of regenerating quickly, especially those which can be harvested as coppice, for example the natural mangroves, Combretum species (e.g. Combretum collinum), and Eucalyptus species (e.g. Eucalyptus saligna which produces good quality charcoal and can be harvested as coppice at least in three consecutive turns).
4. Avoid felling trees on steep slopes or near the river banks since this causes erosion.
5. Avoid cutting all available plants on the land at one particular season, because if this is immediately followed by either fire or overgrazing it can result into extinction of some species or cause erosion or even change the whole land structure into a desert.
6. There should be no felling of trees for charcoal in the present indigenous and exotic forest reserves, except by permission from the Foresters.
7. Use as far as possible, those species which have less economic value as saw timber.

To this list we add the comment that the right for local officers to grant permits for exploitation of charcoal burning (or forest grazing, etc.) is in fact a very severe loophole in the control of forest development.

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6.6. Feasibility aspects

In section 6.4. the collection, synthetising and evaluation of physical land resources and how this ideally should lead up to a division of the plan area into land management units with higher or lower potential to sustain one or several forms of defined land uses were treated. It was also stated that for making a theoretical physical land potential assessment, there was no need for considering present land use, socio-economic and cultural conditions.

However, when the actual land use plan shall be prepared, after which the concrete land development is proposed to be carried out, we must find answers to why and how particular land uses are to be implemented. Furthermore, we must try to assess the long term environmental implications of the land utilisation. All the factors that will influence the answers to these questions may be termed feasibility aspects, i.e. feasibility in relation to the physical land potential.

A very wide array of factors will influence the decisions. They include e.g.:

- development aims as expressed in terms of social, economic, production and other desired changes at different levels (national, regional, project),

- socio-economic factors in a wide sense, including among else number of people to be sustained, technical skills available, educational levels, cultural links to land utilisation, money available, land tenure etc.

- ecological factors, primarily assessments of long-term environmental effects under the particular combinations of physical land utilisations and socio-economic factors, e.g. increased population to be sustained, introduction of new land management techniques etc.

When describing the various steps in a land use planning process in a text or a flow diagram, it is logical to superimpose the feasibility aspects on a completed land potential assessment and then to proceed to the formulation of the land use plan, as has been done in this report.

In reality, of course, the study of feasibility aspects and collection of data to identify bottlenecks of implementing various land uses, ought to run parallel in time and be closely coordinated with, and strongly influence, the physical resource survey and land potential assessments. Thus the physical potential is, in practice, not assessed in isolation from socio-economic, present land use and other conditions. It is, for example, obvious that there is no need in collecting the information required to make a detailed land potential classification for forestry in an area where government aims explicitly states that crop production should be given highest priority, or to survey land potential for agriculture in a National Park which is permanently set aside for conservation.

It is not always obvious, however, that one should exclude the assessment of physical potential for some land uses at an early stage in the planning

process just because present socio-economic and other feasibility aspects seemingly make the introduction of those land uses impossible. Man, with all his traditional legal and cultural links to land, as expressed e.g. in present land use, is after all moveable. Even if moral aspects will have to be considered in addition to all other factors, there are certainly cases where moving the people from a tract of land is clearly justified, or even necessary, from an optimum, regional or national land utilisation point of view or because present land use inevitably leads to an eventual destruction of the land potential. Similarly, the large scale forced movements of people in Tanzania, from their traditional land to villages, sometimes far away, has created and will create large land use "vacuums" in areas where land use planning only a few years ago would have identified insurmountable socio-economic feasibility limitations to some forms of land use.

The section is divided into three subsections dealing with development aims (6.6.1.), social and economic feasibility aspects (6.6.2) and ecological feasibility aspects (6.6.3.).

It should be stressed here that the fact that the socio-economic conditions are considered as feasibility problems in relation to the development potential of the physical land resources does not imply that land utilisation as such is rated as a more fundamental problem than the socio-economic context in which the land is utilised. Looking at the planning of rural development in a wider sense or, for that sake, social and economic development in general, the characteristics and resources of the human population and society could be assessed in terms of development potential and then physical land resources will be treated as feasibility constraints in relation to this socio-economic potential. Naturally these two views are not contradictory, they are just two systematic approaches to the solution of the same problem, namely to plan for an optimum utilisation of the physical resources to achieve maximum benefits for present and future human generations in terms of economic and social development. Land use planning focuses on the physical land resource, partly because it is reasonably stable and it is easy to quantify its characteristics and evaluate them in terms of potential, and partly because physical land resources undoubtedly are the most serious limiting factor to development in large areas of the world, including East Africa.

6.6.1. Development aims

The main problems of rural development in East Africa are: the need for education and training, youth unemployment, low rural incomes and the need for coordinated local development. This is reflected, for example, in the present five-year plan for Kenya which among development aims mentions improvements in income distribution; employment; controlling population growth; production and trade (land use, marketing, pricing policy); Kenyanization (the policy of handing over non-citizen, mostly Asian business to Kenya citizens); environment and conservation; science and technology; education; social services (health, housing, etc.); stability and justice; agricultural, manufactural and natural resources; tourism and wild life; and rural development and District planning.

Both the Kenyan and the Tanzanian governments have committed themselves to development of the rural areas, though they have chosen different ways to achieve this goal.
In Tanzania one could, during the first years of independence, distinguish an "improvement approach" which was intended to continue the conventional and pre-independence extension policy (see 4.1.2.2.). The ambition was to bring about increased production without changing the traditional social and legal structure. When improvements did not occur according to the goals that had been set up, a second strategy, the "transformation approach". was set up. This approach aimed at bringing about rapid production increases via a government-created institutional and legal system. Thus, a village settlement scheme on co-operative basis was established. This also proved unsatisfactory and a third strategy, the policy of establishing ujamaa villages, was employed.
Such experiments to create a rapid change have not been employed in Kenya. The development strategy here is closer to the "improvement approach". These issues have been treated in further detail in chapter 4.1.

Most development efforts are done in the agricultural sphere. Generally speaking, both Governments intend to find strategies for improving rural welfare. The major reason behind these policies is that a large majority of the citizens live in the rural areas. There are more operational reasons also behind this policy, one of them being a tendency for people to "drift" towards the urban centres. In order to check this and avoid slum problems, life in the rural areas must be sufficiently attractive. The general policy of improving rural welfare is then specified in a set of goals, e.g. to raise the agricultural output, to raise the level of education and training, to improve the developmental capacity of the Government machinery, to increase the capacity of local communities to plan and run things for themselves, etc.

Such goals are specified at a national level but often not sufficiently analyzed before a planning process aiming at implementing a certain project takes place. Heyer points out that planning processes today involve a number of choices that are not expressed explicitly. These are choices that severely limit existing alternatives when it comes to planning and implementing specific projects.
Instead, the goals should be clearly defined before a planning phase starts. One should be specific about e.g. what national goals and what local goals should be fulfilled as well as what sections of the population should benefit from a project. It is not sufficient just to produce a project; attention should also be drawn to critical decisions at different stages of this project's development.

The agricultural output, for example, may be raised either by an increased cash crop production or an increased subsistence crop production. It is not always obvious where the emphasis should be, as the economic situation is different in different areas; in some places the nutrition level is low and one alternative would be to stress subsistence crops in order to raise this level, in others it may be sufficiently high and there is room for increased cash crop production.

Some similar considerations are listed in the following sections. Many potentially valuable ideas about rural development are missed, according to Heyer, either because they are not considered at all, or because they are rejected overhastily at an early stage of the planning process. This often contributes to a conservatism in rural development plans in East Africa. Even if this means that a project will need a longer time to be implemented, the goal should be clearly analyzed and defined before the actual planning period of a particular project.

The limitations in the choice-making that are touched upon in the present report are by necessity treated at a national level in spite of the fact that detailed goals for any particular area must be related to its local problems (through considering the fundamental problems of that region). These limitations are organized under the headings "social and economic considerations" (6.6.2.) and "ecologic considerations" (6.6.3.) and the discussion can serve as a baseline for further analysis of limitations at relevant levels.

REFERENCE (6.6.1.):

Heyer - 1971 - The role of choice in the rural development planning process. In IDS: Strategies for improving rural welfare. Occ. Paper No. 4, Nairobi.

6.6.2. Social and economic considerations

When using land potential surveys as instruments in land use planning, there is a variety of social and economic considerations that must be taken into account. First one must consider the meaning of "land", as this is often complex, especially in areas where land is not yet consolidated or in the process of being consolidated. Particularly, this might be the case with those areas mostly affected by land use planning.
It is possible to distinguish two aspects of land from a socio-economic point of view, (1) land as site and (2) land as a means of production. The first aspect is linked with society and its social organization, the second with its economy (cf. also 6.2.)

Land as site defines a territory in which a social group or a people is living. Land in this respect is usually linked with descent at one level or the other.
For farming peoples this is expressed in that geographical names and names of lineages, sub-clans or clans coincide. Symbolically, all land is owned by the ancestor and handled temporarily only by the present generations "as an ancestral trust" kept for future generations to come. The right to use land is linked with descent in that a person's descent implies this right. The emphasis, however, is on the right to farm (or herd cattle etc.), not on a right to use a particular piece of land, when it comes to land as a means of production. Land belongs to a group of people (to put it sharply: land "owns" a group of people).

Individual people do not own land according to common East African traditional custom. The normal political authority lies with clan elders who are responsible for administering land redistribution. An individual can apply to the elders for an additional piece of land if his family grows larger, and this piece might be taken from another family where the children have grown up. He only retains his right to this piece of land as long as he or some of his dependants farms it.

The Meru of Kenya provides an example of this. Traditionally a council of elders, "Njuri Ncheke", representing all sub-tribes was in charge over major issues regarding land questions. In a minute from a meeting of this council in 1942, one can read the following declaration on land rights:

> "Ngwato" is land taken and marked by honey barrels, red aloes, sticks or other marks. The man who places these marks was known as the "Mugwati wa Nthi".

> No Meru today can say - - "this is my 'ngwato'" - - but all Meru land was so acquired by the elders in the past who led their families 'up' the Mountain (i.e. towards Mount Kenya). These families are now our "Mwirigas" and each "mwiriga" today knows its boundaries with other, adjoining "mwirigas".
> The disposition of the land within these tribal boundaries today is in the hands of the elders of the "mwiriga" - - not in the hands of any one man or in the living descendants of any one man - - even the "Mugwati wa Nthi". This is our law, but people from one "mwiriga" are often given land to cultivate in another "mwiriga"'s land (e.g. on marrying a girl of that "mwiriga") and they, or their living descendants, nowadays are claiming rights in the "mborago" (land to cultivate) - - often based on the undisputed fact that their forefathers cut the bush or forest there. This constitutes no valid claim to rights in the land - - all the land within any "mwiriga" boundary is owned by that "mwiriga" and under the absolute control (save as regards inheritable rights) of the elders of the "Mwiriga".

From the way the clans took up their land follows that each clan normally has land rights from the low country up to the high level near the forest, covering several ecologic zones. This can be seen on figure 45 showing the land of Imenti sub-tribe within the Meru tribe. Imenti consists of three clans, whose territories show on the map; Miiriga Mieru, Abothuguchi and Nkweni.

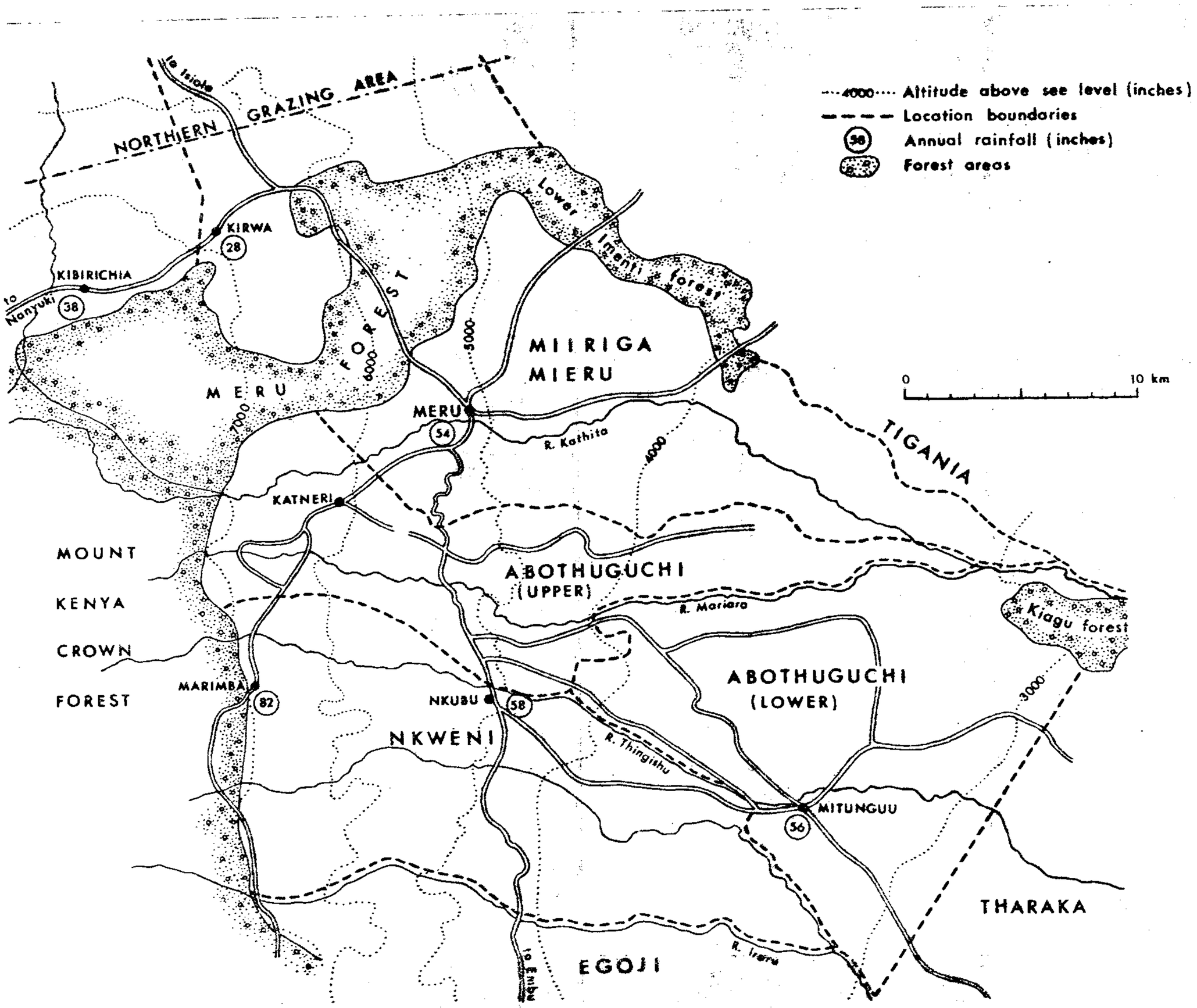
Nomads have a different land use, and this is reflected in the symbolic meaning of land. The Borana of Northern Kenya, for example, consider all land as belonging to Wak (God). Instead, wells and water-holes belong to descent groups in a way that is similar to land owning among farmers.

The traditional system of land ownership was discouraged by the Colonial powers for various reasons. One such reason was that indivudual ownership made taxation more effective. Another reason that is worth some attention in the present context was the attitude that land would be better used if cared for by individuals. One felt that an individual would be more anxious to use a piece of land effectively than a group of people would. This attitude can be questioned from the short discussion presented above. With land using groups based on kinship there is a symbolic continuity via a larger dimension of time, where people count the ownership back to the forefathers and forward to future generations for whom they have the responsibility to administer the land.

In Kenya the policy of individual owner-ship has been continued after Independence, while in Tanzania the policy of ujamaa after the Arusha Declaration aims at continuing a traditional land ownership in a modified way. In Kenya it is accordingly possible to capitalize land when it has become consolidated. The communal ownership based on descent will then be broken down. The effects of this is often fragmentation of land and a development of (relatively) large land owners and a landless class, due to a process of differentiation (see 6.6.2.3.).

In Tanzania the policy has been focused on establishing villages equipped with a certain degree of service. Land is administered within these villages on a cooperative basis. The difficulties in Tanzania seem to arise (apart from the reluctance from those better off who would benefit more from the Kenyan type of land policy) basically from administrative difficulties.

FIGURE 45. Lands of the Imenti sub-tribe within the Meru tribe.
Source: Homan (1963)



Before planning or implementation of a development project, basic local knowledge must be gathered, often via a base-line study. This is time-consuming but essential. One must keep in mind that implementations mostly have very complex impacts; they give rise to processes that are determined from locally existing structures. Therefore, good base-line knowledge is a prerequisite to evaluate societal responses on implementation. Generally speaking it should contribute towards a good understanding of the society or societies in question.

When basic information has been collected it is possible to go on to planning and implementation phases, carrying out continuous evaluations and revisions (see 6.9.) Questions regarding what one wants to know about social and economic effects and how this information shall be gathered should be answered from the collected base-line information, as all local societies, whereever they exist, are unique in some ways. This implies possibly different crucial points or bottlenecks when it comes to implementation.

One example on what a base-line study may include is:

1. mapping the economy in the area: the production of goods for own use and for sale, the marketing of goods and labour, etc.
2. describing different ethnic or other groups, that may be relevant for the area, and their interrelations.
3. sketching the networks and the social relations of the area, e.g. based on ethnicity, kinship relations, patron-client relations, friendship relations and local political relations.
4. writing out the most important characteristics of the relations between the area and hinterlands or surrounding areas. Examples are relations of trade and support.
5. placing the area in a macro-perspective, normally at a national level.
6. studying some historical data that are relevant for the present situation

Other issues that must be looked into, e.g. before an agricultural development project, are national conditions, market contacts, structures of ownership, the degree of active interest from the local population and possibilities of expanding the project to larger areas.
Methods used should be both qualitative and quantitative. The qualitative aspect must be emphasized as a prerequisite for more quantitative and particular evaluations, e.g. with surveys. We shall return to this question in 6.9. and deal more in detail with methods for evaluating impacts.

6.6.2.1. Citizen. The necessity of mobilizing the citizens concerned in any development project has often been emphasized. In the present context a number of basic questions should be answered before implementation, e.g.:

(a) Is the proposal limited to particular ecological zones or particular geographical areas? Many farming and pastoral activities on the household level take place in several zones in order to safeguard against failures in one zone. This can bring complex problems, especially in pastoral societies, as the case of a Maasai group ranching project in Kenya exemplifies. Here the borders of the ranch were agreed upon. At a severe drought, however, the cattle grazed far outside these boundaries. The reason given was that the cattle had been taken to grounds traditionally used at times of extreme drought, which might occur once every ten years.

(b) Is the size of holding important? Such a question is particularly important in densely populated areas, as this imposes severe restrictions on the possibilities for certain land uses. A household's holding may not be large enough for introducing say grade cattle, but suitable for hybrid maize.

(c) Is land tenure to be "individualized"? Individualization of land rights implies that such rights that exist at this particular period of time are "frozen" and old redistribution mechanisms cease to exist. With this the "insurance aspect" on clan-owned land disappears. In times of crisis an individual now has to sell off land on a permanent basis, which in reality might mean another redistribution mechanism, based on economic wealth rather than personal needs.
Individualization has implications also on the household level. The ownership is normally assigned the head of household, but traditionally his wife (wives) have extensive rights to have fields for their own use. Failure to assign land to a wife, especially after children are born, often constitutes ground for divorce. Such relations have usually been regulated by the two respective clan-groups of husband and wife, but land individualization brings them out of clan jurisdiction.

(d) Are skills and know-how critical? The discrepancy between these and introduced technology determine the need for educational efforts linked with administration (see 6.3.4.).

(e) Is capital equipment or other investment critical? If a loan scheme is established, it needs to be thoroughly planned so that the households may benefit from it in a practical way (see 6.6.2.3.).

(f) Is there competition within, say, a farm system for labour or other resources? One must be clear over what preferences the citizens concerned make. A rural water scheme in Meru, Kenya, for example, was expected to increase the agriculture output as the people would get more time to invest in farming activities. Instead, the women preferred to shorten their working day from roughly 13 hours to 11 hours, which in turn had social consequences.

Some of the questions listed above may be answered by gathering background information in time and giving this due consideration in the planning and implementation phases of a particular project (see 6.9.). There are many examples of projects where this has not been done, with unexpected developments as a result.

6.6.2.2. Legal. The present and historical land policies in Kenya and Tanzania are presented in 4.1. Apart from the legal system at the national levels there are coexisting traditional juridical systems. These are often administered by clan elders in cooperation with Government appointed local authorities and administrators.

As one example it may be mentioned that in many areas only married men are invited to meetings concerning land problems and land rights. This in turn is an incentive in these areas to marry early for strategic reasons. When land is turned individual and land claims are put forth, unmarried men may lose the possibility of establishing permanent rights while during the traditional system, land would be set aside for them at marriage.

Relevant traditional legal systems must be sufficiently analyzed before the planning phase of a project can start as they may otherwise present themselves as unexpected "bottlenecks".

6.6.2.3. Economic. A wide range of possible economic effects must be taken into consideration before the implementation of a project. They are mostly closely interwoven with social effects (see 6.9.1.).

(a) Will the planned project imply increased stratification, in terms of increased economic differences within the family, between generations of between "development progressive" and "development conservative"? If the goal simply is to raise the total income of the area, it may best be achieved by concentrating on the better farmers, but this will have spin-off effects in terms of increased stratification.

(b) Is a farming land use planning focused on producing cash crops or subsistence crops or a combination? If the concern is with the standard of living of the majority, it may best be achieved by concentrating on food production rather than higher valued exports. The risk involved when growing cash crops is often considerable due to low world market prices and inflation.

(c) Will the planned land use involve employment of people? If the goal is to provide additional employment for young people, it may be necessary also to introduce non-agricultural activities, e.g. small scale industries or crafts, which do not benefit the farming population very much.

(d) Will the programme need to involve a loan scheme, e.g. for buying seeds and fertilizers? Such schemes must be carefully designed, so that money or correct items are available at exactly the right time. In many schemes, where such items have been sold in the black market, the administration of the loan scheme has not been sufficiently effective.

(e) Who will the middlemen between the producers and the consumers be? If they are likely to be private persons or firms, this means economic savings for a government in the short run, but in the long run the system may have a series of implications, uneconomic and socially negative.

(f) Do necessary infra-structures exist? The roads must be open when the products are to be sold, and the market-system should be effective.

Again, thorough background information is needed in order to understand the situation on the local community level.

6.6.2.4. Administrative. The role of the administrations has been mentioned briefly in 6.3.4. Government officials, also locally, are recruited on traditional merits, i.e. education and job experiences. This might not be the ideal. The critics of the bureaucratic system sometimes say that the administrators form a closed caste that has gradually lost contact with the realities of life (see e.g. Leys) or still employ colonial attitudes (see e.g. Nellis).

Administrative officers have a key position in that they form a link between a government and people at various local levels; they are sometimes considered as "change agents" in the literature. A general difficulty in this role is to create good cooperation with the people concerned, and this is where the criticism is heavy. It seems that when it comes to land use planning a minimum requirement at the local level would be a good land surveyor and an agricultural expert with a wide general knowledge. They should be able to speak the same language as the local people (not only swahili), and live in the area concerned supplementing educational and other innovative efforts (see 6.3.4.).

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6.6.3. Ecological considerations

"The application of ecological principles to land use planning is now undoubtedly the most important application of environmental science." (Odum, 1971).
This quotation may serve as an example of the fundamental importance that ecologists attach to the integration of ecological principles in planning. In recent years a growing awareness and acceptance of these principles among political and economic descision-makers have led to their gradual incorporation in resource utilisation planning. Much confusion, misunderstandings and suspicion still prevail, however, concerning the role of ecologists and ecological principles in the planning process.

A contributing reason is undoubtedly that the most "dogmatic" attitude of conservation of nature and natural resources at any cost often has been motivated as ecologically necessary. The fact that these arguments are, quite naturally, raised in connection with concrete economic development projects in an advanced stage of planning, or already operating, has led many politicians and others to the belief that ecology as such is something basically negative towards development. Often this opinion is further aggravated by the failure of ecologists to present economically viable development alternatives. Still another reason for suspicion against ecology is the extensive misuse of the word in advocating various more or less obscure political aims.

Before proceeding, it may therefore be appropriate to try to identify what ecology actually is and the role that ecological considerations ought to play in land use planning. Many quotations and views in the following are taken from Dasmann et al., (1973) to which reference is made for a more thorough discussion of these questions.

"Ecology is neither an emotional state of mind nor a political point of view, although there are those who seek to use ecological ideas to whip up emotions and influence politics."

Ecology is a science, concerned with the study of the interaction between organisms and their environments. Or, to push the need for definition a step further, ecology is the study of the structure and function of ecosystems.
"Living organisms (plants and animals, including man) and their non-living environment (rock, soil, water and climate) are inseparably interrelated and interact upon each other. Any unit that includes all of the organisms (i.e. the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles (i.e. exchange of materials between living and non-living parts) within the system is an ecological system or ecosystem" (Odum, 1971).

"The concept of the ecosystem is, and should be, a broad one, its main function in ecological thought being to emphasize obligatory relationships, interdependence and casual relationships, i.e. the coupling of components to form functional units."
A distinction is sometimes made between "natural" and "man-made" ecosystems. This may be a useful approach in fundamental ecological research, due to man's unique role as an animal with no fixed ecological niche and to his ability to profoundly influence any ecosystem with his technology. In land use planning, however, where the whole aim is to evaluate and recommend various degrees of ecosystem manipulation for the economic and social benefit of man, the distinction between "natural" and "man-made" systems is pointless. The basic ecological relationships are the same in an irrigated rice-field, a cattle paddock, a man-made lake and in a virgin forest.

Thus, all economic development of natural resources takes place within ecosystems, more or less modified or managed by man, and it is fundamental to recognize that all modifications brought about by development always remains subject to the ecological limitations which operate within ecosystems.

The role of ecology in land use planning is basically twofold:
a) to identify the ecological limitations of present and suggested land use alternatives and to recommend ecologically sound methods of improving carrying capacities of crops, animals etc.
b) to evaluate the total environmental impact of suggested changes in land use with the aim to identify possible negative side-effects of development.

There is thus both a "positive" (increased production) and a "negative" (warn against damaging side-effects of otherwise appealing land use proposals) role of ecology, and it is unfortunate, though natural, that when ecologists have argued in favour of integrating ecology in development planning, it has mainly been by pointing at spectacular mistakes caused by failure to consider the "negative" side.

To fulfil its roles, any ecological feasibility study must be closely coordinated with the basic resource surveys of climate, soils, hydrology and vegetation. Furthermore, to establish the ecological role of man, close coordination must also be made with social and economic surveys.
Thus, ecology is by necessity an integrating science and the ecologist must be, to some extent, a generalist. Naturally, there is no individual all-purpose kind of ecological scientist who can be used to evaluate all the different types of impacts that various development activities may give rise to. There is, however, an ecological discipline and a way of working that may be instilled in people of different professions, such as foresters, agriculturalists, range managers, scientists etc.

The very nature of ecological relations - their complexity and local variation - makes it a practically impossible task to present a generally applicable "computerised manual" of how an ecological feasibility study should be carried out. It is only when an actual area, with its particular and unique environmental features, is considered that a detailed plan of operation can be worked out for the ecological survey. In fact, it is often more dangerous than helpful to try to make a generally valid, oversimplified ecological "check-list".

Some kind of systematic approach must however be adopted in planning, but any system must be used with discrimination and knowledge. The approach used in most recent books and publications containing ecological "guidelines" for development is to present a more or less detailed analysis of the ecological relations that prevail in particular ecosystems- e.g. rain forests, savannas, man-made lakes, agro-ecosystems etc. - and how these are affected by, and set limits to, manipulations of these types of ecosystems. This is a very practical approach but it is only safe when there is space enough, as in a whole book, to mention all important, and in practice often encountered, exceptions and modifications from the "general" cases.

Here, an attempt is instead made to mention some important, basic ecological concepts and "laws" which normally, in one way or another, have to be taken into account in most types of ecosystems and land use developments. Naturally, it is not a complete list and it is certainly not possible to use it as a general guide for ecological feasibility studies at large. It should rather be regarded as an example of a possible "mental framework" to use when designing a detailed survey in a given planning situation.
In the small space available here it is not possible to explain all technical terms though the use of them is necessary to achieve as precise formulations as possible.

1. Identify and delineate ecologial working units - this initial work must be closely co-ordinated with the vegetation, soil, hydrology and topography surveys, and related to the land systems and capability zone units as well as to present land use patterns.

Comments: The units thus delineated provide the first basis for decisions on field sampling and work, and they must be flexible enough to allow for revisions in the light of proposals on land use management units as the plan takes form. One of the main aims in the initial phase ought to be to identify parts of, or whole, ecosystems that deserve particular attention from a conservation point of view.

2. Structure of the ecosystems - decide, where appropriate, species composition, abundance and distribution of plants and animals and how these are governed by environmental factors such as topography, soil and water.

Comments: Structural features are those measurable at any single occasion. Many of them are brought out in the basic surveys of vegetation, soils etc., and in certain economic feasibility studies (e.g. natural forest inventories). A basic knowledge of ecosystem structure is a prerequisite for understanding the dynamic function of the system.

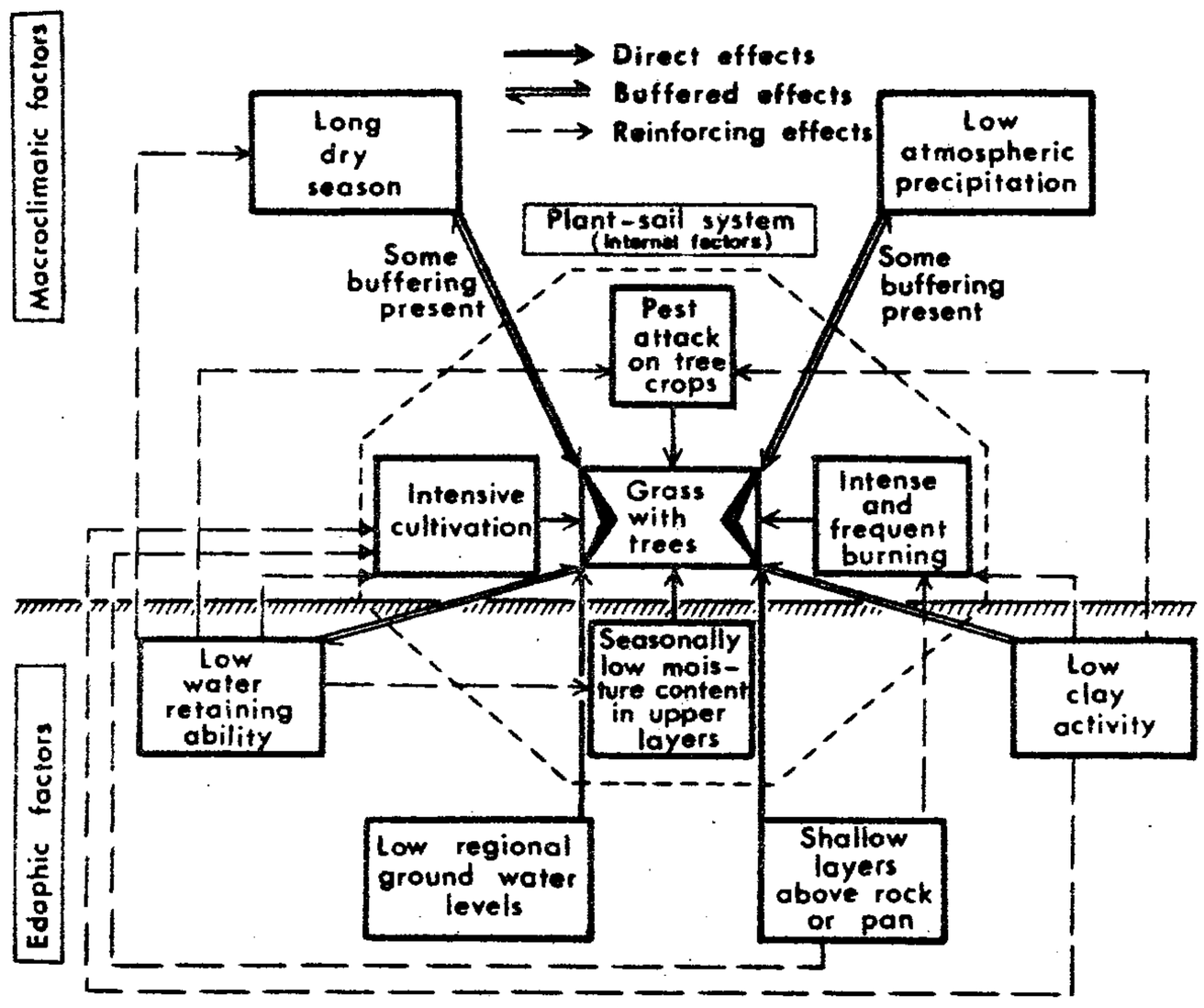
3. Function of the ecosystems - try to establish, with the precision that time and resources allow, the basic functional characteristics of the ecosystem with regard to organic matter production, at both producer (plants) and consumer (animals) levels, mineral and organic matter cycles between soil and vegetation and major energy pathways in the trophic structure.

Comments: Functional features are those involving processes which only can be assessed by repeated measurements over a period of time. It is the main concern of most current ecological research to establish how the function of different types of ecosystems is affected by variation in environmental factors, including human management practices (the world wide Man and the Biosphere-MAB-program tries to co-ordinate this type of research). Needless to say, it is an extremely time- and resourceconsuming task to prepare a detailed model of ecosystem function. It is seldom possible in a practically oriented ecologial feasibility study for a particular land use development project to go into such detail. The aim must be to identify those ecosystem functions that are likely to affect the outcome of the project.

4. Successional stage and trends - try to establish if the ecosystem is stable or changing, and which factors that govern this, as well as which successional stages that are most productive from the current development aim point of view.

Comments: Successional trends and stability are particularly important to understand when natural or semi-natural vegetation is managed as an economic resource, e.g. grazing for domestic and wild animals, natural forest utilization or fishing in lakes and dams. Often the management aim in these cases is to halt the succession towards a climax or even to bring it back to early stages, since the ecosystem net productivity as a rule is higher then. A careful assessment must then be made of the delicately interacting factors influencing the succession before management tools, such as controlled use of fire, arboricides, herbicides, mechanical destruction of "weed" plants and animals etc. are adopted. Failure to understand the successional dynamics of ecosystems is certainly a major cause of development set-backs.
As an example of the complexity of these relations, figure 46 shows the possible interactions involved in a change from closed forest to savanna (according to Moss, 1969).

FIGURE 46. The ecological complex involved in a change from closed forest to savanna
SOURCE: Moss (1969)



5. Characteristics of economic species and populations - determine optimum carrying capacities and limiting factors of those species and populations that form the basis of production (e.g. agricultural or tree crops, cattle, fish species etc.) and evaluate methods to improve the production.

Comments: The growth and level of populations of any organism are limited by a variety of factors, both inherent population characteristics (see e.g. 4.5.4.) and environmental factors, such as other organisms, climate, soil etc. To determine the ways in which these limiting factors jointly affect the "economic" population, and how they safely can be manipulated to improve carrying capacities are fundamental aims of the ecological survey. With optimum carrying capacity is normally meant the population size that can be sustained in an ecosystem without causing any deterioration of that system.
A classical example in East Africa of the importance of identifying the interrelation of limiting factors is that of providing more water to cattle in semi-arid and arid areas. The rapid increase in cattle numbers and their concentrations within reach of the watering places have lead to a serious destruction of the vegetation and often to devastating erosion; i.e. when reducing the primary limiting factor (water) the next factor (food) becomes limiting. Due to the erosive effect of vegetation removal and cattle trampling, plants are unable to reestablish themselves and consequently the carrying capacity may go down far below the initial level (see e.g. 5.3.3.3.).

6. Assessing effects of intensified land use - ecosystem manipulation, e.g. application of biocides, introduction of new species, controlled burning, or creation of new environments such as dams or monocultures, inevitably lead to changes in the interrelations between organisms and their environment which must be assessed.

Comments: Entire safety from negative side-effects can never be achieved, but, based on surveys of the present ecological relations, extrapolations of successional trends and experience from similar undertakings in other areas, more or less qualified predictions can be made. A very important aspect of this is to devise a monitoring system of the environment that can detect ecological changes at an early stage (see 6.9.3.).
It should be underlined here that assessing the whole range of ecological effects of changes in land use management is an enormous task. It may e.g. involve as different things as the effect of farming on erosion, concentrations of pesticides in food chains, soil micro-biological changes under new crops, effect of cattle-fences on wildlife populations, industrial pollution problems, effects on human and stock health of new lakes and dams etc. One of the main functions of any ecological surveyor must therefore be to establish what kind of expertise it is necessary to consult in various projects.

7. Examples of multiple ecological problem complexes in East Africa. Below, mention is made of three main problem complexes which, in one way or another, will affect most integrated development projects in Kenya or Tanzania.

a) Rangeland ecology. The development potential of the vast areas of Kenya and Tanzania covered with various savanna, grassland and woodland types of vegetation depend on our understanding of the complex ecological relations prevailing in them. Seasonal, unrelieable rainfall, use of fire, wild and domestic animals, tsetse flies and infertile, erodible soils all interact to create a still imperfectly understood dynamic pattern of the vegetation resource base. Although a considerable amount of research has been carried out on various aspects of rangeland ecology, a lot more needs to be done

before optimum, long term utilization of these areas can be safely undertaken. An example of the difficulties is that the area of tsetse infestation seem to increase in spite of the large efforts made to control it. Considering that the range areas constitute the only substantial reserve of land for the rapidly growing populations, it is not only necessary but almost a moral obligation to include a research component in all development projects concerning rangeland to increase our foundation of knowledge. This applies not only to cattle development but also to crop production and forestry undertakings.

b) Monoculture crops. Natural successions in tropical humid and sub-humid warm climates develop as a rule towards a climax ecosystem characterised by great form and species diversity at all trophic levels. This ensures a considerable biological buffering capacity against pest catastrophies. In monoculture crops, both food and tree crops, and particularly if these are made up of exotic species, as is the case with most cash crops in East Africa, no such buffering capacity against pests is developed. Pests and vermin are consequently a major economical problem to all intensive agriculture and forestry. The technical solutions to the problems can only be found by an increased knowledge of the ecology of the monocultures and of the pests affecting them. A general view can certainly already be formulated, namely that it is extremely hazardous to base the economic development of an area on too few crop species.

c) Man-made lakes and dams. Dams and lakes created for various reasons, e.g. hydro-electric power production, fish production, irrigation schemes or domestic and stock water supply, have in many cases given rise to very negative side-effects. One of the main reasons why these projects have attracted particular attention during the last decade or two is probably that serious human health problems often have developed in connection with them. The erection of a dam or lake ecologically means that an entirely new, aquatic ecosystem is created, and there is a wide array of complex interrelations that have to be assessed. They may e.g. include problems like the effect of land use in the catchment on surface erosion and sedimentation, aquatic vegetation and animal colonisation patterns, human and animal disease vector ecology and down-stream effects of changes in water quantity and quality.

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6.7. Developing a land use plan

In sections 6.4., 6.5. and 6.6. all the various basic resource surveys, inventories, capability ratings and feasibility aspects which are considered necessary components of the foundation on which the final land use plan ought to be based have been discussed. It has been pointed out several times that the design and type of the individual surveys, the relative importance attached to each of them and the way in which they ought to be co-ordinated in time and space (on maps) depend, to a very large degree, on the actual planning situation.
At the initial survey levels of the planning process, e.g. basic surveys of soil, climate etc., the principles of their execution are still, however, possible to generalise into some form of schedules, applicable in most situations. As the planning proceeds from basic sectorial surveying to classifications, ratings, evaluations and other planning steps including multiple variables, it becomes progressively more difficult to give comprehensive and unambiguous recommendations on how to proceed with the planning. Particularly in the final stage of the planning procedure - the development of the land use plan - it would have been difficult to avoid a high level of abstraction, with a consequent lack of tangible information, if the discussion were not referred to a particular planning situation.

In this section we have therefore chosen to present a comprehensive version of a real land use planning operation - "Southern Darfur Land-Use Planning Survey" - carried out by Hunting Technical Services Ltd. for the government of the Sudan and published in 1974. The main reasons for chosing this particular plan are three:

a) the area concerned is ecologically similar to large parts of semi-arid East Africa,
b) it is a very recent plan carried out by a leading international consultancy firm in the field of natural resources surveying and planning,
c) the principles of planning and methods used are in accordance with our opinions about land use planning.

Naturally, all aims of development, opinions and recommendations on land use expressed in the following are based on the particular set of environmental, political and social factors prevailing in this planning situation and should not be regarded as a generally applicable rules.

The Southern Darfur area covers 27,000 km^2 between latitudes 10° to 12° N and has an average annual rainfall from 450 mm in the north to 750 mm in the south.

The work was performed by a multi-disciplinary team of six persons during a period of two years.
In table 47 the general structure of the planning procedure is shown.
In the first year a systematic survey of the physical and human resources was carried out. The second year was principally devoted to the synthesis of the development plan.

"In the course of the Survey, a careful balance was maintained between the investigation of the physical factors and the economic, social and political ones. Equal time and energy was devoted to a study of the people of the Survey Area, and the physical environment in which they live and work. We have constantly borne in mind that plans need to take account of political and social criteria first and last, even though the physical resources are the basis for planning. Careful attention has been paid to the examination of the likely problems of implementation, and to the design of an institu-

tional framework for the execution of the Land Use and Investment Policy."

The objective of the plan is "principally . . . the improvement of rainfed production and focuses attention on the needs of the small farmer." This means that other land use practices, such as irrigation farming, forestry or range management are given a lower priority in the planning, a decision which might raise criticism from people who make other priority assessments. The case for improving conditions for the small rainland farmer is based on an earlier special report, in which the author centres his argument on the problem of "providing agricultural employment for the rapidly expanding population which cannot be absorbed by the towns". The reasoning for the objective mentioned continues as follows.

Two important features typical to population conditions in the Sudan, as well as in many other developing countries, are the rapid growth rate, "which probably exceeds 3% per annum" and "the low degree of urbanization, with all but 15% of the labour force engaged in agriculture or similar occupations . . . The growth in the rural population should clearly be taken into account in agricultural planning. The increase in numbers seeking agricultural employment can at least partially be taken up by adding to the area under cultivation. The problem, however, is not one of merely providing extra land for farming by existing methods. Techniques must be changed so that those engaged in agriculture can achieve higher real incomes. The desire for such improvement is likely to grow with the expansion of education and increasing awareness of the outside world."
Concerning potential modernised agriculture in the area, such as irrigated cotton and mechanised crop production schemes, it is stated that their capacity to absorb the expanding population in agricultural employment is limited to their immediate locality.

On the basis of this argumentation, the collection and assessment of information on the phenomena listed in table 47 were performed during the first year of the survey. During the second year the synthesis of the development plan was performed.

A strong association between soils, geology, geomorphology and vegetation of the project area and its large size, "indicated that a survey method similar to that of the Land Systems concept would be most suitable". With this system the landscape is broken down into a number of distinct units, within which there is a recurring pattern of soils, geology, geomorphology and vegetation. Each Land System is then sub-divided into its component parts, which for the Darfur case are soil and related geomorphological sub-units. A rapid interpretation of the 1:40,000 scale aerial photographs was carried out and four basic Land Systems and fifteen sub-units identified. These preliminary units were continually revised as field work progressed.

The vegetation survey and map was done using aerial photography (scale 1:40,000) and mosaics (scale 1:100,000) as well as information from more than 150 transects and other field observations. The information is published in Annex 1: "Soil and vegetation resources", with maps in scale 1:250,000 (Soils and geomorphology, resp. Vegetation).

Annex 2 of the plan is a volume on "Water Resources and Engineering". It contains two parts: "Hydrology and Engineering", dealing with surface water and flood irrigation projects; Part two, "Hydrogeology", deals with the geology and groundwater resources of the area and also has a chapter on groundwater development.

TABLE 47. Structure of developing a land use plan for Southern Darfur, Sudan.
Source: Hunting Technical Services Ltd. (1974)

Phenomena	Stage I: Assessment	Stage II: Planning	Stage III: Execution
Physical Surface Water Ground Water Climate Soils Vegetation	Hydrological survey Hydrogeological and Geophysical survey Climatological survey Soil survey Range and Forest survey		Land use policy
Economic Agriculture Livestock Taxes Commerce & Transport Industry	Yield sample survey Agronomic trials Livestock survey and census Economic survey Survey of primary processing	Synthesis of the development plan	Financial and investment policy
Social Population Cash Income & Expenditure Household Production & Consumption Land Tenure Population migration etc.	Socio-economic survey		
Administrative and political Aspirations of the People Government Institutions	Problem census Local Administration survey		

"Animal Resources and Range Ecology" is dealt with in Annex 3 of the survey. The total time in man-months devoted to these aspects of the survey was 44, of which 42 were actually spent in the survey area. Initially a rapid survey was made to establish the herd and flock age and type of the survey area. Later on some selected herds and flocks were intensively recorded for a period of a year in order to establish birth and death rates, offtake and growth rates.

Annex 4, "Agriculture", is a presentation of a thorough study of the existing situation with the purpose of planning the expansion of agriculture by increasing the cultivable area, and at the same time raising the productivity of existing cultivators and their land on a sustained basis. Some basic experimental work was carried out in an attempt to narrow down the problem.

"Social Organisation" is the title of the Annex 5 volume. It draws together the work of the two social anthropologists and the political scientist assigned to the survey. Their task was to:

a) study the goals, priorities and organisations of society, bearing in mind the constraints imposed by the environment,
b) determine how these features of society change in response to changes in the constraints, and
c) cooperate with the physical scientists and economists in devising a development plan, which satisfied the three development goals (welfare, revenue and foreign exchange for government, and conservation of natural resources).

The studies of stock-keepers and cultivators led to the conclusion that their production and marketing activities are rational economic responses to identifiable external constraints.

Annex 6. "Economics and Projects Evaluation", analyses the total crop and livestock production in the area and suggests a number of development projects. An estimate of the budget for a Development Authority and a Land Use Planning Unit is also made.

The summary volume, "Development Plan" has a chapter devoted to "development strategy", where conclusions are drawn under the following headlines.

Major constraints on development. The major obstacles to the achievement of the development objectives are first and foremost the rapidly growing population. The bulk of future investments must be allocated to maintain existing standards and to prevent regression. Associated with this expansion of human population is the severe over-stocking and shortening of the fallow period which are reducing the carrying capacity of the land.

Project selection criteria. The first priority is to provide as many people as possible with employment in the rural areas which will discourage them from drifting into urban unemployment. Solutions must therefore be broad based and have a strong demonstration effect. Such projects are of higher priority than those which merely "pick out the eyes" of the area, for example the development of small irrigation schemes on areas of fertile, irrigable land. Individual projects must fit into a comprehensive and regional plan.

Proposals must take account of the aspirations of the people and be based on a thorough understanding of the forces operating in the rural economy. Proposals must be based on well tried intermediate methods of production. No radically new technology can be introduced in the short run. Large capital inputs must be kept to a minimum.

TABLE 48. Proposed phasing of the implementation of the land use plan
Source: Hunting Technical Services Ltd. (1974)

Projects	Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mixed Farming																				
Qoz Development																				
Water Spreading																				
Tullus																				
Sigadi																				
Ragag																				
Buta Raya	Feasibility Study																			
Wadi Irrigation																				
Land Use Planning																				
Establishment of Unit																				
Enclosure of Basement																				
Closure of Wells																				
Infrastructure																				
Development Farms																				
Workshop																				
Nyala Buram Road																				
Nyala Tullus Road																				
Rahad el Berdi Road																				
Railway Wagons																				
Extension Service																				
Expected Improvements																				
Yields Increasing																				
Cultivable Land Increasing																				
Cultivation Factor Increasing	MF																			
Export of Young Stock				Q																

Land use policy. Without controls the economic benefits of new wateryards to livestock are very short-lived. The ultimate control must be the closure of wateryards which are the foci of over-stocking. However, if this is to be feasible, land use plans must distinguish between areas allocated to grazing and those allocated to cultivation.
The first essential of any land use policy in the savanna belt must be to obtain control of watering points, especially shallow wells.
The second essential of a land use policy is to distribute land to individuals or groups in such a manner that vested interests are created in its conservation. Once land has been distributed, those responsible for maintaining optimum stocking rates and fallow periods can be identified and given the necessary encouragement.

The future relationship between crop and livestock husbandry. The rapid development of cultivation in the last fifteen years was the inevitable result of population expansion. Once the livestock carrying capacity of the pasture was exceeded, there was no longer scope for absorbing the growing population in nomadic pastoralism. In areas of rainfall above 500 mm/year, far more people can be maintained per unit area by tillage than by pastoralism. Crop production has become the mainstay of the rural economy and will remain so.
Since pasture is free, the individual cattle owner cannot strike an optimum balance between pasture resources and animal numbers. If a cattle owner agrees to reduce his herd, he has no guarantee that the pasture will not be invaded by other pastoralists.
Improving traditional methods of livestock production by modernizing grazing rights, rotational grazing, feeding concentrates and generally improved husbandry is the most appropriate proposal. In the survey area, for economic, ecologic, and socio-political reasons, commercial ranching must be ruled out. The improvement of the traditional system is the only way in which trends can be reversed.

Small stock. In view of the considerably greater efficiency of goats and sheep as meat producers, compared to cattle, the future role of these animals in the economy should be re-assessed.

"Development of crop production", "Infrastructure" and "Government services for rural development" are other points dealt with in the land use plan.

Implementation period. The implementation of the development plan is expected to take ten years. During the first decade it is proposed that implementation is placed in the hands of a Development Authority. As projects are completed, "responsibility for extension and control will pass to the local departments".
The proposed phasing of the implementation is set out according to table 48, which is also a list of the proposed projects. These are in summary:

1. Mixed Farming Projects, located in the Alluvial Complex Land System
2. Sandy Area Development Projects: Units based on two, newly-opened, deep wells, 14 km apart in an uninhabited area for supplying water to stock-keeper-cultivators and their animals from the destocked Alluvial Complex area
3. Rotational Grazing Area: Consisting of the balance of the Alluvial Complex area outside the Mixed Farming Project managed on a rotational basis
4. Flood Irrigation Projects

TABLE 49. Proposed allocation of grazing, cultivation and watering rights
Source: Hunting Technical Services Ltd. (1974)

Development Project	Grazing Rights		Cultivation Rights	Water Rights		
	Range	Stubble		Tube-wells	Shallow wells	Irrigation
Qoz						
Village Ranch	Village Council	-	-	Village Council	-	-
Cultivation Area		Individual	Individual	Village Council	-	-
Alluvial Complex						
Mixed Farming	Individual	Individual	Individual	-	Village Council	-
Garden Irrigation	-	-	Individual	-	-	Individual
Rotational Grazing	Individual or group at discretion of Rural Council	-	-	Individual or group at discretion of Rural Council		
Flood Irrigation		Individual	Individual			Individual
Basement Complex						
Wadi Rain-fed Cultivation	-	Individual	Individual		Village Council	
Irrigation	-	Individual	Individual			Individual
Inter-Wadi Grazing	Village Council or Nomad Council	-	-	-	Village Council	-

Proposals are summarized in table 49.

The consultant has drawn up a regional plan and defined a land use policy on the basis of a general survey of the ecosystem. The translation of the plan into viable micro-plans requires setting up of a "Land Use Planning Unit" which will constitute the most important service organization attached to the Development Authority.
The following points are stressed for the work of the land use planning team:

1) Each village community and surrounding area is different from the next. There will be no universally applicable formula. However, the principles of the land use policy must be strictly adhered to.

2) The relationship of man to his environment in each land use planning situation should be constantly kept to the fore. Ecological, land use and demographic mapping should all be integrated. It is necessary to spend more time in the village locality than in the office. The work cannot be done on the basis of flying visits to the countryside.

3) Survey work must not become academic and specialized. For example, it is enough to recognize the basic land classes according to the terms used by the local people. This basic ecological classification has the special merit of being readily understandable by local farmers.

4) It will be necessary to provide the land planning team with on-the-job training concerning the basic survey techniques, the local ecosystem and their role in the development programme.

REFERENCE (6.7.):

Hunting Technical Services Ltd. - 1974 - Southern Darfur Land Use Planning Survey.

6.8. Implementation

The implementation of a development project, e.g. a land use plan, not only includes the execution of the activities decided upon, but also a continuation of the surveys started in the previous phases of the work, with the aim to determine the progress of the efforts and the accomplishment of the objectives.
In the previous section (6.7.) a summary of an actual land use planning process was presented, including basic resources surveying, land systems mapping, feasibility considerations and how these, together with the development aims, are synthetised into a land use plan. Brief mention was also made of the implementation of the plan, mainly with regard to timing and administrative resources required.
In the following some more general points to be considered in the implementation phase of a project will be touched upon.

a) the goal of the project has to be clearly stated. Often the ultimate aim is to improve the standard of living for the majority of the population in an area. Another important objective ought to be to activate and motivate the local people to participate in the implementation process by increasing their responsibilities.
In the fulfilment of the goals the constraints to development should be identified and taken into account. In most developing countries these may include social, technical, economical and infrastructural problems.

b) A successful strategy to combat all factors hindering development implies a close co-ordination between various government bodies and institutions working in the project area. In countries and areas where the local administrative infrastructure is not well developed it might be an advantage if a land development project is managed by an independent governing body with its own budget and a far-reaching executive authority over the implementation of the project. This is quite a common approach in internationally assisted projects. It is, however, important then that there are clearly stated plans of how the project shall eventually be integrated in the national adminstrative structure.
A system of built-in evaluation will help to continuously follow up what has been achieved and the success of the project.
c) The organisation of the project should be such that fast action can be taken to promote the main objectives of the project as a whole and the subgoals of various activities to be carried out within different sectors, e.g. agriculture, irrigation, forestry etc.
If the project is implemented by an aid-giving country it is often the responsibility of that country to recruit expatriate staff members. In this connection stress should be put to the importance of assigning competent local counterparts, working together with the expatriates with the aim to take over the responsibilities of the activities concerned after some years of co-operation and training.

d) The increasing shortages of agricultural land, water, energy and fertilisers in the world have created new problems to be considered when implementing an agricultural development plan.
Agricultural technology to be introduced to the farmers has to be adapted to the natural conditions in the area.
Improved farming practices, implements and tools and other production means should create employment opportunities and be economically profitable to the farmers. Fertilisers, pesticides and improved seeds, if available, have to be carefully tried before introduced. Water availability for irrigation should be surveyd.

Very often the storing facilities for grains are not sufficient and in bad conditions.

e) The employment of staff for the implementation phase, both in executive and extension positions, must take into account the type of special knowledge needed to realize the particular goals of the project. If an organisation of agricultural extension is not already available, it should be started. It has to be an integrated part of the project and also it has to work in close co-operation with research institutions in the country.
The tasks of the extension agents are to demonstrate to the farmers the advantages of improved farming technology and to teach them how to implement the new methods and production means recommended. A system with demonstration plots and model farms, which has proved to be an efficient tool in the dissemination of knowledge in many countries, ought to be organised by the agents.
To be well acquainted with the physical and farming conditions in the area the agents also have to acquire a detailed knowledge about climate, soils, crops, farming pattern etc.

f) Various inputs recommended to the farmers should be available to them on credit. By ensuring market outlets and fair prices, the farmers will get the economic incentives to be interested in the project activities.
It may also be important to organise, at an early stage, training activities in preparation for conversion of administrative powers to farmers' co-operatives.

g) Data must continuously and systematically be collected about the natural conditions, such as climate, soil and water available for irrigation, and about crop yields in relation to the natural conditions and the activities introduced by the project. This should be done in order to adjust and improve the farming conditions. For these reasons a special survey and field experimental division ought to be attached to a project. The survey activities will at the same time serve as a tool in the built-in evaluation of the project.

h) The land ownership relations, rights of pasturing and other tenurial conditions sometimes create both economical and social problems in the implementation process. Also soil erosion and other land degradation problems may sometimes be traced to land tenure practices.
There must be government laws permitting the peasant farmer to safely cultivate his land as well as regulations on how the land should be protected against depletion and erosion.

6.9. Evaluation of impact

6.9.1. General

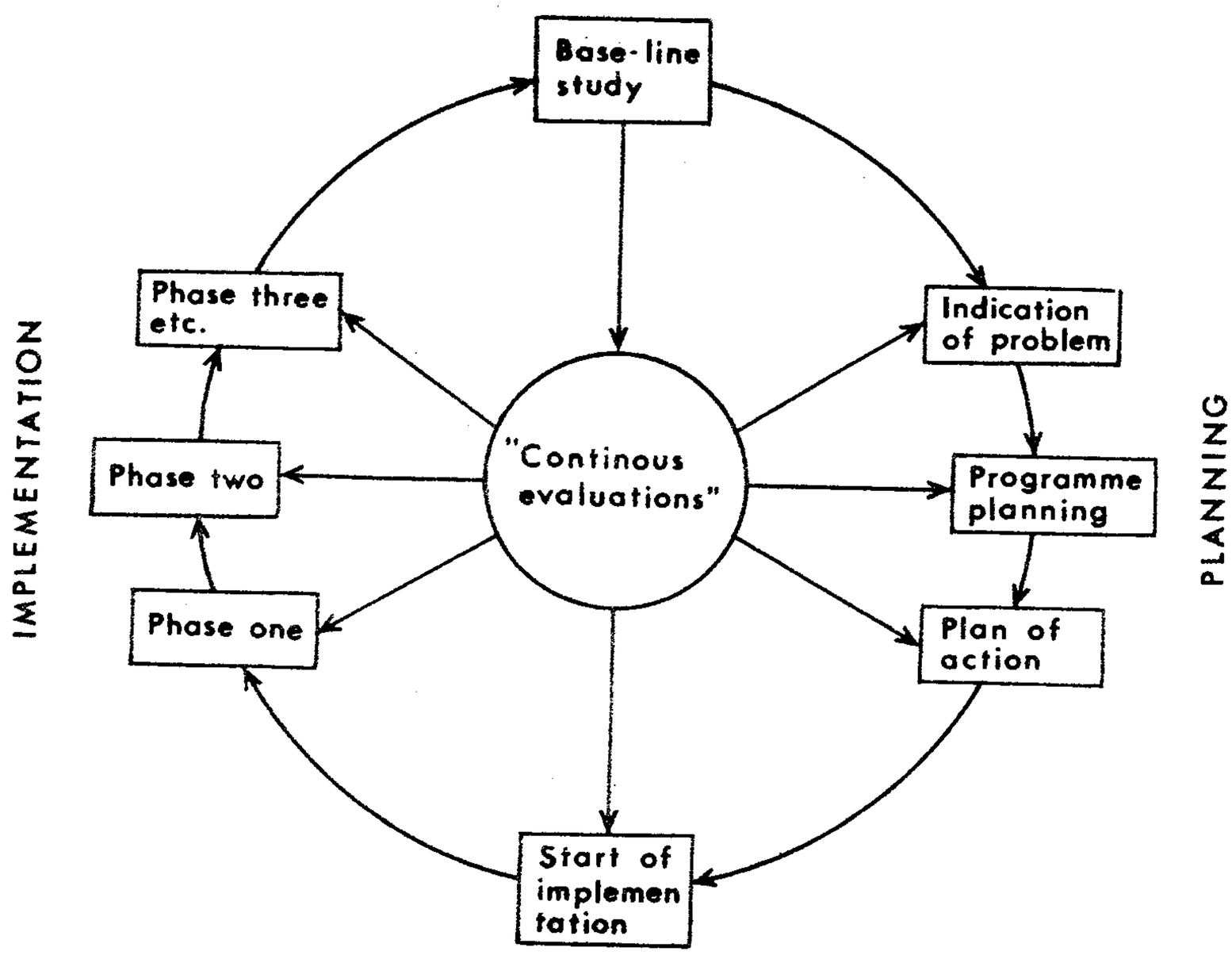
The purpose with evaluation is, generally, to create an information flow about impacts of a project from the field to planners, administrators, etc. The information shall be used as a check on that the implementation works in a way that is intended and, when this is not the case, as a basis for adjustments.

The word evaluation covers a wide range of concepts and it is often used somewhat careless. It can be replaced by words like measurement and appraisal. In connection with technical assistance, evaluations have a built-in function specifically designed to observe the progress of the project and to assess its impact. From the point of extension work it is considered as a feed back from the people when disseminating innovations. It may also be considered as a method for determination of how far an activity has progressed and how much further it shall be carried to accomplish the objectives.

The need for thorough basic knowledge has been stated earlier. This may be collected via a base-line study carried out before both planning and implementation. The purpose of such a study is to develop a proper understanding of the local community. Given this, reactions on implementation efforts may be understood and evaluation of impacts carried out correctly. It will, for example, be possible to have a critical attitude towards results of different evaluation methods and thus also to succeed in keeping errors within estimable limits.

The ideal role of evaluation may be summarized in the following diagram, which may be regarded as a spiral seen from above.

FIGURE 47. The role of evaluation in relation to planning and implementation



Evaluation includes various kinds of techniques to be used, starting from the time of investigation of the possibilities of launching a development project programme until the project starts and then continuously during the implementation period. These techniques consist of surveys, studies, experimental field trials and observation reports, various records and stories.

The so called "continuous evaluations" should be repeated with a certain frequency. Together they make up the evaluation of impact. By calling the evaluation continuous, we want to emphasize that they should be included in a project as a component running parallel in time with both the planning phase and the implementation phase. Furthermore, they should be carried out by personnel familiar with the intentions and general experiences of a project and who are familiar with technical personnel on the project.

Before implementation starts, one must also be specific about what goals actually are to be achieved since, generally speaking, national and local aims often may be conflicting. This is hinted in figure 46 above within "indication of problem". The results from evaluations of impact must also have practical effects on the implementation via continuous revisions. Therefore, evaluations must be built into the plan in a careful manner.

There will also be other aspects of the evaluation. The people in the aid-giving country may, for example, want to know how the money has been spent. Sombody may want to know to what extent the evaluation affects the management and the flexibility of the project.
However, in many cases projects should be regarded as experiments and technical assistance as a process of trial and error. "Evaluation endeavours to reduce the error margin not only by generalizing the experiences gathered for the benefit of future projects but also by preparing for the eventual follow-up of projects."

6.9.2. Socio-economic aspects

Social and economic aspects are treated together, as the division between these by no means is obvious, like it is in Western societies. The reason for this is, that institutions are "multi-purpose"; economic and social activities are intervowen in a complex manner. A well-known example is the "East African cattle complex", where cattle have both basic economic and basic social and ritual implications. Another example that has been mentioned earlier (6.6.2.) is the structure of land-rights.

The evaluations of socio-economic impacts take a starting point in a base-line evaluation and the focus is given from the organization and goals of a project. They may touch on many aspects and it must suffice here to present a number of important examples.

The economy of households concerned must be carefully and continuously evaluated, starting already in the base-line study. Households are generally the best suited smallest economic unit, as different productive activities in both cash and subsistence economy are allocated here.

People's economic independence is another economic aspect. This is especially important to evaluate if a project implies increased cash activities as this may threaten the position of women and younger people if the implementation is not carried out properly.

The strength of traditional insurance systems against risks must be calculated as well as possible risks with the new project. For example, what are the effects of a bore hole? People who would otherwise migrate seasonally with a certain loss in cattle that may be compensated for via kinship networks, might be tempted to remain until the water is finished and they must face a total loss that can not be compensated for via networks.

The nutritional standard in the area should be watched closely to analyze changes in the overall standard level as well as differentations that may be due to introduced projects. An ambition to keep nutrition at an unchanged level may often be conflicting with a country's economic goals to increase GNP.

Division of labour is clearly defined in a traditional setting. In a change situation in East Africa the general tendency is for men to expand into new cash activities, often as traders or middlemen, leaving wives and children with more duties for the family but less rights. Such tendencies must be taken into account and compensated for during implementation.

Changing in time budgets are extremely relevant. Many projects have not taken into account how time is spent on different activities, e.g. going to the "shamba", farming it, carrying firewood and water, etc.

The access to markets is fundamental for trade to increase. Market activities should be evaluated continuously in order to see what changes occur and if they coincide with defined aims. Special attention should be given to the total turnover at the market, structural changes, if the middlemen increase in number of importance and if new goods are introduced. A certain infra-structure is needed for a market system to function, especially roads, but water and electricity may also be valuable.

Cooperative efforts, whether planned in a project or spontaneous, deserve attention; how they are organized, how members are recruited, what members are recruited, what kinds of credit system are developed within the cooperative and what kinds do not, etc.

In order to make the analyzing as relevant as possible, comparisons should also be carried out with other areas not exposed to planned development efforts, in order to see what changes may be attributed to implementation and what may be due to people's own innovations or applications of innovations. The way implemented methods or ideas spread outside the area selected is still another important aspect of evaluating impacts.

Many different methods must be employed to carry out such evaluations of impact. The evaluations must be carried out continuously and by the same people, so that they become familiar with the situation even to the point of participating observation.

A number of formal methods may be used as one step in the evaluation. The thorough knowledge of the society makes these possible and also accounts for a possibility to keep errors within agreeable limits. Knowing, for example, that Turkana and peoples of many other ethnic groups never count their cattle and consider it a bad omen to do so, all surveys involving interviewing about number of cattle must be dropped and the information gathered by other means. Unfortunately, there are many examples of surveys that have been carried out without proper local knowledge with sometimes almost absurd results.
In the following a few examples on formal methods are presented.

A household survey dealing with different economic and social aspects is normally necessary. Two major methodological problems are: a) how to collect data (what data is possible to collect in this way?) and, b) the selection of households to be interviewed. Sampling may prove difficult. One can paint a number on each house of the population and from there make a random sample, one can use different geometric methods or start from a map over the area. The results from the survey should be controlled in at least two ways: the questions should be tested on a few known households and a limited number of the most essential questions should be asked to a large number of the total population; this in search for possible discrepancies that indicate

systematic errors. A similar survey may have to be carried out with businessmen in the area dealing with their economic but also social activities.

Time budgets may be employed to cover major day-to-day activities for each household member. The purpose with these is to map different time consuming activities in order to identify possible implications that these may have during implementation. In order to account for seasonal fluctuations they should cover a period of at least a year. It should be sufficient to select a limited number of cases, based on earlier knowledge about the community. A schedule of the yearly domestic, pastoral and agricultural workcycle should be compiled.

Consumption lists covering the same period of time with similar selection should include what different foodstuff is consumed by each household member on a day-to-day basis as well as the quantities consumed. From this material the nutrition situation, which may be of direct relevance to the implementation of a project, may be analyzed.

Genealogies may prove useful in providing a picture of migratory patterns (for each individual one should ask for name, age and place of residence), to check certain demographic facts and to get a further control on the answers to the surveys. General difficulties that may occur are that deceased children are often "forgotten", that some people refuse to mention their dead people and that it may be hard to achieve correct ages.

6.9.3. Technical aspects

The technical development is an evolution proceeding very slowly. Most of the rural population in East Africa is occupied by agriculture carried out in a very simple way resulting in low yields.

Any evaluation of technical development and of success or failure of introduced methods must be referred to the situation before a land use plan is implemented. A general agricultural base-line survey should therefore be carried out to obtain knowledge of the conditions of the peasant farmers in the area. The design of such a survey is important and it must be borne in mind that evaluation surveys during the implementation in principle should be carried out in the same way, so that direct comparisons can be made. The survey may, for example, be done by taking a large sample of farmers which are interviewed on items such as their area under cultivation, land ownership, farming practices, crops grown, number of cattle owned etc. Actual measurements should, where appropriate, supplement such interviews.
Another valuable supplementary survey are case studies, in which a small number of farmers are subject to a scrutiny of a large part concerning their daily life and are regularly visited, starting before implementation and continuously throughout the period of the project.
The information obtained through the case studies is very detailed and precise but cannot normally claim to be statistically representative for all farmers in the area.

The main objectives of these general agricultural base-line and evaluation surveys are the following:

1. To get as reliable information as possible about local conditions.
2. To enable project activities to be adapted or adjusted to local conditions in the best manner possible.
3. To gather information facilitating the current operations of the project.
4. To provide information on progress and achievements of the project.

Within and/or beside the general agricultural survey and case studies, other surveys could be carried out, e.g. statistically designed surveys aiming at assessing the overall impact of the project on matters like sizes of holdings, land tenure, changes in income and consumption patterns and changes in farming practices as a result of an extension program.

Annual crop sampling surveys will assess the impact on yields of improvements introduced by the project, such as new machinery, new crop varieties, fertilisers, irrigation etc.

An intensive farm management study might be initiated where some farmers will be visited very frequently (say twice a week) throughout an entire year asking them about their farming practices, consumption habits, sales and purchases etc.

Experimental fields, simple trials and demonstrations are necessary components in a land development project. The results from these field trials, run by a research station in the area and preferably managed by the project, will be the main source of getting innovations to be distributed to the farmers. To demonstrate the technical results of the agricultural research findings, and also to complete the research activities, a substantial demonstration activity may be necessary. From these activities the profitability of various farming practices and inputs can be evaluated. This is one of the most important methods for getting data on crop yield potential under optimal conditions.

Special studies to be carried out may be designed to explore certain problems or aspects concerned wtih project activities and may sometimes be urgent and have high priority.

The system of quarterly, semi-annual and annual reports to be written about the activities in a project is also of importance for the evaluation.

All these surveys, studies, reports on results of research and demonstration activities and reports on administrative performance will be the base for an overall evaluation of a project concerning assessments of the program and a comparison between the goals and what has actually been achieved.
The evaluation report could be described as a study of the means and the effects of introducing technical and social change into a rural society in the area concerned.

6.9.4. Ecological aspects

In section 6.6.3., ecological pre-surveys and feasibility studies were discussed. An evaluation of the ecological impact of a development project is, in principle, a continuation of these surveys and studies.

Ecological aspects of evaluation, in a wide sense, include all interactions between different organisms and between organisms and their physical environment. The study and evaluation of many types of impacts, which traditionally are regarded as falling under well-defined disciplines, such as entomology (e.g. insect pest outbreaks), soil science (e.g. impact of soil salinity on crop growth), crop pathology, veterinary medicine (e.g. tsetse infestation), are thus truly ecological in nature. The effects of these types of problems, although not always their deep-lying causes, have often received due attention in evaluating studies.
There are, however, many other interrelations which often cause problems in the implementation of land development, the evaluation of which have been neglected due to their complex, interdisciplinary nature. This may include as widely separate questions as the impact of application of artificial fertilisers in a catchment on dam fishery, or the impact of DDT in the trophic structure of an agro-ecosystem. Ecological evaluation should thus quite obviously not be understood as dealing with a welldefined type of impact, possible to be carried out by a single "ecologist", but rather it includes the assessment of a wide range of problems with an ecological approach.
To make the results of an ecological evaluation efficient in terms of feedback to land use activities it has to be closely co-ordinated with socio-economic and technical evaluations.

The more general aim of an ecological evaluation is to study the actual outcome of various land development activities compared to the predicted outcome, and to assess whether possible differences between these are due to ecological factors. If so, these should be identified and preferably quantified, so that corrective measures in the land utilisation can be taken, i.e. if the factors act in a negative direction.

More specifically, an ecological evaluation may be designed to monitor and assess particular problem complexes, identified as potentially dangerous in the ecological prefeasibility studies. In many land development projects in East Africa this may e.g. include continuous or frequent studies of the impacts created by dams, long term effects on soil fertility or particular crops or cropping patterns, impact on range conditions by management practices, impact of some forms of land use on erosion etc.

Technically, the ecological evaluation, both in general and of more specific problems, should be a continuation of the ecological feasibility studies and surveys made in connection with the preparation of the land use plan. One of the major requirements of the study of ecological impacts is the availability of sufficient, reliable data on the physical environment. The first preparatory steps for a continuous evaluation, planned already during the prefeasibility surveys, should therefore be to identify the quantity and quality of data required in each particular land development project, and to decide on methods how to acquire these data. The collection of the following type of information ought to be carried out in the implementation phase of practically all land development projects in East Africa:

- Climatic records are often scarce or non-existent and high priority should be given to the establishment of a network of meteorological stations, sufficient to characterise the climate of the project area, including local variations, with regard to precipitation and evaporation.

From the ecological point of view there are two obvious advantages with an improved flow of climatic data. First, it will increase the reliability of climatic statistics, thereby facilitating a higher accuracy in predicting occurence intervals of climatic extreme events, which often are the most serious limitations to land use. Secondly, it will make possible an objective quantification of the relation between climatic conditions and actually occurring events, such as crop failures, pest outbreaks, range degradation, storm-flows etc. Where climatic data is insufficient these types of events are often attributed to "drought", "intensive rainstorms" and similar generalised speculations.

- An improvement of hydrological data collection, mainly by installing stream gauging stations, is often necessary, particularly in areas where surface water availability is permanently or seasonally a limiting factor and where the utilisation of water, e.g. for irrigation, dams etc., is an important element in the development project. As with climatic data, an improved collection of hydrological data will increase the accuracy in predicting normal and extreme events, e.g. stormflow discharge, minimum and maximum flows etc., all important to know in relation to irrigation capacity, dam constructions etc. Regular or, preferably, continuous silt sampling may give early warnings about increased erosion in the catchment, often before this can be discovered by casual field observations.

- A systematic program of regular soil sampling, analysis and evaluation should be designed for areas where there is a potential for serious pedological disruptions due to the introduction of new intensive land uses, e.g. irrigation, mono-cropping, fire etc.

- For many forms of land use, an ecological evaluation of impact, will have to be based on regular studies of permanent sample plots. This is valid for range management projects where the conditions and trends of the range in terms of plant biomass, species composition (relation between palatable and unpalatable species) and erosion can only be safely evaluated by this approach. The same is applicable for the utilisation of natural forests and woodlands for timber or firewood production.

Together with other studies which are considered relevant in connection with certain projects or components of a project - such as control of disease vector occurrence in man-made lakes, studies of weed and pest situations in crops etc. - these data will form the basis for an ecological evaluation of the impact of the land development project in question.

An additional tool, which has proved to be extremely useful in ecological evaluation work of many forms of land utilisation, is the use of aerial photos. It was clearly stated in section 6.4. that an aerial photo survey in the planning phase of a project was necessary for the surveying and mapping of physical resources, and its desirability as a documentation of conditions just prior to implementation of land development activities was emphasised. Given a pre-implementation aerial photo coverage, the ecological evaluation of factors such as range condition, erosion spread, wildlife population fluctuations, forest clearing etc., will be greatly facilitated by repeated aerial photographing during the implementation. The desired intervals will depend on the types of land use being implemented. Aerial photo interpretation will not only be useful for studying ecological impacts, but also in socio-economic (e.g. trends in population settlement patterns) and agrotechnical (e.g. changes in crop relations, areas under cultivation etc.) evaluation work.

More sophisticated remote sensing techniques may also be justified in evaluation work.

There are probably many contributing reasons why the evaluation of ecological impacts of development projects has been almost completely neglected in the past and only recently has started to become integrated in the overall project evaluation work. One major reason is certainly that the interdisciplinary approach necessary in ecology falls outside the sectorial approaches to development which have dominated international cooperation efforts. For the same reason, the people responsible for planning, implementation and evaluation of development projects have by tradition been recruited from the disciplines directly concerned with the specific activities of a project, e.g. water engineers, agronomists, foresters, veterinaries, etc. Whether ecological feasibility aspects and evaluation will be integrated in the project will often depend on the individual competence and interests of these experts.

However, as indicated above, the solution will not automatically come by employing the services of an "ecologist", for the simple reason that no such person exists who can carry out an evaluation of all conceivable types of ecological impacts. Ideally, an expert or a group of experts, with training or experience in the ecological relations of the main types of land utilisation considered within the particular project, e.g. crop ecologist, forest ecologist, fresh-water ecologist etc., should be responsible for the surveying and evaluation of ecological aspects, including coordination of data collection. One of the most important tasks of such a person or group would then be to identify the type of expertise needed for more specialised data interpretation and evaluation aspects.

A fairly common experience in many recent development projects, where ecological surveys have been carried out is the difficulty of integrating these in the practical development activities. The same problem arises in designing efficient corrective feed-back mechanisms from ecological evaluation undertakings. It has thus proven to be far easier to be aware of potential ecological pitfalls than effectively to avoid them. These difficulties often stem from problems of communicating and interpreting information between ecological surveyors and project implementation administrators. It is therefore of fundamental importance that due attention is paid at a very early stage in land development projects to the organisatory problems of fully integrating ecological concepts in the planning, implementation and evaluation phases.

Finally, it should be underlined that the application of ecological feasibility surveys and evaluation, whatever resources allocated to them, will not be a guarantee against ecological set-backs in development projects. The very complexity of ecological interrelations and the large gaps in knowledge that exist about even fundamental aspects of tropical ecology makes a complete elimination of risks impossible. There will always be a fairly high risk of negative disturbances when introducing new technologies, new crops and cropping systems or entirely new ecosystems in a tropical environment, higher than in temperate environments. A fully integrated, competently conducted ecological evaluation, given adequate personnel and financial resources, will however, substantially increase the ability to predict and quantify the ecological risks involved in various land use development.

6.10. Summary and conclusions

Information needs, problems and methods for correctly describing and considering the various components of land potential surveying and land use planning are analysed and discussed in this chapter, with particular reference to Kenya and Tanzania. The aims have been:

- to indicate and explain the information needs in land potential assessment for land use planning, both at the national and at the project levels, with particular reference to Kenya and Tanzania, and
- to present an idealised framework for integrated land use planning operations at the local development project level.

In summary, the contents of the various sections in the chapter are:

Introduction (6.1.) identifies the objects, frames and points of departure for the discussions. An attempt is made to analyse the larger context in which land use planning should be seen, the rationales for adopting it as an instrument in development and the need for identifying over-all priorities and criteria before adopting it. An introductory discussion on the problems of land evaluation connects to the general theme of the chapter, namely the fundamental importance of basing decisions on land use on adequate and relevant information about the physical resources and how they affect land use.

Definitions and concepts (6.2.) gives a general frame for the use of the key words of this report in general and chapter 6 in particular. Various concepts of "land" are presented and definitions of "land use", "land resources", "land evaluation" and "land suitability" are presented and discussed.

National land potential surveys (6.3.) discusses the aims of preparing country-covering small-scale reconnaissance surveys. Further, the present status and desired development of the various national surveys and mapping of the basic land resources determining physical land potential - topography, geology, climate, hydrology, soil and vegetation - are discussed. The two different approaches used by the two countries in preparing national land potential maps are described and their limitations are analysed. A third approach, "evapotranspiration ratio", is tentatively presented and its applicability to Kenya and Tanzania is discussed. Finally, the general social considerations, against which physical land potential has to be tested before defining national land development policies, are treated.

Local, integrated land potential surveys (6.4.) is dealing with the basic problem of physical information needs for land potential classification at a local (project) level. Methods and problems of basic resources surveying are discussed in some detail and an approach to delineating physically uniform land management units is presented. Finally, the USDA land capability classification is described to show one possible method of rating land units with reference to a particular use.

Special surveys (6.5.) discusses the information needs for the planning of five different land uses. The examples are taken from the fields of specialisation of the members comprising the group preparing this report.

Feasibility aspects (6.6.) should be read as a continuation of 6.4. The various sets of factors - national and project goals, social and economic considerations and ecological considerations - are discussed, which are necessary to superimpose on the physical land potential before a realistic,

feasible land evaluation, which can serve as a basis for land use decisions, can be achieved.

Developing a land use plan (6.7.) describes, as an example, an actual land use planning operation in the Sudan, including how the type of surveys and pre-feasibility aspects discussed in 6.4. and 6.6. have been carried out and considered in the plan formulation.

Implementation (6.8.) discusses briefly some important aspects and potential bottle-necks in the implementation phase of a land development project.

Evaluation of impact (6.9.) emphasises the importance of an efficient continuous evaluation of the socio-economic, technical and ecological impacts of a land development project to ensure that corrective feed-back mechanisms are available.

The large number of factors and steps involved in land development planning makes an exhaustive analysis of the whole process impossible. In this chapter there are considerable differences in the emphasis laid on the various factors - some are treated at some length, others more comprehensively and still others are only made superficial mention of. As pointed out in the introduction, this does not imply a rating of importance. For this reason, however, it may also be difficult to realise in what way the various sections are connected to each other into a logical sequence of activities in land development planning. Therefore, a schematical presentation of the various components and the main lines of information and action between them is given in figure 48.

The chapters and sections in which the various "boxes" are treated in the text are indicated, including references to the previous descriptive chapters 2-5. Primarily, the figure should be regarded as a structural frame for local land use planning operations.

From left to right in the figure, a time-axis can be imagined, starting with an observation phase and then proceeding via a compilation phase to the implementation and finally the evaluation phase. This time sequence should however not be taken too literally - e.g. development aims are naturally considered from the very beginning, planning the evaluation of impact must start at the same time as the basic observations etc.

The main conclusions are summarised below with reference to the figure.

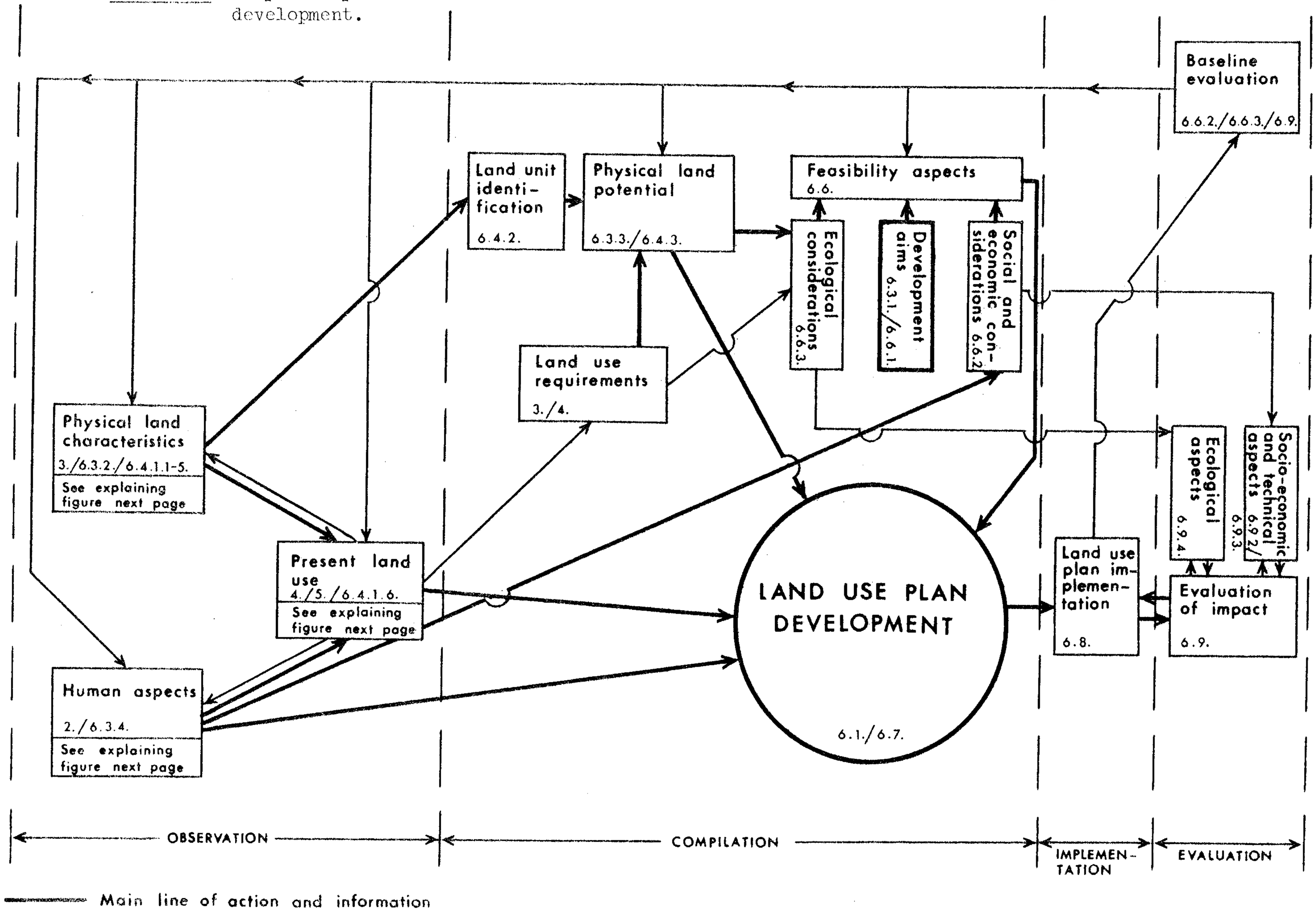
A. Observation phase

Any land use planning, national or local, must start by adequately describing the existing physical land characteristics and the human society, and the present land use that the combination of these have given rise to. The principal type of activities - observation and description - are, more concretely, carried out as surveys, inventories, mappings and statistical data collection.

One of the first priorities regarding "physical land characteristics" and "human aspects" is to identify minimum levels of knowledge sufficient for national coverage.

The aim should be that this level of knowledge will serve as a base from which more elaborate surveys could start, serving local development projects. When determining these national levels, therefore, the possibilities of quickly gathering the additional information needed for local projects must

FIGURE 48. Graphical presentation of main lines of action and main interrelations in planning land use development.



PHYSICAL LAND CHARACTERISTICS 3./6.3.2./ 6.4.1.1-5	Climate	Rainfall: Mean annual Reliability Seasonal distribution etc.
		Evaporation
		Temperature
		Wind
		Etc.
	Soils	Physical conditions Erodibility Stoniness Workability etc.
		Chemical conditions
	Hydrology	Hydrological cycle
		Drainage
		Groundwater
		Quality of water
		Etc.
	Topography	Slope
		Altitude
		Etc.
	Vegetation	Type
		Coverage
		Stability
		Etc.

Examples of further break-downs of the "boxes" in the observation phase in figure 48.

HUMAN ASPECTS 6.3.4.	Quantifiable	Population density
		Age structure
		Sex structure
		Birth rates
		Death rates
		Migration
		Incomes
		Etc.
	Non-quantifiable	Social aims and norms
		Administration
		Education
		Innovation
		Health
		Security
		Population pressure
		Infrastructure
		Etc.

PRESENT LAND USE 4./5./ 6.4.1.6./6.5.	Crop production	Subsistence
		Cash crops
	Animal husbandry	Pastoralism
		Ranching
	Forestry	Subsistence
		Industrial
	Wildlife	Tourism Cropping
	Others, e.g. fishery, urban, soil and water conservation	

be emphasized. For example, climatic data must have been collected for a fairly long period to be of value as a base for further planning. Thus, keeping a high level of climatic knowledge, even without any certain projects in mind, is necessary. As a contrast, local soil surveys can, if necessary, be carried out quickly if resources are available.

After fixing such minimum levels, gaps in knowledge in relation to these levels should be identified, and adequate measures for filling these gaps should be decided on. The actual work, in the form of national surveys etc., in filling these gaps may be very resource-demanding in terms of money, knowledge and equipment. It is our opinion that this is a field where external assistance often will be necessary.

It is of utmost importance, when using national resource surveys for local purpose that the available data are carefully scrutinized with regard to their reliability. Knowledge about at which time and in which way they have been collected is essential. The interpretation of their reliability must be done by competent experts.

At the level of local projects, decisions on gathering further information must be based on the physical requirements of the anticipated land use. The principles should be similar to what was recommended for the national level, i.e. defining minimum levels of knowledge and taking measures to fill the identified gaps in knowledge.

As a base for further planning at the local level, an inventory of the "present land use" is necessary. Such an inventory must include an assessment of the relation between present land use and physical land characteristics and human aspects.

B. Compilation phase

"Identification of land units", suitable as planning and management units in the subsequent processes, is essential. The establishment of land units should be a synthesis of the basic resources surveys and will, to a large extent, be based on topography and air photo interpretation.

With input from the basic surveys, land unit identification and "knowledge of physical requirements" for various types of land use, determination of "physical land potential" can be carried out. Gaps in knowledge about land use requirements must be filled by research and experiments or, when anticipated land use is the same as present land use, by assessing present land use.
An important output from a systematic identification of physical land potential should be the preparation of national land use potential maps, based on a more adequate background than those maps now available in the National Atlases.

When physical land potential has been established, it has to be tested against various "feasibility aspects". Among these are the "national development aims". Although they are usually expressed in too general terms to serve as detailed guide-lines for the planning, every land use plan must be in concord with the spirit of the national aims.

Also of utmost importance are the "ecological feasibility aspects". It is absolutely necessary that potential ecological problems, both in the short and the long run, are identified and that, if not satisfactorily solved in the plan formulation, a reliable system for monitoring them is deviced, so that unfavourable side-effects can be noticed in time and adequate action

taken. A good example of conflicts between short and long term effects is the problem of water supply for cattle in semi-arid areas. After improving the water supply, the cattle population may at first increase, but in the long run, because of subsequent overgrazing, the land productivity may decrease.

The physical land potential must also be scrutinized in the light of "social and economic feasibility aspects", e.g. anticipated effects on behavioural patterns.

The final synthesis of the compilation phase is "development of the land use plan". In this process, the four main information input factors are "Human aspects", "Present land use", "Physical land potential" and "Feasibility aspects", as shown in figure 48. This very intricate synthetising process is impossible to give general recommendations on - it will vary from case to case depending on the four groups of input.
A successful plan can only be formulated through integrated teamwork, with experts from the various relevant fields of knowledge.

C. Implementation phase

In the implementation phase it is essential that sufficient financial and personal resources are engaged. It is also essential that the implementation is closely coordinated with the evaluation. Working systems for the interaction between these two phases must be available already at the very beginning of the implementation.

D. Evaluation phase

The evaluation is basically of two kinds:

- an evaluation of the degree to which the aims given in the land use plan are achieved,
- a survey of possible side effects, preferrably carried out as baseline surveys.

Examples of evaluation by base-line surveys in the field of human aspects could be studying changes in the production of goods for private use and for sale, the marketing of goods and labour etc.

In the ecological field, studies of e.g. changes in species composition, abundance and distribution of plants and animals, can give valuable feedback information to the feasibility effects, and give a better foundation for assessing long-term effects.

E. General about the planning

Essential for the whole concept of land use planning is that the plan should never be looked upon as anything for ever stable. Future findings will necessitate changes and revisions, and it is necessary that the plan in the future is kept flexible. Continuous evaluation will keep it up to date.

Finally, the need of establishing integrated teams including the necessary range of expertise at a very early stage in all planning for land use development, should once again be stressed.

AVAILABLE BASIC DATA ON LAND RESOURCES IN KENYA AND TANZANIA

This appendix is not an attempt to compile all available, published data on land resources. It only treats those natural resources that are surveyed in a systematic way by centralised departments, i.e. climate, geology, hydrology and topographic mapping. Soils and vegetation data are not treated for this reason - the Kenya Soil Survey has only recently started its systematic soil mapping activity and, as yet, only few sheets have been published. For vegetation and soil data reference is therefore made to respective chapters and sections in the text and to the Bibliography.

1. CLIMATE.

Recordings, compilations and publication of climatic data in Kenya and Tanzania are carried out by the East African Meteorological Department (EAMD), an East African Community service. EAMD has its headquarters in Nairobi with three regional meteorological headquarters in each of the three member states (see further appendix 2).
The number of stations - run by different Government departments, private estates, missions, EAMD, etc. - that have produced records over the three countries (incl. Uganda) has approached three thousand, and more than two hundred stations have records for over forty years. Most of these, however, only record rainfall. As seen in Map 21, the stations are very unevenly distributed, with an adequate coverage in densely populated highland areas only.

EAMD publishes annual compilations on the records from a number of important stations. All stations sending records to EAMD have got code numbers and the data are stored in computers. On request to the EAMD Headquarter, extracts can be obtained of all available records from any of these stations. A number of valuable publications on East African climate have been published. They are listed in the EAMD "List of publications", which is available on request.

National maps of climate prepared by EAMD are published in the National Atlases. In the Atlas of Tanzania (1967) there is one "Mean Annual Rainfall Map" and one "10% Rainfall Probability Map", both in scale 1:3,000,000.
In the National Atlas of Kenya (1970), a "Mean Annual Rainfall" in scale 1:3,000,000 is published and smaller maps and diagrams present Rainfall Probability and Potential Evaporation conditions.
For East Africa as a whole the following maps are available:

"Mean Annual Rainfall Map of E.A." (2 sheets), 1:2,000,000
"Monthly Rainfall Maps of E.A." (2 x 12 sheets), 1:2,000,000
10% resp. 20% "Rainfall Probability Maps of E.A." 1:2,000,000
"Monthly and Annual Potential Evaporation Maps" have been published separately for Kenya and Tanzania by Woodhead in 1968 (see ref. list section 6.3.3.3.).

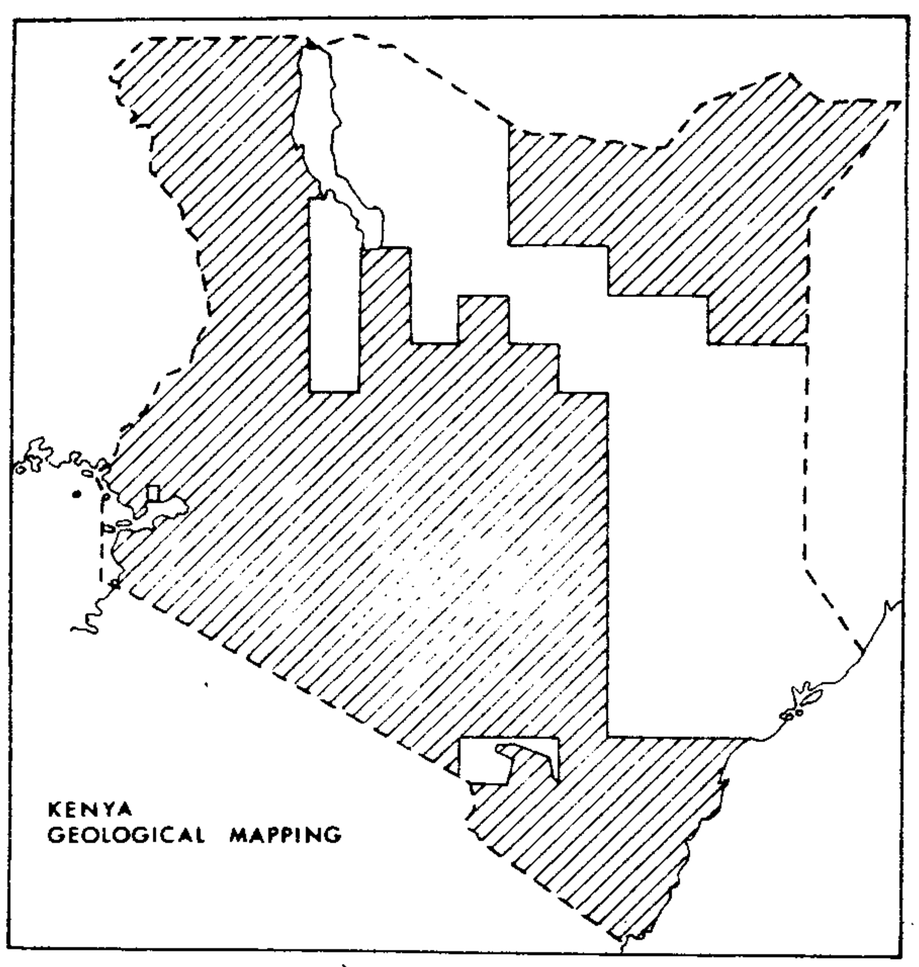
2. GEOLOGY

In Kenya, geological surveying is the responsibility of the "Mines and Geological Department" within the Ministry of Natural Resources, and in

Tanzania the same work is done by the Mineral Resources Division within the Ministry of Commerce and Industries (see further appendix 2).
The enormous amount of publications on geology from the two countries is fortunately compiled into two huge Bibliographies:
"Bibliography of the Geology of Kenya 1859-1968" containing 1160 titles and with Regional register. Published in 1970 by Mines and Geological Department, Nairobi.
"Bibliography of the Geology and Mineral Resources of Tanzania to December 1967", BRALUP Res. Note No 5c 1969.

Comprehensive monographs on the geology of each country are available:
"Summary of the Geology of Tanzania" with map 1:2,000,000, by Quennell et al., 1960.
"Geology and Mineral Resources of Kenya", 2nd revised edition, by Pulfrey & Walsh, 1969.

"Geological maps" in scale 1:3,000,000 are published for each country in respective Atlas.
The large-scale geological survey and mapping work is well underway in both countries. In the figures below, the coverage of geological maps in scale 1:125,000 are shown for Kenya (situation 1968) and Tanzania (situation 1970).



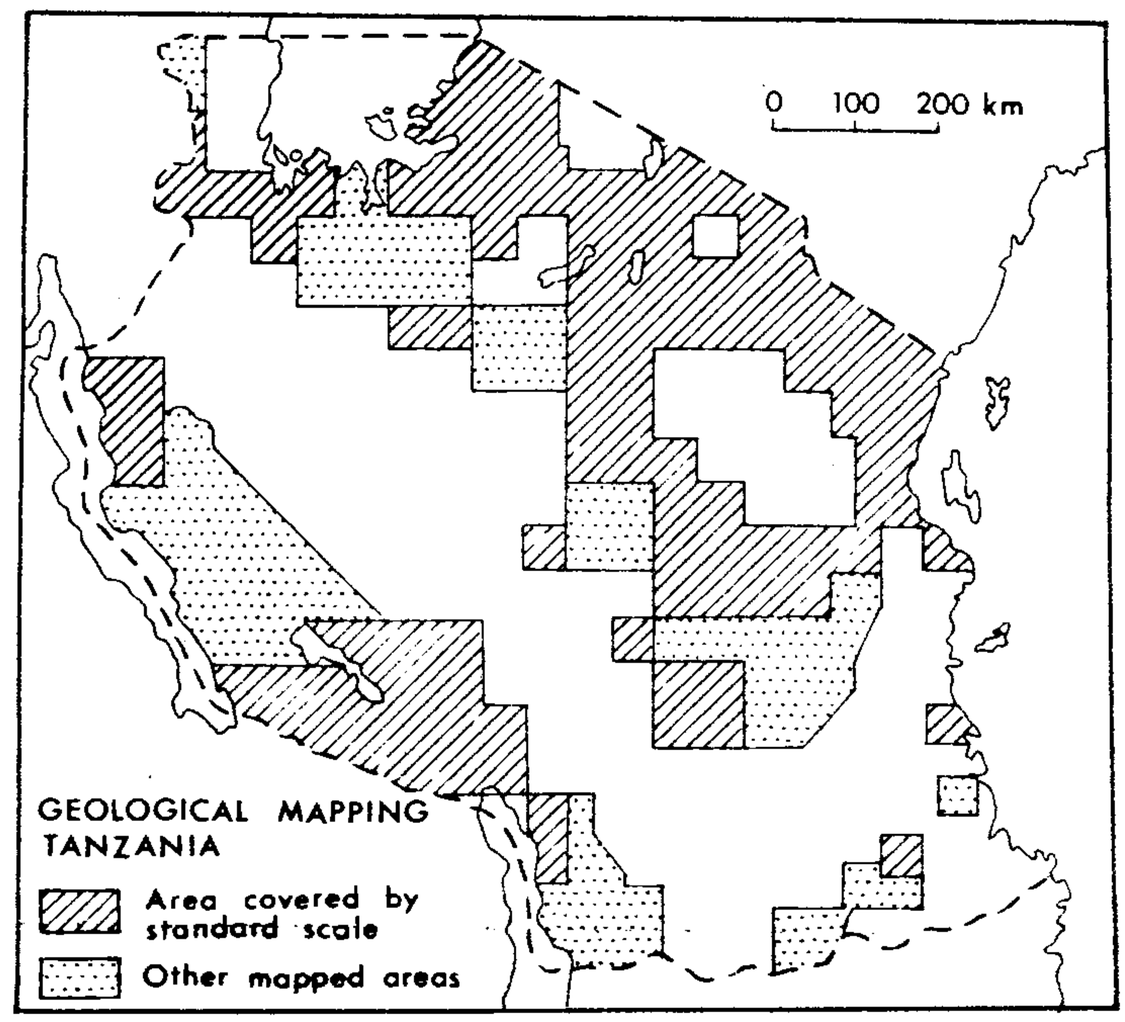


Figure a. Coverage of geological maps in scale 1:125,000 in Kenya (1968) and Tanzania (1970).

3. HYDROLOGY

In Kenya the Water Development Department (WDD) within the Ministry of Agriculture is responsible for collecting data on stream flow and water resources. WDD operates a network of Regular Gauging Stations on the rivers, streams and lakes. The distribution of these on major drainage area and of water level recorders, raingauges (most operated by EAMD), evaporation pans and complete hydro-meteorological stations, is shown in the table below.
Stream flow records from 70 river gauging stations are published biannually. Data on individual stations are available on request.

Table: Hydrological recordings in operation in Kenya (June 1967)

Type	Drainage Area (see map 12)					
	Lake Victoria	Rift Valley	Athi River	Tana River	Ewaso Ngiro	Total
River Gauging Stations	101	57	66	95	42	361
Water Level Recorders	11	2	6	15	8	42
Standard Raingauges	224	150	220	161	73	828
Autographic Raingauges	16	8	12	14	4	54
Storage Raingauges (Mt. Kenya)	-	-	1	21	20	42
Evaporation Pans	22	13	22	15	9	81
Full Hydro-Met.Stations	4	2	6	6	2	20

In Tanzania it is the Water Development and Irrigation Division (WD & ID) of the Ministry of Water Development and Power that has the responsibility for collecting information on the water resources of the country.
A network of around 100 permanent Hydrological Base Stations are in operation. In addition, secondary stations are set up for limited periods until correlation with corresponding base station is established. The marked regional imbalance in the distribution of the stations is seen in the figure below.
A "Hydrological Yearbook" was published by W.D. & I.D. in 1967, covering data from stations in the Pangani, Wami, Ruvu and Rufiji Basins from the years 1960-1965.
Records for individual stations are available at W.D. & I.D.

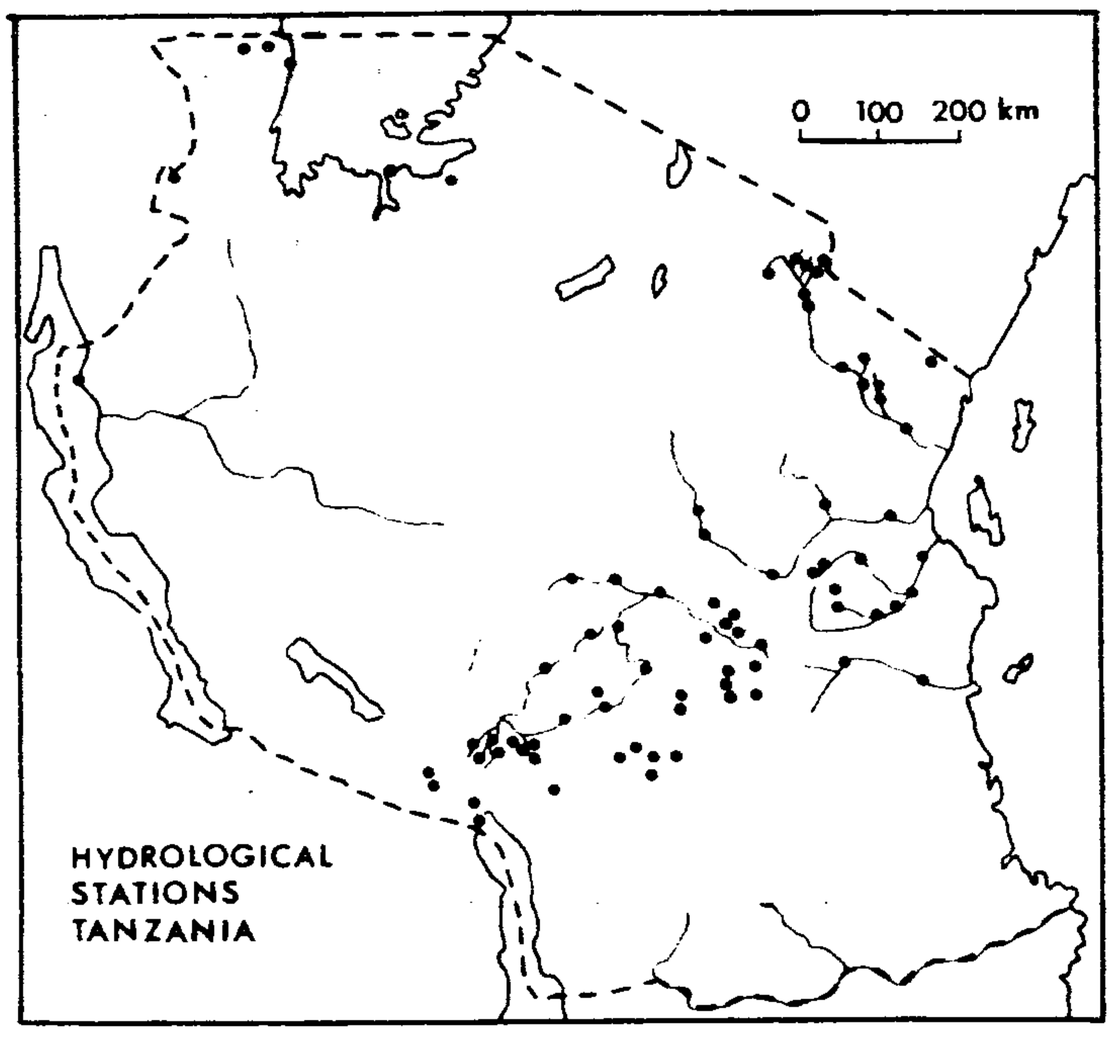


Figure b. Hydrological stations in Tanzania.

4. MAPS AND AERIAL PHOTOS.

The present status of coverage and types of different maps are summarised below. The information is taken from:
"Catalogue of Maps" published by the Survey of Kenya, 1971
"Catalogue of Maps" published by the Surveys and Mapping Division of Tanzania, 1972.
The Survey of Kenya under the Ministry of Lands and Settlements, is responsible for preparing the following types of maps: topographical maps, township maps, cadastral maps, some special maps, and aerial photographs. All maps can be obtained from the Public Map Office, P.O.Box 30089, Nairobi, or through the Provincial Surveyors at Mombasa, Nakuru, Kisumu and Nyeri.

The most important topographical map series in Kenya are:

a) KENYA (Y 731 Series), 1:50,000. In 4/5 colours with some sheets contoured at 50 ft. or 100 ft. vertical interval. Some sheets now in production with 20 m v.i. contours. Coverage: see figure below. Size 1/4° x 1/4°.

b) KENYA (Y 633 Series), 1:100,000. In 5 colours. Coverage supplements Y 731, see figure below. Form lines at appr. 200 ft. vertical interval. Vegetation and surface classification shown. Size 1/2° x 1/2°.

c) EAST AFRICA (Y 503 Series), 1:250,000. In 6 colours with additional layer tints. Coverage practically complete (see fig. below). Size 1 1/2° x 1°.

d) KENYA (SK 57), 1:1,000,000. In 6 colours plus layer tints at 2000 ft. vertical interval. Covering the whole of Kenya and printed as two sheets (North and South of Equator). Size (joined) 10° x 7 3/4°.

e) WORLD SERIES 1301, 1:1,000,000. In 5 colours with layer tints. Standard sheet size 4° lat. x 6° long. Coverage: see figure below.

f) EAST AFRICA (SK 80), 1:2,500,000. In 6 colours plus layer tints. Covering the whole of Kenya, Uganda and Tanzania. Size 75 x 57 cm.

The "National Atlas of Kenya" (1970) contains 43 Maps in full colour in standard scale 1:3,000,000. The most relevant sheets from the point of view of this report are:

Internal Transport	Maize Cultivation
Kenya Physical	Coffee, Sisal, Tea, Wattle and Coconuts
Physical and General	Cattle Distribution
Sectional Maps (West, Central, Coast) 1:1,000,000	Distribution of some Cattle Ticks and East Coast Fever
Mean Annual Rainfall	Distribution of Tsetse Species
Mean Monthly Rainfall and Diurnal Variation	Density of Population
Rainfall Probabilities, Relative Humidity and Sunshine	Ethnic and Linguistic
Temperature	Classification of Land
Geological	Provincial and District Boundaries
Soil	Distribution of some Selected Wild Animals
Ecological potential	Forests
Vegetation	Water Supply
Crop Combinations	Game Reserves and National Parks
Cultivated Land	Drainage and Water Board Areas

Aerial Photographs. Practically the whole of Kenya has been photographed from the air since 1954 at various scales, ranging from 1:80,000 covering the Northern areas to 1:10,000 covering some towns. Contact prints or enlargements are available and inquiries should be addressed to the Director of Surveys.

The Surveys and Mapping Division of the Tanzanian Ministry of Lands, Housing and Urban Development is responsible for preparing the following types of maps: topographical maps, district maps, township and urban maps, some special maps and aerial photos. Maps can be bought directly from the Map Sales Section in Dar es Salaam or requested in writing from The Commissioner for Surveys and Mapping, P.O.Box 9201, Dar es Salaam.

The important topographical map series are in principle the same as for Kenya:

a) TANZANIA (Y 742 Series), 1:50,000. Multi-coloured or single colour. Size 1/4° x 1/4°. These sheets are compiled from aerial photographs and are highly accurate. The quality varies, however, from single colour planimetric sheets to five coloured contoured maps. In general, the sheets in the west and south-west are of poorer quality. Coverage: see figure below.

b) EAST AFRICA (Y 503 Series), 1:250,000. Same standard as for Kenya, though in certain cases where full contour coverage is not yet available, unlayered sheets have been published as first editions. Coverage: see figure below.

c) WORLD SERIES 1301, 1:1,000,000. Same standards as for Kenya. Six layered sheets cover Tanzania (see figure below).

d) TANZANIA, 1:2,000,000. Shows the whole of Tanzania and depicts physical features, roads, railways and administrative boundaries.

The "Atlas of Tanzania" (1968) contains 20 Maps in scale 1:3,000,000. The most relevant sheets are:

Physical	Game Conservation
Geological	Fisheries
Soils	Regions and Districts
Potential Land Use	Population
Geophysical	Population Characteristics
Hydrology	Tsetse and Sleeping Sickness
Mean Annual Rainfall	Agriculture
Rainfall Probability	Cattle Distribution
Vegetation	Water Supplies
Forests	

A new edition of the Atlas is now awaiting publication, or has very recently been published. It will, apart from up-dating older maps, contain the following additional maps:
Capability of soils for agriculture (revised Potential Land Use)
Climate
Main Export Crops
Food Crops
Urban Development-Ujamaa Villages
Internal Communications

Aerial Photographs. Tanzania has been completely covered by aerial photography of varying age and at different scales. Generally, the photography used for small scale mapping (i.e. for the 1:50,000 topographical maps) is in scales between 1:30,000 and 1:40,000. A print of each photograph is filed in the Air Photo Library in Dar es Salaam. The photos are compiled to either photo mosaics or print laydowns. In the photo mosaic the photos have been trimmed and detail on each fitted to its neighbour. They are at a scale of 1:50,000 and cover $1/4^{o}$ x $1/4^{o}$.
A print laydown is a photographed copy of the assembly of all air photos in that area. They are usually at a scale of 1:125,000 and cover $1/2^{o}$x $1/2^{o}$.
Coverage: see figure 38 in section 6.4.1.4.

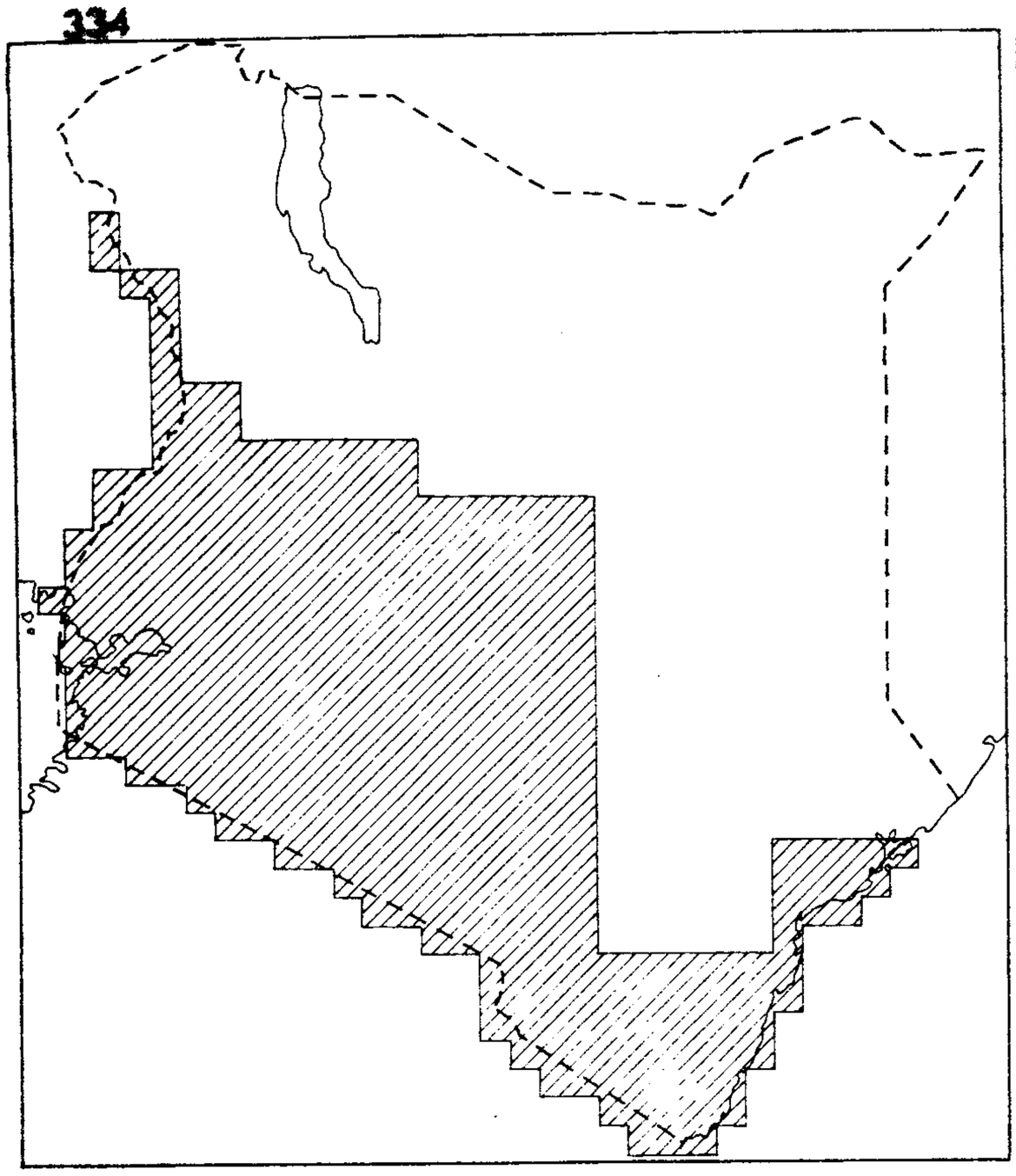


Figure c. Coverage of KENYA Series Y 731, scale 1:50,000.

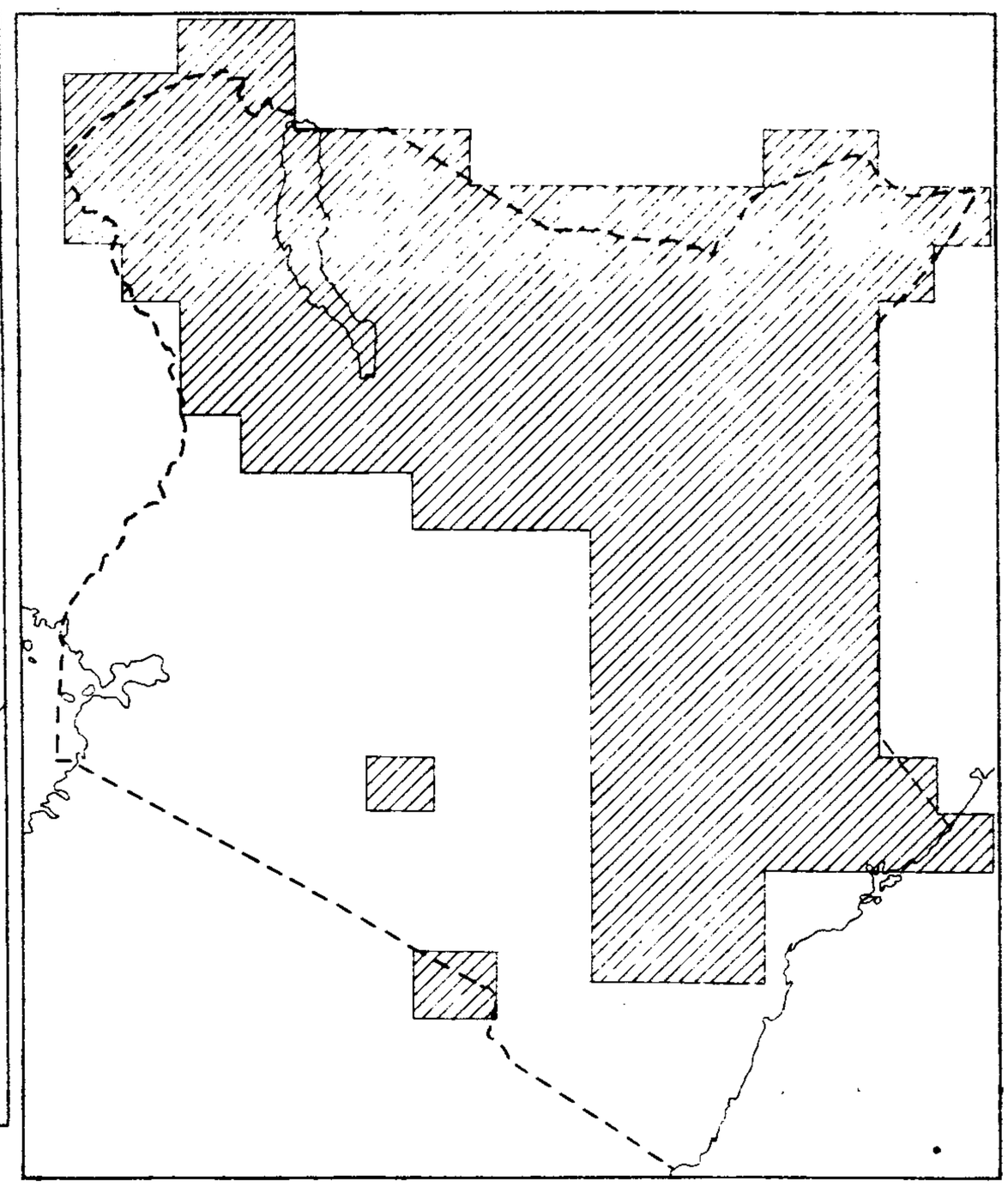


Figure d. Coverage of KENYA Series Y 633, scale 100,000.

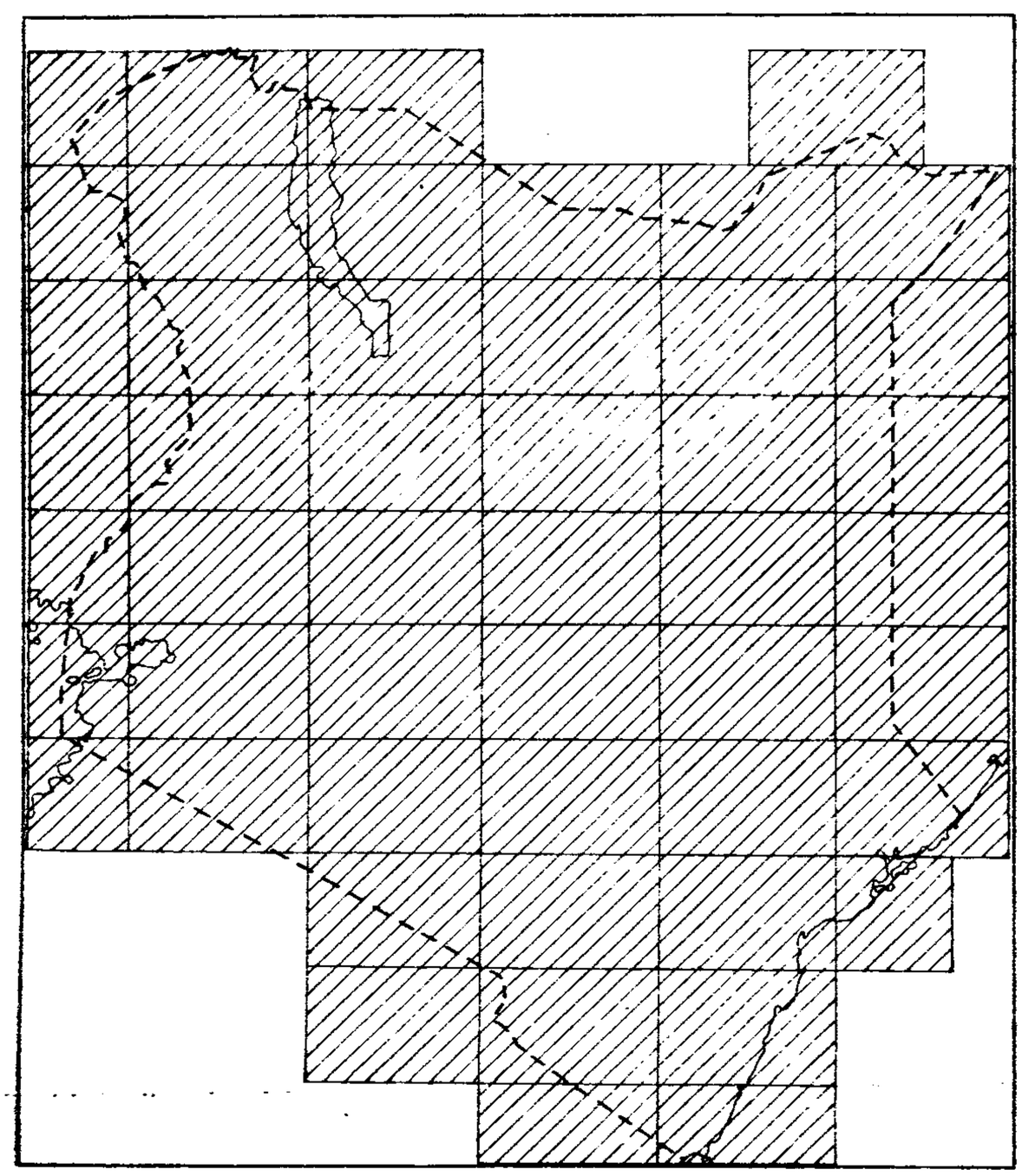


Figure e. Coverage in Kenya of EAST AFRICA Series Y 503, scale 1:250,000.

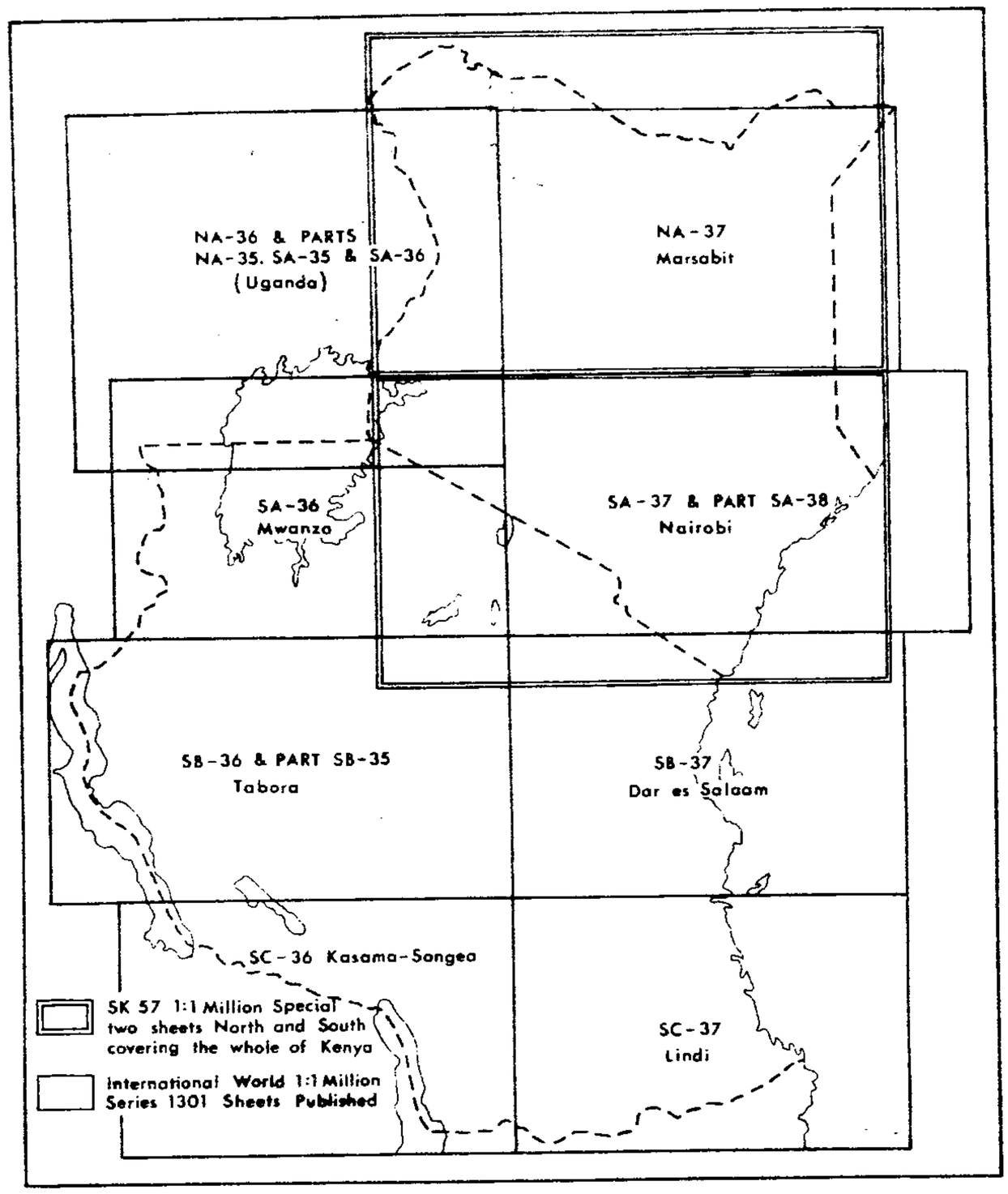


Figure f. Coverage of WORLD SERIES 1301, scale 1:1 mill. and of KENYA SK 57, scale 1:1 mill.

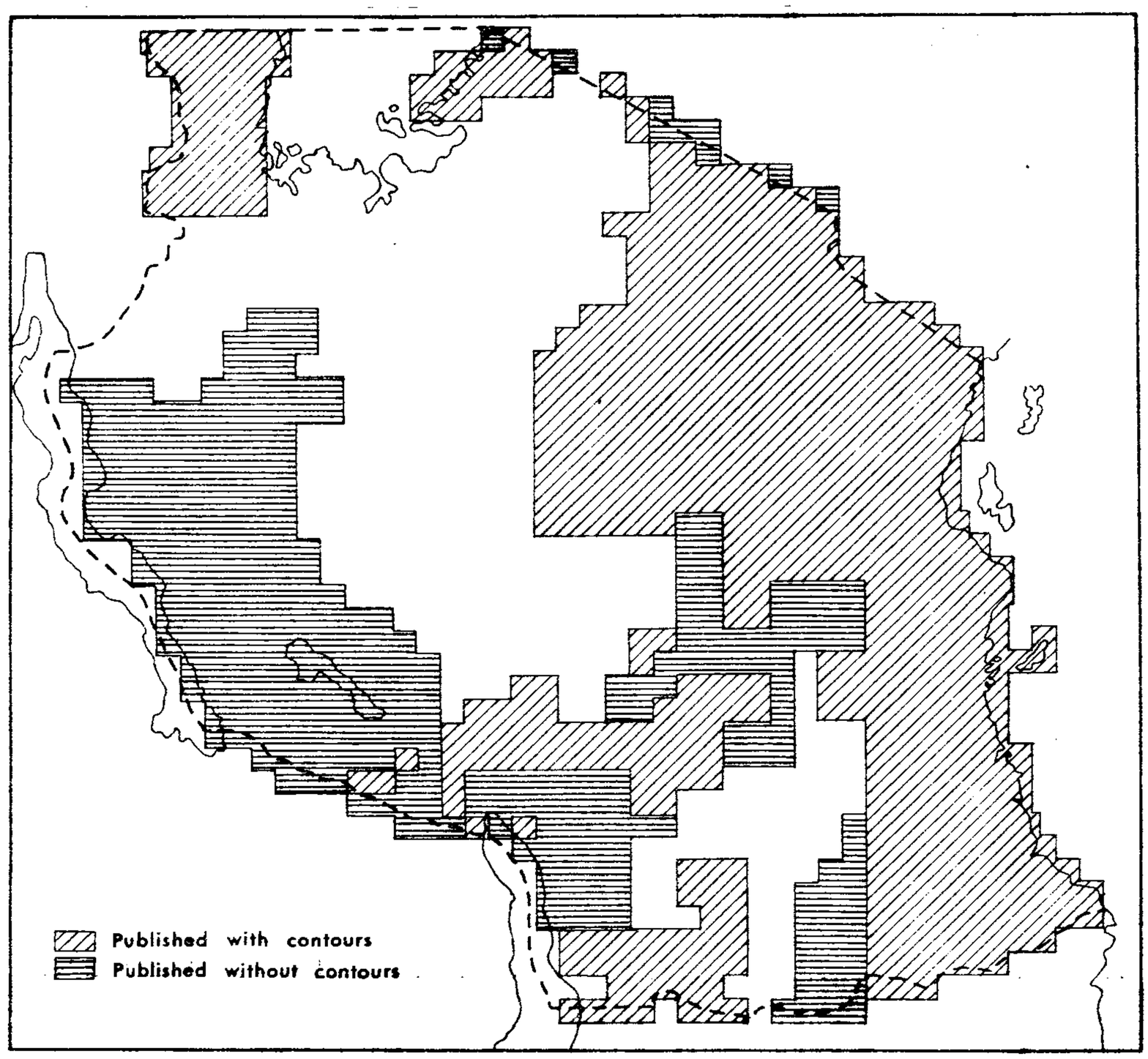


Figure g. Coverage of TANZANIA Series Y 742, scale 1:50,000.

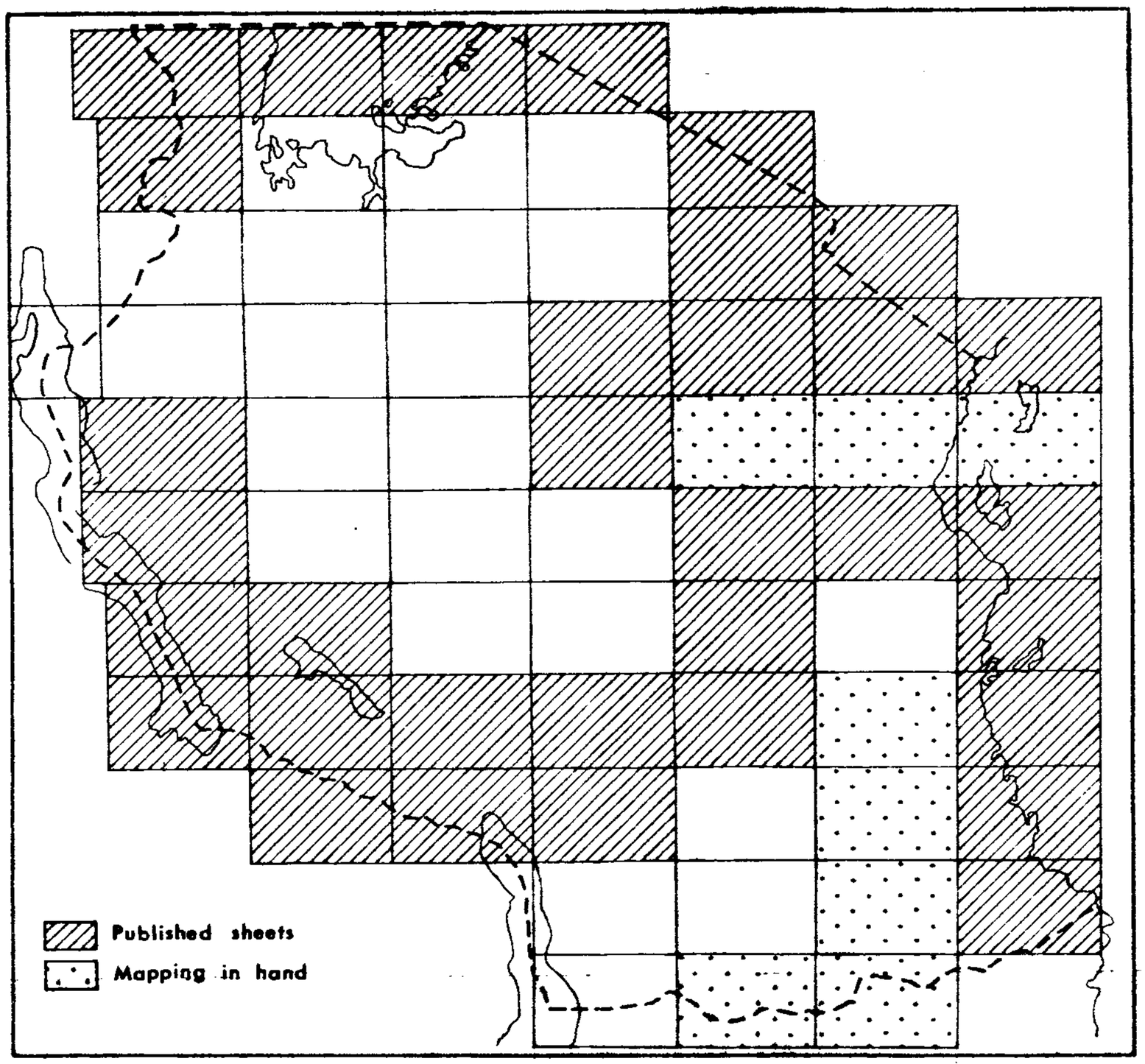


Figure h. Coverage in Tanzania of EAST AFRICA Series Y 503, scale 1:250,000.

APPENDIX 2

RESEARCH INSTITUTIONS AND ORGANISATION

Research concerning various aspects of land resources and land use is spread over a vast number of International, Government, Private and other agencies and departments. It is an almost impossible task to make an exhaustive survey of research going on in this wide field. Government Research Councils have been established in both Kenya and Tanzania to coordinate research work and establish priorities, but so far no comprehensive compilation of research services, covering all aspects of land use, has been made. Below, an attempt is made to list the most relevant institutions and departments responsible for research. It is thus not a list of research projects. A division is made between E.A. Community research, Kenya respectively Tanzania Government research institutions, and others. Short introductions are given on E.A.C. administration and on Government organisation in the two countries. The main sources of information have been:

"Survey on the scientific and technical potential of the countries of Africa", Unesco, 1970.
"The world of learning 1973-74", Europa Publ.,1973.
"Africa South of the Sahara 1974", Europa Publ., 1974.
"Natural Resources Research in East Africa", M.Zumer,Bull. Ecol. Res.Comm. 12, Stockholm 1971.

I. EAST AFRICAN COMMUNITY (EAC).

Established in 1967 the EAC provides an institutional and legal framework to strengthen the Common Market between Kenya, Tanzania and Uganda and has absorbed the common services and research activities formerly controlled by the East African Common Services Organization. The EAC Headquarters is situated in Arusha, Tanzania.
The following "Community Services" are of relevance in connection with research on land use questions:

1. East African Meteorological Department (EAMD).
   P.O.Box 30259, Nairobi.

Principally engaged in operational work (see appendix 1), but also in research. Includes 3 regional meteorological headquarters: Kenya (P.O.Box 30005, Nairobi), Tanzania (P.O.Box 3056, Dar es Salaam) and Uganda.
Fields of research: climatology, meteorology, weather forecasting, hydrometeorology, agrometeorology.
Publications: Annual Reports, Memoirs, Technical Memoranda, Climatological Statistics, Observers Handbook, Weather Messages.

2. East African Fresh Water Fisheries Research Organization (EAFFRO).
   P.O.Box 343, Jinja, Uganda.

Principally engaged in research about the exploitation of fisheries in Lake Victoria and other lakes and rivers in East Africa.
Fields of research: fish taxonomy, physiology, parasitology, limnology, ecology, statistics, population dynamics, fishing development.
Publications: Annual Report.

3. East African Marine Fisheries Research Organization (EAMFRO).
P.O.Box 668, Zanzibar.

Engaged in research on exploitation of marine fisheries in the Indian Ocean.
Fields of research: oceanography (physical and chemical), marine biology (taxonomy, biology, migration studies, primary productivity), marine fisheries.
Publications: Annual Reports

4. The Tropical Pesticides Research Institute (TPRI).
P.O.Box 3024, Arusha, Tanzania.

Principally engaged in research on the application of insecticides, herbicides and fungicides, etc. Includes the following sections: Mosquitoes, Tsetse, Bilharzia, Agricultural Entomology, Botany, Chemistry, Physics and Engineering.
Fields of research: Organic chemistry, plant biology (botany, taxonomy), animal biology (zoology), radiobiology, ecology, meteorology, contagious diseases and vectors, herbicides, insecticides, forest pathology, animal production, animal products, animal health.
Publications: Annual Report

5. East African Agriculture and Forestry Research Organization (EAAFRO).
P.O.Box 30148, Nairobi.

Principally engaged in research.
Includes divisions for Physics and Chemistry; Maize Genetics (at Kitale, Kenya); Sorghum/Millet Breeding; Sugarcane Breeding (at Mtwapa, Kenya); Plant Pathology, Nematology and Plant Quarantine; East African Herbarium; Armyworm; Forestry; Animal Production and Statistics;
Fields of research: Biochemistry, radiation physics, general chemistry, cell biology, genetics, general physiology, botany, taxonomy, zoology, radiobiology (plant and animal), ecology, pathology, virology, pedology, agricultural meteorology, hydrobiology, water, soil and air hygiene, soil management, hydrology, crop production, crop protection, forestry and forest products, food technology, application of isotopes as tracers in agriculture, fertilizers, animal production.
Publications: Records of Research (Annual Report), East African Agriculture and Forestry Journal.

6. East African Veterinary Research Organization (EAVRO)
P.O.Kabete.

Principally engaged in research.
Includes research divisions for: Virus Diseases, Bacterial Diseases, Helminth Diseases, Protozoal Diseases, Animal Production which includes Metabolism Section, Genetics Section and Physiology Section, General Bacteriology and Pathology which includes Histopathology Section, Livestock Section, Small Animal Section.
Fields of research: Genetics, general physiology, animal biology, ecology, animal health and nutrition, animal production and products, research into control of animal diseases.
Publications: Annual Report

7. East African Natural Resources Research Council
P.O.Box 1002, Arusha, Tanzania.

Responsible for the co-ordination of research relating to the natural resources of East Africa, including the research activities of the above listed organizations 2-6.

8. East African Institute of Malaria and Vector-Borne Diseases (EAMVBD).
P.O.Amani, Tanzania.

Principally engaged in research.
Includes a Department of Malaria Protozoology and Immunity, a Department of Clinical Investigations, a Department of Mosquito Vectors, a Department of Helminthology, a Department of Blackfly and other Vectors, a Department of Biochemistry, and field stations with laboratories at Muheza, Gonja, and Mto wa Mbu in Tanzania, and Taveta in Kenya.
Fields of research: Biochemistry, vector genetics, vector ecology, parasitology, diseases (malaria, onchocerciasis), chemotherapy, immunology.
Publications: Annual Report.

9. East African Institute for Medical Research (EAIMR).
P.O.Box 1462, Mwanza, Tanzania.

Engaged in research.
Fields of research: Organic chemistry, biology, medical physics, medical biochemistry, physiology, endocrinology, anatomopathology, bacteriology, contagious diseases and vectors (medical entomology, helminthology), chemotherapy, antibiotics, antiseptics, medical chemistry, pharmacology.
Publications: Annual Report, scientific papers.

10. East African Trypanosomiasis Research Organization (EATRO)
P.O. Box 96, Tororo, Uganda.

Principally engaged in research.
Experimental station in Lugala, Uganda; pupae collection station at Singida, Tanzania.
Fields of research: all aspects of trypanosomiasis research including genetics, physiology and ecology of the vectors, epidenirology, immunology and chemotherapy of the disease in man and livestock, physiology and biochemistry of the trypansomes.
Publication: Annual Report.

11. Office of the East African Medical Research Council
P.O.Box 1002, Arusha, Tanzania

Directs and co-ordinates the activities of, among else, the institutes 8-10 above.
Publications: Annual Report, papers.

II KENYA GOVERNMENT

The Kenya Government is organised under 19 Ministries, of which the following are responsible for direct planning, operational and research activities concerning land utilisation:
Ministry of Finance and Economic Planning
Ministry of Agriculture and Animal Husbandry
Ministry of Power and Communications
Ministry of Tourism and Wildlife

Ministry of Lands and Settlement
Ministry of Natural Resources
Below, the principal governmental research institutes and departments are listed under respective Ministries or, if autonomous, separately.

A. MINISTRY OF AGRICULTURE AND ANIMAL HUSBANDRY

The research activities are organised under the following Departments and Divisions (figures refer to the list below):

Department of Technical Services
- Animal Husbandry Division (1,2)
- Range Management Division (3)
- Scientific Research Division (4-20)
- Veterinary Services Division (21-22)

Water Development Department
- Water Development Division (23)

1. Animal Husbandry Division
   P.O.Box 30028, Nairobi

Includes National Animal Husbandry Research Station, Naivasha, (see 2 below); Beef Research Station, Nakuru; 10 extension farms of appr. 150 ha each, throughout the country.
Fields of research: Genetics, animal production, animal products, animal nutrition.

2. National Animal Husbandry Research Station
   P.O.Box 25, Naivasha

Fields of research: Animal production (cattle, pigs, sheep), animal products.

3. Range Management Division
   P.O.Box 30028, Nairobi.

The Division includes 2 sub-stations at Chemogoch, Baringo District and Bachuma, Coast Province. Plans are in hand and finance available to build a major research centre at Kiboko, Machakos District.
Fields of research: Plant physiology, plant biology, ecology, range botany, wildlife biology, bush control, animal production.

4. Scientific Research Division
   P.O.Box 30028, Nairobi

The Division includes Headquarters at Nairobi, central services at the National Agricultural Laboratory, specialized services: coffee, pyrethrum, sisal, maize, sugarcane, pasture, cotton and horticulture, and the research stations listed below as Nos. 5-20.

5. Coast Agricultural Research Station
   P.O. Kikambala.

The stations includes 3 main sub-stations: Manakani Animal Production Station (900 acres; dairy and beef cattle), Msabaha Cotton Station (100 acres; cotton and arable crops), and Matuga Tree Crops Station (80 acres; irrigated citrus).
Fields of research: Soil management, crop production (tree crops, fodders, arable food and cash crops), crop protection (sugarcane, maize, tree crops), animal production, animal products.

6. Cotton Research Station
P.O. Kibos, Nyanza Province.

Substation at Busia, Western Province and Msabaha, Coast Province.
Fields of research: Insect ecology, agronomy (cotton), entomology.

7. Eldoret Agricultural Research Station
P.O.Box 95, Eldoret.

Fields of research: Soil management, crop production (maize, wheat), crop protection (maize, wheat), animal production, animal products.

8. Embu Agricultural Research Station
P.O. Box 27, Embu.

Fields of research: Soil management, crop production (maize, bananas, pasture), crop protection (maize, bananas, pasture), animal production, animal products.

9. Grassland Research Station
P.O.Box 144, Molo

Under the National Agricultural Research Station at Kitale (see no. 13 below).
Fields of research: Pasture research (high altitude zone).

10. High Level Sisal Research Station
P.O.Box 7, Thika.

Fields of research: Soil management, crop production (sisal), crop protection (sisal).

11. Katumani Agricultural Research Station
P.O.Box 340, Machakos.

The Station has a sub-station at Kampi-ya-Mawe, Eastern Province, Southern Part.
Fields of research: Crop production (maize, beans, cotton, castor).

12. National Agricultural Laboratory
P.O.Box 30028, Nairobi.

Fields of research: Soils and agricultural chemistry, pathology, entomology.

13. National Agricultural Research Station, Kitale
P.O.Box 450, Kitale

The National Agricultural Research Station Kitale includes the Pasture Research and Maize Research Sections; has sub-stations at Kakamega (Western Kenya), Molo (high altitude), Katumani (southern Kenya) and Embu, (central Kenya).
Fields of research: Genetics (maize), crop production, plant introduction and testing, pasture evaluation in terms of animal production, plant chemistry, soil chemistry, legumes bacteriology, seed production.

14. National Horticultural Research Station
P.O.Box 220, Thika.

The station includes 3 sub-stations, 1 at Molo, Rift Valley Province, 1 at Mutuga, Coast Province and 1 at Perkerra Irrigation Scheme.
Fields of research: Soil management, horticultural crop production, horticultural crop protection.

15. Nyandarua Agricultural Research Station
Private Bag, Ol Joro Orok.

Fields of research: Crop production (wheat pyrethrum, pasture), animal production, animal products.

16. Nyanza Agricultural Research Station
P.O.Box 523, Kisii.

Includes a sub-station at Homa Bay (South Nyanza).
Fields of research: Crop production (maize, groundnuts, soya-beans, cassava), animal production, animal products, soil management (fertilizer use).

17. Pyrethrum and Horticultural Research Station
P.O.Box 100, Molo.

Fields of research: Crop production (pyrethrum), crop protection (pyrethrum).

18. National Sugar Research Station, Kibos
P.O.Box 1221, Kisumu.

Includes sub-stations at Mumias (Western Province), Ramisi (Coast Province).
Fields of research: Soil management, crop production (sugar), crop protection (sugar).

19. Western Agricultural Research Station (WARS)
P.O.Box 169, Kakamega.

Includes sub-station at Sangalo (Rift Valley Province) and Busia (Western Province).
Fields of research: Soil management (fertilizer use), crop production (maize, groundnuts, soyabeans, cassava), pasture (grass/legume mixture, fodder grass).

20. Wheat Research Station (Plant Breeding Station)
P.O.Njoro.

Includes 10 sub-stations in other parts of Kenya.
Fields of research: Genetics (small-grain cereal breeding).

21. Veterinary Research Laboratory
P.O. Kabete.

The laboratory was established in 1910; includes laboratories on diagnosis, bacteriology, virology, parasitology, chemistry, serology, pathology, poultry and separate laboratories for tsetse and foot and mouth disease; vaccine production.
Fields of research: Animal production, animal products, animal health (virus diseases, bacterial diseases, parasitology, serology, toxicology, physiology, etc.).

22. Wellcome Institute for Research on Foot and Mouth Disease (WIRFMD)
P.O. Box 18021, Nairobi

The Institute was established in 1960; sub-centre to determine and classify types of foot-and-mouth disease virus in East Africa; vaccine production.
Fields of research: Animal virology (foot-and-mouth disease: research into the development of vaccines, epidemiology).

23. Water Development Division
P.O.Box 30521, Nairobi.

Administrative and operational service. Also engaged in research.
Fields of research: Hydrology, hydrogeology.

B. MINISTRY OF NATURAL RESOURCES

1. Research and Planning Conservancy (R. & P.) of the Forest Department
P.O. Box 30513, Nairobi.

Sub-station at Kikuyu, P.O. Box 74, Kikuyu.
Fields of research: Soil management (soil nutrients), hydrology, forestry, crop protection (forestry), forestry and forest products (utilisation), tree growth,entomology, tree diseases.

2. Mines and Geological Department
P.O. Box 30009, Nairobi.

Operational and research services.
Fields of research: Analytical chemistry, geomorphology, cartography, weight, magnetism, mineralogy, petrography, geology, vulcanology.

3. The National Museum
P.O. Box 658, Nairobi.

Under Statutory Board of Trustees. Includes a Department of Entomology, a Department of Mammology, a Department of Ornithology, a Department of Herpetology and Amphibians, a Department of Ethnography, a Department of Osteology, an Education Department, a Technical Department and a Snake Park.
Fields of research: Animal biology (anatomy, taxonomy, ecology), marine biology, fresh water biology, geology, primate biology (osteology, anatomy), ethnography.

C. MINISTRY OF TOURISM AND WILDLIFE

1. Fisheries Department
P.O. Box 241, Nairobi.

Includes outstations located at: Kisumu and Homa Bay on Lake Victoria; Ferguson's Gulf on Lake Rudolf; Lake Baringo; Lake Naivasha; Fish Culture Farm, Sagana; Trout Hatchery, Kiganjo; Mombasa, Malindi and Lamu. Laboratory facilities are possessed by the stations at Kisumu, Ferguson's Gulf Sagana, Lamu and Nairobi H.Q.
Fields of research: Population studies, gear technology, fish processing, technology and spoilage.

2. Research Division of the Game Department
P.O.Box 241, Nairobi.

Includes a field research station at Maralal, Northern Province.
Fields of research: Animal biology (wildlife), animal and plant ecology.

2.a. Kenya Wildlife Management Project
P.O.Box 30559, Nairobi.

A cooperative program of the Kenya Game Department and FAO.
Mainly operating in the Kajiado District.
Fields of research: Wildlife ecology, ethology, game cropping, economics of game utilisation.

3. National Parks of Kenya
P.O. Box 2076, Nairobi.

Quasi-government organization established by an act of Parliament under a Board of Trustees.
Includes a Wildlife Education Centre and an Animal Orphanage at the Nairobi National Park, and 10 National Parks and 3 National Reserves:
Fields of research: Animal and plant ecology, soil sciences.

D. OTHER KENYA GOVERNMENT RESEARCH ORGANISATIONS

1. National Irrigation Board (NIB)
P.O.Box 30372, Nairobi.

Statutory Board. Also engaged in research.
Includes Ahero Irrigation Project (see: a), Mwea Irrigation Settlement (see: b) and Tana Irrigation Scheme (see: c).

1.a. Ahero Irrigation Research Station
P.O. Box 1961, Kisumu.

Fields of research: Hydrology, crop production, crop protection, rice agronomy.

1.b. Mwea Irrigation Settlement
P.O. Box 80, Kerugoya

Fields of research: Hydrology, crop production, crop protection, rice agronomy.

1.c. Tana Irrigation Scheme
P.O. Galole (via Malindi)

Fields of research: Hydrology,crop production, crop protection, cotton agronomy.

2. Egerton College
P.O. Njoro.

Autonomous institution engaged in teaching and research.
Includes a Department of Animal Science, a Department of Biology, a Department of Chemistry, a Department of Crop Husbandry, a Department of Dairy Technology, a Department of Economics, an Education and Extension Department, a Department of Engineering and a Department of Range Management.
Fields of research: Soil management (profile), crop production (pasture), crop protection (weed control), animal production, animal health.

E. UNIVERSITY OF NAIROBI
P.O. Box 30197, Nairobi.

Autonomous institution engaged in teaching and research.
The University includes a Faculty of Agriculture, a Faculty of Architecture, Design and Development, a Faculty of Arts, a Faculty of Commerce, a Faculty of Engineering, a Faculty of Law, a Faculty of Medicine, a Faculty of Science, a Faculty of Veterinary Science, an Institute for Development Studies, an Institute of Adult Studies and a School of Journalism.

1. Faculty of Agriculture

Includes, among else, a Department of Soil Science, a Department of Agricultural Economics and a Department of Crop Production. (No further information was available when compiling this appendix).

2. Faculty of Architecture, Design and Development
P.O. Box 30197, Nairobi.

Includes, among else, a Department of Land Development.

3. Faculty of Arts
P.O. Box 30197, Nairobi.

Includes, among else, the following Departments:
Economics; Education; Geography (see below); Government; History; Sociology.

3a. Department of Geography

Fields of research: Population carrying capacity of the land, geomorphology, cartography, ecology, meteorology, climatology, soil crop potential survey, economic aspects of crop production forestry and forest products, animal production and animal products, fisheries (continental and maritime), resource and economic aspects of hydroelectric power.

4. Faculty of Engineering
P.O.Box 30197, Nairobi.

Includes, among else, the following departments:

4a. Department of Civil Engineering.

Fields of research: Hydrology, timber engineering, hydraulics, highway engineering, building materials, structural engineering, soil mechanics, public health engineering.

4b. Department of Mechanical Engineering

Fields of research: Crop processing, solar energy, metallurgy, saw milling.

4c. Department of Surveying and Photogrammetry.

Fields of research: Geophysics, field astronomy, satellite geodesy, photogrammetry, land planning.

5. Faculty of Medicine
P.O. Box 30588, Nairobi.

Includes, among else, the following department:

5a. Department of Community Health

Fields of research: Anthropology, contagious diseases, nutrition.

6. Faculty of Science
P.O. Box 30197, Nairobi.

Includes, among else, the following departments:

6a. Department of Botany

Marine Botany Field Station at Diani.
Fields of research: Plant biology, ecology, marine biology.

6b. Department of Geology

Fields of research: Geomorphology, mineralogy, petrology, geology, vulcanology, structural geology, seismology, geophysics, geochemistry, geology of the Rift System.

6c. Department of Meteorology

Fields of research: Meteorology, hydrometeorology, agrometeorology.

6d. Department of Zoology.

Fields of research: Cell biology, endocrinology, parasitology, ecology (insect and vertebrate), entomology, zoology for agriculture.

7. Faculty of Veterinary Science
P.O. Kabete.

Includes, among else, the following departments:

7a. Department of Animal Production

Fields of research: Genetics, animal breeding, statistics, animal nutrition, ecology and management.

7b. Department of Veterinary Pathology and Microbiology

Fields of research: Anatomopathology, bacteriology, virology, immunology, protozoology, entomology, helminthology.

8. Institute for Development Studies (IDS)
P.O. Box 30197, Nairobi.

IDS is divided into two Divisions:

8a. Social Science Division

Fields of research: Rural development, rural-urban migration, agricultural pricing and marketing, pastoral group ranching, tourism and economic development, secondary school education, technology transfer.

8b. Cultural Division

Fields of research: Archaeology, history, social anthropology, medical anthropology and cultural beliefs concerning medical practices, human ecology (pastoralism), traditional art, literature and belief systems, musicology, linguistics.

III. TANZANIA GOVERNMENT

The Tanzania Government is organised under 18 Ministries, of which the following are responsible for direct planning, operational and research activities concerning land utilisation
Ministry of Finance
Ministry of Agriculture
Ministry of Economic Affairs and Development Planning
Ministry of Natural Resources and Tourism
Ministry of Communications and Works
Ministry of Lands, Housing and Urban Development
Ministry of Water Development and Power
Ministry of Commerce and Industries.

There is a considerable Regional autonomy on questions concerning land development.

A. MINISTRY OF AGRICULTURE

The Ministry of Agriculture was recently re-organised, and research activities are now the responsibility of two Research and Disease Control Sections, one under the Crop Development Division and one under the Livestock Development Division.
There are nine Agricultural Research Institutes under the Crop Development Division. Livestock research programs include five institutes and five veterinary investigation centres (at Mpwapwa, Arusha, Mwanga, Iringa and Tabora).

1. Research and Disease Control Section
   Crop Development Division
   P.O. Box 9071, Dar es Salaam

A comprehensive report on crop research was recently published: "National Agricultural Research Programme 1974-1975". Reference is made to this for details about the fields of research for each of the Institutes (2-10) listed below. The report is available on request to the address above.

2. Agricultural Research Institute, Lyamungu
   P.O. Box 3004, Moshi.

3. Agricultural Research Institute, Ukiriguru
   P.O.Box 1433, Mwanza

4. Agricultural Research Institute, Ilonga
   Private Bag, Kilosa.

5. Agricultural Research Institute, Mlingano
   Private Bag, Ngomeni, Tanga.

6. Agricultural Research Institute, KATRIN
Private Bag, Ifakara.

7. Agricultural Research Institute, Mbeya
P.O. Box 400, Mbeya.

8. Agricultural Research Institute, Mtwara
P.O. Box 509, Mtwara.

9. Agricultural Research Institute, Maruku
P.O. Box 127, Bukoba.

10. Agricultural Research Institute, Tumbi
P.O. Box 306, Tabora.

11. Research and Disease Control Section
Livestock Development Division
P.O. Box 9071, Dar es Salaam

Includes the following:

12. Central Veterinary Laboratory
P.O. Box 9254, Dar es Salaam.

Fields of research: General chemistry, organic chemistry, biochemistry, botany (taxonomy), disease vectors, ecology of tsetse fly, parasitology, bacteriology, protozoology, virology, pathology, helminthology, nutrition (cattle and sheep), hygiene (water testing, milk testing), animal health, dipping.

13. Agricultural Research Institute, Mpwapwa
Private Bag, Mpwapwa

National Centres for Animal Research, AI-service.
Fields of research: Genetics, general physiology, nutrition, animal production and animal products (cattle, pigs, poultry), animal health (beef and dairying), range management.

13a. Pasture Research Station (PRS)

Sub-station of 13.
Fields of research: Soil management (cultivation methods), range management, bush and weeds control, pasture improvement, animal production and animal products (cattle, goats).

14. Agricultural Research Institute, Tanga
P.O. Box 5016, Tanga.

Fields of research: Reproductive physiology, physiology, endocrinology, animal nutrition, pasture research, animal production, animal products, animal health (cattle, pigs).

15. Agricultural Research Institute, Ilonga.
(same as no. 4)

Fields of research: crossbreeding, sheep, goats.

16. Agricultural Research Institute, Mbeya
(same as no. 7)

Fields of research: dairy production, forage.

B. MINISTRY OF NATURAL RESOURCES AND TOURISM

1. Forest Division
P.O. Box 426, Dar es Salaam

Principally operational and administrative services. Two research branches:

1a. Forest Utilization Section
P.O. Box 10, Moshi.

Fields of research: forest products, wood technology

1b. Silviculture Research Station
P.O. Box 95, Lushoto.

Includes arboretum, forest herbarium and laboratories.
Fields of research: silviculture, tree breeding, forest botany, forest entomology, forest ecology and soil science.

2. Fisheries Division
P.O. Box 2462, Dar es Salaam

Principally administrative and extension work. Also engaged in research.
Fields of research: fisheries (continental and maritime).

3. Game Division
P.O. Box 1994, Dar es Salaam.

Administrative service. Also engaged in research.
Fields of research: animal biology (wildlife), ecology.

C. MINISTRY OF WATER DEVELOPMENT AND POWER

1. Water Development and Irrigation Division (W.D. & I.D.)
P.O. Box 9153, Dar es Salaam

Includes one water laboratory and one soil laboratory.
W.D. & I.D. collects and evaluates basic data (see appendix 1), deals also with construction, maintenance and operation of water works and irrigation schemes.
Fields of research: Surface water, groundwater hydrology, irrigation, water supply.

D. MINISTRY OF COMMERCE AND INDUSTRIES

1. Mineral Resources Division
P.O. Box 903, Dodoma

Fields of research: Regional geological mapping, geochemistry, geomorphology, cartography, mineralogy, petrography, seismology, thermochemical energy, geothermal energy.

E. TANZANIA NATIONAL PARKS

Under a Board of Trustees.
All research is carried out by:

1. Serengeti Research Institute
P.O. Box 3134, Arusha

Situated at Seronera in the Serengeti National Park.
Fields of research: Plant biology, plant ecology (forest ecology, grassland productivity), animal biology, animal ecology (elephant, buffalo, impala, zebra, Thomson's gazelle, lion, vulture), radio biology, animal behaviour (elephant, impala, dik-dik, lion), parasitology, soil science, animal health (wild animals), game cropping, meat hygiene, geology, photogrammetry.

F. UNIVERSITY OF DAR ES SALAAM
P.O. Box 35091, Dar es Salaam.

Autonomous institution engaged in teaching and research.
The university includes a Faculty of Agriculture and Forestry, a Faculty of Arts and Social Science, a Faculty of Law, a Faculty of Medicine, a Faculty of Science, an Institute of Adult Education, an Institute of Education, an Institute of Public Administration, an Institute of Swahili Research, a Bureau of Resource Assessment and Land Use Planning and an Economic Research Bureau.

1. Bureau of Resource Assessment and Land Use Planning (BRALUP)
P.O. Box 35097, Dar es Salaam.

Issues important publication series
Fields of research: Resources analysis including population resources, land use and regional planning.

2. Faculty of Agriculture and Forestry
P.O. Box 643, Morogoro.

Includes a Department of Agricultural Chemistry, a Department of Agricultural Engineering, a Department of Animal Science, a Department of Crop Science, a Department of Rural Economy and a Division of Forestry.
Fields of research: Organic chemistry, biochemistry, genetics, plant biology, animal biology, animal and plant ecology, animal nutrition, soil management, crop production (vegetables, maize, sorghum, rice, beans, cassava, sweet potatoes, cashew nuts, coffee, citrus), crop protection, horticulture, plant pathology, animal production and animal products

Includes, among else:

4a. Department of Botany
P.O. Box 35060, Dar es Salaam.

Fields of research: Morphology, anatomy, classification and systemtics, physiology, biochemistry, cytology, genetics, locally occurring plants, fungi and archegoniate plants, marine algae, heterostyly.

4b. Department of Zoology
P.O. Box 35064, Dar es Salaam.

Fields of research: Cell structure and organisation, cytology, genetics, comparative embryology, morphogenesis, ecology, parasitology, animal evolution, adaptive radiation, land and marine field courses (taxonomy, faunistics, measurement of biotic factors), genetics, bionomies and growth phenomena (cryostaty, histochemistry, electron microscopy, plankton analysis).

5. Economic Research Bureau(ERB)
P.O. Box 35096

Fields of research: rural economy, sociology.

IV OTHER RESEARCH INSTITUTIONS AND ORGANISATIONS IN KENYA AND TANZANIA

1. Coffee Research Foundation
Coffee Research Station
P.O. Box 4, Ruiru, Kenya.

Private organisation, principally engaged in research.
Includes Research Sections on Plant Pathology, Entomology, Crop Physiology and Plant Breeding, Chemistry (soil and plant nutrition), Chemistry (quality), Field Research and Radio-Isotopes, 3 substations at Kisii and Koru, Nyanza Province and Meru, Eastern Province, one additional laboratory in Upper Kiambu. Associated with the Coffe Board of Kenya; works in close co-operation with the Department of Agriculture of the Ministry of Agriculture.
Fields of research: Soil management, production of coffee, coffee diseases, entomology, physiology, biochemistry, soil chemistry, application of isotopes as tracers in agriculture.

2. Pyrethrum Marketing Board
   Pyrethrum Bureau
   P.O. Box 420, Nakuru, Kenya.

Private institution; principally engaged in research.
Fields of research: Organic chemistry, instrumental analysis, animal biology, bio-assay insecticides (particularly household insects), crop production (pyrethrum), crop protection (pyrethrum).

3. Tea Research Institute of East Africa (TRIEA)
   P.O. Box 91, Kericho, Kenya.

Private institution fully financed by the East African Tea Industry Includes stations at Kericho, Kenya, Fort Portal, Uganda, Marikatanda and Ngwazi, Tanzania.
Fields of research: Mathematics, chemical sciences (tea nutrition), genetics (tea plant improvement), plant biology (tea), soil management (tea), hydrology (tea), crop production (tea), crop protection (tea), processing technology (tea).

4. National Primate Centre
   P.O. Box 30239, Nairobi.

Private organisation; principally engaged in research.
Fields of research: Genetics, general physiology, animal biology, ecology, primate diseases and treatment, relation of diet to fertility, animal production, animal products, animal health.

5. Medical Research Centre Nairobi
   P.O. Box 9370, Nairobi.

Private institution (department of the Royal Tropical Institute of Amsterdam, the Netherlands). Engaged in research, teaching and training. Includes a Department of Epidemiology, a Department of Nutriton, a Department of Parasitology, a Department of Tropical Medicine, a Department of Virology, a Workshop/Technical Department, a Family Planning Training Project and a Rural Health Training and Research Project.
Fields of research: Virology (arbovirus, enterovirus, Aedes survey, rubella), human biology, anthropology, contagious diseases and vectors (medical entomology and helminthology; dermatoses, venereal disease, smallpox, poliomyelitis, yellow fever, bitharzia, intestinal parasites, brucellosis, leptospirosis, leprosy, etc), chemotherapy and antibiotics (drugs trials), medical chemistry, nutrition (nutritional anaemias, longitudinal growth, market survey, birthweights, lactose intolerance, etc.), water and soil hygiene, epidemiology including operational research and work studies.

6. World Health Organization/Medical Research Council/Tanzania Bilharziasis Chemotherapy Centre
   P.O. Box 950, Tanga, Tanzania.

Joint project of WHO, UK-MRC and Government of Tanzania.
Fields of research: Contagious diseases (controlled clinical trials in bilharziasis, hookworm disease and filariasis).

7. Fisons East Africa Limited
P.O. Box 12300, Nairobi.

Private international company. Also engaged in research.
Fields of research: Botany, zoology, entomology, helminthology, chemotherapy, antibiotics, soil management, crop production, crop protection, forestry.

8. Fisons Pest Control Limited East Africa Research Unit
P.O. Box 24947, Nairobi.

Tropical branch of Chesterford Park Research Station, Saffron Walden, Essex, part of Fisons Cambridge Division.
Fields of research: Botany, zoology, radiobiology, vectors of contagious diseases, crop production, crop protection.

9. Twiga Chemical Industries Limited
P.O. Box 30172, Nairobi.

Private company, established as an associate of Imperial Chemical Industries Limited for the marketing of agricultural chemicals; mainly concerned with trials of new agricultural chemicals (fungicides, herbicides, insecticides and seed dressings).
Fields of research: Crop production and crop protection (coffee, tea, pyrethrum, wheat, maize, hroticultural crops).

10. Shell Chemical Company of Eastern Africa Limited
P.O. Box 30056, Nairobi.

Private company; also engaged in research.
Fields of research: Organic chemistry, biochemistry, plant biology, animal biology, ecology, contagious diseases and vectors, crop protection, animal health.

11. Cooper, McDougall and Robertson (East Africa) Ltd.
P.O. Box 596, Nairobi.

Private company; also engaged in research.
Research is carried out in so far as it related to the marketing of chemicals, drugs and insecticides for the animal industry; works in close collaboration with the Wellcome Research Laboratory (East Africa (see: 12), the Wellcome Institute for Research on Foot and Mouth Disease, the Veterinary Research Laboratory (Kabete) of the Ministry of Agriculture and the East African Veterinary Research Organization.
Fields of research: Antibiotics, antiseptics, pharmacology, hygiene, animal health (all parasitic diseases), animal nutrition.

12. Wellcome Research Laboratory (East Africa)
P.O. Kabete.

Private company, principally engaged in research into diseases of domestic animals in tropical and sub-tropical Africa.
Fields of research: Animal health (East Coast Fever, anaplasmosis, helminthology), chemotherapy.

13. Desert Locust Control Organization for Eastern Africa
P.O. Box 30023, Nairobi. Headquarters in Addis Ababa, Ethiopia.

Operational and research activities.
Fields of research: all aspects of locust biology, ecology and control.

14. Interafrican Bureau for Animal Resources
P.O. Box 30786, Nairobi.

Veterinary and livestocks production activities covering all the Member States of the OAU in Africa. Publications: Bulletin of Expizootic Diseases of Africa (quarterly), IBAR Information Leaflets (monthly).

15. College of African Wildlife Management
Mweka, Tanzania
P.O. Box 3031, Moshi.

FAO sponsored higher education in Wildlife management for english-speaking African countries.
Fields of research: ecology and management of wildlife.