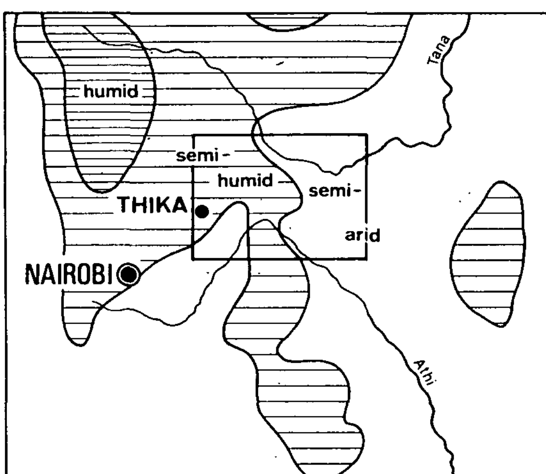
Ralph Jaetzold

AGRO-CLIMATIC CONDITIONS FOR LAND USE IN THE SETTLEMENT AREAS EAST OF THIKA



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AGRO-CLIMATIC CONDITIONS FOR LAND USE IN THE SETTLEMENT AREAS EAST OF THIKA (Haraka Settlement Schemes)

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Summary

The Haraka Settlement Schemes (Haraka means haste) were started in 1966, mostly on lands of neglected, formerly European, plantations or ranches. As the agro-climatic and other physical conditions of the area were not well known, the schemes were laid out in the wrong way: plots allocated to settlers were generally too small, except in a few areas with more rainfall and better soils. And in the two driest zones (see Fig. 19) the risk of crop failure is too high under present land use and farm size conditions.

It is proposed to improve yields by new techniques and introduction of new crops or species. It is also suggested that settlers on poorer plots of Ndalani, Nzukini, and to a certain degree also of Mamba, Ngoliba A - D and Ndithini, should be resettled elsewhere, possibly in the new settlement projects near Lamu. Actually, both Ndalani and Nzukini normally receive insufficient rainfall for crop agriculture, and these schemes should be used for grazing. However, the growing of crops and the degradation of potential grazing grounds have progressed too far to make this change feasible.

The population of the areas suggested for technical aid consists of approximately 7,77o settlers, who, with their families, make a total of about 4o,ooo people. Of these, around 2o,ooo cannot sustain themselves sufficiently and they must receive welfare support to prevent famines.

The introduction of land use techniques and farm sizes which are more suitable to climatic conditions and soils may function as an example for the surrounding areas. These are now increasingly settled by people from the overpopulated highlands. This movement has so far been unchecked. It concerns tens of thousands of people each year and unless they receive some aid, famines amongst them seem unavoidable.

Table 1: <u>The Haraka Settlement Schemes east of Thika</u>

Name	Area (ha)	Nr.of Farms total	of which good ones	Prevailing farm size	Population density/km^2	Start of settlement
Gatuanyaga Scheme	1 36o	approx. 55o	approx. 1oo	2.o ha	23o	1974
Ithanga Basin Ext.	1 4o3	221	5o	4.o	88	1973
Ithanga Sch.	6 855	1 611	368	2 - 2.5	131	1968
Mamba Scheme	1 o4o	319	3o	2.o	172	197o
Munyu Scheme	1 968	499	5o	2.8	142	1967
Ndalani Scheme	7 432	1 475	35o	2.8	111	1968
Ndithini Scheme	1 28o	56o	16o	2.o	245	1971
Ndula Scheme	55	15	approx. 5	2.8	151	197o
Ngoliba A Scheme	4oo	163	2o	2.o	228	1966
Ngoliba B Scheme	579	255	5o	2.o	247	196o
Ngoliba C Scheme	7o4	261	7o	2.o	2o8	1967
Ngoliba D Scheme	1 9o2	613	2oo	2.o	18o	1969
Nzukini Scheme	2 88o	1 225	12o	2.5 - 3.2	238	1969
Total	27 858 ha	7 767	1 568			

Source: Descriptions of separate projects by the Ministry of Lands and Settlements, Kenya, with some corrections.

1. Introduction to the geographical conditions

1.1 Topography, soils and erosion

The settlement projects east of Thika are situated on the gentle eastern slopes of the Kenyan highlands. The general gradient is around 5 % and elevations in the area range from about 1100 to 1500 m. The area is mainly a peneplain, that are the eroded remains of worn-down mountains, formed about 600 million years ago, of which the exposed core consists of granites and gneisses. This peneplain was covered by volcanic lavas and ashes from the Aberdares in the west. These volcanic deposits reach as far as Munyu, Gatuanyaga and Ndula and the western edges of Ngoliba A. In the southeast of the area another lava stream forms the Yatta plateau, which covers the edges of the Mamba project. On these volcanic materials the soils are relatively fertile (Table 2, a), except where they are shallow or poorly drained, as is the case in some parts of Munyu.

The general slope is interrupted by the Ithanga Hills and some smaller hills, remnants of a block mountain, uplifted about 10 million years ago and eroded in a typical tropical fashion into inselbergs and wide shallow valleys. On the extensive gentle slopes of the inselbergs the eroded material is well sorted: coarse sands in the upper parts change to clay and silt near the bottom of the valleys. This type of soil prevails in the Ithanga, Ndithini, and Ngoliba C and D projects.

The dark alluvial soils of the valleys are rather fertile (Table 2, d).

The soils on the lower slopes are more fertile than those of the old peneplain, where it is not covered by volcanic deposits. The soils on the lower slopes are better because they received fresh alluvial material (Table 2, b).

The projects Mamba, Ndalani and Nzukini are situated mainly on the peneplain, about 10 million years old, which is covered by senile, leached soils over the acid parent material, rather short in minerals (Table 2, c). Young uplifts of about 1 million years ago have reactivated erosion on the peneplain and young valleys reach depths of up to 1oo m. The dark alluvial soils which had accumulated in the shallow valleys of the peneplain (Table 2, d) were largely removed by this renewed erosion. The soils on the valley slopes, younger than those on the peneplain itself, are richer in minerals (Table 2, e). However, these soils are in great danger of erosion, caused by deforestation, overgrazing and-cultivation of the area. Conservation measures are urgently peeded (see Chapter 5.1). The projects Ngoliba A and B are characterized by these young valley slopes, which also predominate in the lower parts of Mamba, Ndalani and Nzukini, exceptinthe narrow valley bottom along the Thika river.

Small remnants of inselbergs also occur in the projects Ndalani and Nzukini (the rocky hill Mbambathaana, 65 m high,and Nzukini-hill, which reaches about 1oo m above the peneplain; the indication Nzukini Mt. on the maps 1:25o ooo and 1:5o ooo is incorrect, the indicated mountains are Mbeiani and Uovauni in Ngoliba D). Despite the low height of these mountains the soils on their lower slopes are slightly better, as freshly eroded material has been deposited on them, though this material is largely sandy close to the mountain.

The young uplift unfortunately also caused reactivated erosion in the other project areas. Both plains (Munyu) and gentle slopes (Ndithini) have been cut and the danger of soil erosion is serious. Sheet erosion (denudation) is also very active and it has increased recently because of cultivation and overgrazing. Near Ndalani an erosion of more than 5 mm per year was recorded on a slope of only 2°.[1] Especially endangered by erosion are the slopes of the inselbergs where they are cultivated, as for instance in Ithanga.

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1) This process is indicated by the exposure of grass roots since settlement began (Plate 4).

Table 2: Analysis of some soil samples from Haraka Settlement Schemes[1]

Settlement Scheme	Soil type	pH in H_2O	Na ppm HCl	Na ppm H_2O	K ppm HCl	K ppm H_2O	Ca ppm HCl	Ca ppm H_2O	Mg ppm HCl	Mg ppm H_2O
a) Volcanic areas										
Munyu	black cotton soil									
	topsoil 0-1o cm	5.o	258	211	1148	4o6	5311	338	1597	154
	lower soil 1o-3o cm	5.o	45	3o	858	198	2424	1o8	1384	89
Munyu	brown-red soil									
	topsoil 0-1o cm	5.o	31	2o	1o46	649	574	1o5	389	74
	lower soil 1o-3o cm	5.2	77	65	776	459	94	24	1oo	71
b) Lower slopes of inselbergs										
Ithanga	red sandy loam									
	topsoil 0-1o cm	4.8	44	33	218	138	83	24	84	26
	lower soil 1o-3o cm	5.o	24	22	427	2o6	88	1	142	15
Ndithini	brown-red sandy loam									
	topsoil 0-1o cm	4.8	45	4o	5o5	3o3	166	36	278	77
	lower soil 1o-3o cm	4.8	139	5o	319	262	96	9	1o2	49
Ngoliba D	brown-red sandy loam									
	topsoil 0-1o cm	5.o	32	27	668	446	348	28o	32o	116
	lower soil 1o-3o cm	5.o	28	17	771	443	143	6	299	69
Nzukini	red sandy loam (cultivated with subsoiler) 0-3o cm	5.o	22	22	353	2o7	53	36	133	38
c) Old peneplain										
Kamba	brown loamy sand									
	topsoil 0-1o cm	5.o	35	25	492	31o	9	6	97	3o
	lower soil 1o-3o cm	5.o	26	19	496	244	--	--	7o	5
Ndalani	red sandy loam									
	topsoil 0-1o cm	5.o	16	11	499	294	44o	391	198	39
	lower soil 1o-3o cm	5.o	43	35	386	2o1	284	87	282	42
Ngoliba D	red sandy loam									
	topsoil 0-1o cm	5.o	36	2o	1o42	378	9o	--	283	34
	lower soil 1o-3o cm	5.o	39	17	617	274	--	--	59	12
Ngoliba D	red sandy loam									
	topsoil 0-1o cm	4.9	39	21	1135	358	134	3	378	31
	lower soil 1o-3o cm	5.o	42	23	931	336	85	--	346	33
Nzukini	grey brown loamy sand, shallow 1-1o cm	5.o	55	33	62o	3o2	346	112	33o	56
d) Shallow valleys on the peneplains or between inselbergs										
Ithanga	black loamy sand 0-2o cm	5.o	35	26	247	166	79	1o	77	18
Ndalani	black cotton soil 0-2o cm	5.o	26	17	756	315	268	92	3o1	32
e) Young valley slopes on the peneplain										
Ngoliba A	reddish-light brown sandy loam									
	topsoil 0-1o cm	5.o	114	86	57o	2o1	77o6	398	239o	14
	lower soil 1o-3o cm	5.o	26	23	533	269	1oo	12	13o	25

1) Judgment of soil fertility was not required in this report, therefore the number of samples per area was rather small. Samples were taken at the end of the short dry season. Analysis was carried out by the soil science laboratory of the University of Saarbruecken.

Generally the red latosols on granite and gneiss, which predominate on the peneplain and lower slopes, consist mainly of kaolinite, which is extremely poor in nutrients and weak in absorption. There is no montmorillonite and little illite or partly decomposed mica, as shown by an X-ray analysis.[1] Contents of iron oxide are naturally high. The rest of the soil consists of quartz-sands. Low yields are therefore not only caused by climatic conditions, but also, especially where cultivation is continuous, by soil conditions. Formation of humus is therefore very important (see Chapter 5.1.1), also because it helps to retain artificial fertilizer.

1.2 Population and economic conditions

The area of the Haraka Settlement Schemes is a transition area, not only regarding its natural conditions, but also in relation to climate, land use (Chapter 2) and population. Here meet the settlement areas of the Kikuyu and Kamba. Therefore the area belongs administratively to various districts: the northwestern parts up to Ngoliba A and C belong to Thika district, the southeast with the other projects to Machakos district. This creates problems in administrative authority.

Except for a few settlers from other tribes, most of them belong to the two main tribes, which are related, but also competing. At the moment, this has not created any problems, but it may cause tension under different conditions.

The population densities in the settlement schemes are very high: 15o to 25o inhabitants per square kilometre, which, in a rural area with relatively low rainfall, must be considered excessive. This is especially the case in Mamba, Ngoliba D, Ndalani and Nzukini (Table 1). For the calculation of the population, an average family was counted as 5-6 persons. The number of people not employed in farming (tradesmen, teachers, civil servants)

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1) This analysis was carried out by Mr. Ralph Hansen, whose assistance is gratefully acknowledged.

is very low and remains under 3 %. Therefore the population computed on the basis of the number of farms was rounded by adding 2 %. In the next few years a clear increase in the size of families may be expected. Numerous farms are already occupied (illegally) by two families. Considering these factors, the total number of people living in the settlement schemes will soon reach 45.ooo.

In the surrounding areas of unorganized settlement the population density is only about 3o per square kilometre. Here, settlers know by experience that they need much larger plots than in the schemes in order to have a basis of existence.

In the western parts of the area a number of formerly European plantations are situated, which produce sisal or irrigated coffee. They now mostly belong to African companies. Moreover the pineapple plantation of Kenya Canners in Thika has expanded almost to the Ithanga Hills and in the southeast beyond Gatuanyaga. Because of the many seasonal workers employed by these plantations, it is of little use to calculate the population density in these areas. The employment possibilities are of great importance for the settlers who live close to these plantations (Gatuanyaga, Ndula, Ngoliba A, B, D and Ithanga), especially where their farms are too small or in years of poor crops. The only other source of employment are the industries in Thika, but here, competition is so strong that the settlers have little chances. Rather, the opposite has happened: labourers and employees from as far as Nairobi have secured themselves a place in the settlement projects, farmed by their wives. This has particularly happened in Munyu and that is why aid for that scheme is less urgent than for the other ones.

Plate 1 : Inselbergs and pediments in Ngoliba D

This type of topography prevails also in Ithanga and Ndithini. The animals draw a primitive type of sleigh.

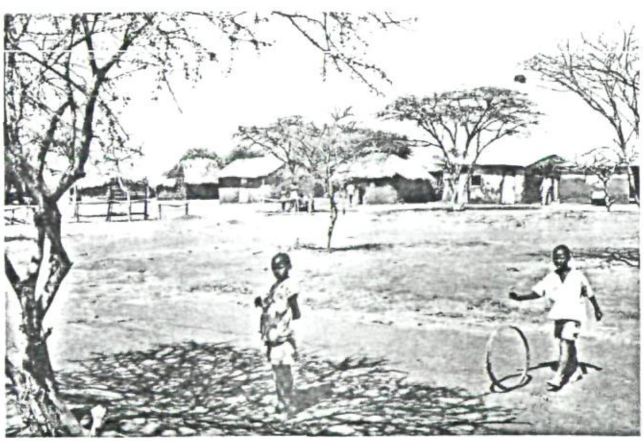


Plate 2 : The trade centre in Ndalani

Its scantiness illustrates the low purchahasing power of the local population.

1.3 Infrastructure, central places and services

The communication network in the area is not very good. Only Ngoliba A and Gatuanyaga are situated on an all-weather road with regularbus and taxi-services (matatus). Ithanga, Hamba, Munyu, Ndalani, Ndula and Nzukini are connected by secondary roads, which are not always passable during the rainy seasons, and serviced only by occasional buses. Some of the roads within the schemes are very poor and impassable during the rains. This is also the case for the supply roads to Ngoliba C and D, and to a certain extent to Ndithini, which are mainly used by supply vehicles of small shops. Marketing of products from these areas is therefore often impaired. For instance, from Ngoliba D to the main road is a distance of 18 km, part of it consisting of private roads which are closed to lorries.

Services supplied by central places are few. An exception is Ithanga where the trading centre is well developed, illustrating the relatively favourable economic situation there with extra purchasing power available. Very poorly developed on the other hand are the trading centres in Ndalani (Plate 2) and Nzukini, showing how problematic the economic situation is in these areas. Primary schools are numerous, but the health services are poor, except for Munyu. The distance from the nearest doctor for about 35 ooo inhabitants of the settlement-projects is between 5o and 9o km. Moreover, private cars are not available (except in Ithanga) and there is no telephone service, except for Kithimani, and there is a police phone in Ithanga. Agricultural advisory service is very poor. For the whole area of 27 9oo ha and 8ooo farms one settlement officer, one agricultural field officer (untrained) and about a dozen field assistants (primary school level) are responsible. Moreover, the farms are distributed over a total area of more than 1oo ooo ha, but only the two officers first mentioned, who are stationed inThika, have sometimes a car at their disposal, if there is petrol available. Three Dutch volunteers, who have their own motorbicycles, are presently concerned with the prevention of soil erosion in Ithanga, Ndalani

Ndithini and Ngoliba B - D.

A few employees of the agricultural and veterinary departments and of the Ministry for Cooperative Development occasionally visit the settlement areas to look after the settlers and their problems, but because of the size of the areas these visits are too seldom.

2. Agro-climatological conditions

The main problems in the settlement areas are of a climatic nature. Most of the projects are in marginal areas for crop agriculture without irrigation. It is therefore essential to know the climatic conditions in order to choose optimal land use methods under the considerationof the risk of crop failures.

2.1 Distribution and probability of precipitation

Within the area, there are vast differences in precipitation, both, regarding total amounts and reliability. This is caused by the relief: the Ithanga Hills and their continuation to the southwest form a barrier for the humid air masses from the Indian Ocean, causing orographic rainfall. In the highest parts of Ithanga and Ndithini the mean annual rainfall therefore exceeds 1ooo mm. Even around 12oo m elevation the annual mean reaches 8oo mm (Fig. 2). But in the areas where no uplift took place the precipitation is not much higher than in the very dry eastern lowlands of Kenya. Especially unfavourable are the slopes of Ndalani and Nzukini towards the Thika river, since they are in the rain-shadow (moisture coming from the southeast). Here, the annual mean values less than 6oo mm. Munyu is also in a rain-shadow, from the Kamba Hills and Ol Donyo Sapuk to the east of this project area. The annual mean here is only 7oo mm.

The annual amounts seem reasonably high and the differences not of great importance, but it should be remembered that the annual rainfall is divided into two rainy seasons and the totals, therefore are close to the limit for crop agriculture (Fig.3-6, 22 and 24-26). There are two rainy seasons: the long rains around

April and the short rains around November. In the lower areas of the eastern parts the short rains usually bring more precipitation than the long rains, because they cause more frequent thunderstorms which occur over the plains rather than in the mountainous areas.

The long rains may start as early as March and end as late as July. Taking the mean values for these months, totals in the area of the settlement schemes vary between 5oo and less than 25o mm (Fig. 3). The totals are lower if one counts only the precipitation between the actual start and end of the rains which may be end of March and middle of May, excluding earlier and later small and uneffective falls. This seems to be a more realistic method (Fig. 4). The projects in the eastern lower parts normally receive less than 3oo mm per rainy period which corresponds to the agricultural growing seasons, and this amount is the limit for unirrigated crops. During the short rains, conditions in these parts are more favourable, as indicated above. But even then, most of Nzukini project and almost all of Ndalani are still below the rainfall limit for unirrigated crops (Fig.6). In good years, special crops, such as Katumani-maize, sorghum and millet may produce reasonable yields, but the risk of crop failure is too high. This is indicated by the diagrams illustrating variations in rainfall (Fig. 28, 32, 34 and 36) and the maps showing rainfall probability (Fig. 7, 8). A total of about 25o mm is generally considered to be the minimum water requirement for Katumani maize, with monthly totals of about 7o, 11o and 7o mm (including soil moisture storage), and this amount should be reached at least in two years out of three. Probabilities to reach these limits in the two settlement projects mentioned above are, however, only 4o % during the long rains and 35 % during the short rains (Fig. 2o, 21). Therefore almost every third year a total crop failure will occur in both rainy seasons. Only when rainaccumulating techniques are used (Fig. 3o). or when crops with very low demands of moisture are planted, (Chapter 5.2.1) unirrigated crop agriculture could be practiced here.

The monthly distribution of rainfall is very important, because in most areas they are concentrated during periods shorter than two months, which is very unfavourable. Therefore, the duration of the rainy seasons as the growing seasons for crops must be considered (Chapter 2.2).

Some information may also be derived from the numbers of days with rain. These are especially useful to indicate the beginning, intensity and end of the rainy periods and they are therefore included in the most important diagrams (Fig. 22-26).

2.2 Evaporation, humid and arid seasons

There are no stations within the Haraka Settlement Schemes recording data necessary for the computation of evaporation according to Penman (1948, 1956; in East Africa corrected by an elevation factor by McCulloch, 1965), but there are some in the surrounding areas. These are the former Sisal Research Station near Thika and the nearby National Horticultural Research Station. Other data were obtained from the Tana Power Station and further north by Mwea Tebere Project, and these values were used for extrapolation. It is possible to use even more distant stations, because the evaporation differs with location according to clear rules.

Evaporation data were taken from Woodhead (1968) and extra- and interpolated. Accordingly, the annual evaporation from an open water surface (E_o) is around 1650 mm in the highest parts of the area increasing to over 2000 mm in the lower parts in the east. Annual values of the potential evapotranspiration of the vegetation (E_t) are about 20 % lower.

The ratio of precipitation to E_o is about 55 % in the highest parts of the Ithanga-project, decreasing to values below 25 % in Ndalani and Mzukini. The ecological zones accordingly stretch from sclerophyll evergreen forest (only in the highest areas) to woodland, bushland and dry bushland.

Tab. 3: Mean precipitation (in mm) at the stations in the area with at least five years of records

Station Number	Station Name	Latitude Longitude	Elevation m	Nr. of years	End of period	J	F	M	A	M	J	J	A	S	O	N	D	Year
9o37oo1	Makuyu, Sisal Ltd.	0°55'S 37°10'E	154o	53	1975	39	35	1o6	235	126	22	13	12	15	78	179	81	941
9o37o16	Kitito Coffee Est.	0°58'S 37°18'E	146o	45	1976	47	41	115	254	121	16	7	7	12	81	211	111	1o23
9o37o18	Makuyu, S.Rutherf.	0°54'S 37°11'E	143o	4o	1975	35	45	1o7	271	152	22	9	12	1o	83	191	9o	1o27
9o37o28	Makuyu, Kithumu	0°54'S 37°14'E	149o	51	1975	43	39	112	253	134	2o	7	1o	11	87	2o8	1o7	1o31
9o37o37	Muranga, Tana Power	0°47'S 37°15'E	1o6o	44	1975	34	33	82	239	154	23	1o	16	14	81	173	63	922
9o37o44	Makuyu, Karatina	0°52'S 37°09'E	1455	33	1975	38	41	1o7	258	164	25	18	15	17	83	19o	78	1o34
9o37o47	Thika, Bendor Pl.	0°55'S 37°03'E	158o	49	1975	35	39	1o3	232	14o	31	21	2o	23	73	155	76	948
9o37o61	Makuyu, Mananja	0°51'S 37°16'E	145o	21	1966	44	24	87	259	155	24	9	18	19	86	2o3	1o8	1o36
9o37o94	Maragua, Ridge Settl.	0°47'S 37°11'E	1157	16	1971	46	28	1o6	312	248	27	13	14	2o	74	195	57	114o
9o371o4	Embu, Machanga	0°45'S 37°40'E	126o	13	1971	35	25	1o2	151	85	6	3	4	24	85	213	89	83o
9o3713o	Thika, Horticult. Res.	0°59'S 37°04'E	1447	19	1974	42	44	114	2o9	163	32	25	25	15	75	163	65	982
9o37143	Makuyu, Distr.Off.	0°53'S 37°10'E	1523	9	1975	26	39	97	229	172	33	2o	1o	1o	87	185	39	946
9o37146	Embu, Kindaruma Dam	0°48'S 37°48'E	819	1o	1975	28	23	67	146	52	3	2	2	9	42	181	38	593
9o37147	Embu, Murubaru Vill.	0°35'S 37°55'E	1218	1o	1975	18	33	88	242	159	36	29	14	17	74	158	26	895
9137oo	Thika, Ngoliba	1°05'S 37°25'E	14oo	34	1957	38	4o	1o9	222	72	5	3	5	9	47	196	1o3	85o
9137oo2	Thika, Sassa Coffee Est.	1°02'S 37°08'E	1455	59	1975	35	31	1o7	2oo	96	2o	1o	1o	12	68	15o	74	813

Continuation

Tab. 3: Mean precipitation (in mm) at the stations in the area with at least five years of records

Station Number	Station Name	Latitude Longitude	Elevation	Nr. of years	End of period	J	F	M	A	M	J	J	A	S	O	N	D	Year
9137oo6	Mitubiri Nanga Est.	1°02'S 37°11'E	1523	6o	1976	41	37	11o	2o6	89	23	8	1o	14	72	175	84	869
9137oo7	Donyo Sabuk Est.	1°05'S 37°15'E	1463	3o	196o	34	34	1o6	222	87	13	7	1o	9	62	176	1o5	865
9137o15	Donyo Sabuk La Finca			39	1958	44	35	122	23o	67	11	4	7	9	62	2oo	1o8	9o2
9137o18	Thika, Distr.Off.	1°02'S 37°04'E	149o	45	1975	37	42	92	187	1o2	28	15	17	15	61	14o	69	8o5
9137o19	Ruiru,Juja Sisal Farm	1°10'S 37°05'E	146o	5o	1975	27	35	95	159	9o	19	11	8	12	46	138	66	7o6
9137o48	Thika,Sisal Exp.	1°01'S 37°06'E	1461	34	1975	36	34	1o7	211	129	25	19	17	17	62	145	7o	872
9137o53	Mitubiri, Chui Est.	1°01'S 37°13'E	1485	39	1976	37	34	1o7	214	1o1	13	8	8	9	66	169	85	851
9137o54	Donyo Sabuk, Kianzabe C.Estate	1°09'S 37°18'E	1475	59	1974	41	34	112	219	77	12	5	7	1o	69	2o6	12o	912
9137o55	Donyo Sabuk, Muka,Mukuu	1°08'S 37°16'E	15o5	22	197o	3o	45	117	217	95	9	5	5	12	71	22o	112	938
9137o72	Thika,Water Supply	1°02'S 37°06'E	1462	24	1975	41	47	1o3	195	1o9	29	2o	2o	19	62	151	72	868
9137o74	Kangundo, Kithimani	1°12'S 37°27'E	128o	25	1976	39	32	95	15o	65	1o	3	6	1o	53	197	73	733
9137o76	Kitui,Yatta B2 Vet.St.	1°08'S 37°43'E	125o	20	1974	26	19	64	132	38	3	1	3	6	4o	191	62	585
9137o83	Ruiru,Juja Sisal Est.	1°11'S 37°07'E	1464	1o	1972	4o	42	78	151	11o	14	1o	3	5	46	164	72	734
9137o88	Donyo Sabuk,Munyu	1°07'S 37°10'E	1462	6	1966	33	34	111	189	76	2o	9	2	6	83	194	74	83o
9137o9o	Donyo Sa-[redacted]uk,N[redacted]	1°06'S 37[redacted]E	1294 [redacted]	19 [redacted]	1975 [redacted]	6o [redacted]	35 [redacted]	126 [redacted]	2o8	94 [redacted]	9 [redacted]	7	7 [redacted]	1o	73 [redacted]	2o4	89 [redacted]	922 [redacted]

Continuation

Tab. 3: Mean precipitation (in mm) at the stations in the area with at least five years of records

Station Naumber	Name	Latitude Longitude	Elevation	Nr. of years	End of period	J	F	M	A	M	J	J	A	S	O	N	D	Year
91371o3	Thika, Yatta Furrow	1°06'S 37°2o'E	1523	12	1975	45	29	117	212	81	11	7	7	13	58	172	56	8o8
91371o8	Koma Rock Ranch.Off.	1°02'S 37°03'E	1553	7	1976	28	26	81	144	34	7	8	3	15	25	1oo	5o	521
9137117	Yatta Scheme 35	1°10'S 37°31'E	1527	6	1976	32	21	33	123	53	32	4	5	19	31	149	49	551
9137121	Ngoliba A Scheme	1°06'S 37°21'E	137o	5	1976	36	2o	89	227	59	35	17	8	25	8o	158	48	8o2

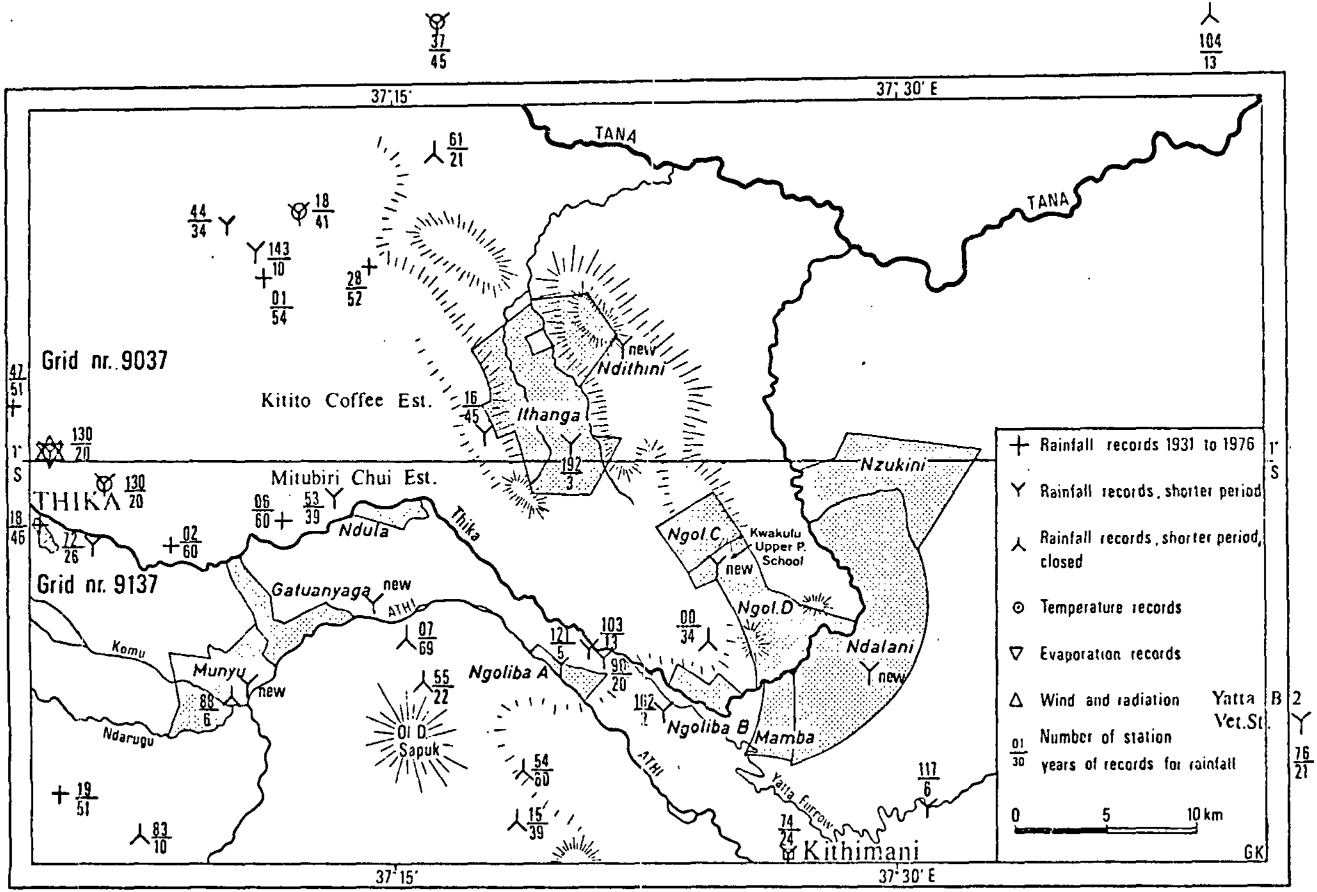


Fig. 1 Settlement schemes and climate stations
Sample stations for diagrams are named.

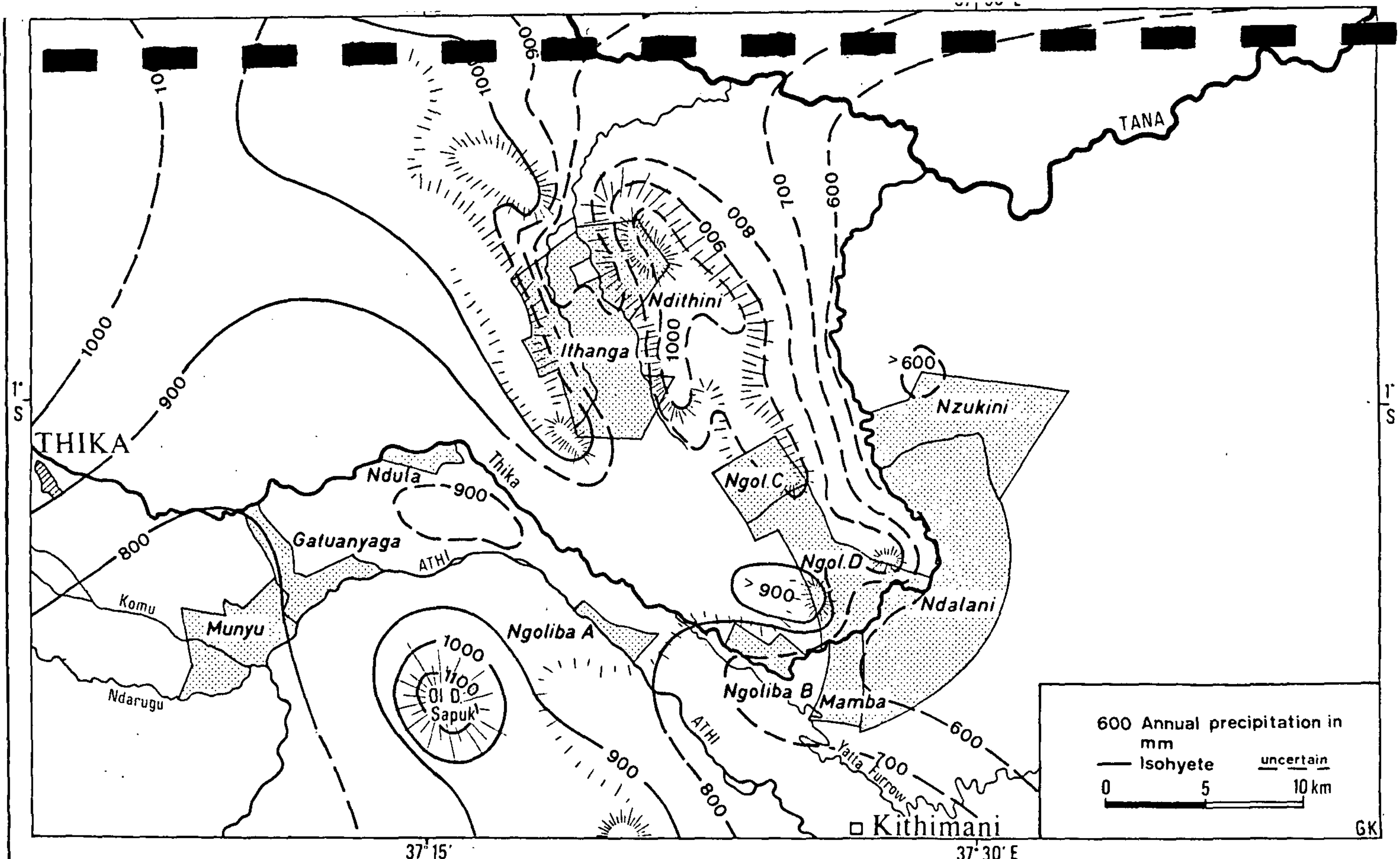


Fig. 2 Mean annual precipitation

The strong reduction of rainfall between Ngoliba C and Ndalani was established by a comparison of the natural vegetation, as there are no rainfall stations at all in that area.

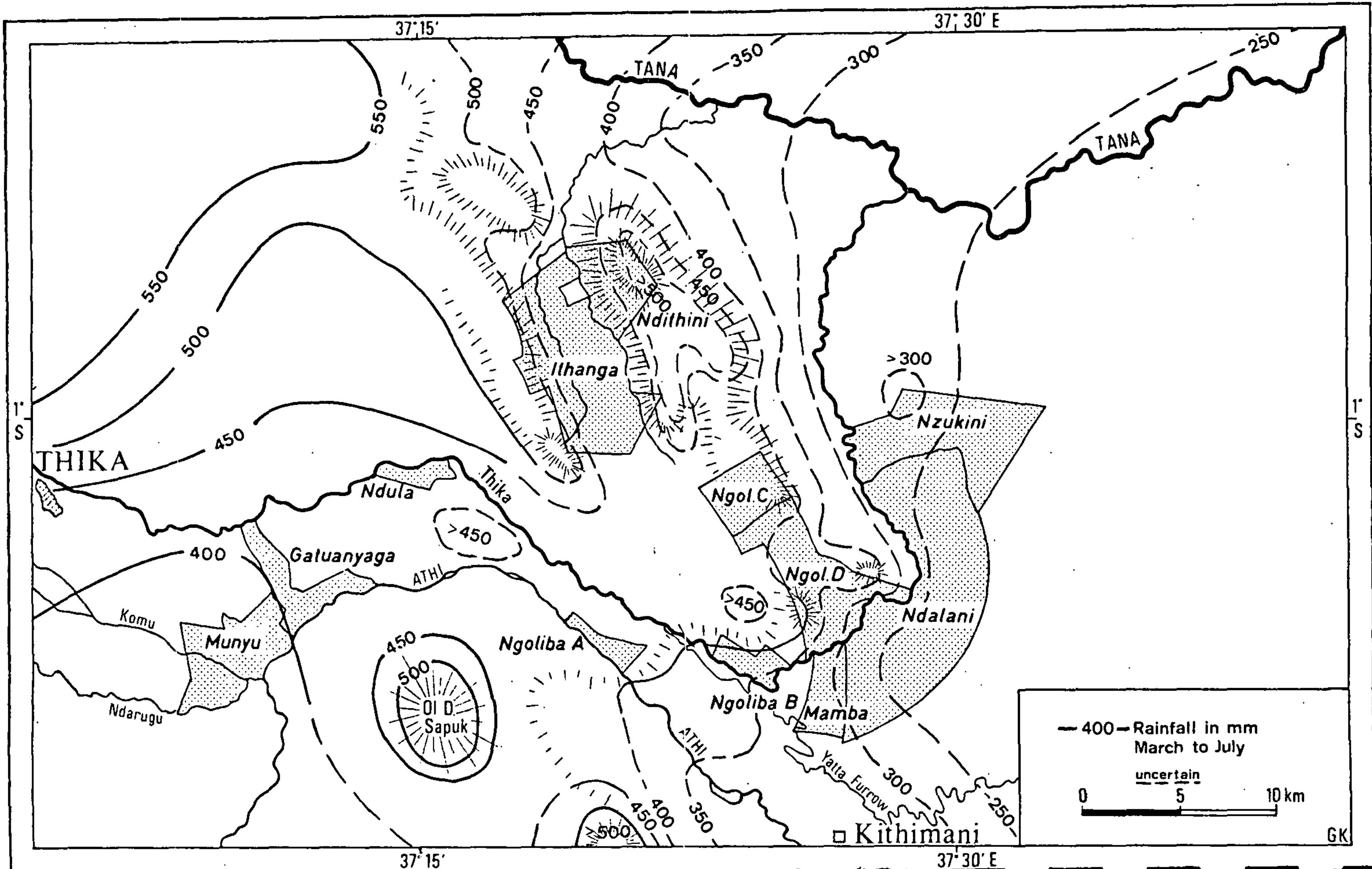


Fig. 3 Mean precipitation during the period from March to July

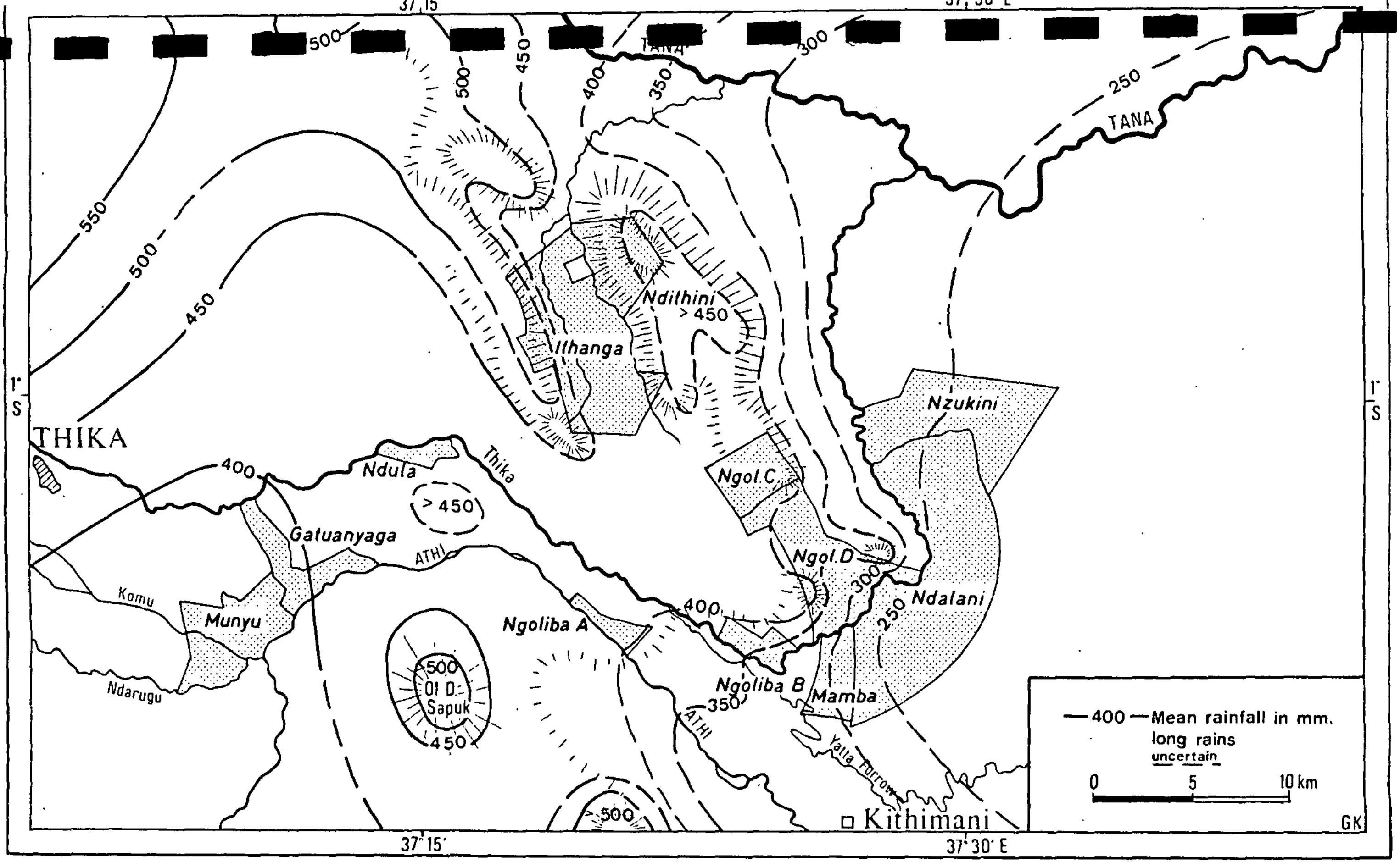
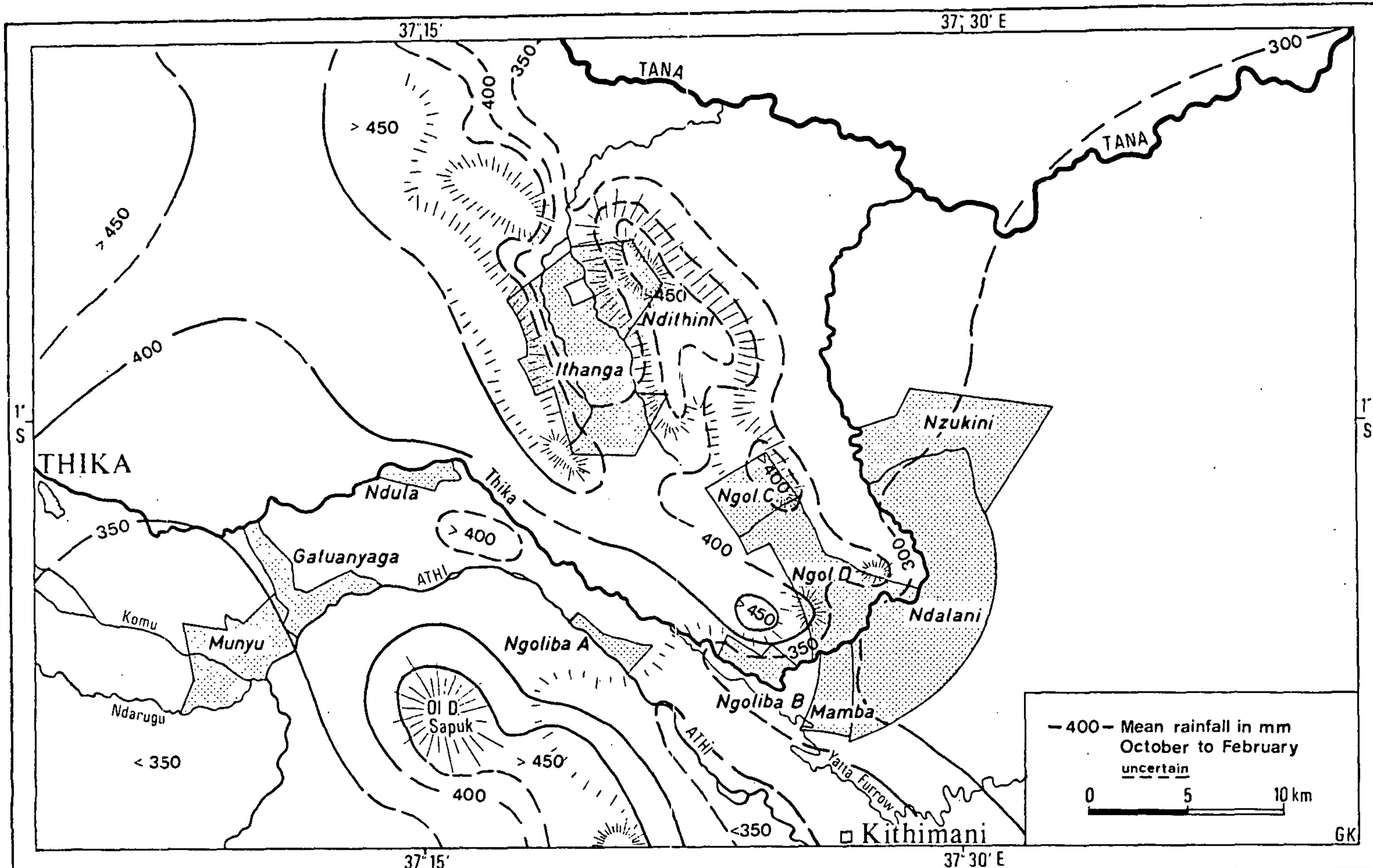


Fig. 4 <u>Mean precipitation during the long rains</u>

Here, the amounts of the long rains are indicated, excluding earlier and later falls which are largely ineffective in relation to agriculture. Means are therefore lower than on Fig. 3.



[redacted]ig. [redacted] Mean pr[redacted]ipitat[redacted] dur[redacted] the [redacted]od f[redacted] Octo[redacted] to F[redacted]ary

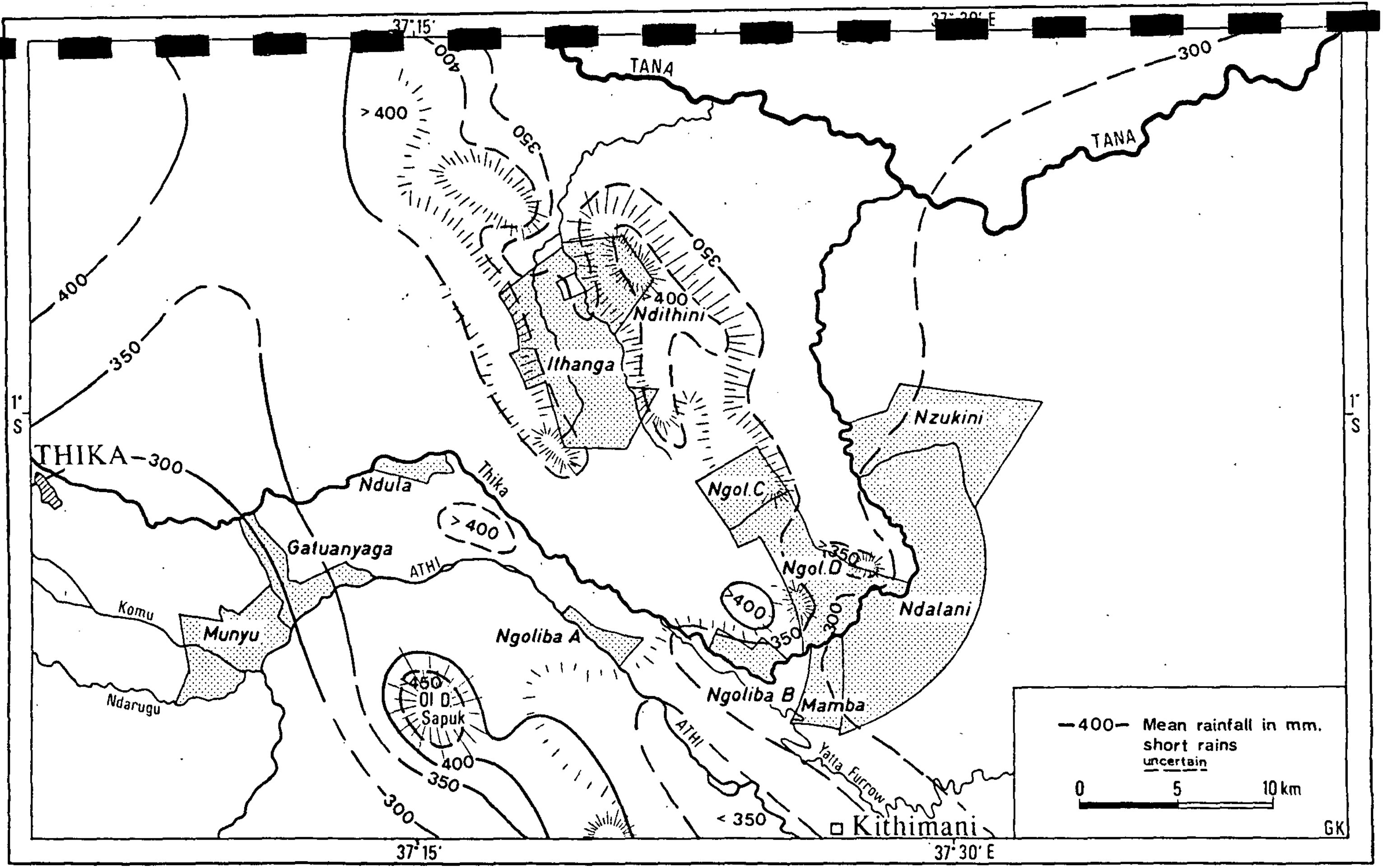


Fig. 6 Mean precipitation during the short rains

Table 4: Probabilities of seasonal rainfall in Kenya between 0° - 2° 30' S and 37° - 38° 40' E

March-May — Percentual probability to receive more than

Mean precipitation	100	150	200	250	300	350	400	450	500 mm
200 mm	74%	54	38	23	15	9	5	2	0
250	86	70	76	42	28	18	12	7	3
300	93	83	72	59	44	31	21	14	8
350	98	92	85	74	59	44	31	23	15
400	100	97	92	84	72	58	43	33	23
450	100	99	96	89	82	69	57	43	34
500	100	100	98	92	87	80	68	56	44
550	100	100	99	95	91	86	78	69	56
600	100	100	100	97	93	91	85	80	69
650	100	100	100	99	97	95	92	89	80

October-December

Mean precipitation	100	150	200	250	300	350	400	450	500 mm
100 mm	45%	18	5	1	0				
150	80	46	23	10	4	1	0		
200	89	70	44	27	11	7	4	1	0
250	94	83	62	43	25	16	11	5	1
300	96	90	74	58	39	27	19	12	5
350	99	93	83	69	55	40	29	20	11
400	100	96	88	78	66	52	38	29	19
450	100	98	91	85	78	65	50	38	28
500	100	99	93	89	83	74	62	49	39
550	100	100	95	92	88	81	71	59	49
600	100	100	97	95	91	85	78	68	58

Source: information received by H. M. H. Braun

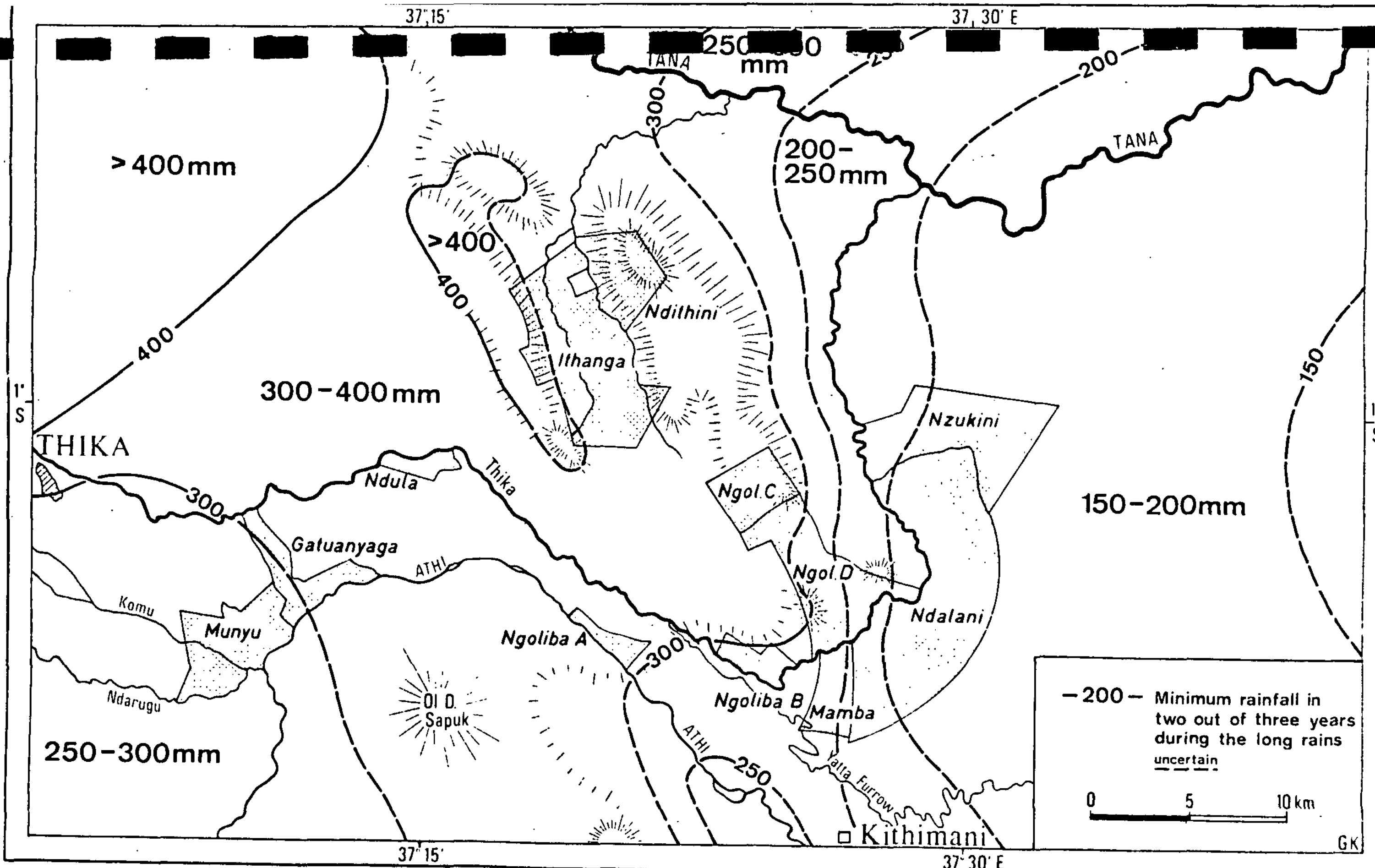


Fig. 7 Minimum precipitation during the long rains that can be expected in two out of three years

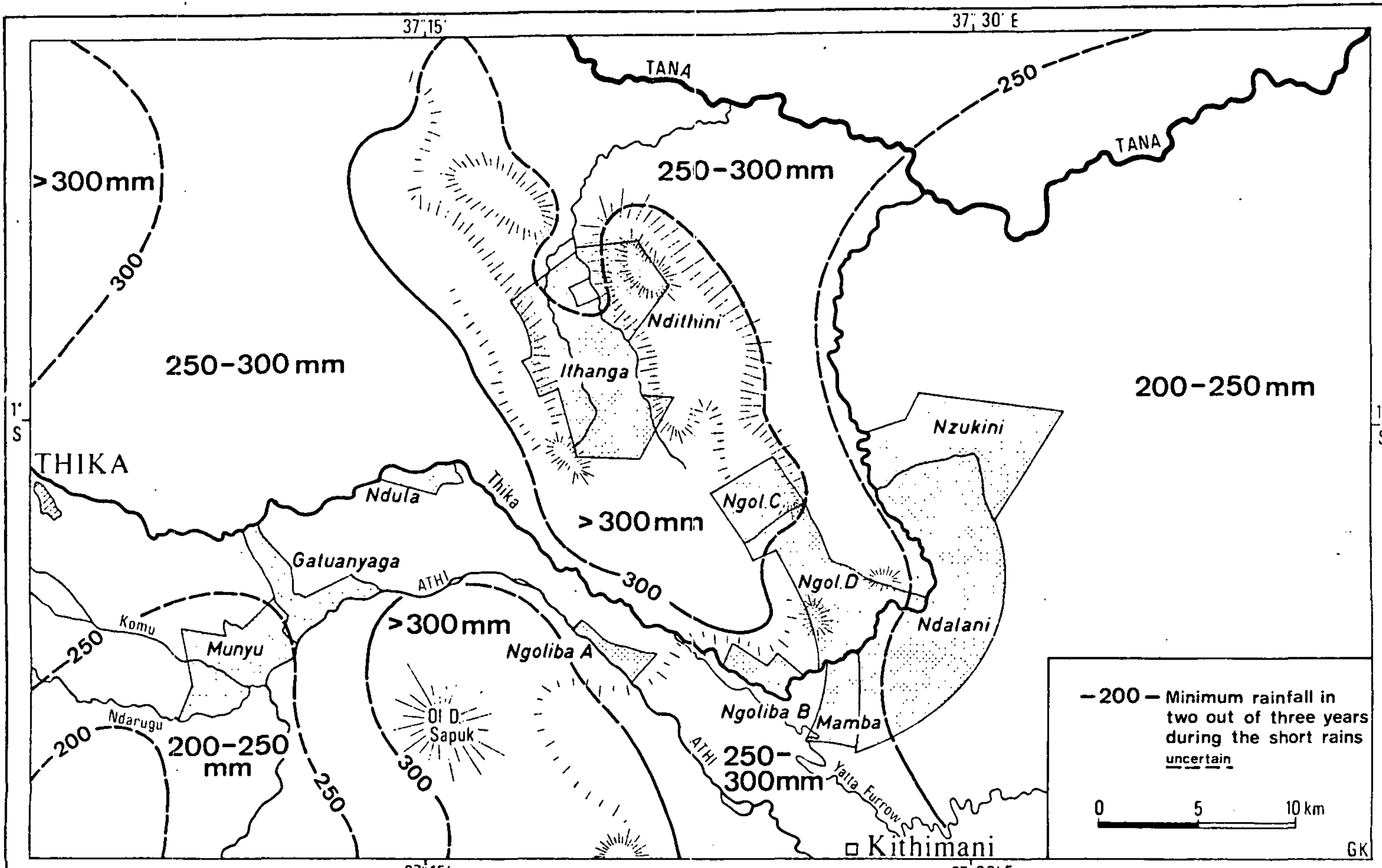


Fig. 8 Minimum precipitation during the short rains that can be expected in two out of three years

Very generally, one can say that tree- and bush-crops are possible where the ratio of rainfall to E_o exceeds about 5o % if the annual variability is not too high, so that the annual totals always exceed about 2o % of E_o.

Sisal can still be cultivated where the precipitation equals about 25 % of E_o, but then grows very slowly. The growth of grasses also depends on the water balance, and thereby the possible number of animals that can be fed per unit of area depends on it, too. For one stock unit of cattle less than 2 ha are required where P exceeds 5o % of E_o, about 2-4 ha where P is between 25 and 5o % of E_o, and where P is below 25 % of E_o more than 4 ha are necessary per stock unit (on sandy loams of moderate fertility).

For our topic, a differentiation according to the annual balance of rainfall and evaporation is not sufficient, as it is decisive only for perennial crops and for the carrying capacity of pastures. The main problem in the Haraka Settlement Schemes is the short duration of the humid seasons.[2] Most of the settlement projects experience only four humid months per year (Fig. 9): from the end of March until the end of Mai and from the end of October until the end of December (Fig. 15). Both rainy seasons therefore last only for two humid months and for most annual crops this is not long enough. But there are considerable differences in the duration of the humid periods according to elevation and exposure. In the higher areas exposed to the east, three humid months occur per rainy season, while in the lower parts of the region one and a half humid months prevail.

When the storage capacity of the soils for excess rainfall is considered, the time with growing potential for most cultivated crops is considerably extended in the highlands (Fig. 15, 16), but in the lower areas this extension is only half a month per rainy season (Fig. 17, 18 and 23). These, we shall call "agro-humid" months, because here the moisture availability for agri-

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2) Seasons with sub-humid or humid conditions. Sub-humid: Precipitation between 5o and 1oo % of the average potential evapotranspiration E_t. Humid: P exceeds 100 % of E_t. E_t averages about 0.8 E_o. Therefore we can also calculate sub-humid: P exceeds 0.4 E_o; (full-) humid: P exceeds 0.8 E_o.

Table 5: Maximum water storage capacity of some samples of the main soils of the Haraka Settlement Schemes[1)]

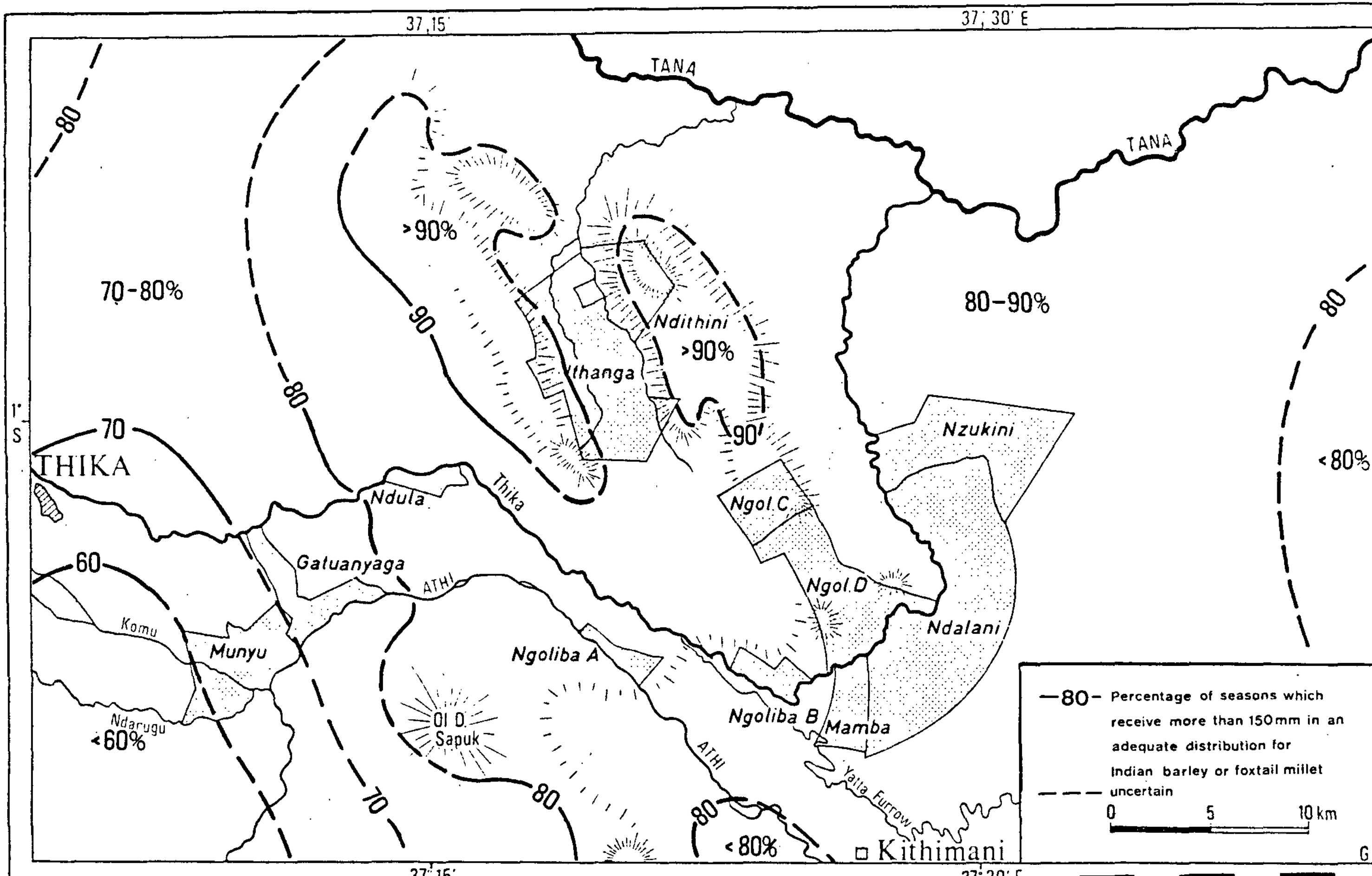
Settlement Scheme	Soil type	Max.storage cap. in mm/10 cm soil		Max.storage in 10 topsoil and 70 cm subsoil	C (
a) Volcanic areas					
Munyu	black cotton	topsoil	116[2)]		1
	soil	subsoil	92	760[2)]	1
Munyu	brownish red	topsoil	38		3
	soil	subsoil	52	402	1
b) Lower slopes of the inselbergs					
Ithanga	sandy red loam	topsoil	53		1
		subsoil	20	193	1
Ndithini	redbrown sandy	topsoil	33		1
	loam	subsoil	26	215	2
Ngoliba B	redbrown sandy	topsoil	28		1
	loam	subsoil	31	245	1
Nzukini	red loamy sand (mixed with subsoil)				
		undiff.	18	144	2
c) Old peneplain surface					
Mamba	brown loamy	topsoil	4[3)]		1
	sand	subsoil	16	116	2
Ndalani	sandy red loam	topsoil	31		1
		subsoil	20	171	1
Ngoliba B	sandy red loam	topsoil	27		1
		subsoil	32	251	1
Nzukini	grey-brown loamy sand, shallow		7[3)]		1
d) Shallow valleys on the peneplains or between inselbergs					
Ithanga	blackish loamy sand	topsoil[4)]	4[3)]	approx.150	1
Ndalani	black cotton soil	undiff.	96[2)]	approx.350	1
e) Young valley slopes on the peneplains					
Ngoliba A	reddish-light	topsoil	28		1
	brown sandy loam	subsoil	20	(168) shallower than 80 cm	1

1) Analysis carried out by Dr. H. Kutsch. As the number of samples small, approximate values are indicated in this table, assuming rather loose soil condition on cultivated plots.

2) Theoretical value, assuming uninhibited swelling of the soil. Actual value approximately 350 mm.

3) Theoretical value because of the permeability of the sand. In nature, with less permeable subsoil, about 20 mm.

4) During dry season very hard subsoil, of which samples could not be taken with a hand-drill without hammer.



37°15'
37°30' E
1° S
TANA
TANA
80
>90%
70-80%
90
80
Ndithini
>90%
80-90%
80
Ithanga
70
90
Nzukini
THIKA
<80%
Thika
Ndula
Ngol. C
60
Gatuanyaga
ATHI
Ngol. D
Komu
Ndalani
Munyu
Ngoliba A
Ngoliba B
Mamba
Ndarugu
<60%
Ol D. Sapuk
ATHI
Yatta Furrow
70
80
80
<80%
Kithimani
—80— Percentage of seasons which receive more than 150mm in an adequate distribution for Indian barley or foxtail millet
— — — uncertain
0
5
10 km
GK

culture is considered. The main condition is a good protection against soil erosion, so that surplus rainfall can be stored in the soil and is not lost by surface runoff (see Chapter 5.1). Soil samples of the most important soils indicate that the water storage capacity of these soils, for a root zone of about 8o cm, lies between 85 and 35o mm (Table 4).

Further research in this direction is necessary. However, since the extent of the various soil types is not exactly known and the amounts of rainfall that are stored in the soil are relatively small anyway, a simplification was introduced by assuming a general soil moisture storage capacity of 2oo mm. Soil moisture usage was computated according to tables by Thornthwaite and Mather (1955). About half of the stored moisture can be used by the normal crops in the area.

Maps of the number of agro-humid months (Fig. 1o, 11) only very generally indicate the conditions of cultivation possibilities of crops according to their growth periods. In the drier eastern lowlands (Mdalani and Nzukini) only one and a half agro-humid month occur per rainy season, which is normally not enough for crops. In these areas only 2o % of all rainy seasons reached three agro-humid months and in 5o % there were less than two. The long rains can be rather short if the I.T.C.Z. (inner tropical convergence zone) moves rapidly northwards when the Sudan heats up quickly. In seven out of twenty years the long rains lasted about one month or less and the moisture stored in the soil during these rains was so little that the agro-humid time was the same. The short rains are more reliable in the lowlands than the long rains. Only once in twenty years they lasted for only one month.

2.3 Temperature conditions and other climatic factors

There are no temperature stations inside and near to the Settlement Schemes, so that for the higher parts of the region values of the former Sisal Research Station and the National

See page 84

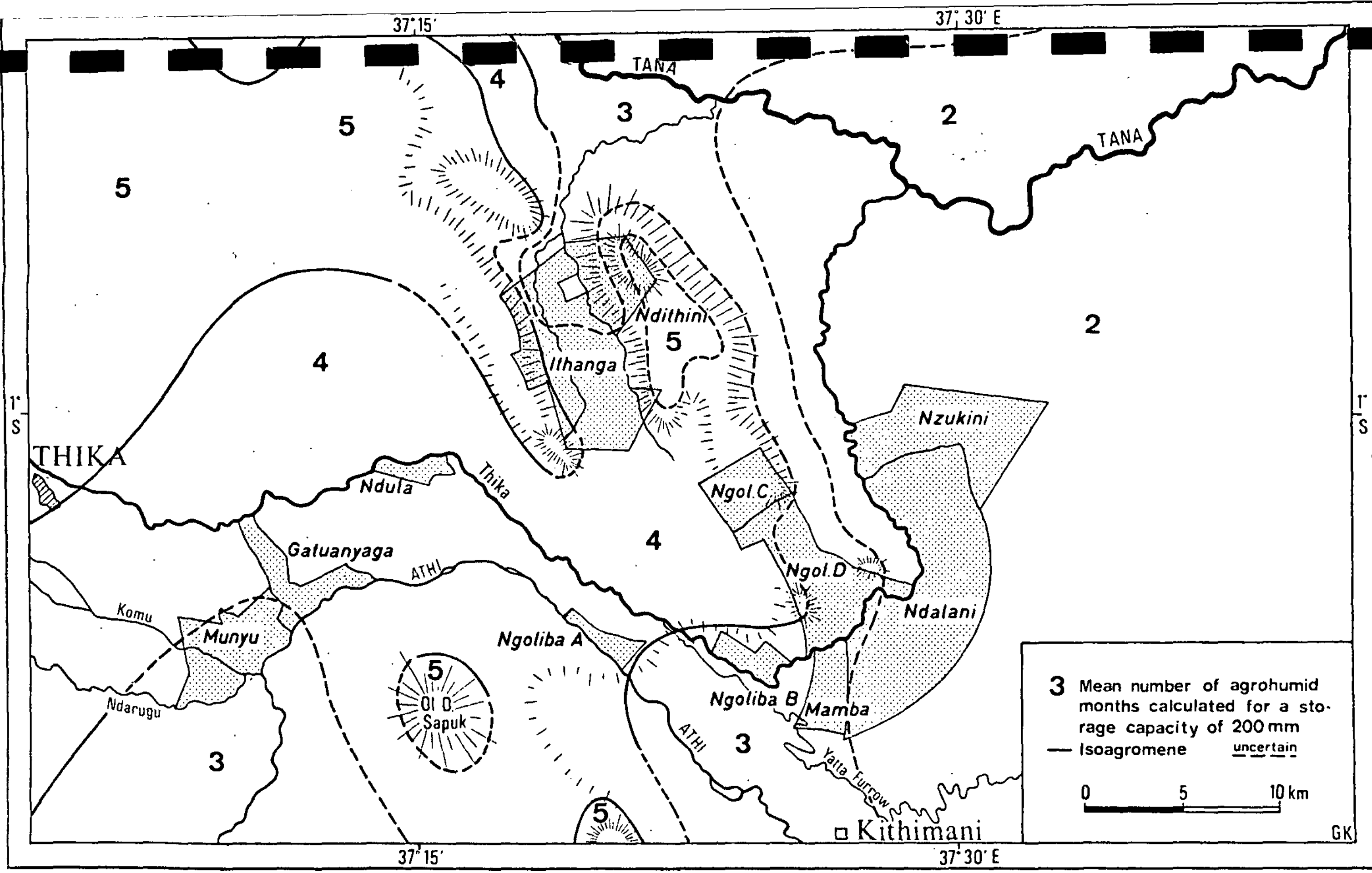


Fig. 1o Isoagromenes for the long rains

The mean number of months with sufficient moisture for the cultivation of most crops (soil storage capacity 2oo mm) is indicated

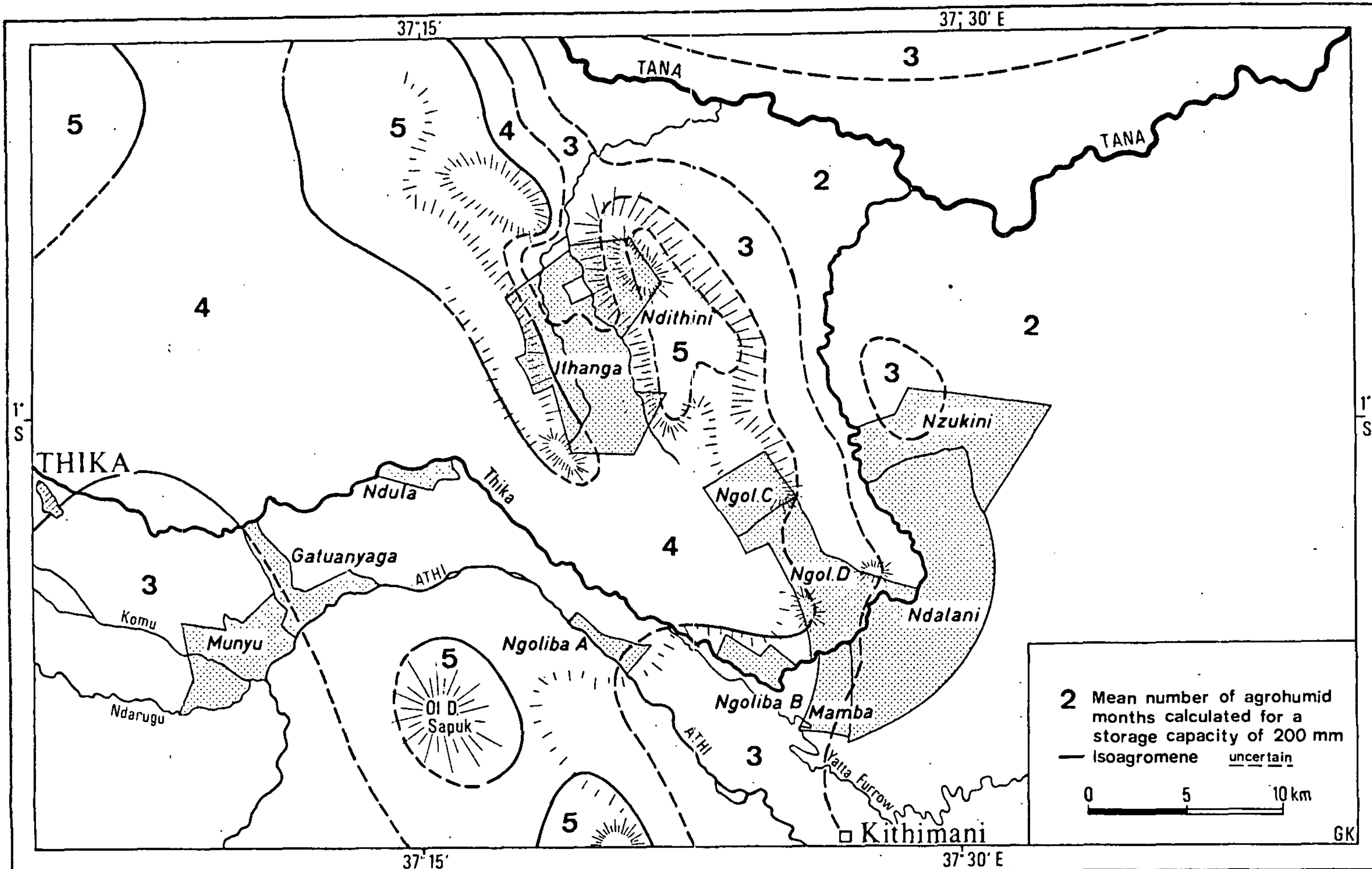


Fig. 11 Isoagromenes for the short rains

Horticultural Station near Thika[1] were extrapolated (Table 6).

Except for these stations, only some older records from a sisal plantation in the northwestern Ithanga Hills are available. For the lower parts of the region the only sources are Mwea Tebere and the Tana Power Station and both of these stations are outside the area shown on the maps. It was therefore not possible to construct isotherm maps for the rainy seasons. However, since the reduction of temperature with elevation is well known, it was possible to construct a map of approximate annual isotherms, on which local inversions are considered, despite the small number of recording stations in the region. These isolines of important limits of annual mean temperatures and the mean annual diurnal minimum are indicated on the climatic map, where they are shown in relation to the hygric zones (Fig. 13).

The most important temperature value is the mean diurnal minimum of 14°. For a number of crops (cotton, groundnuts, cassava), the value of 15° has often been used, but new varieties of these crops have improved their tolerance of cool nights. Almost the whole region lies below the elevation which produces such low temperatures, except the cool Ithanga Hills, above 14oo m, where in June and July the beginning southeast monsoon causes heavy cloudiness and a relatively cool period. Munyu and Gatuanyaga are close to this limit. Here, clear nights may cause inversions of cold air between the hills. But most Settlement Schemes have no thermal problems. They might be introduced with the cultivation of barley, because temperatures in the lower regions may be too high, favouring the development of diseases (rust).

Of the other climatic elements only the wind is of some significance. During the monsoon periods, winds reach force 4 during the afternoons, when anabatic winds of the Aberdares reinforce the monsoon. Shelterbelts are advisable for sensitive plants, also because they reduce evaporation.

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1) At this station, values starting in 1973 were not considered, as they were affected by a measuring error (personal communication Holler).

Tab. 6: Temperatures of the only available stations

Station Nr.	Station Name	Elevation in m	Period		J	F	M	A	M	J	J	A	S	O	N	D	Year
9o37 o18	Punda Milia Estate	137o	1931-4o	abs.max.	31,1	33,3	33,9	32,2	3o,6	29,4	28,3	3o,o	31,7	31,7	3o,6	28,9	33,9
				mean max	28,2	29,6	29,6	27,6	26,2	24,7	24,3	24,3	27,6	27,9	26,3	26,1	26,9
				mean temp.	2o,5	21,8	22,7	21,8	2o,9	19,1	18,4	18,6	2o,5	21,5	2o,8	2o,2	2o,6
				mean min.	12,8	14,o	15,7	15,9	15,5	13,4	12,5	12,8	13,4	15,1	15,2	14,2	14,2
				abs.min.	8,9	9,4	1o,o	12,8	1o,6	7,8	7,8	6,7	8,3	11,7	12,2	1o,6	6,7
9o37 o37	Muranga, Tana Power St.	1o65	since 1962	abs.max.	33,9	35,6	37,5	33,3	31,1	31,1	31,4	31,1	35,o	33,3	31,1	31,7	37,5
				mean max.	29,6	31,2	3o,6	28,7	27,8	27,1	26,3	26,4	29,2	3o,2	28,3	28,3	28,6
				mean temp	21,8	23,4	23,9	23,3	22,2	21,4	2o,6	2o,8	22,5	23,8	22,7	22,o	22,3
				mean min.	13,9	15,6	17,1	17,8	16,8	15,6	14,8	15,1	15,7	17,4	17,1	15,6	16,o
				abs.min.	5,6	1o,6	12,2	1o,o	8,3	9,2	8,2	6,7	8,6	9,4	9,2	7,5	5,6
9o37 13o	Thika, Horticultural Research Station	1547	since 1962	abs.max.	3o,o	31,1	31,1	31,1	31,7	27,8	27,8	28,9	28,9	33,3	3o,6	31,7	33,3
				mean max.	26,1	27,4	27,2	25,2	24,2	23,5	22,5	22,9	25,3	26,2	24,4	25,1	25,o
				mean temp	19,2	2o,1	2o,7	2o,3	19,5	18,2	17,3	17,5	18,8	2o,2	19,7	19,4	19,2
				mean min.	12,3	12,8	14,2	15,4	14,7	12,8	12,1	12,o	12,2	14,2	14,9	13,7	13,4
				abs.min.	5,6	6,1	8,9	12,2	8,9	7,2	6,7	5,6	6,9	8,9	11,1	8,9	5,6
9137 o48	Thika, Sisal Research Station	1462	1941-68	abs.max.	32,5	32,8	32,8	33,3	3o,5	3o,6	28,9	3o,3	31,7	31,7	3o,6	32,2	33,3
				mean max.	27,4	28,3	28,6	26,8	25,6	24,8	23,4	23,8	26,5	27,4	25,7	25,8	26,2
				mean temp	19,7	2o,4	21,3	21,2	2o,3	18,9	17,8	18,1	19,2	2o,7	2o,2	19,7	19,8
				mean min.	12,o	11,9	13,9	15,5	15,o	12,9	12,2	12,4	12,8	14,o	14,6	13,6	13,4
				abs.min.	5,6	6,1	7,2	1o,o	8,3	5,3	5,o	6,o	4,4	6,1	8,6	6,7	4,4

2.4 Agro-climatic types

2.4.1 An agro-climatic classification of the tropics

An agro-climatic classification was developed, based on the duration and intensity of the humid and arid seasons, as the most important factor controlling land use, in combination with thermal conditions (Jaetzold, 1970, 1977). This classification uses decimal indicators. For the hygrotypes, the first of these indicates the duration and distribution of the humid and arid seasons, the second digits their intensity. A prefix of a or h shows whether the annual water balance is predominantly arid or humid (Fig. 12).

h_1: predominantly humid climate, with two arid seasons (about 5 - 7 arid months, separated by at least 2 humid months).

For the subdivision of this tropical wet and dry climate according to intensity of the seasons there are four basic types:

1. The humid seasons are weakly developed, the arid ones strongly.
2. Both are weakly developed.
3. Both are strongly developed.
4. The humid seasons are well developed, the arid ones weakly.

In the humid seasons, weakly developed: sub-humid, well developed: full-humid.[1] The arid seasons are divided in the middle, so well developed is full-arid, weakly developed is semi-arid. So the subdivision becomes:

$h_{1.1}$	humid months predominantly sub-humid, arid months predominantly full-arid
$h_{1.2}$	humid months predominantly sub-humid, arid months predominantly semi-arid
$h_{1.3}$	humid months predominantly full-humid, arid months predominantly full-arid
$h_{1.4}$	humid months predominantly full-humid, arid months predominantly semi-arid

1) Sub-humid: P exceeds 0.4 E_o;(full-) humid: P exceeds 0.8 E_o . The value 0.8 E_o approximates the average evapotranspiration of a tree crop. E_o = evaporation of an open water surface.

h_2: predominantly humid climates with a long arid season (5 - 6 arid months)

$h_{2.1}$: humid months predominantly sub-humid, arid months mainly full-arid

$h_{2.2}$: etc.

h_3: predominantly humid climate with a short arid season (3 - 4 arid months)

h_4: predominantly humid climate with a very short arid season (1 - 2 arid months)

h_5: humid climate without an arid season

Normally, all months are humid. However, relatively dry seasons may occur, which are sub-humid. The subdivision is accordingly:

$h_{5.1}$: normally all year humid, but with 2 sub-humid seasons
$h_{5.2}$: practically continuously humid with 1 long sub-humid season
$h_{5.3}$: practically continuously humid with 1 short sub-humid season
$h_{5.4}$: practically continuously humid

The <u>arid climatic</u> types are subdivided similarly:

a_1: predominantly arid climate with two humid seasons (about 4 - 6 humid months, separated by at least two arid months)

$a_{1.1}$: arid months predominantly semi-arid, humid months predominantly full-humid
$a_{1.2}$: arid months predominantly semi-arid, humid months predominantly sub-humid
$a_{1.3}$: arid months predominantly full-arid, humid months predominantly full-humid
$a_{1.4}$: arid months predominantly full-arid, humid months predominantly sub-humid

a_2: predominantly arid climate with a long humid season (5 - 6 humid months)

$a_{2.1}$: arid months predominantly semi-arid, humid months predominantly full-humid

$a_{2.2}$: etc.

a_3: predominantly arid climate with a short humid season (3 - 4 humid months)

a_4: predominantly arid climate with a very short humid season[3] (1 - 2 resp. 3 humid months)

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2) In equatorial latitudes another arid month may occur in the second, very short, dry season. This type is identified $h_{(1)}$

3) Near the equator there may occur two very short humid seasons. In this case crop agriculture may be impossible even with 3 humid months per year, except for a few cases (p. 24). This type is identified as $a_{(1)4}$.

Table 7: Thermal elevation zones in the inner tropics according to agroclimatic conditions

Formula	Temperature limit (°C.)	Thermal denotation	Mean elevation on the eastern slopes of the Kenyan highlands
t_5		= tropical iceclimate	over 46oo m
	mean annual temp. 2°		
$t_{4.2}$		= very	about 36oo - 46oo
	mean minimum 2°	cold tropical climate	
$t_{4.1}$		= moderate	about 3ooo - 36oo
	mean annual temp. 11°		
$t_{3.2}$		= rather	about 25oo - 3ooo
	mean minimum 8°	cool tropical climate	
$t_{3.1}$		= moderate	about 19oo - 25oo
	mean annual temp. 17.5° 1)		
$t_{2.2}$		= cool	about 14oo - 19oo
	mean minimum 14°	temperate tropical climate	
$t_{2.1}$		= warm	about 1ooo - 14oo
	mean annual temp. 23°		
$t_{1.2}$		= moderate	about 5oo - 1ooo
	mean minimum 2o° 2)	hot tropical climate	
$t_{1.1}$		= very	about 0 - 5oo

1) or absolute limit of soil frost (upper limit of coffee, bananas etc.)

2) or mean minimum of the coldest month over 18°

a_5: arid climate without a humid season

All months are arid. However, relatively wet seasons may occur which are only semi-arid. For many desert species this is sufficient, so that a temporary grasscover may form.

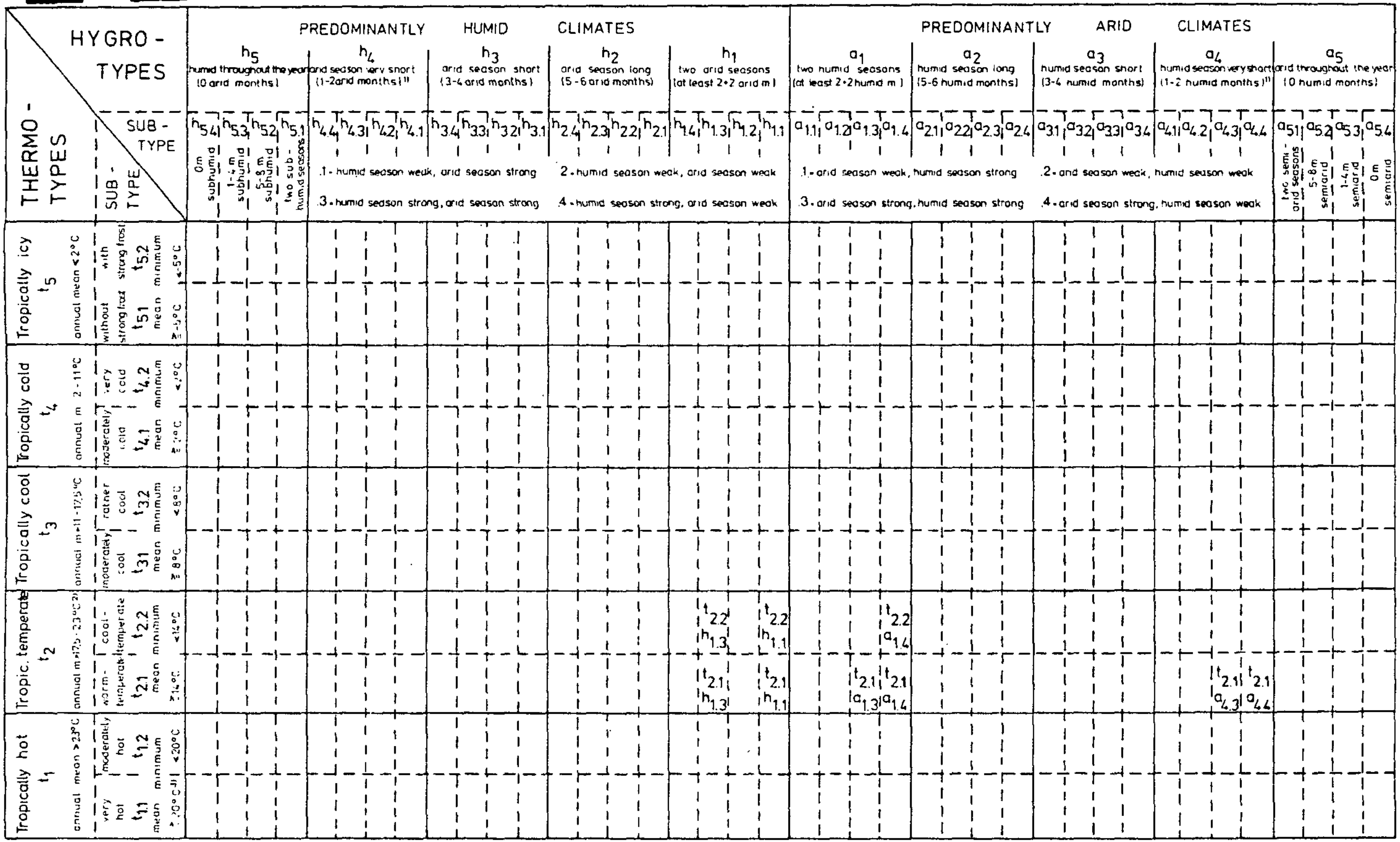
Subdivision accordingly:

$a_{5.1}$: Normally all year arid, but with 2 semi-arid seasons
$a_{5.2}$: practically continuously arid with 1 long semi-arid season
$a_{5.3}$: practically continuously arid with 1 short semi-arid season
$a_{5.4}$: practically continuously full-arid.

Combination of these humidity zones with thermal elevation zones (Table 7) produces a large mumber of climate types (Fig. 12). Their significance regarding land use is indicated in Fig. 14. The thermal zones were subdivided by the first indicator according to the annual mean temperature, by the second digit according to the mean minimum. Both criteria are important in the tropics. The mean maximum may also be indicated by a third digit. Here, this is not necessary, as the maximum temperatures are not a limiting factor.

2.4.2 The agro-climatic types which occur in the area of the Haraka Settlement Schemes

In the Haraka schemes only the types h_1 and a_1 with two humid and arid seasons occur because the rainy season is divided (Fig. 13, 15 - 18). Thermally, it is also an intermediate area between cool-temperate type $t_{2.2}$ and warm-temperate type $t_{2.1}$. The intensity of the rainy seasons decreases towards the eastern lowlands and on the leeward side (Munyu), therefore, only the weak types $h_{1.1}$ and $a_{1.4}$ dominate there; the agricultural potentials of the various climatic types are shown in Fig. 14. Obviously, not all crop species are indicated and differences caused by varieties are not included. Further indications follow and are also found in Chapters 3 and 5.



1) Also 1+1, 2+1 or 1+2 months 2) Absolutely free of ground frost 3) Mean minimum of the coldest month > 18°C

Fig. 12 Agro-climatic classification of the inner tropics and the combinations which occur in the Haraka Settlement Schemes

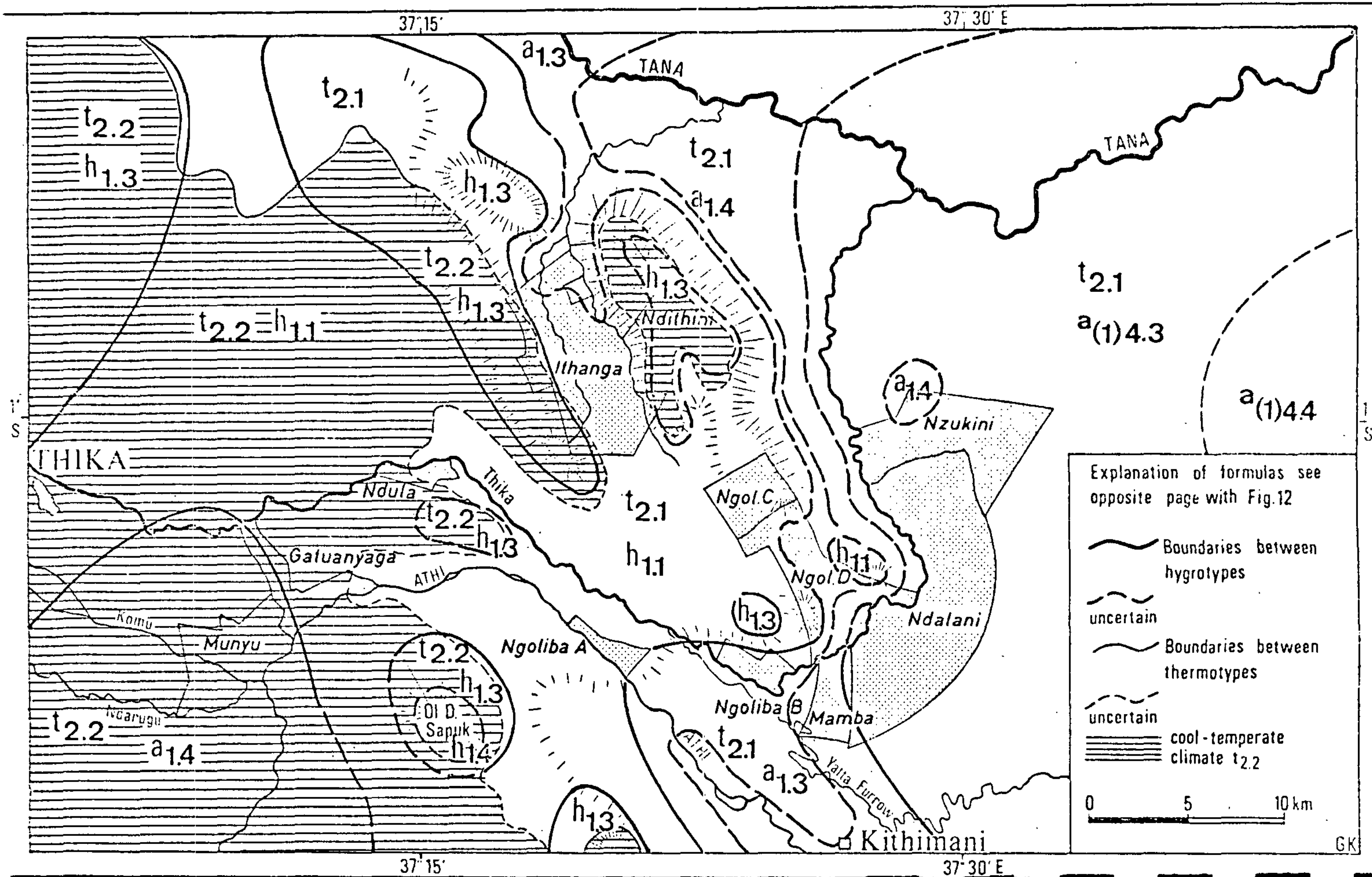
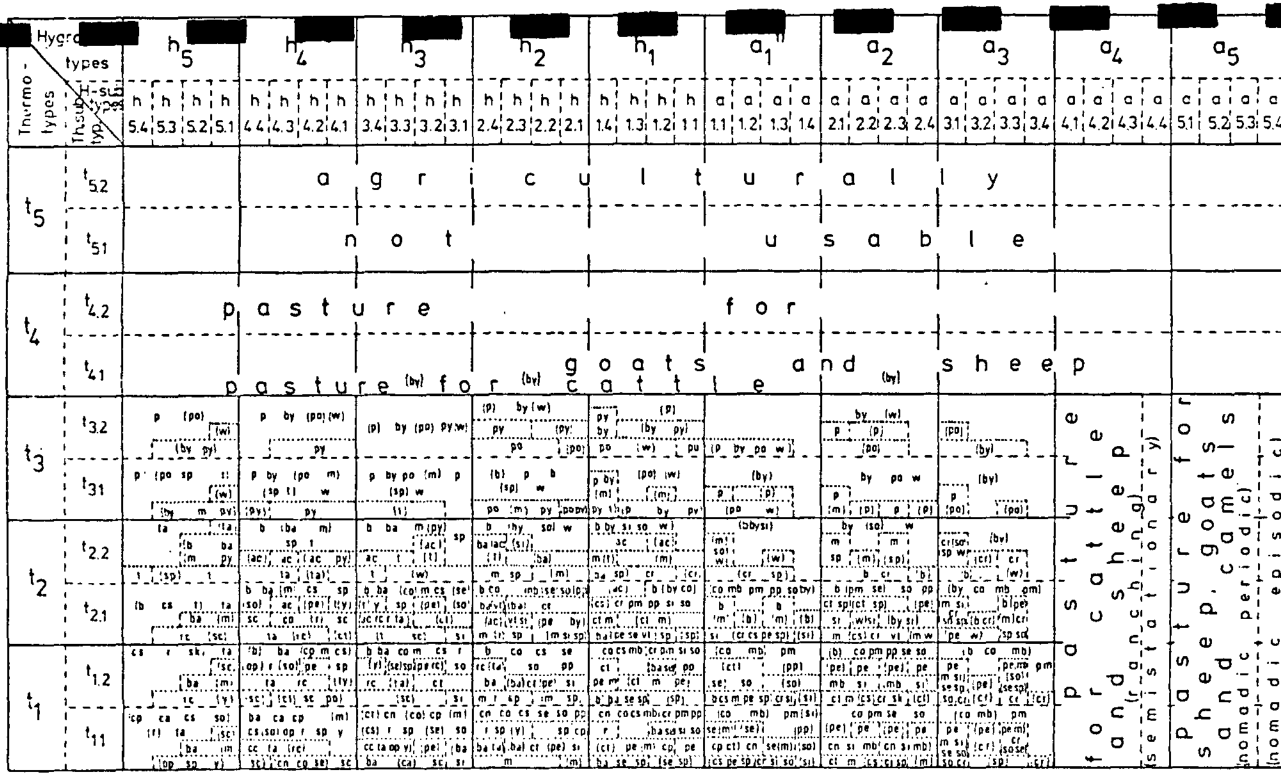


Fig. 13 Agro-climatic types

$a_{(1)4}$ = mixed type between a_1 and a_4



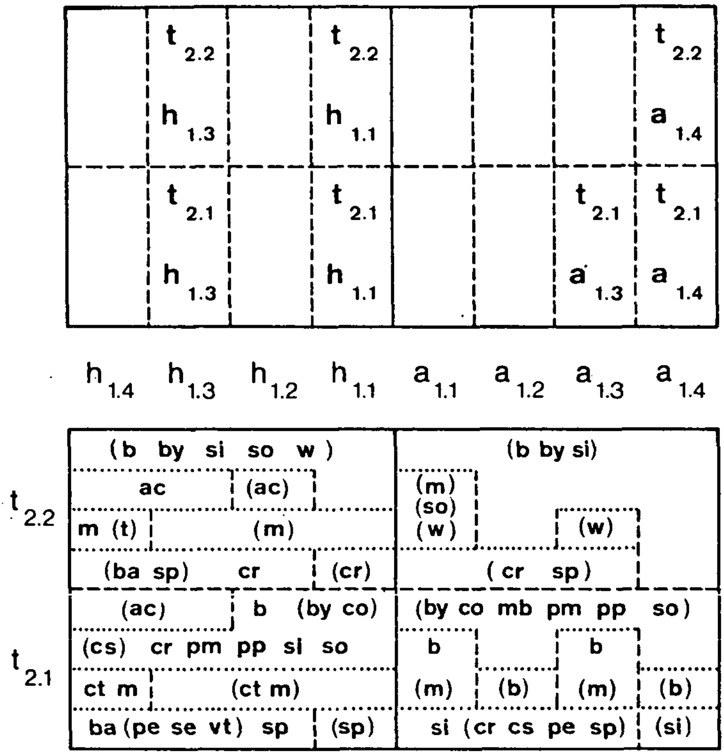
1) When there is 2+2 humid months, only special varieties of cultivated plants

( ) = less favourable climate

ac	arabica coffee	cc	caoutchouc	cs	cassava	p	peas	py	pyrethrum	si	sisal	vt	virginia tobacco
b	beans	cn	cashew nuts	ct	cotton	pe	peanuts=groundnuts	r	rice	so	sorghum	w	wheat
ba	bananas	co	cowpeas	m	maize	pm	pennisetum millet=bulrush m.	rc	robusta coffee	sp	sweet potatoes	y	yams
by	barley	cp	coconut palms	mb	mungo beans	po	potatoes	se	sesame	t	tea		
ca	cacao	cr	castor	op	oil palms	pp	pigeon peas	sc	sugar cane	ta	taro		

Fig. 14 Potential land use in the inner tropics according to favourable climates
Partial enlargement see fig. 14a

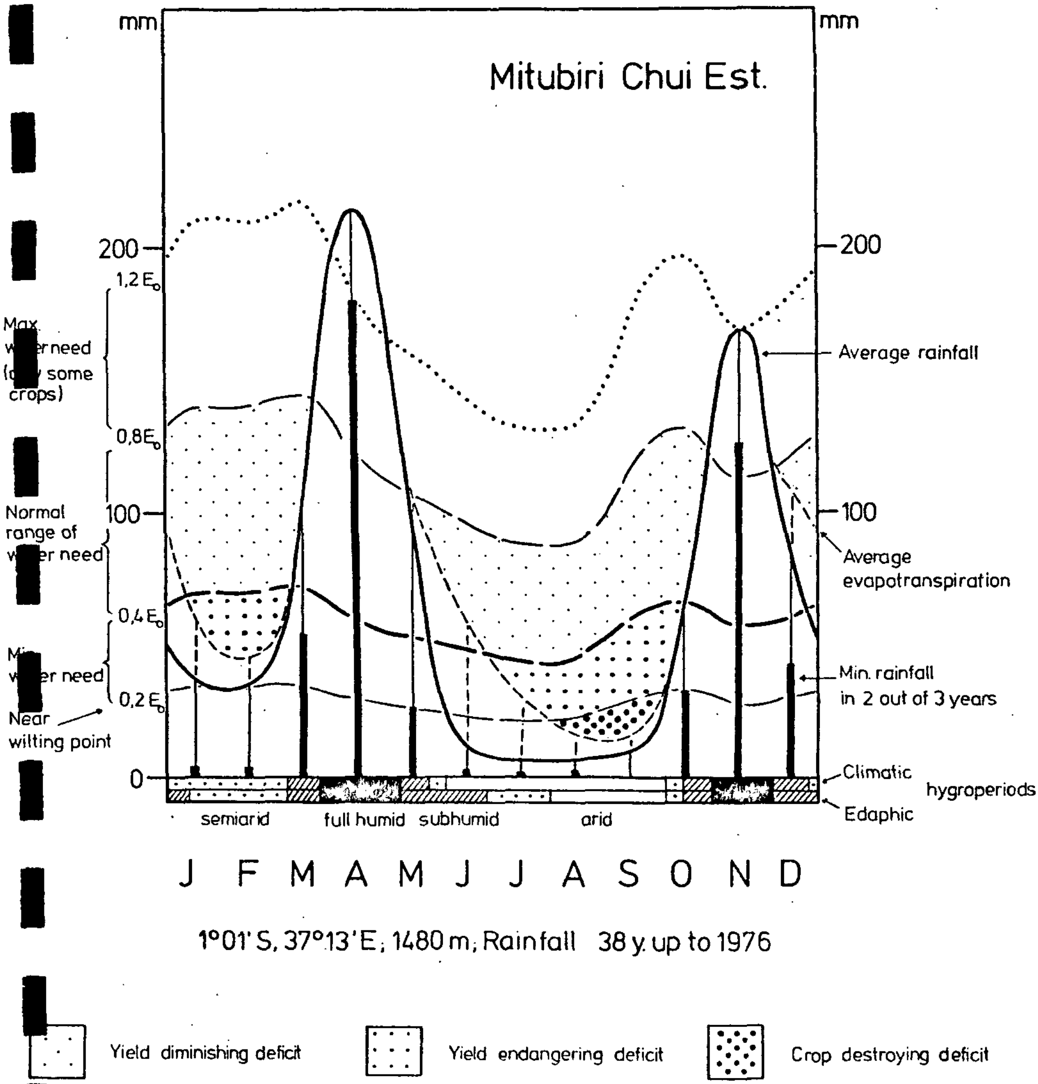
Agro-climates of the Haraka Settl. Schemes



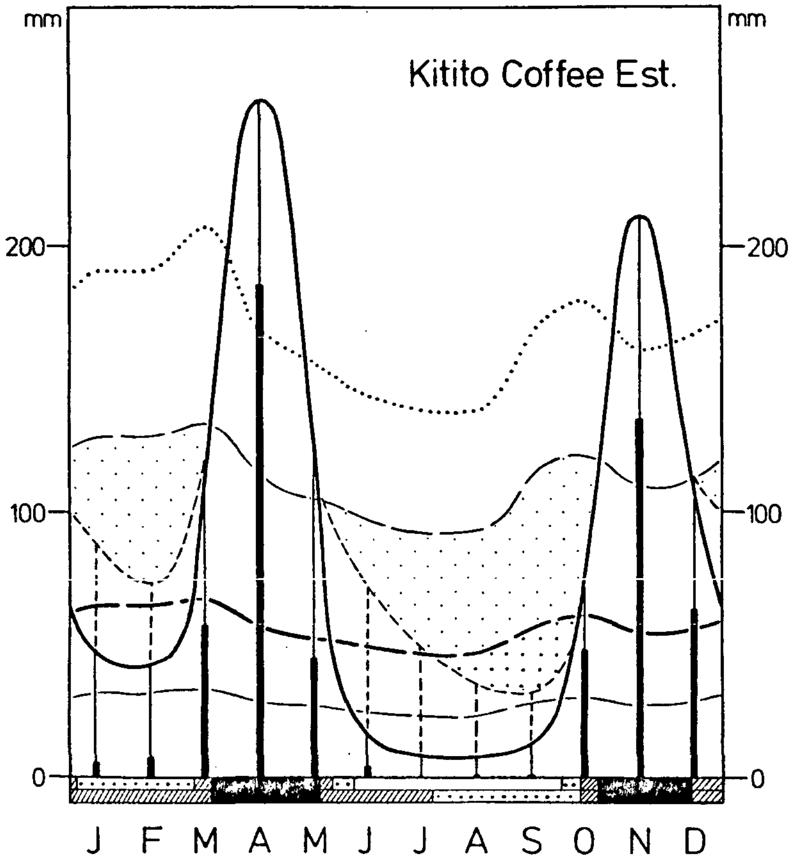
ac arabica coffee
b beans
ba bananas
by barley
co cowpeas
cr castor
cs cassava
ct cotton
m maize
mb mungo beans
pe peanuts = groundnuts
pm pennisetum millet = bulrush m.
pp pigeon peas
se sesame
si sisal
so sorghum
sp sweet potatoes
t tea
vt virginia tobacco
w wheat

( ) = less favourable climate

Fig. 14a Comparison between fig. 12 and 14



g. 15 Station Mitubiri Chui Estate as an example of $h_{1.1}$ climate
Of the 5 humid months, 3 are only subhumid,
of the 7 arid months, 5 are fully arid. Therefore, the humid seasons are poorly developed, but the arid seasons are stronger. (The effects on soil moisture storage are not considered when climate types are identified). The station is centrally located in the area of this climatic type and quite typical. Only in Ngoliba A and C the short rains may be slightly more plentiful (Fig. 6).



0°58'S, 37°18'E; 1455 m; Rainfall 44 y. up to 1976

Fig. 16 Station Kitito Coffee Estate as an example of $h_{1.3}$ climate
Of the 6 humid months almost 4 are fully humid, of the 6 arid months, 4 are fully arid. Therefore, both, the humid an the dry seasons are clearly developed. The name of the station indicates the possibility of cultivating perennial crops with relatively high water requirements.

$t_{2.1}h_{1.1}$: <u>warm-temperate tropical climate, predominantly sub-humid with two, generally full-arid seasons</u>

This climate with its poorly developed and short humid seasons (Fig. 15) is suitable for low sorghum varieties, bulrush millet, beans with short growing periods, pigeon peas, mungo beans, sunflowers, castor and sisal. Maize grows poorer (Katumani is the best variety), cowpeas, sweet potatoes, cassava, macadamia nuts, pineapples and mangoes also do not grow very well, tobacco even less. Cotton is possible as a ratoon crop.

$t_{2.1}h_{1.3}$: <u>warm-temperate tropical climate, predominantly full-humid, with two, generally full-arid seasons</u>

Here maize (Katumani), sweet potatoes and pineapples find normally sufficient humidity. The same applies to very rapid growing cotton varieties, sesame, beans (Phaseolus vulgaris), passion fruits and agrumes. The crops mentioned under $h_{1.1}$ grow well here anyway. Arabica coffee can be tried successfully if diseases which occur more frequently here because of the high temperatures, are sufficiently prevented and mulching is used to conserve soil moisture. Mulching is essential for bananas too.

$t_{2.2}h_{1.1}$: <u>cool-temperate tropical climate, predominantly sub-humid with two, generally full-arid seasons</u>

Potential cultivation is more restricted than in $t_{2.1}h_{1.1}$, as it is too cool for bulrush millet, cowpeas, cassava, cotton and tobacco, though it is difficult to identify the exact boundary. Some wheat and potato varieties might be tried here. Maize is not suitable, as it ripens too slowly.

$t_{2.2}h_{1.3}$: <u>cool-temperate tropical climate, predominantly full-humid, with two, generally full-arid seasons</u> (Fig. 16)

As the full-humid months produce sufficient soil moisture for the dry seasons, this climate is suitable for perennial crops, such as arabica coffee, bananas, agrumes, castor and passion fruits. For pineapples, mangoes and sisal temperatures are not in the optimum range.

$t_{2.1}a_{1.3}$: warm-temperate tropical climate, predominantly full-arid with two humid seasons which are generally full-humid

This is a subtype with only 4 humid months (Fig. 17). These are divided into two each for both humid seasons. Therefore for all farms of cultivation there is a high risk of droughts, and for most crops a humid season of only two months is not long enough, despite the moisture stored in the soil. This climate is most suitable for grazing land. However, it is partly infested by tsetse flies.

Commercially, only sisal and probably castor are possible crops. Subsistence agriculture would be best with bulrush millet, cowpeas, pigeon peas, chick peas, rapid growing bean varieties (for instance mwezi moja beans) and mungo beans. However, by tradition and because of bird damage, maize is preferred over bulrush millet, despite crop failures caused by droughts. A certain adaptation is Katumani maize. In Fig. 14 the crops barley, sorghum, sweet potatoes, cassave and groundnuts are indicated for this type $t_{2.1}a_{1.3}$ in brackets, because it is not very favourable for these crops. Large rainfall during the humid seasons produces a high amount of green leaves. Therefore, the production of fodder and conservation in silos for dairy and beef cattle should be considered in this climate.

$t_{2.1}a_{1.4}$: warm-temperate tropical climate, predominantly full-arid with two, generally sub-humid seasons

Because of the short duration and low intensity of the humid seasons, this climate offers no optimum conditions for any crop. To a certain extend suitable are bulrush millet, dwarf sorghum, Indian barley varieties, mwezi moja beans, mungo beans, chick peas, cowpeas, pigeon peas, castor and sisal.

$t_{2.1}a_{(1)4.3}$: warm-temperate tropical climate, predominantly full-arid with two, generally full-humid seasons which are too short for most crops

In Ndalani and Nzukini the two rainy seasons are both shorter than two months. This type is an equatorial dry climate, rather rare, but unfortunately typical for eastern Kenya (Fig. 18, 22). It is an intermediate type between a_1 and a_4, indicated by the formula $a_{(1)4}$. This climate is, like the normal a_4 type, favourable for ranching only, with the advantage that fodder crops will grow twice per year.

Settlement in this climate with small farmers forces crop agriculture. With special methods cultivation of extremely undemanding and rapid growing crops like these mentioned above is possible (Chapter 5.2.1). Rainy seasons are very short, but intensive, as indicated by the symbol $a_{(1)4.3}$.

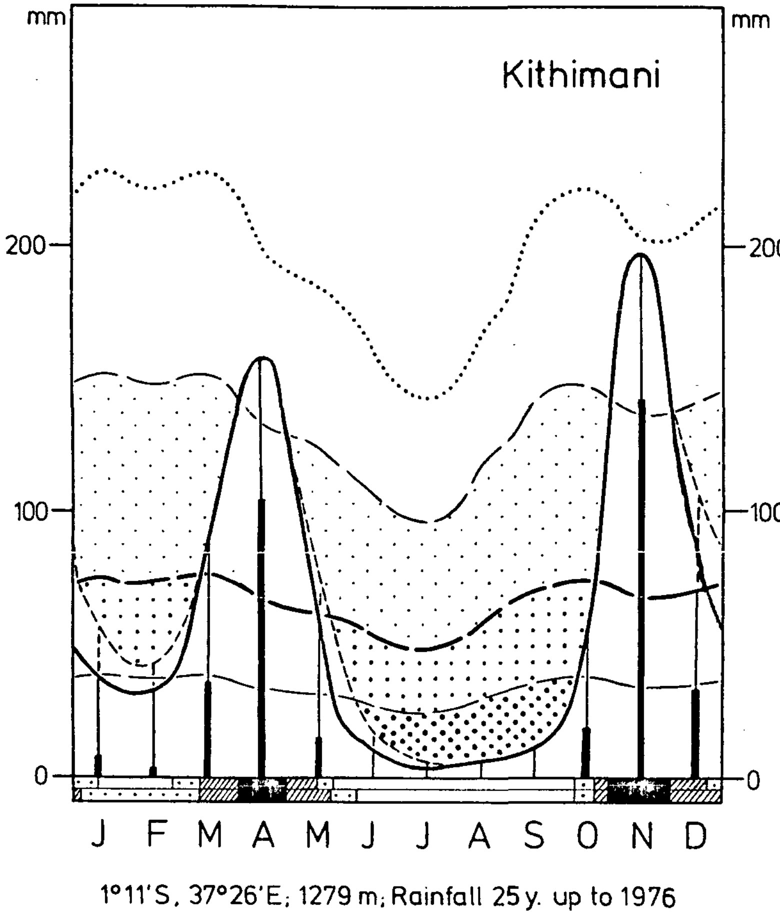
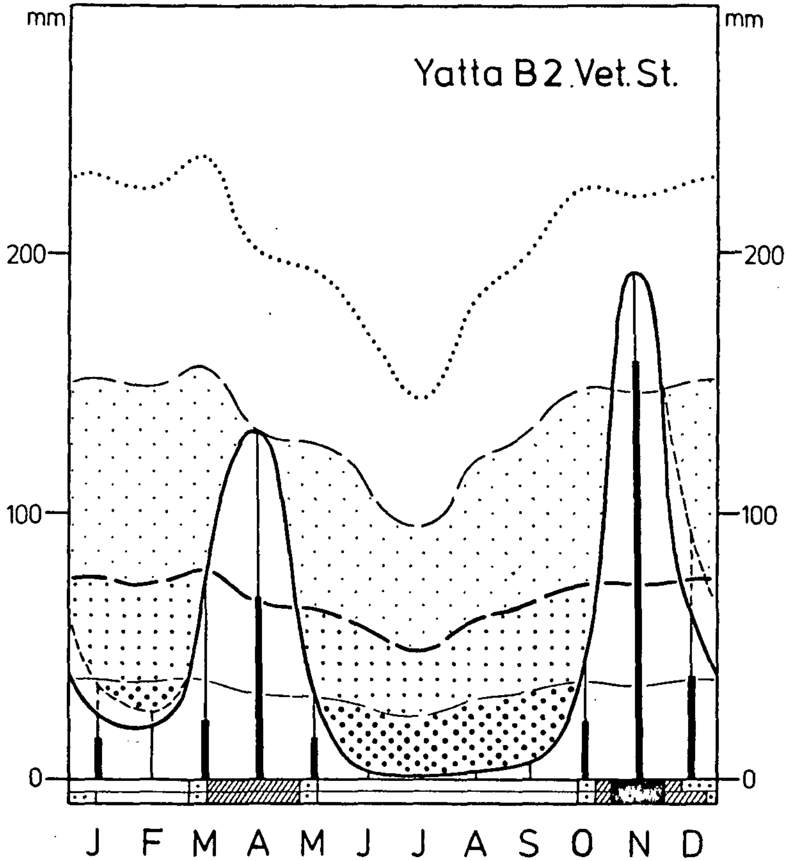


Fig. 17 Station Kithimani as an example of the transition zone between $a_{1.3}$ and $a_{1.4}$ climates

About 5o % of the 4 humid months are fully humid. This station is therefore a borderline case. Of the 8 arid months, 5 are fully arid and the dry seasons are therefore well developed.
The station is situated near the District Office in Kithimani. It is typical of the Mamba, Ngoliba B and D schemes. Near Munyu, rainfall during the short rains is slightly lower (Fig. 4).



1°07'S. 37°40'E; 1248 m; Rainfall 20y. up to 1974

Fig. 18 <u>Yatta B 2 Veterinary Station as an example of the transition zone between hygrotypes</u> $a_{(1)4.3}$ <u>and</u> $a_{(1)4.4}$

Both humid seasons are shorter than 2 months. Therefore, this climate belongs to type a_4. Like a_1, it has two humid seasons, but they are mostly too short for crop cultivation. The other intermediate situation between $a_{(1)4.3}$ and $_4$ is caused of the fact that there are 3 humid months (twice 1 1/2), with one season being fully humid and the other one being a borderline case.

The settlement schemes Ndalani and Nzukini are on the wetter side of the boundary and therefore have the hygrotype $a_{(1)4.3}$. The difference is not great, and vegetation types on both sides of the boundary are the same, indicating a strong climatic similarity. A comparison with records in Ndalani confirmed this conclusion. Although the station Yatta B 2 is a few kilometres away, it had to be used for this example since it is the only station with records over a period of at least 2o years.

3. Delimination of the areas to be promoted for development

The decision regarding which areas should be promoted, was made according to need: where the danger of famines is most urgent, development aid should be given first. According to the climatic potentialities, four degrees of priority were formed (Fig. 19). Climatic potential is decided by possible agricultural yields under existing conditions and the risk of crop failure. As farm sizes are approximately the same in the whole area of the Haraka Settlement Schemes (Table 1), areas with the lowest yields and the highest risks of crop failure with present maize-cultivation are also the areas most in need of development aid (Fig. 2o-21). This would not be the case if larger units, for instance ranches, had been formed in these areas. Since no soil map is available, variations in the climatic potential caused by this factor could not be fully considered.

Four types of areas are indicated (Fig. 19). They are:

- areas of first priority, or very low potential zone (vlpz),
- areas of second priority, or low potential zone (lpz),
- areas of third priority, or medium potential zone (mpz),
- areas of fourth priority, or semi-high potential zone (shpz).

These zones largely correspond to the agro-climatic zones. The first priority area is the $a_{(1)4.3}$-climate, where the land use methods and farm sizes are in clearest conflict with the climatic conditions which are most suitable for ranching, as the risk of crop failure for maize is too high (Fig. 28). Most of the rainy seasons will bring famine. Only by the introduction of new methods and crop varieties and the enlargement of farm sizes will it be possible to avoid new catastrophies (Chapter 5.2.1).

This economically weak zone contains the projects Ndalani and Nzukini, with the exception of two small areas which are situated at a higher elevation. In addition, the lower parts of Mamba belong to this zone.

The second priority area is the zone of $a_{1.3}$- and $a_{1.4}$-climates. Here, crop failures of the main cultivation of Katumani maize are less predominant, but still rather frequent because of the short duration of the humid season (Fig. 19, 2o). In this zone, increasing farm sizes and new methods are necessary too, together with a certain change in crops.

This zone of low climatic potential prevails in the wide valleys of the lower parts of Ngoliba D and Ndithini and also in the rain shadow areas of the Athi plains, where the Munyu Scheme and the western parts of Gatuanyaga are situated. The largest part of the Hamba project also belongs to this zone. Priority for development aid is slightly lower in Munyu and Gatuanyaga, because in these schemes volcanic soils produce higher yields and employment possibilities exist in Thika for many settlers of these two schemes.

In the third priority zone the probability of receiving the minimum water requirements of the main crop maize is already more than two thirds (Fig. 34). Here, the main problem is the protection and improvement of soil fertility. Precipitation is normally sufficient, even for some hygrophytic perennial crops, as this zone belongs to the predominant humid climate $h_{1.1}$. However, problems exist because the humid seasons are frequently poorly developed. This is the largest zone in the area of the Haraka Settlement Schemes. It includes most of the projects Ithanga, Ndithini and Gatuanyaga, in addition Ndula, Ngoliba A and C, and the higher parts of Ngoliba D.

The fourth priority zone has no problems of survival. Since here, a relatively high probability of 75 % is reached for the minimum water requirements of maize. Here the main question is to improve income conditions. This can be attained by making full use of the possibilities of the $h_{1.3}$-climate, especially in relation to perennial crops. However, as in the other zones a danger of soil erosion and destruction exists here, therefore development aid should not be postponed for too long. The area is small, containing only those parts of Ithanga and Ndithini which are over 135o m above sea level.[1)]

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1) In Ndithini only a small and rather steep area belongs to this zone. It may be disregarded.

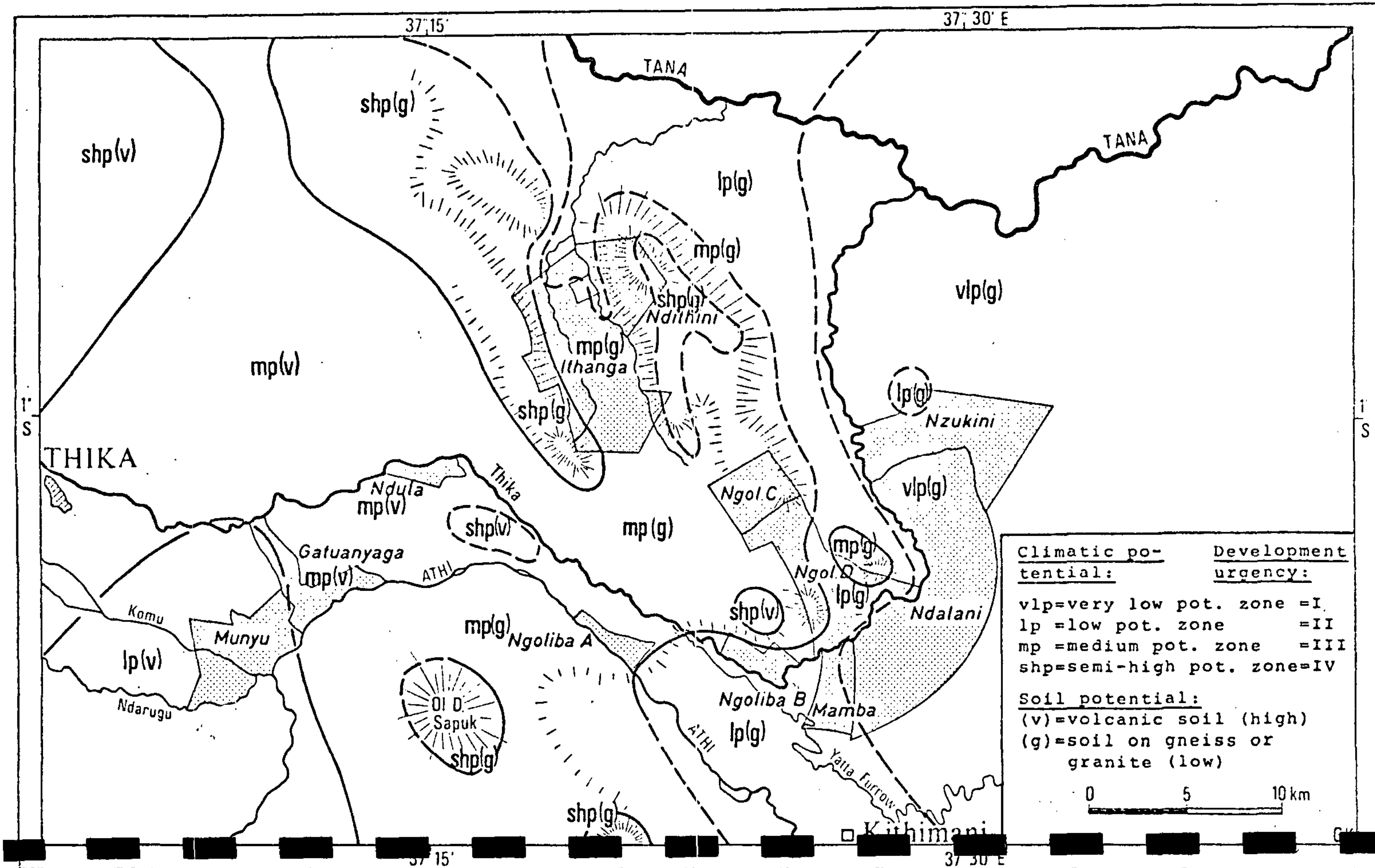

Fig. 10 Climatic potential and development priorities

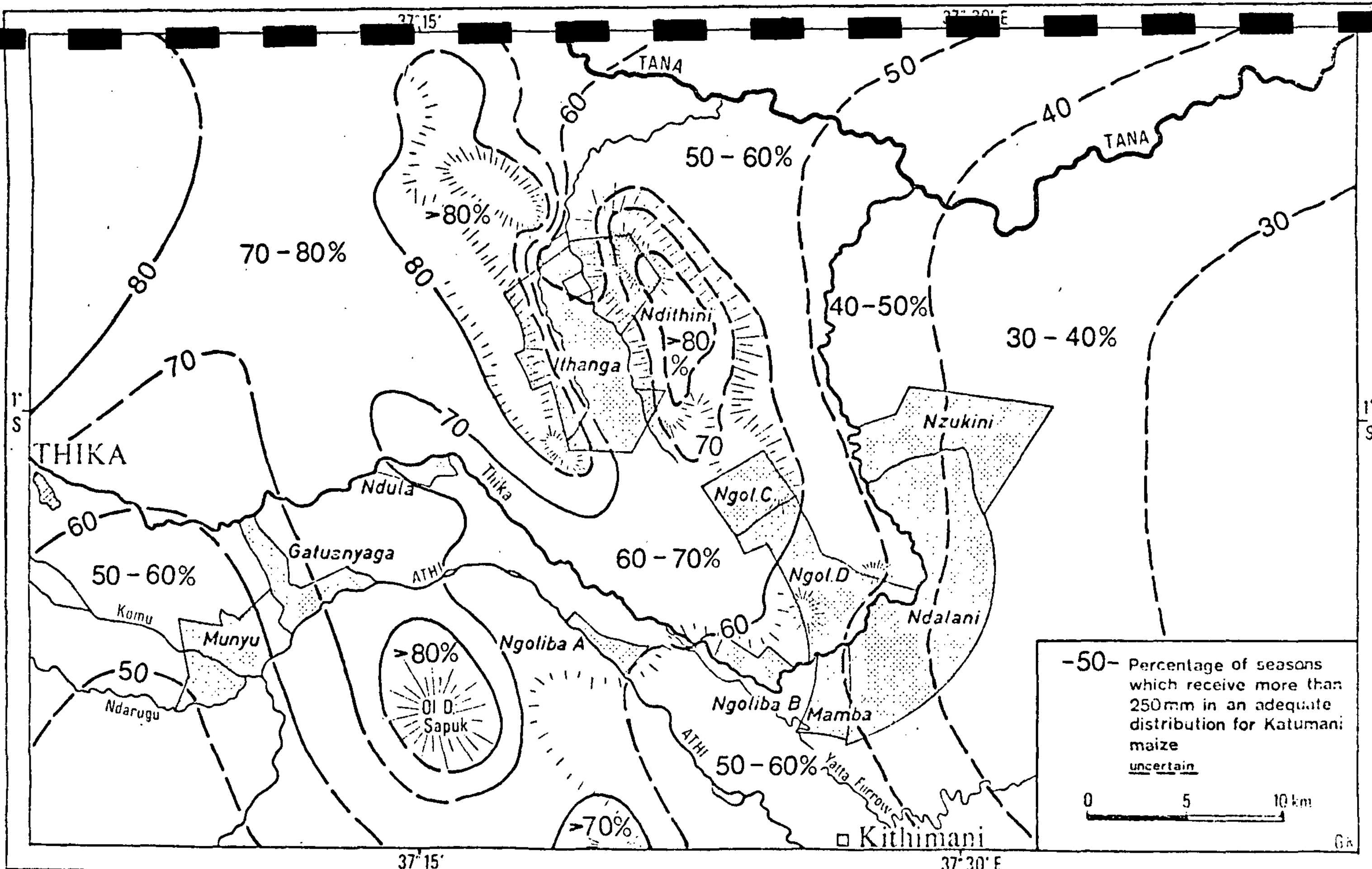

Fig. 2o Probability of receiving more than 25o mm of precipitation during the long rains in an adequate distribution for Katumani maize

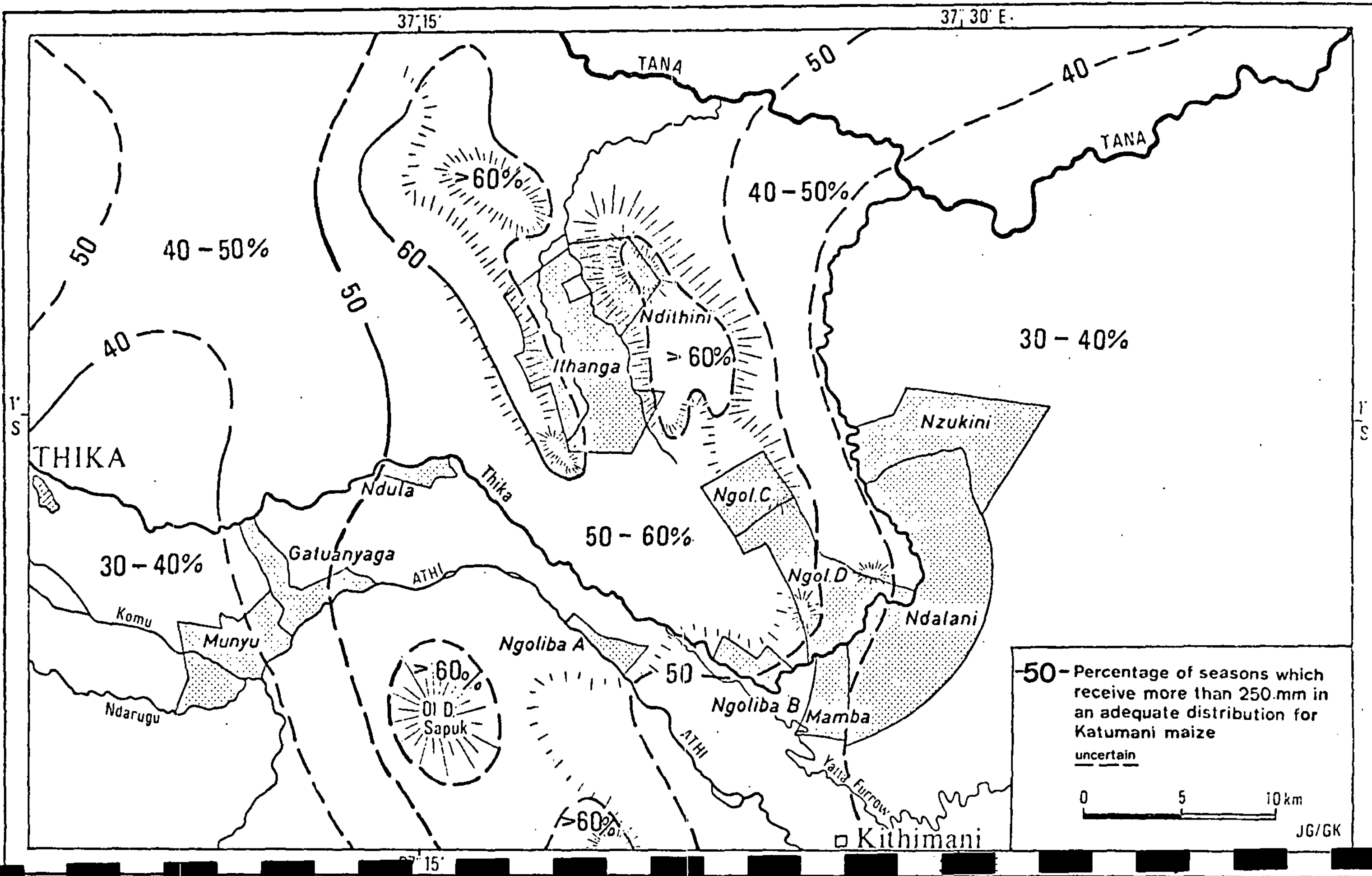

Fig. 21 Probability of receiving more than 25o mm of precipitation during the short rains in an adequate

4. Basic agro-climatic information about the various priority areas

4.1 Areas of first priority (vlpz: very low potential zone)

The vegetation of this zone consists mainly of Acacia-Commiphora bush, showing an adaptation to semi-desert conditions. This illustrates that here in Ndalani and Nzukini aridity is the main problem. Precipitation is generally below 6oo mm per year (Fig.2). Records over three years, made at the trading centre of Ndalani, produced a mean of only 4oo mm, but the reliability of these data is doubtful and the period too short. The long-term mean is probably higher, but not very much. Rainfall records, obtained during the long rains of 1977 indicated only 25o mm. The teacher, who did the readings, had the opinion that the long rains during that year had been fair. Therefore, with two rains per year a total of 5oo mm is considered quite normal. The comparable station Yatta B 2 Vet. Station indicates a mean of 585 mm (Table 3).

Potential evaporation in these areas may reach 2ooo mm per year. This is caused by dry air masses from the east, brought by the predominant trade winds. The water deficit is over 14oo mm per year, so that even unpretentious perennial crops, such as sisal or castor, cannot reach reasonable rates of growth.

The seasonal distribution of precipitation and humid periods causes a very difficult condition for annual crops. The long rains start around the end of March and end already in the middle of May, the short rains last from November until December. Compared with the potential evapotranspiration, the mean amounts of rainfall produce just two humid months (Fig. 23) during which the minimum water requirements of crops in their growing period are exceeded (5o % of their potential evapotranspiration). Therefore, maize cannot produce well in normal years (Fig. 22).

The variability of precipitation and humid seasons clearly indicates the very difficult conditions for maize introduced here as the main staple crop. Katumani-maize, the least demanding maize variety, generally used here, has water requirements at the temperatures prevailing here of about o.6 E_o in the first month, 1.o E_o in the second and o.7 E_o in the third month of growth (Brown and Cochemé, 1969, p. 291)[1]. Calculated as amounts of rainfall, this means a water need of 1oo mm in the first month, 17o mm during the second and 1oo mm in the third month of growth during the long rains[2] and 11o mm, 185 mm and 135 mm during the short rains. Totals for a good crop are 37o resp. 43o mm. This optimal distribution in three months was never actually realized in this zone (records for 1953 - 1974 at the only station with a comparable climate, Yatta B 2 Vet. St.). Every year, the rains were either shorter, less or interrupted. But even taking all the precipitation during a rainy season and assuming that good soil moisture storage conditions prevailed and that surface runoff was largely prevented, so that some soil moisture was available during the third month, only 4 long rains and 2 short rains during the indicated period of observation had sufficient moisture for a good Katumani maize crop. This represents only 2o % resp. 1o % of all years (Fig. 28).

But even the probability of receiving 25o mm as a minimum requirement for a small Katumani crop[3] (Brown and Cochemé, 1969, p. 295), which still assumes a good storage in the soil and no dry periods during the main growing period, is only 4o % during the long rains and about the same for the short rains (Fig. 2o and 21). On the average, every second year brings a crop failure during both rainy seasons (Fig. 27), and about two third of these are total failures. The mean yield of all years is only about 3 bags maize/ha, caused by many crop failures, general paucity of rainfall and poor soils[4]. Development aid is therefore absolutely necessary for survival here. Despite the poor natural conditions this aid can be quite effective with relatively modest

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1) Water requirements of the rapid ripening Katumani maize are different from those of maize varieties with longer growth periods (Table 8).

2) June is relatively cool and potential evapotranspiration is therefore less than during April. Therefore o.7 x E_o in June is the same amount in mm as o.6 x E_o in April. The diagram (Fig. 22) seems to use different amounts, but here, the sowing date in mid-March was used as a base and therefore amounts were calculated for half a month.

3) The distribution of this minimum requirement of water would be about 7o mm in the first, 11o mm in the second and 7o mm in the third month. It is assumed that part of these can be supplied by soil moisture.

4) An exact comparison of climatic conditions and crop yields during the rainy periods is not possible in the Haraka Schemes because of the lack of data.

technical and financial means (Chapter 5.2.1).

The rainfall minimum that may be expected in two years out of three, which is around 2oo mm during the long rains and about 23o mm during the short rains, would for instance be sufficient for certain bulrush millet andfoxtail millet varieties. A total over 2oo mm is also sufficient for cowpeas (Vigna sinensis), green gram (Vigna aureus), Mexican beans 142 (Mwezi moja, Phaseolus vulgaris) and pigeon peas (Cajanus cajan). Crop failures are mainly caused by insects, especially at pigeon peas or by short dry periods during the rains.

4.2 Areas of second priority (lpz: low potential zone)

The nearby station Kithimani (Fig. 24) is typical for the Mamba scheme in this zone. In Munyu conditions are similar, but the short rains are a bit smaller. The mean annual rainfall is less than 8oo mm (Fig. 2), but it exceeds the necessary minimum for unirrigated crop agriculture, which is, with a divided rainy season, about 6oo mm. The water deficit in relation to the potential evapotranspiration amounts to 8oo - 1ooo mm, so irrigation for perennial crops would normally be too expensive. Only sisal and castor are adapted to the long dry periods which last from January to March and from June to October. April/May and November/December are usually humid months with a mean rainfall of 3oo - 35o mm each season (Fig. 24). But a humid season of only two months is normally too short for annual crops. If soils are protected against erosion and surface runoff can be prevented, moisture for a third month and a little more could be stored in the soil if there is any surplus of rainfall over evapotranspiration. In this case at least, 25o mm should be received in the two rainy months. Under these circumstances a minimum yield of about 4 bags/ha could be expected of Katumani maize, which needs about three months to ripen here. On the volcanic soils of Munyu the minimum yields are 6 bags/ha under the same weather conditions.[1)]

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1) This advantage in Munyu is compensated by less favourable short rains, caused by the rain-shadow of Ol Doinyo Sapuk (Fig. 6).

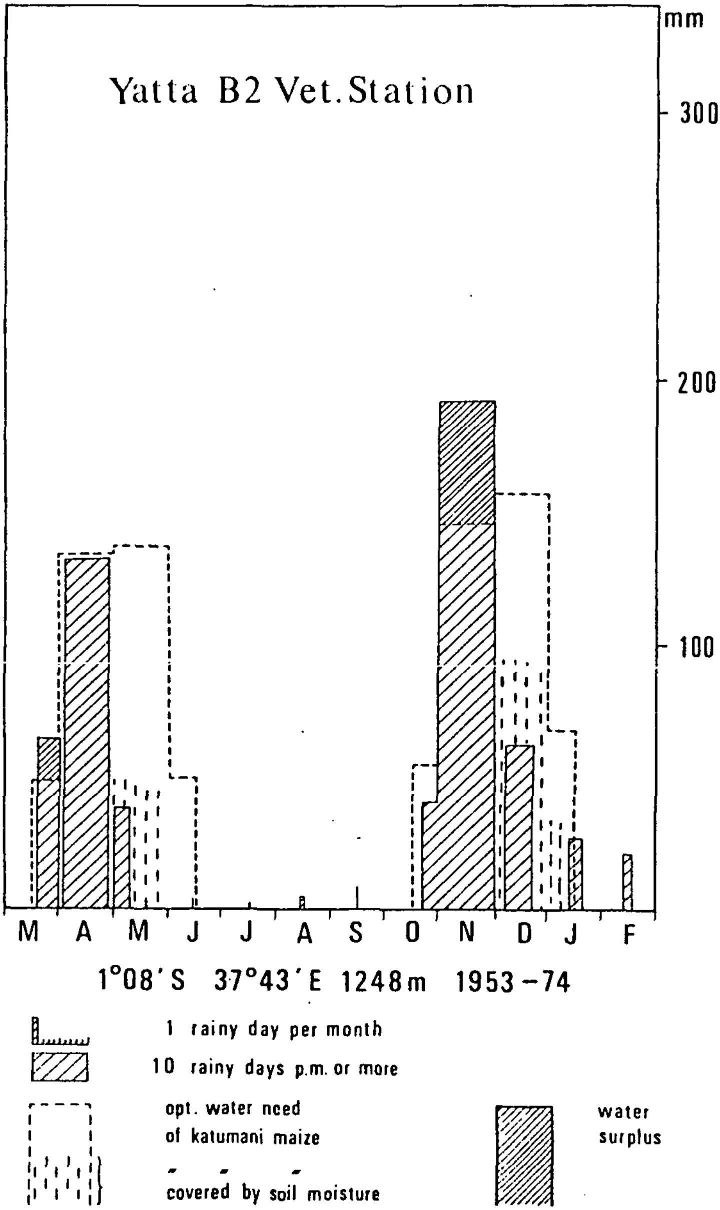

Fig.22: Seasonal rainfall distribution and the water requirements of Katumani maize at the most typical station of the first priority area

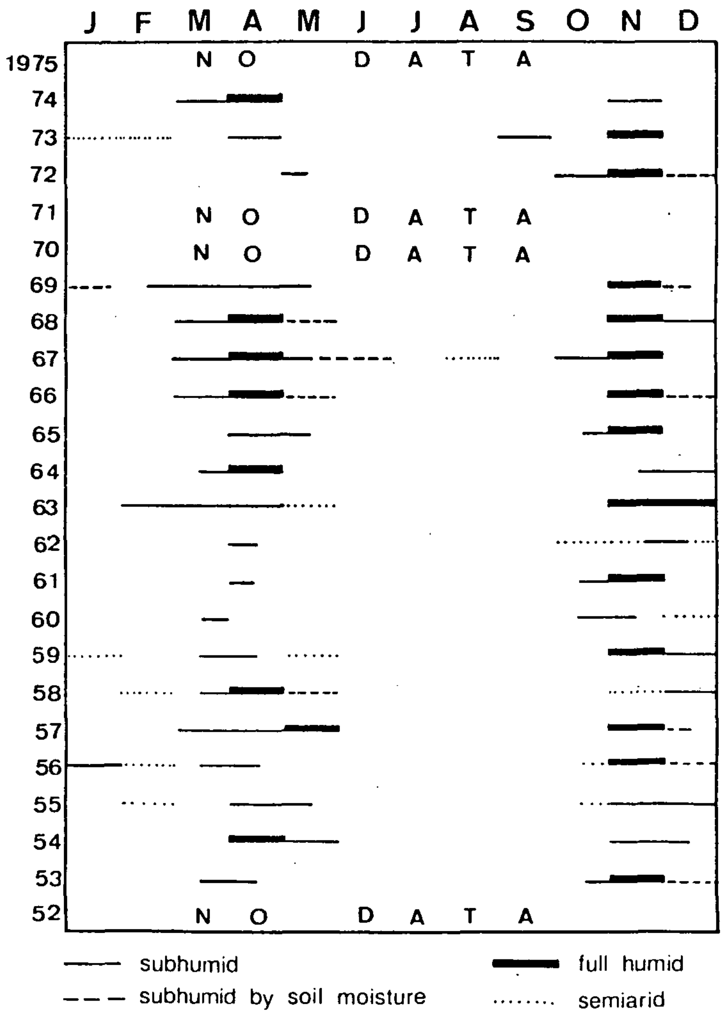

Fig. 23 Arid and humid seasons at Yatta B 2 Veterinary Station

Table 8: Water requirements of some crops which can be grown in the Haraka Settlement Schemes (in % of E_o)

Annual crops	youthful period	main growing period	ripening stage
Cotton	4o	12o	--
Beans	7o	125	8o
Groundnuts	45	9o	8o
Vegetables	8o	12o	8o
Barley	4o	9o	4o
Alfalfa	55	1oo	8o
Maize	5o-7o	8o-12o	5o
Sorghum	5o	12o	(8o)

Perennial crops	youthful stage	main growing stage	rest-or ripening stage
Avocados	9o	1oo	9o
Arabica coffee	5o	8o	4o-7o
Citrus fruits	9o	1oo	8o
Bananas	4o	11o	8o
Vine	(4o)	8o	(4o)

Calculation of E_o according to Penman (1956), modified for the highlands after McCulloch (1965). Water requirements after Brown and Cochemé (1969), Goldberg (1971), Laycock (196o), Nieuwolt (1973), Pereira (1957), Rijks (1965), Saxen et al. (no year), Wallis (1963).

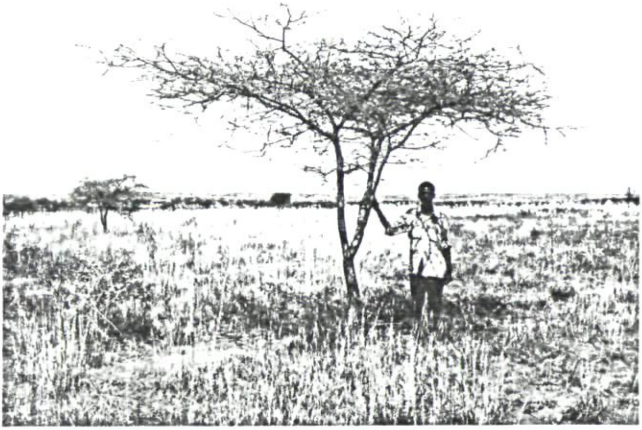

Plate 3 : Natural thorn-savanna, with Acacia albida and the grass species Cenchrus ciliaris in Ndalani

One of the few undestroyed areas. Replanting of these trees is necessary.

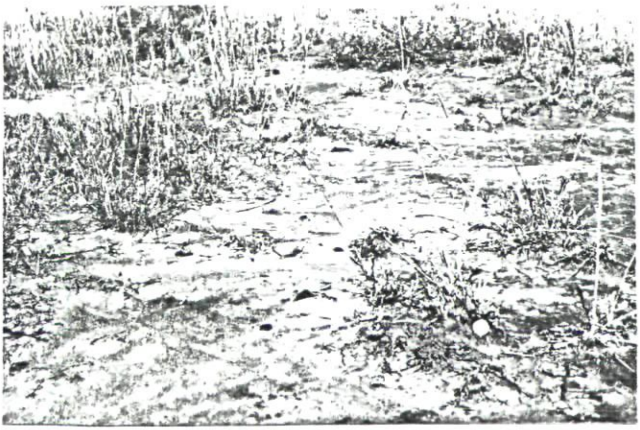

Plate 4 : Beginning overgrazing and soil erosion in Ndalani

Where the grass is missing, more than 3 cm of soil was eroded during a period of not more than 7 years, dispite the absence of slopes. This effect is indi= cated by the 10 cent coin near the free grass roots.

Plate 5 : Man-made desert in Ndalani

Overgrazing and soil erosion. The picture was taken after the relatively good short rains of 1976, on 4th March 1977.

Plate 6 : Soil erosion despite terracing (Ngoliba D)

Because of the high intensity of tropical rainstorms, terracing alone is not suf= ficient to prevent soil erosion.

The probability of reaching this amount in a suitable distribution for Katumani maize, is about 5o - 6o % during the long rains and 4o - 5o % during the short rains.

Therefore, in the low potential zone maize-agriculture should be carried out with care, because good yields are rare (except with special water-conserving measures, Chapter 5.1). Optimum conditions of water availability over the necessary period of three months occurred only in 2o % resp. 1o % of the rainy seasons.

If the sums of rainfall during the rainy seasons are considered without regarding distribution, 25 resp. 3o % reached the optimal value (Fig. 32), which, however, assumes very good moisture storage conditions and is not enough for economic production. But total crop failure in both rainy seasons occurred in only 15 % of all years.

Except for maize, following crops are cultivated: sorghum, bulrush millet, some finger millet, beans, cowpeas, pigeon peas, cassava and, as cash crops in small quantities: cotton, tobacco and sunflowers. Yields are normally low, averaging about 5 bags/ha for grain crops, 3 bags/ha for beans and peas, 3oo kg/ha for cotton and 45o kg/ha for tobacco. Trials with groundnuts during the short rains of 1976/77 were successful, but rains were exceptionally good. Groundnuts need a minimum of 25o mm of rainfall over three months in a similar distribution as for Katumani maize. Yield prospects are therefore not better (Fig. 32).

4.3 <u>Areas of third priority</u> (mpz: medium potential zone)

The mean annual precipitation is between 8oo and 95o mm (Fig.2), mainly because this area receives more orographic rainfall compared with the lower eastern schemes. The potential evapotranspiration reaches only 16oo mm per year, mainly because of lower temperatures and more cloudiness. Normally, the water deficit is still too large for most perennial cultures, as it reaches

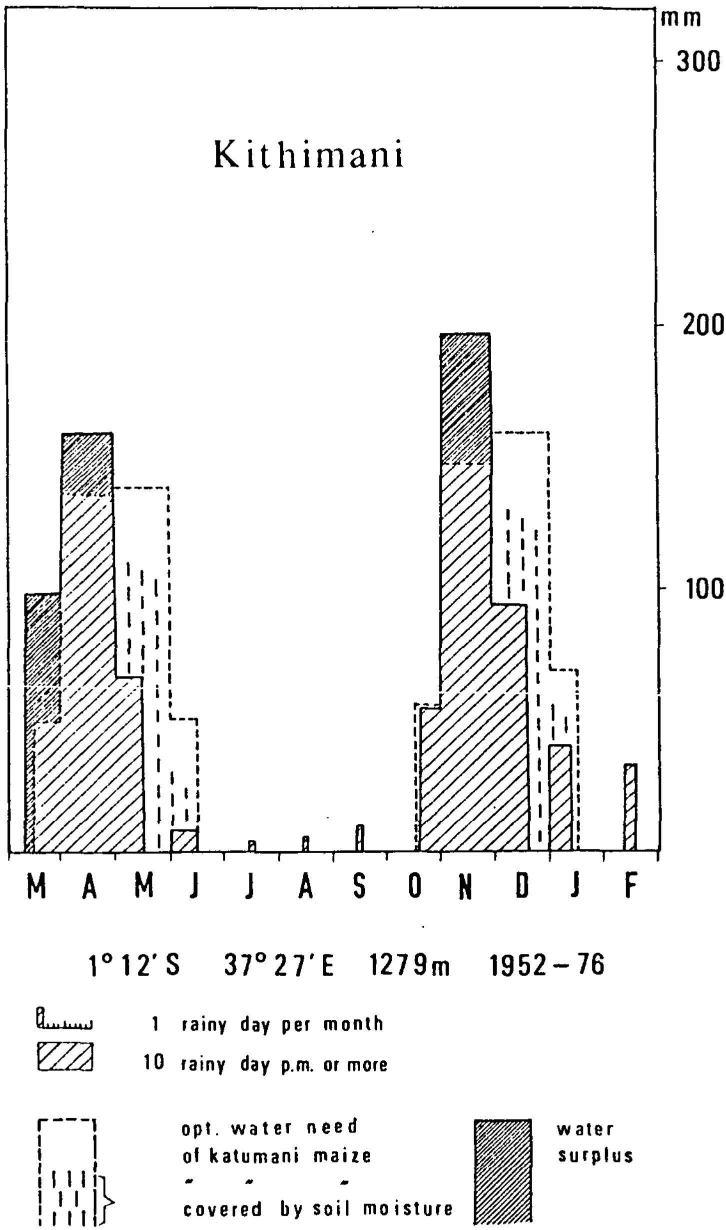

Fig. 24 Seasonal rainfall distribution at the most typical station of the second priority area, compared to the water requirements of Katumani maize

65o - 8oo mm per year (exceptions are sisal and castor). However, coffee and pineapples can be grown with some irrigation and mulching or covering of the soil during the four arid months of the long dry period and the two arid months of the short dry season. This is clearly demonstrated by the plantations in the western parts of this zone. With special measures, such as planting in holes with mulch, and some irrigation during the beginning stages of the growing cycle, bananas, papayas, mangoes (for subsistence use) and citrus fruits can be grown here.

Macadamia-nuts can be grown without these special measures. They only need some protection against termites. Passion-fruits would also grow well in this zone. However, the investments for trellises are probably too large in comparison to present producer prices.

Rains are concentrated during the periods between the end of March and the beginning of June and November/December. The mean value during the long rains is over 4oo mm and for the short rains between 35o and 4oo mm. The probability of receiving 25o mm, as the minimum for Katumani maize in a suitable distribution for this crop, is between 6o and 7o % for the long rains (Fig. 2o) and 5o - 6o % during the short rains. Gatuanyaga and Ndula have only a probability of 4o - 5o % in the latter case, as the short rains diminish towards the west. The risk of two consecutive crop failures is only about 1o % (Fig. 34). Therefore, this zone is well suited for the growing of Katumani maize as a subsistence crop. Most crop failures occur because of the short duration of the rainy periods, as even a slight reduction in the length of the rains makes the wet period too short for crop cultivation. Sometimes even May is without rain. Therefore, the yields vary strongly from year to year. For Katumani maize, they may be between 0 and 50 bags/ha. Yield variations depend not only on rainfall, but also on cultivation methods and soils. In the medium potential zone poor soils occur on granites and gneisses where maximum yields are 30 bags/ha. But on fertile volcanic soils, on the lava flows from the Nyandurus, which reach

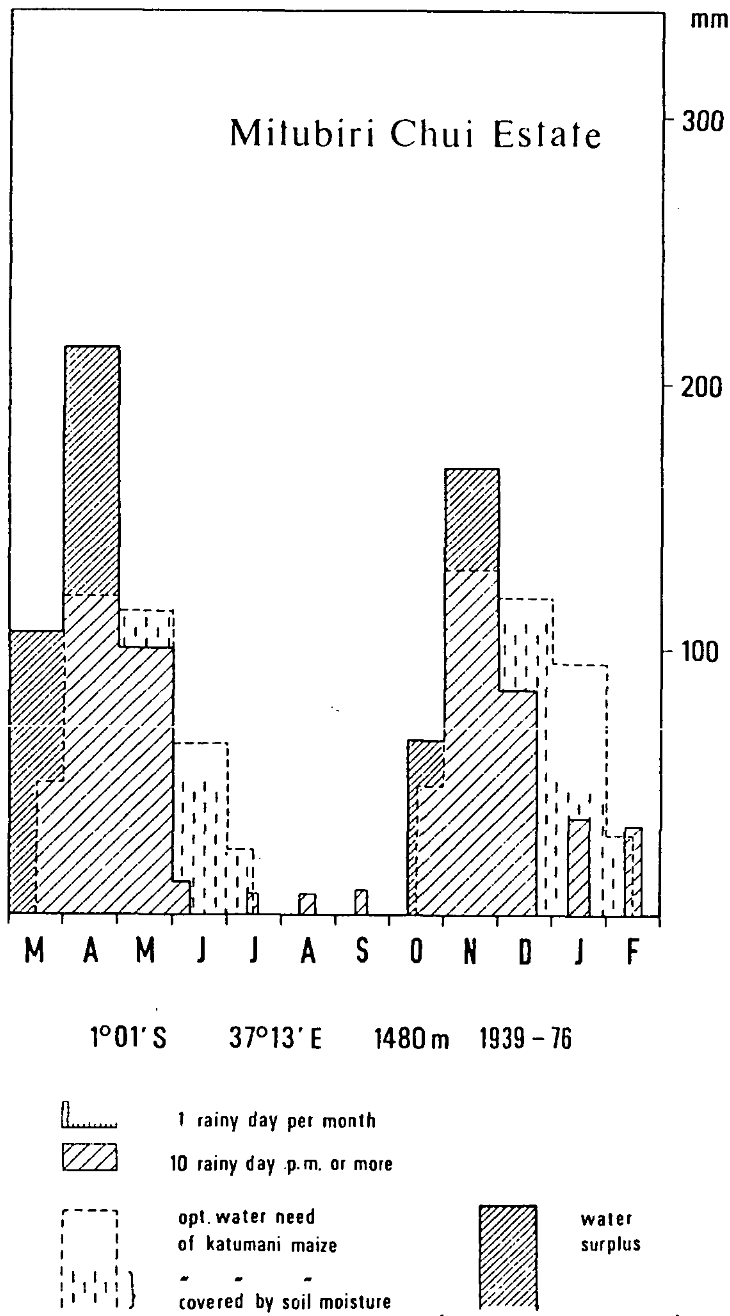

Fig. 25 Seasonal rainfall distribution at the most typical station of the third priority area, compared to the water requirements of Katumani maize

as far as Gatuanyaga, Ndula and the western parts of Ngoliba A, yields may be as high as 50 bags/ha when there is enough rain for three agro-humid months. These optimal amounts of rainfall of about 4oo mm must be distributed so that three and a half months consecutively meet the water requirements of Katumani-maize (Fig. 25).

During this period the monthly totals should be about 9o, 15o and 95 mm, and in addition, half a month with about 25 - 5o mm for the ripening stage. These conditions are fulfilled only during 15 % of the long rains and 1o % of the short rains. Because of the high risks of crop failures and the cultivation methods which need some improvement, mean yields are about 8 bags/ha on the granites and gneiss-soils and about 1o bags/ha on volcanic soils.

Beans produce more equal yields, with a mean of around 4 bags/ha, without large differences caused by soil types. The observed yield differences caused by climatic conditions are between 1 and 2o bags/ha for the fast ripening varieties, such as mwezi moja beans (one month-beans), which show a beginning fruit after only one month, ripening in two months. This variety is very suitable for the short rainy periods in this zone.

Cowpeas are also suitable for this seasonal rainfall distribution and produce similar yields. Pigeon peas were also planted, as they are drought resistant, but yields were reduced by insect damage.

As cash crops cotton and tobacco were tried. Yields for cotton during the favourable 1974/1975 season (short and long rains) amounted to about 6oo kg/ha. The low yields in 1975/76 of less than 2oo kg/ha were not caused by drought, but by lacking insecticides. In 1976/77 the yield went up to 960 kg/ha in Ithanga.

Tobacco was introduced by the British African Tobacco Cy. in 1975. Farmers produce air-cured leaves of about 7 oo kg/ha. It is still too early to estimate yields in relation to climatic conditions,but I would advise to continue the cultivation of tobacco in this zone. (The two earlier mentioned zones are too dry, the next one too cool and variates too much by relief for this crop).

1) In the diagram (Fig. 25) values are slightly different, since here, according to the planting dates, medio March is taken as the beginning, starting with half a month.

4.4 Areas of fourth priority (shpz: semi-high potential zone)

Here are the favourable $h_{1.3}$-climates with a mean annual precipitation of 95o - 1o5o mm (Fig. 2). The potential evapotranspiration is about 15oo mm. Though the annual water balance is still negative with a deficit of about 5oo mm, rainfall is sufficient for perennial crops such as coffee, bananas, pineapples, passion fruits, papayas, oranges, lemons and mangoes, where soils are not eroded and have a depth of at least one meter in order to store the water surplus during the rainy periods.[1] In this climate the rains produce usually sufficient surplus.

The long rains last normally from medio-March until the middle of June, with the maximum in April (Fig. 16). The mean rainfall total is about 45o mm (Fig. 4), compared to an estimated evapotranspiration of 3oo mm. The surplus therefore amounts to 15o mm, which can be stored in the soil and can be used to supply the minimum requirements of the perennial crops mentioned above, except during extremely dry years (Fig. 36). The short rains from the middle of October until the beginning of January have a mean rainfall of about 4oo mm (Fig. 6), which gives a surplus of around 1oo mm which can be stored in the soil. During many years, the other months also have some rain, bringing the annual total to 95o mm or more.

The humid seasons are long enough for many annual crops, as they last for three or three and a half months, and considering soil moisture storage even for five months each (Fig. 1o, 11). The rainfall reliability is relatively good. The probability of receiving the minimum of 25o mm for Katumani maize is about 9o % during the long rains and 8o % for the short rains (Fig. 36). But because a good distribution over three months is required the probabilities are reduced to a bit over 8o % resp. 6o % (Fig. 2o, 21). Due to the mean temperatures around 2o°C. which prevail here, Katumani-maize needs about four months for its growing and ripening period. In normal years the var. 511 gives higher yiel[redacted].

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1) Many perennial cultivations only need moisture amounting to about half of the potential evapotranspiration (sub-humid or semi-humid conditions).

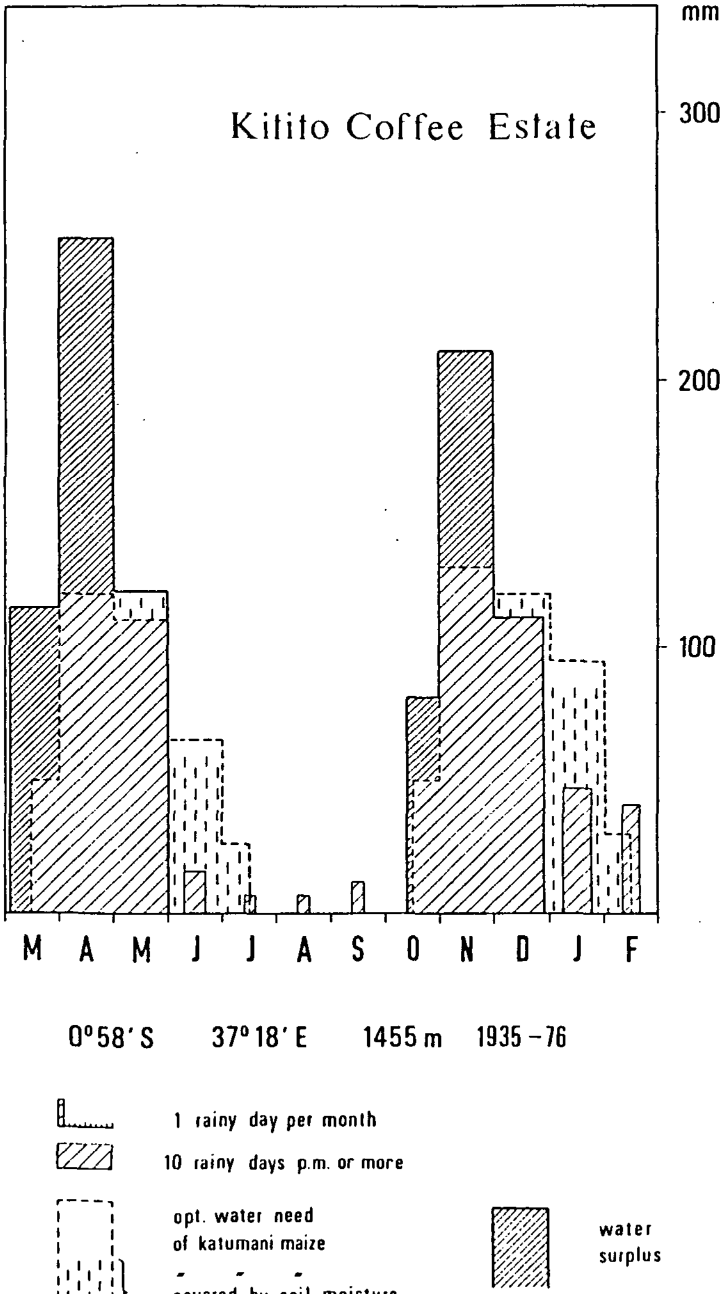

Fig. 26 Seasonal rainfall distribution at the most typical station of the fourth priority area, compared to the water requirements of Katumani maize

This means that the water surpluses of the three wet months should not be allowed to run off,but should be stored in the soil for the fourth month. Suitable planting methods are necessary (Chapter 5.1). Mulching is favourable to reduce evaporation from the soil surface.

According to information obtained, yields of Katumani maize are between 2 and 4o bags/ha (in this zone there are no volcanic soils with particularly high yields, as in the mpz). The mean yield is around 12 bags/ha. In this climate they should reach at least 2o bags/ha, but soils are poor on the granites and gneisses of this zone. Fertilization, especially of nitrogen, would be of great benefit. Protection against soil erosion is also important.

Optimum conditions for good crop yields in this temperate highland climate would mean water supplies of about 5o mm during the second half of March, 12o mm in April, 11o mm in May,65 mm in June and 25 m during the last half month. Such conditions can be expected with a probability of about 5o %. Mean values for the above months are 115, 25o, 12o, 15 and 5 mm. Therefore, the deficit during June and July can normally be covered by soil moisture. During the short rains the probability figures for good maize yields are less favourable (25 %).

As a cash crop, maize is not recommended,and it should be planted only as a subsistence crop, as the area has many steep slopes where erosion is a threat. For cash crops the perennial cultures are ecologically more suitable.

5. Proposals for the development of the areas

5.1 General proposals

I. Introduction of the matuta-system for protection against soil-erosion, for water conservation and for preservation of soil fertility

Because of the high amount of local relief, protection against soil erosion is very necessary. The short duration of the humid season makes conservation of water an important matter, and the rapid loss of soil fertility in relation to the dense settlement pattern requires measures to protect nutrients in the soil. All these functions can be supplied by the matuta-system, consisting of small ridges following contour lines, and strip mulching.

To prove the efficiency of this system I organized an experiment on the crop area of the Kwakulu primary school in Ngoliba n where slope and soil conditions are typical for the settlements outside the volcanic areas (Table 9). Soils are sandy red loams, which change at a depth of about 1o cm into a very hard and dense subsoil, caused by the transportation of loam particles, which is so hard when dry that the soil borer is difficult to use. This subsoil obviously takes in water very slowly. The infiltration speed of the dry soil is below 1o mm per hour. Therefore surface runoff values are very high already in the beginning of the rainy seasons. Two small maize fields of about 3 square metres each[1)] were cultivated: one in the usual way, the other one according to the matuta-system (Plate 8). Precipitation was recorded with a normal raingauge and a self-recording one.

---

1) A larger surface would have required a larger water container. However, the effect of the size of the area is rather small, as shown by experiments of Prof.G.Richter at the Bodenerosionsmeßstelle (soil erosion measurement Institute) of the University of Trier in Mertesdorf. Even for the small surfaces used here the containers of 18 litres were often too small and had to be emptied during rains. This loss of measuring time of about 5 minutes indicates, that the highest values of surface runoff (over 18 l/day) must have been even higher.

Plate 7: Anti-erosion dam in Ngoliba D

Planted with Panicum makarikanensis. Protects against the formation of erosion-gullies of larger size. This measure must be supported by small ridges following contour lines, as shown in Plate 8.

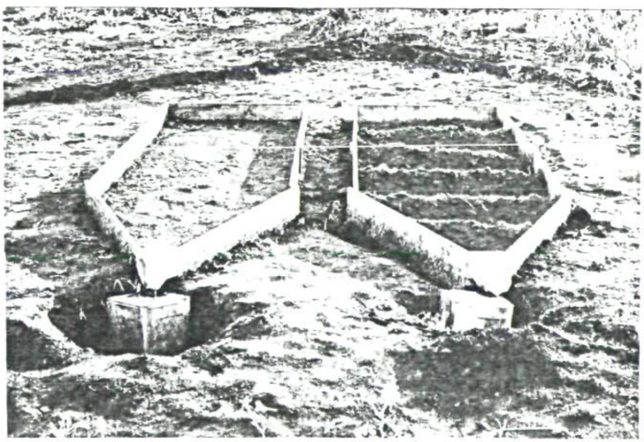

Plate 8: Experiment to reduce surface runoff with the matuta-system (Kwakulu Upper Primary School, Ngoliba D)

Both fields are 3 square meters and planted with maize. Despite the gentle slope (4.5%) runoff of the left field amounted to 540 litres, while on the field at the right, with the matuta-system, runoff and soil losses were negliable. Collection shields are covered with plastic and funnel into water containers of 4 gallons capacity.

[redacted]le 9: <u>Reduction of water losses with the matuta-system at Kwakulu, Ngoliba D, during the long rains of 1977</u>[1)]

[redacted]te	Rainfall(mm) = $1/m^2$	Runoff with usual cultivation		Runoff with matuta-system		Ratio of runoff losses
		$1/m^2$	% of rainf.	$1/m^2$	% of rainf.	
[redacted].3.	11.4	9.o	79	o.oo5	about o	18oo:1
[redacted].3.	2.5	-	-	-	-	-
[redacted].3.	47.o	22.3	48	o.o2	about o	1ooo:1
22.3.	3.o	-	-	-	-	-
26.3.	o.5	-	-	-	-	-
[redacted].3.	2.3	-	-	-	-	-
[redacted].3.	34.6	15.o	43	o.oo7	about o	21oo:1
2.4.	11.4	3.4	3o	o.oo4	about o	85o:1
4.4.	9.1	2.8	31	o.oo4	about o	7oo:1
[redacted].4.	38.1	11.9	31	o.5	1.3	24:1
[redacted].4.	17.5	5.8	33	o.oo7	about o	83o:1
[redacted].4.	7.6	1.7	22	o.oo2	about o	85o:1
1o.4.	7.o	1.7	24	o.oo3	about o	57o:1
11.4.	38.9	7.o	18	o.13	o.3	55:1
[redacted].4.	1.6	o.2	13	o.oo8	o.5	25:1
[redacted].4.	27.2	7.o	26	o.15	o.6	45:1
[redacted].4.	5o.o	8.o	16	o.35	o.7	23:1
21.4.	1o.o	7.o	7o	o.o8	o.8	88:1
23.4.	2.o	o.3	15	o.ooo4	about o	75o:1
[redacted].4.	31.5	7.6	24	o.27	o.8	28:1
[redacted].4.	1.o	o.3	3o	-	-	-
[redacted].4.	23.4	8.o	34	o.1	o.4	8o:1
1.5.	3.1	o.7	23	o.oo1	about o	7oo:1
[redacted]5.	28.1	9.9	35	o.o5	o.2	2oo:1
[redacted]5.	26.4	11.5	44	o.1	o.4	115:1
[redacted]5.	3.5	2.2	73	o.o3	1.o	73:1
6.5.	15.1	8.4	56	o.o5	o.3	17o:1
9.5.	17.3	9.2	54	o.o7	o.4	13o:1
[redacted]5.	8.2	5.9	74	o.o2	o.3	3oo:1
[redacted]5.	6.5	-	-	-	-	-
[redacted].5.	6.o	2.1	35	o.o3	o.5	7o:1
14.5.	26.5	1o.4	39	o.1	o.4	1o5:1
15.5.	15.7	8.5	54	o.o4	o.3	21o:1
[redacted]6.	4.4	o.7	18	-	-	-
[redacted]6.	5.1	1.1	22	-	-	-
7.7.	1.5	-	-	-	-	-
[redacted]als [redacted]r long rains	539.2 $1/m^2$	189.6 $1/m^2$	35 %	2.2 $1/m^2$	o.4 %	86:1

1[redacted] Slope 4.5°, sandy loams (at about 1o cm depth: subsoil of loamy character), maize cultivation. Records taken by the teachers Julius Kimani and Peter Njeroge.

The results exceeded all expectations (Table 9). Water losses by surface runoff with the usual cultivation methods amounted to about one third of the precipitation, with the matuta-system to only 0.4 %.[1)]

During the long rains, the loss of 183 mm from a total rainfall of 533 mm was not fatal for maize-cultivation, as the remaining 35o mm are sufficient for Katumani maize. But in normal years the rainfall is often only 25o - 35o mm and then the losses of about one third will reduce the available moisture below the critical minimum value for Katumani maize.

Increased evaporation, caused by the enlarged surface area of the ridges, is almost negligible, as total solar radiation per square meter being the most important factor controlling evaporation, remains the same. Moreover, evaporation is reduced by strip mulching as the soil is partially covered. The maize plants in the matuta field were stronger and larger and the cobs were larger (yields were not measured as the fields were too small and scales not accurate enough). The fact was surprising that the plants on the matuta field grew more rapidly and that the maize was ripe about one week earlier. This may be an important advantage as the rainy periods are short (Fig. 22).

It is clear that the reduction of surface runoff also reduced the soil erosion. Even on nearly flat lands erosion reaches about 5 mm per year (Plate 4). The protection by the matuta-system is much more effective than by terracing, which needs more labour and reduces the slope not enough, because with the high intensity of tropical rains already slopes of only 1^o may suffer from sheet erosion.

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1) In addition there is some loss by percolation into the subsoil (interflow), but because of the character of the soil these losses are small.

Table 1o: Loss of fertility and necessity of fertilization of a cultivated soil in Awakulu, Ngoliba D, in comparison with the undestroyed grassland of the nearby school grounds[1)]

Soil depth in cm	Organic matter in %	C in %	Max.waterholding cap.in weight % of dry soil	pH (KCl)	mg per 1oo g soil phosphoric acid	potassium	magnesium	borium
Field, since 4 years under cultivation (mainly maize)								
0 - 1o	1,6o	o.93	33.6	4.9	o.4	31.5	22.o	o.21
1o - 2o			39.3	4.8	o.4	29.o	23.2	o.o8
2o - 3o			34.4	5.o	o.1	31.o	28.5	o.o7
Grassland on the school grounds								
0 - 1o	2.46	1.43	4o.2	5.6	o.6	44.o	27.o	o.16
1o - 2o			4o.6	5.6	o.1	43.o	32.4	o.18
2o - 3o			38.5	5.o	o.1	38.o	27.4	o.o9
Reduction after 4 years of cultivation, in %								
	35	4o	15	1o	1o	25	15	18

1) Analysis of the soil samples were carried out by the Landeslehr- und Versuchsanstalt, Trier. Reduction values seem not very high, because the soil was already relatively poor in minerals.

Contour banks are also not very effective. An interruption of the slopes of course has the advantage that soil particles settle down again, but the shorter length of the slopes has little effect on the amounts of runoff (Footnote 1, page 73).

An effective conservation of soil fertility is caused by the compost-building of the strips of mulch.[1] The supply of organic material is especially valuable, as humus can retain about 25 times as many nutrient-ions as the prevailing kaolinite. Therefore also artificial fertilizer is retained for a much longer period and much less washed out. Moreover, mulching has a favourable effect on micro-organisms in the soil. Because of the short duration of the experiment and the lack of technical instruments, it was not possible to measure soil conservation results, but this favourable effect of the matuta-system is known from comparable areas in East Africa (southern Tanzania, Lake Victoria). In the Haraka Settlement Schemes it is of particular interest, as farming units are too small to allow rest periods for the soil.

The combination of these three advantages makes the matuta-system the best suitable for semi-arid areas in the tropics (modifications see Fig. 3o). It is preferable over the dry-farming method, which would cause large amounts of runoff, soil erosion and soil deterioration (as it is exposed to the hot sunshine) during its fallow period.

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1) Grass, weeds and crop residues are deposited in the areas between the ridges. The next year, the ridges are constructed over these deposits.

II. A fertilization programme is urgently required

Farm sizes are so small that most settlers are unable to give their fields a fallow period to restore soil fertility. On the poor, red latosols which occur over granites and gneisses (Table 2), where kaolinites prevail, the loss of soil fertility is so rapid, that after four years of cultivation, or even after two years when both rainy seasons have been used, a fallow period, lasting at least a few years, is necessary. Cultivation of leguminous fodder crops would be even better.

As Table 1o shows, the deterioration in soil fertility is very serious. In this case, soil samples were taken from the fields of a very good farmer, who has constructed erosion dams and who regularly fertilizes his fields with dung. Nevertheless, the fertility of his soil after four years of cultivation is serious. For comparison, soil samples from an undestroyed grassland, about 1o m away from the first sample, were analyzed. Though a larger number of samples would have been desirable to check the results, the tendency is very clear. Mineral contents in the cultivated soil have been reduced sharply.[1] Humus contents is 35 % lower, water holding capacity is reduced and 3o % of the silt in the topsoil was lost.

Humus can be returned to the soil by using the matuta-system with strip mulching, but fertilization is necessary. A simple system of making mineral fertilizers available on credit should be introduced. Where payments would be outstanding, it may result in reducing the number of animals being too high anyway. Problems could be expected in Ndalani and Nzukini where crop risks are very high. There, fertilizers are also very necessary, but they will be effective only if other measures to conserve water and reduce water losses are carried out simultaneously (Fig. 3o).

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1) The higher amount of phosphor in the subsoil may have been caused by a measuring error or by infiltrated cow-dung.

III. More extensive weather forecasts are necessary

Since the rainy seasons are short, it is very important that crops are sown as early as possible (Fig. 31). On the other hand, sowing should not take place during a short rainy period before the actual rains start, as the seed would wilt then. Therefore, farmers usually wait until several good rains passed and start sowing when they are sure that the rainy season has really started. In this way, many valuable days, in some years even weeks, are lost and this delay can be decisive with regard to crop yields.

Synoptic climate-stations and satellite pictures can, however, give reasonably accurate information about the position of the Inter Tropical Convergence Zone with its wide belt of reliable rainfall, and about the speed of its movement. This could be daily communicated by radio after the weather forecast. It would enable farmers to choose the right moment for sowing, especially if a radio service would inform the various districts about this. Transistor radios are found in most villages and information would be distributed quickly.

5.2 Proposals for separate areas

5.2.1 Proposals for areas of first priority (vlp-zone)

These are especially the problematic settlements of Ndalani and Nzukini. Situated beyond the normal limit of rain-fed crop agriculture, they should be converted into grazing areas, but this cannot be suggested as development of crop agriculture and degradation of pastures has progressed too far. Therefore, only an intensification of agriculture can be tried, but farm sizes must be increased first (p. 9o).

I. Introduction of new plant species

The present agricultural practice of using maize as the main crop gives rather uncertain results, as in about 6o % of the long rains and around 5o % of the short rains yields are practically nil. Good crops occur only in 2o % resp. 1o % of the seasons. It is therefore necessary to emphasize other crops, use special methods (Fig. [illegible]) and improve animal husbandry (p. 89).

Using some undemanding bulrush millet varieties[1] or dwarf-sorghum, crops which need only about 2oo mm of precipitation, the probability of obtaining good yields is increased to about 5o % during the long rains and 8o % in the short rains. If the distribution within the seasons is considered, these values are reduced to 45 resp. 55 %, but only in lo % of all years conditions would be totally unfavourable during both rainy seasons. (These figures are based on the data from the only example available, Yatta B 2 Vet. Station, Fig. 27). However, it should be remembered that these figures are only valid if runoff losses are reduced to the absolute minimum; if this is not done the number of crop failures would be about twice as high.

Regarding rainfall conditions, the best crops would be some Indian foxtail millet varieties (Setaria italica), which need only 15o mm in 4o days. For this crop, 75 % of all long rains and 9o % of all short rains at Yatta B 2 would have been sufficient. In Ndalani and Nzukini, probabilities are even more favourable (Fig. 28 and 29).
It would be advisable to obtain technical aid for the introduction of these new crop varieties from India (ICRISAT Institute Hyderabad for drought resistant bulrush millet and dwarf-sorghum varieties, Central Arid Zone Research Institute = CAZRI in Jodhpur for foxtail and hog millet varieties).
For the problem of peeling the very small grains of this millet CAZRI has developed easy manual peeling techniques by rolling it between rubber sheets.

Another possibility would be to introduce particularly unpretentious barley varieties from Northwest India or South Maroc which can mature with 15o mm of rain in 55 days. The problem of barley diseases (rust) in the warm climate can be overcome easier than the lack of sufficient rainfall with present grain crops.

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1) The Westafrican variety barbed bulrush millet, which is not eaten by birds because of its long awns. Dwarf-sorghum is also able to withstand short interruptions of the rains in a sort of dormant condition.

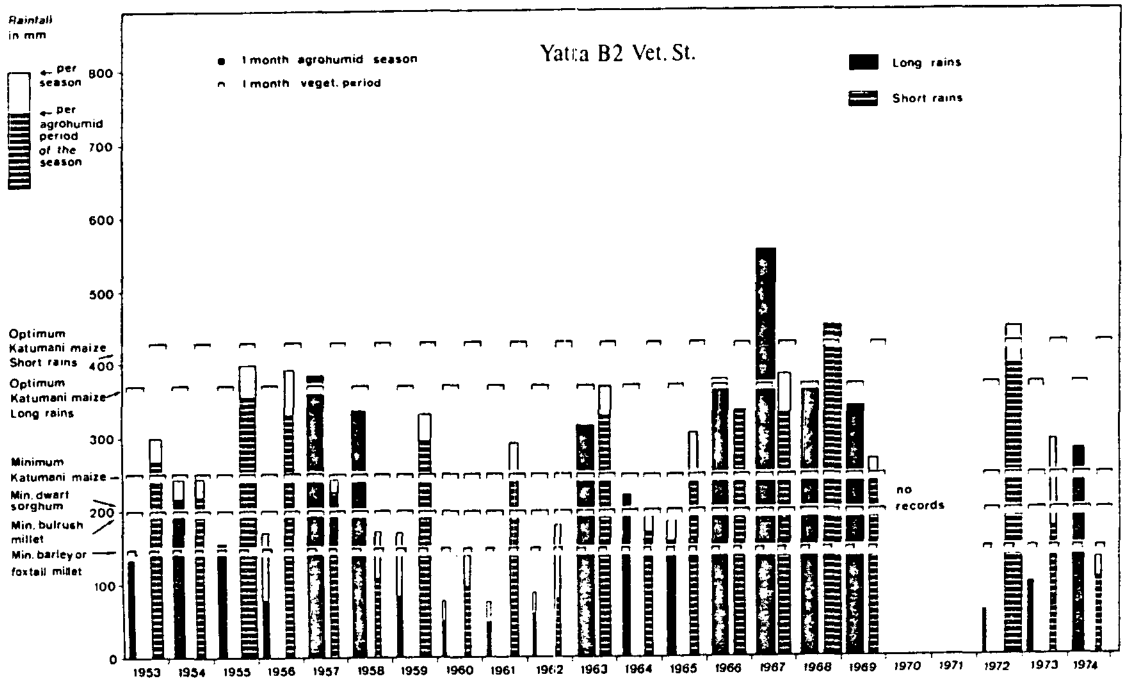

Fig. 27 Seasonal rainfall amounts at the most typical station of the first priority area, compared to the water requirements of some barley and millet varieties and the less suitable maize

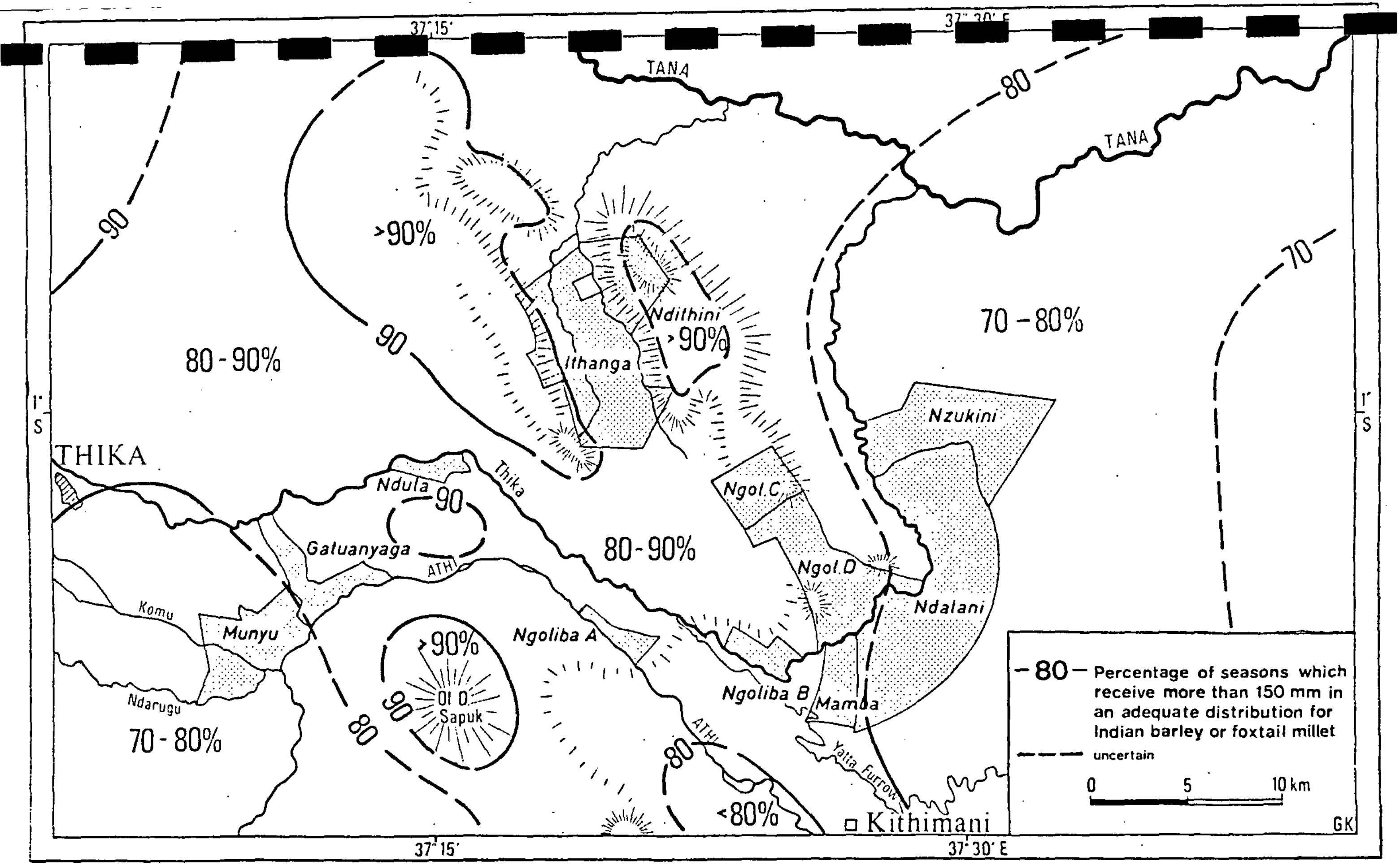

Fig. 28 Probability of receiving more than 15o mm of rainfall in an adequate distribution for Indian barley or foxtail millet during the long rains

See page 33

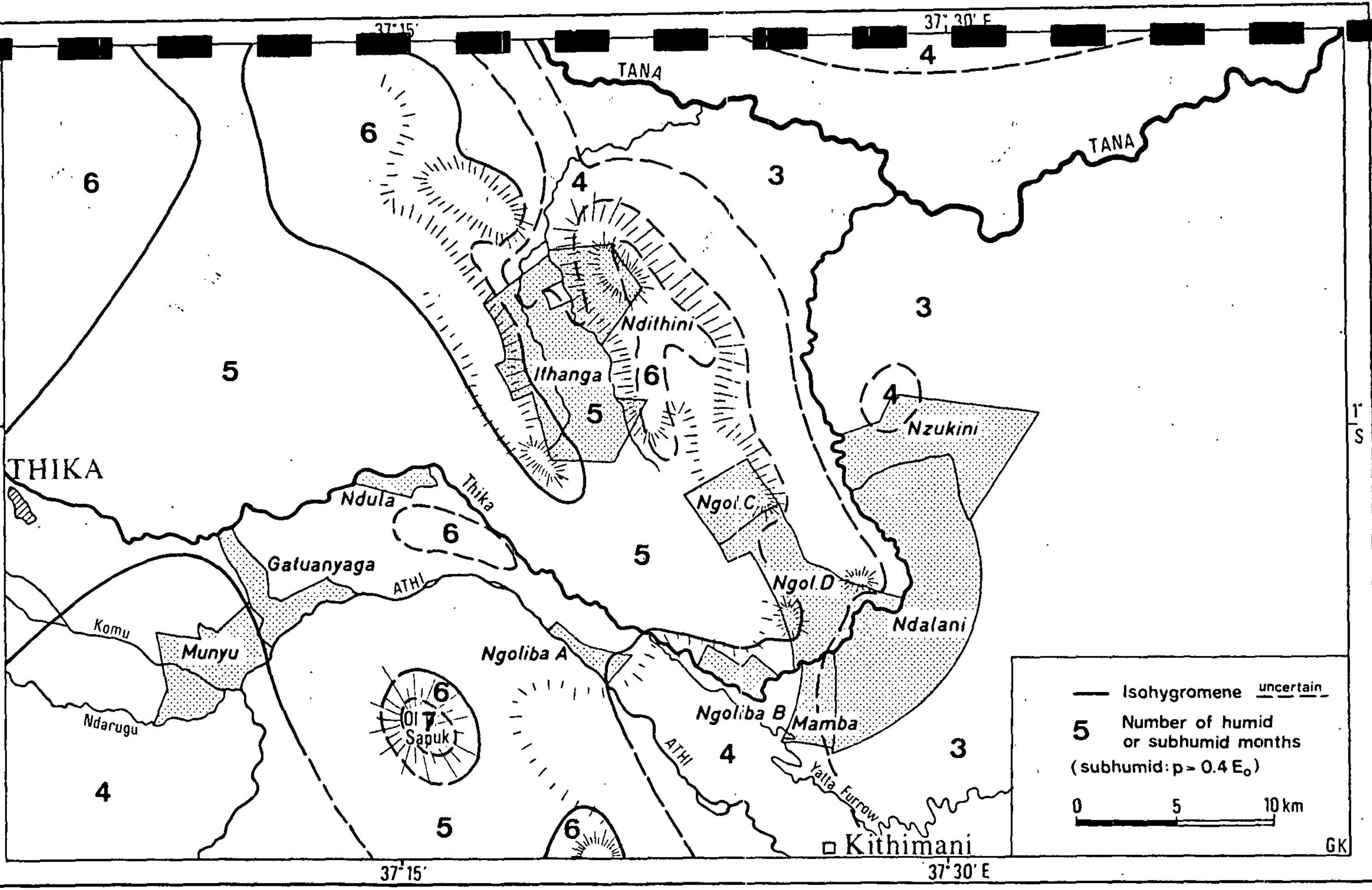

Fig. 9 Mean number of humid months per year

The limit for sub- or semi-humid months (precipitation larger than 4o % of E_o) equals approximately half of the potential evapotranspiration

In addition, other crop varieties could be considered, but their worth in this respect has not been well recognized. The buffalo-gourds (Cucurbita foetidissima) from Mexico and the southwestern United States[1] seem to be most important. These grow under very arid conditions and produce about 25oo kg of seeds per ha which contain about 33 % oil and the same proportion of proteins. This is about the same amount produced by groundnuts under much more humid conditions. In addition a large root is produced which accumulates about 1oo kg of starch after three years. The starch is mixed with bitter substances, but it can be washed with saline solutions. Experiments with the buffalo-gourds have started in Beirut, founded by the Ford Foundation, and these are rather promising. At least this crop could be used as a food crop in emergencies.

II. Improved techniques and water concentration

Even when longbarbed millet varieties, dwarf-sorghum and barley are introduced, settlers will still cultivate maize. To protect people from starving as a result of poor yields, it is suggested to introduce a combined system of water-harvesting, compost-formation and protection against soil erosion by using the matuta-system of small ridges (Chapter 5.1). However, every second ridge is left out and in between about 1o cm of topsoil is used to build the ridges (Fig. 3o). This will result in flat spaces of about 8o cm which, when the slope is about 4 - 5°, will have a surface runoff of at least one third of the rainfall (Table 9). This water will be stopped by the small ridges and be available to the plants. Probably the surface runoff is much higher, because of the hard and flat subsoil, as the above values were recorded on a loose topsoil.

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1) Nat. Ac. of Sc.: Underexploited tropical plants with promising economic value, Washington, 1975, p. 94 passim.

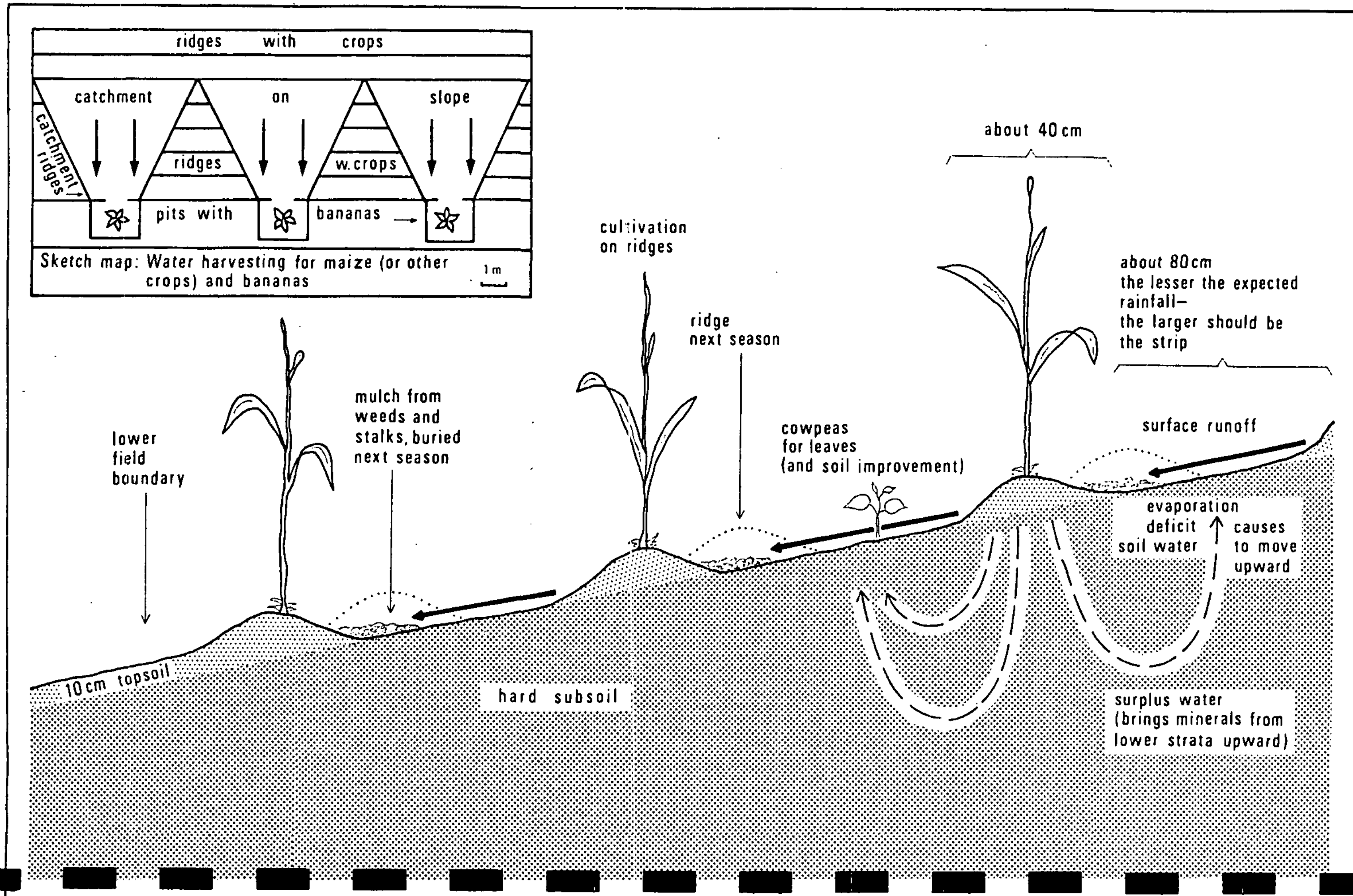


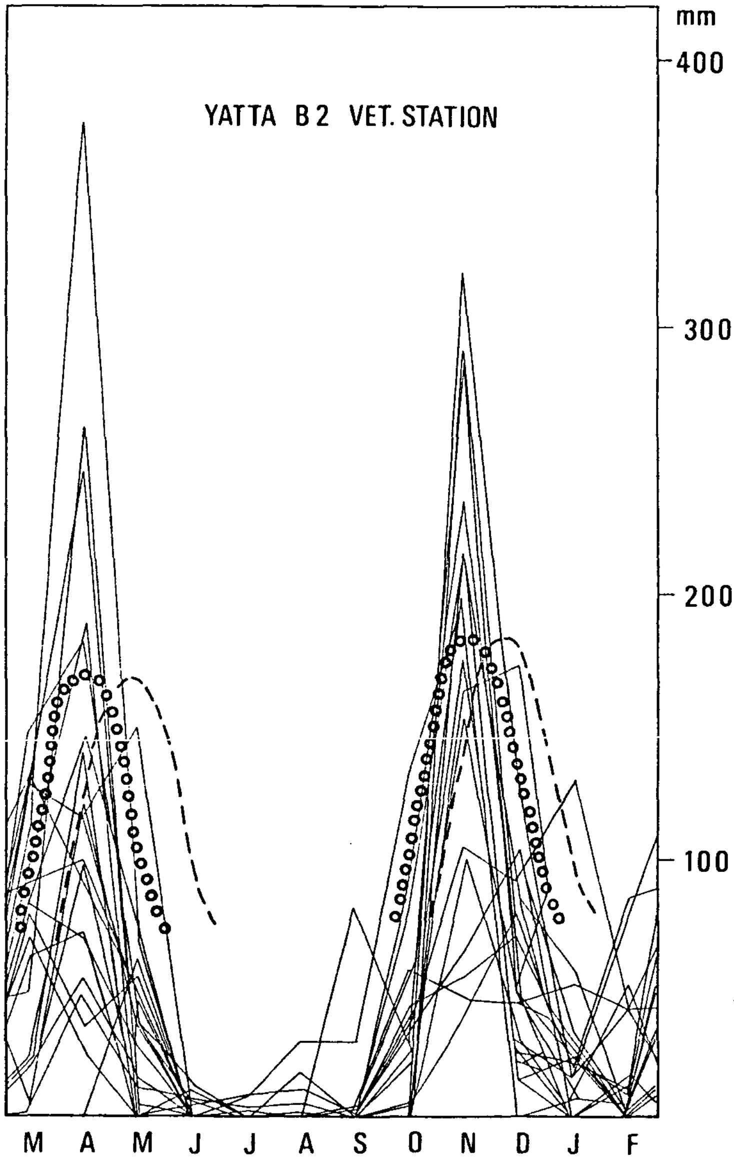
Fig. 3o Runoff agriculture with ridges, as a possibility of improving soil-water conditions in the

On gentler slopes the surface runoff will not be much lower, because the high intensity of tropical rainfall causes sheet floods on slopes as gentle as 1° and even on the peneplains slopes are rarely gentler. On steeper slopes the runoff is, of course, higher. But even when assuming only one third of rainfall as runoff, the available amounts of water near the ridges are increased by the decisive amount to reach the minimum requirements of most crops.

At a rainfall total of about 2oo mm, as is the case during many rainy seasons in this area, about 7o mm would be added. A total of 27o mm would be sufficient even for Katumani maize. The probability of reaching this minimum requirement in a suitable distribution would increase for the long rains from under 4o % to about 6o % and during the more reliable short rains from 4o to about 8o %.

Expenses for this improvement are small. Some demonstration fields and probably a folder with a drawing similar to Fig.3o would be sufficient for a start. When larger fields are improved by this method later, suitable plows and rollers of about 8o cm width could be used. Since farm sizes are very small, it could be considered to plant cowpeas on the ridges, as they would produce leaves which can be used as a substitute for spinach. Moreover, it would improve shading and increase nitrogen contents of the soil. The following year the flat strips would be turned and the new ridges erected over these areas. This would substitute for a fallowing period.

But even with these improvements of the water concentration, it will be necessary to adapt the vegetation period of maize to the shortness of the rainy seasons (Fig. 31). Preparation of the fields before the start of the rains and sowing as early as possible would be the first condition. Seeds pregerminated for 24 hours in water can shorten the vegetation period of about one week. For small surfaces, seedbeds irrigated by hand, followed by transplantation, can save up to two weeks.



o o o o Water needs of Katumani maize, improved cultivation

– – – – Water needs of Katumani maize, present cultivation

Fig. 31 The need to adjust the water requirements of maize to the seasonal rainfall distribution in the area of first priority

III. Fodder crops and fodder trees

Cattle is especially needed as a source of food and cash income during years of poor crop yields. For the growing of fodder crops rains are usually sufficient. The carrying capacity of the natural pastures is one stock unit per 4 ha according to the ecological zones by Trapnell. If one assumes 5 stock units per family, 2o ha would be needed for animals. However, overgrazing and soil erosion have turned the natural pastures into "man-made deserts" and the carrying capacity is much lowar. With the cultivation of fodder crops and the planting of fodder trees, the surface needed for the animals could be reduced to about 5 ha. Ecologically it is correct to use the short rainy seasons, which are often not sufficiently long to allow proper ripening of maize for the cultivation of fodder where their intensity is an advantage. In this climate, green maize would produce the highest yield of fodder per ha (about 2o t green fodder/ha per rainy season, compared with about 3 t/ha from the savanna grasslands with Cenchrus ciliaris as the main variety). Silage production is necessary for the dry seasons. Technical problems (cutting, pressing, protection against termites) would require technical aid and advice. Production of hay from good fodder grasses, such as sordan grass, would also be possible, but would result in less mass. An experiment with Guinea-grass in Ndalani[1] during the long rains of 1977 produced good results, as it ripened well with an amount of rain which was not above the mean value. In all cases, fertilization would be essential.

As a fodder tree the Acacia albida should be considered. Its fruits constitute a very good fodder. The Australian Cassia sturtii could also be planted, as its leaves, which contain

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1) Sorghum guineense planted by Technical Officer Mr. E.M. Sumbi.
2) about 75 kg per tree

a lot of protein, are preferred by goats.[1)]

Sheep and goats would suit better to the prevailing farm size than cattle. Indian dairy goats, for example Barbari, should be imported. About 13 of these can be kept per ha, with good management and Pangola grass (Digitaria decumbens) up to 45 can be carried per ha (DEVENDRA, 1974, p. 132).

Cattle is also necessary when farm sizes are increased (see below), because plowing will be necessary especially with the matuta-system described above.

IV. Enlargement of farms and resettlement of surplus population

As yields are in average only 3 bags/ha (p. 58), a family of 6 persons would need about 3 ha to obtain the minimum need of 9 bags grain per year. The same field cannot be used twice a year, because the soil needs a fallow period to restore its fertility and to store water for the next crop season (dry-farming method). In every rainy season the family could cultivate an area of about 1 1/2 ha which they could also cover regarding weeding.

Cultivation of pulses should be increased, because many varieties need only 2oo mm of rainfall in two months, amounts that occur relatively often (Fig. 27). A family needs at least 1 ha for this cultivation or they have to intercrop with grains enlarging those fields. Cowpeas and green grams (Vigna aureus), together with pigeon peas[2)] and mwezi moja beans are most suitable. One humid month producing at least green beans and, with cowpeas edible leaves, occurs in 9o % of all rainy seasons.

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1) 1ooo kg/ha, in mixed cultivation with grass or similar crops. All indications according to Nat. Acad. of Science: Underexploited Tropical Plants with promising Economic Value, Washington, 1975.

2) Pesticides are necessary for these crops.

Yields of pulses are lower, than those of grain crops, averaging 2 bags/ha, but they are more reliable because they have shorter vegetation periods. Cowpeas are particularly important, because even if the peas do not reach full maturity, leaves are produced which can be used as spinach. However, marketing to Nairobi is still poorly developed and should be improved in organization.

This totals at least 4 ha for food crops. To obtain larger surpluses for cash income, another 1 ha with pulses would be favourable. This would also help in rotation. As was indicated above, animal husbandry would need at least 5 ha, so for a healthy farm the size should be around 1o ha at least.

The present average farm size of 2.8 ha (Table 1) is therefore too small. To change this to larger farms, about 7o % of the present population should be moved out of the area or be provided with other means of income. However, the surrounding areas around the projects are already settled with irregular settlers with farms of about this order of size. Therefore, the best solution might be to give technical and financial aid to those families (about 8o %) who are not living on as "good" classified plots, to enable these people to move to new settlement projects near the coast (Hindi and Magogoni).

Presently, people make an existence by cutting the trees on their farms[1] and by exhausting soils and pastures. This will in time create a man-made desert. If present methods continue, the settlement projects will need about 3 million shillings per year to prevent famines and starvation.

V. Limited possibilities of irrigation and chances of dam construction

Irrigation would be a solution for the continued existence of the farms which are too small. However, irrigation is only possible on the flat plains between Yatta Furrow and Ndalani Market. A small canal has been dug as a Harambee-project, but

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1) They produce charcoal, which they sell to the city.

it is not working. Moreover, water rights have not been cleared. If irrigation is possible, bananas and mulberry trees (for silk production) would be suitable crops, because they give high yields per ha. If technical aid is available, vines (obtainable from the National Horticultural Research Station near Thika) could be introduced as an intensive cultivation with good sales prospects, both for grapes as well as for wine.

Small dams can be constructed for the breeding of fish and for watering livestock, but they would rapidly be filled by sediments unless some measures to stop soil erosion are carried out in the catchment areas. This is clearly shown by the existing dams (2 in Ndalani, 5 in Nzukini).

Water temperatures would generally be above 25^{o}C. Therefore, the reservoirs would be very suitable for the Chinese grass-carp (Ctenopharingidon idella) which grows very fast at temperatures of this order. This fish feeds on the waterpest (Eichhornia spec.) and also on fresh-cut grass. In this way an ecosystem with very high yields per surface area could be constructed.

5.2.2 Proposals for areas of second priority (lp-zone)

I. Fewer crop failures by using better cultivation methods

Here, in the projects of Mamba and Munyu the amounts of precipitation are much more favourable for the cultivation of maize than in the vlp-zone, but the growing periods are still very short. If one considers the storage possibilities for moisture in the soil (Table 2), about three agro-humid months occur on average during the long rains and two to three during the short rains (Fig. 1o, 11). But these months are not always consecutive, especially during the short rains. Fig. 33 shows that by sowing as early as possible and by using the methods described on p. 84, the growing period can be shortened and the cultivation may be better adjusted to the occurrence of rainfall.

The matuta-system (Fig. 3o) should be adopted for maize in the method of water concentration, for the other crops in the normal form of ridges along contour lines. Mulch tillage is an important way to reduce evaporation losses, as yields may be increased by as much as 5o % (ROCKWOOD and LAL, 1974).

II. More secure food supplies by cultivating different grain crops and cassava

Since the cultivation of maize carries a high risk of crop failures or low yields, grain cultivation should be extended to sorghum varieties, which are much less sensitive to dry periods. Below an elevation of 13oo m bulrush millet varieties, which need even less moisture, should be cultivated. Weaver birds, which eat a large part of millet crops, can be kept away by using the longbarded bird-rejecting variety with its long awns from West Africa, instead of ordinary bulrush millet which is popular in East Africa. Moreover, the cultivation of cassava should be compulsory as a precaution against periods of famine.

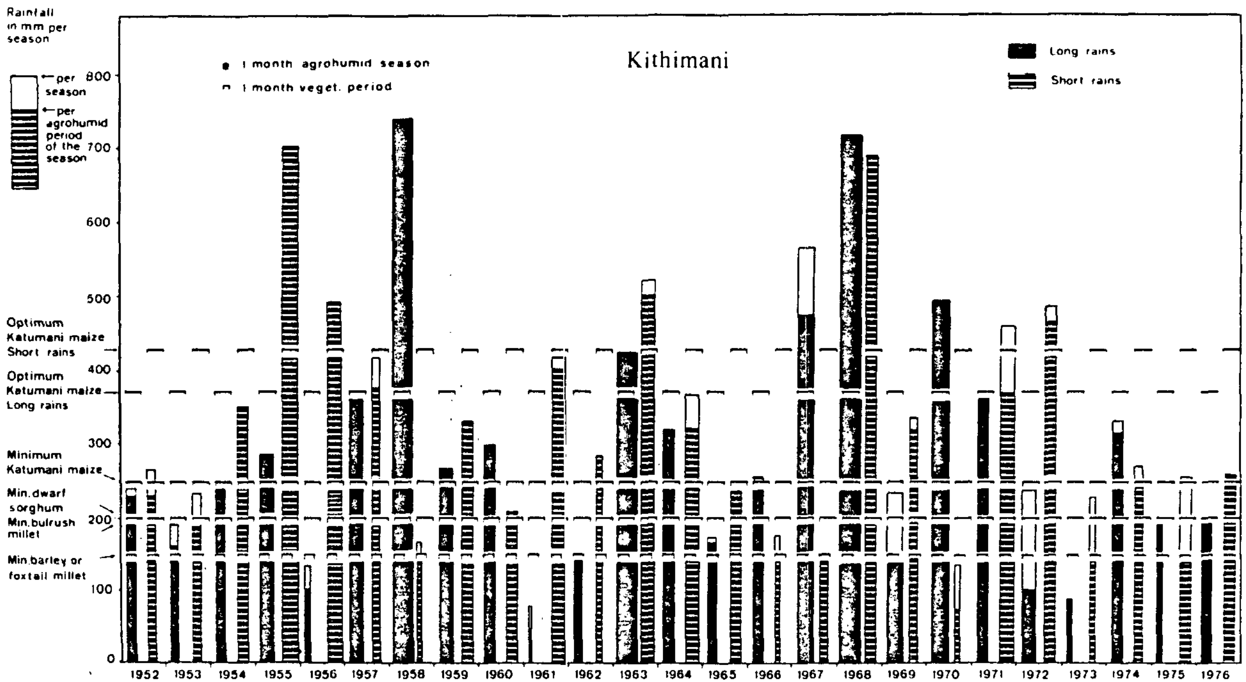

Fig. 32 Seasonal rainfall amounts at the most typical station of the second priority area, compared to the water needs of suitable grain crops

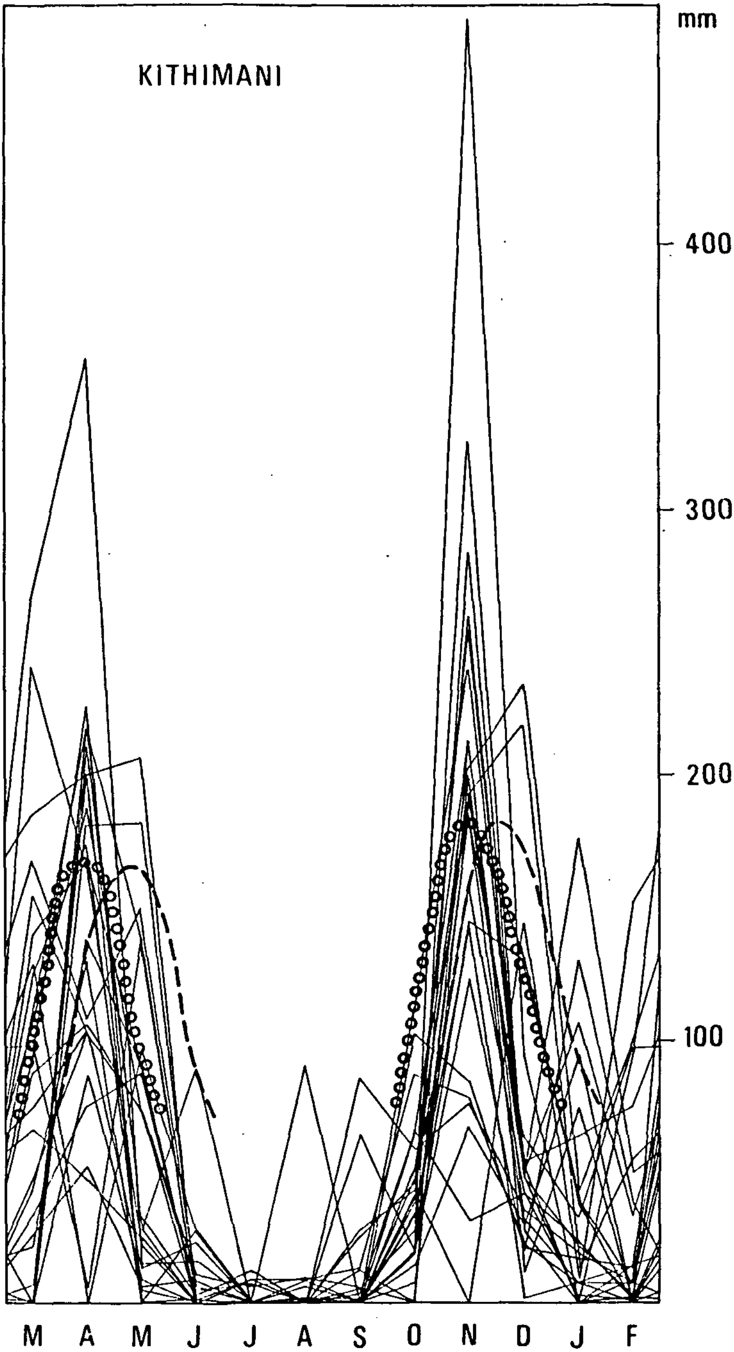

Fig. 33 Need to adjust the water requirements of maize to the seasonal rainfall distribution in the second priority area. Key on Fig. 31

This root crop grows very well on anti-erosion ridges as the soil is loose and the water supply is improved by water collected on the slope.

III. More pulses as cash crops

Castor seems to be the most suitable cash crop in relation to the climate, but its price is not attractive. It will be necessary to reorganize the marketing of this crop. At the present, farmers in Ngoliba D for example do not know how to sell the product, as nobody collects it.

Climatic risks would also be very small for sisal, but it is not a suitable crop for small farms. On the basis of the old sisal, which exists in Munyu and near Mamba as remains of the former plantations, it might be possible to organize a cooperative plantation (under experienced and strict management) which could be additionally supplied by the surrounding small farms (nucleus-system).

For the cultivation of cotton, tobacco and sunflowers the risk of crop failure is too high, and these crops should not be promoted. It is advisable to concentrate on peas and beans. Cowpeas and mwezi moja beans are most suitable, though yields are only 4 bags/ha, but one can also sell the green leaves and beans. Green beans can be dried, which may be useful for subsistence food during the dry periods.

On the black vertisols in Munyu, chick peas (Cicer arietinum) should be tried, as they grow well on this type of soil. In the hotter areas, such as Ngoliba D and Mamba green and black grams (Vigna aureus and V. mungo) would be able to do well with very little rainfall. The method of intercropping maize with pigeon peas should be continued as these crops supplement each other and the pigeon peas are very resistant to droughts.

Protection against insect pests (especially Heliothis armigera) is, however, necessary. Protection against game is also required, especially in Munyu for cowpeas.

IV. Enlargement of farm size

Considering the low average yields and the risk of crop failure, there is no doubt that present farm sizes, with an average of about 2 ha, are too small to provide an economic base of existence, except in the volcanic areas, where the soils are good. For subsistence and a minimum cash income of about 6o Shillings per month, a minimum farm size of 4 ha is required. At least 6 ha (4 ha on volcanic soils) are necessary to have income levels comparable to those of an unskilled labourer in the town, which would help to stem the movement to the cities.

V. Intensification of animal husbandry

Cattle is necessary for the settlers, both as a source of food and of cash income, as well as for draught animals when plowing. But the possibilities for grazing are limited, as overgrazing and soil erosion have been widespread. A programme of fodder production and of feeding cattle in the stables is needed, combined with the introduction of upgraded animals. Under natural conditions, this zone has a carrying capacity of one stock unit per 3 ha. The production of the natural grass cover, as far as it is still present, is about 4 - 5 t/ha of fresh grass per rainy season. Green maize could produce about 2o - 4o t/ha per rainy season of comparable fodder. Techniques to produce silage[1] should be introduced. The green maize should be mixed with sordan grass for this purpose, the latter would provide a permanent grass cover which is in any case an advantage.

Crop rotation of normal crops with leguminous fodder crops like Clitoria ternatea, Lablab purpureus or Macroptilium atropurpureum would considerably contribute to an improvement of the fodder situation and the soils.

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1) Protection against termites is necessary.
The new promising cross-bred gamma grass could also be tried.

Plate 9 : Conservation of pastures by rotation, Ngoliba B

A low hedge of thorny bushes is sufficient - but unfortunately this method is not used very often.

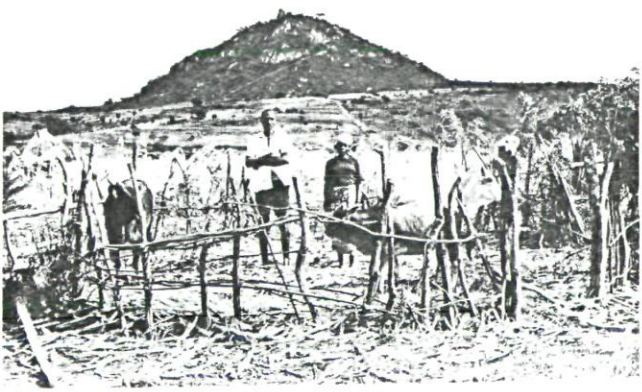

Plate 10 : Start of a fodder economy

Cattle is kept within the compound and fed with maize cobs (Ngoliba B).

Indigenous fodder trees, like Acacia albida, Albizzia amara or the Mexican evergreen tree Brosimum alicastrum would provide fodder with a high protein content also during the dry periods. This would be particularly suitable for goats and sheep which are better suited for small farms than cattle (p. 9o). It will be necessary to plant many trees anyway, as the supply of fuel is already becoming a problem.

VI. Small-scale irrigation and dam construction

In the Hamba-project near the Yatta furrow small scale irrigation would be possible, if the available water is sufficient. This condition is investigated by the Water Department. For irrigation cooking bananas as a food crop would be suitable and mulberry trees to feed silk worms. The production of silk cocoons has been tried in the nearby camp of the Kenyan Youth Service with great success. Bananas and mulberry trees would yield enough to make irrigation worthwhile. If problems of organization and quality standards can be solved, vegetable crops like green beans (French beans, haricots verts) could also be introduced. Combined production from rain-fed and irrigated fields would result in a constant supply over the seasons which could be the basis for a canning plant.

Where possible, small dams should be constructed. In the reservoirs, water plants, algae and fish could be introduced. Especially the Chinese grass-carp would find suitable water temperatures (as suggested already for the vlp-zone). At the moment the only dams in the lp-zone are in the Mumyu-project (7 small ones).

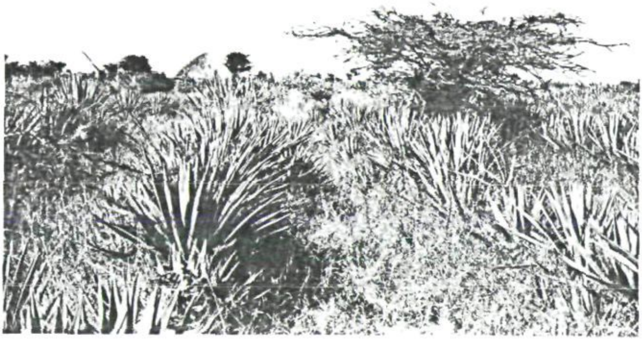

Plate 11 : Remnants of a former sisal plantation in Munyu

In the climatic area of lowest potential, sisal is the most reliable crop.

Plate 12 : Bananas cultivated in pits, with some additional irrigation from piped water Ngoliba A

5.2.3 Proposals for areas of third priority (mp-zone)

I. Intensification of cultivation and protection, resp. improvement of soil fertility

Actually it would be necessary to increase the farm size of around 2 ha (Table 1)[1] with about 5o %, at least in the non-volcanic areas. With the present practice of cultivation during both rainy seasons and every year, soils will be soon exhausted. Secondly, the relatively high risk of crop failure (p. 64, Fig. 34)can be compensated by larger farm sizes, and thirdly the pastures for cattle, which the settlers need as a security against crop failures, are not sufficient. If a reduction in the number of settlers is rejected because of the social complications, land use must be intensified and fodder crops must be planted. Possibly the distribution of artifical fertilizers on a simple credit- or barter-scheme (fertilizer against cattle) could help the farmers to get enough income from their small farms. Nevertheless new techniques, such as contour ridging and strip mulching (Chapter 5.1) and the application of cowdung should help to improve water storage, soil conservation and increase soil fertility. The growing of cassava as a precaution against famine should be compulsory everywhere. This crop does especially well on sandy soils. Fodder crops, such as green maize and napier-grass should also be introduced to increase yields of fodder per ha.[2]

Moreover, for the intensification of their land use the farmers need a water supply system as already exists in Ngoliba A. This would enable them to give supplementary irrigation to bananas and fruit trees (p. 66 passim).

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1) Only in the area of Ithanga Basin Extension farm sizes of about 4 ha per family are more suitable to prevailing conditions.

2) Experiments in this zone with a fully dried natural grass-cover of Hyparrhenia rufa yielded 15o gr/square meter, with not fully dried maize 2.5 kg/m^2, that is 1.5 t resp. 25 t per ha. This is the equivalent of about 5 t resp. 5o t per ha of fresh fodder. As the grass may be cut twice, the final comparison could be 1o against 5o t per ha.

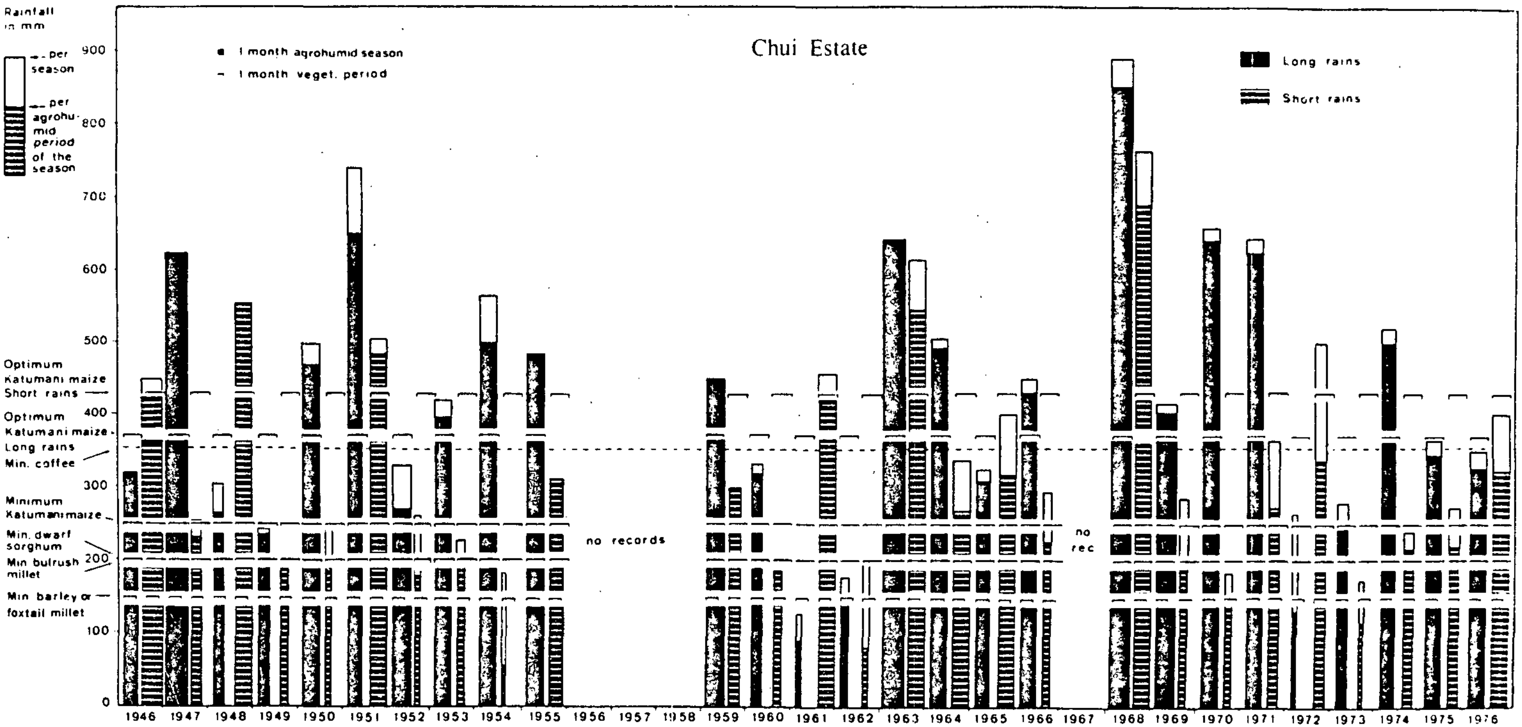

Fig. 34 Seasonal rainfall amounts at the most typical station of the third priority area, compared to the water needs of suitable grain crops and coffee

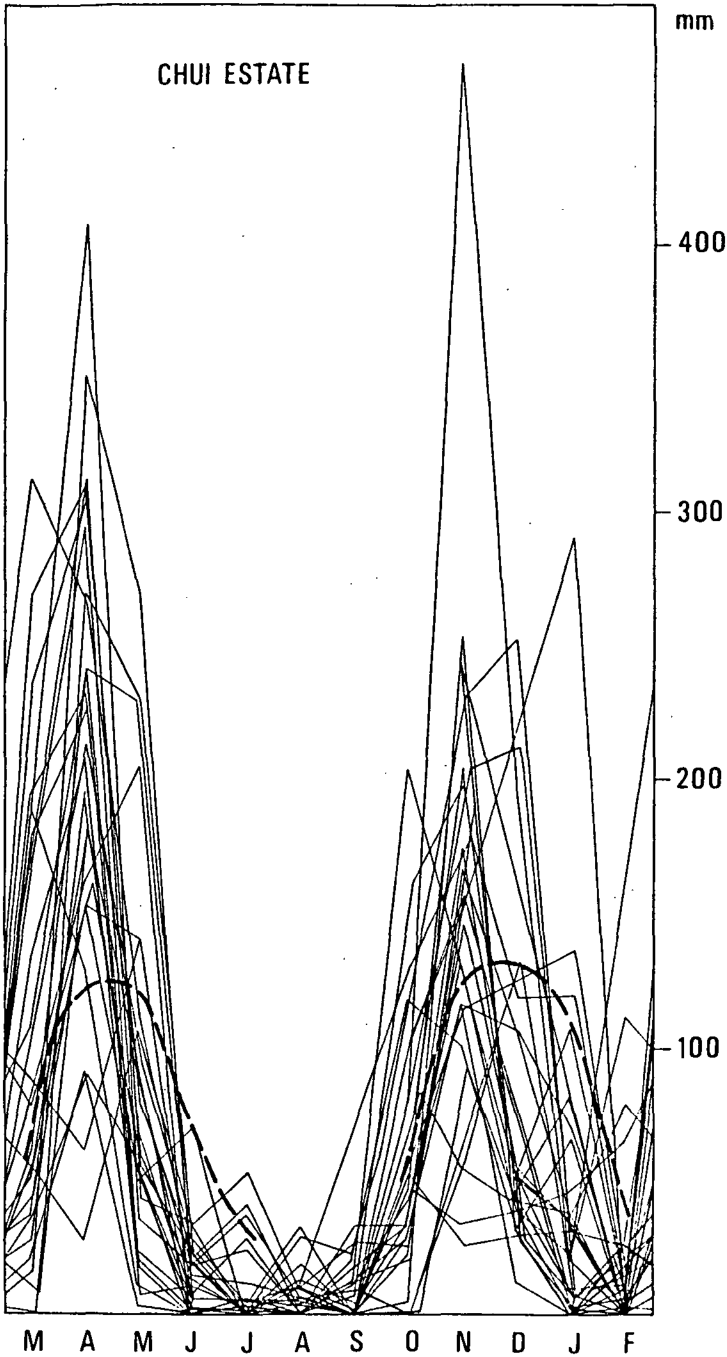

Fig. 35 Water requirements of Katumani maize compared to the rainfall curves in the third priority areas

Even coffee cultivation might be possible. During about half of all rainy seasons the rainfall is sufficient for this crop (Fig. 34). During another quarter the plants would survive, but during the remaining quarter of rainy seasons conditions are critical for this crop, so that the plants would partly wilt and die unless they receive some supplementary irrigation. Cultivation of coffee might be possible in these areas without irrigation if the bushes would be planted parallel to contour lines on ridges of about 5o cm height making the distance between the rows about twice as much as normal for coffee. On slopes, this system would bring a considerable concentration of moisture (Fig.3o). Between the rows of coffee it would be possible to plant leguminous fodder crops which should be cut early during dry years to provide more moisture for the coffee.

With all these measures of intensification and a good product like coffee, the farmers could attain a reasonable existence also on the present farms with an average size of 2 ha.

The smaller projects need protection against game animals. These projects are surrounded by large farms and plantations where the game find protection (Ndula, Ngoliba D and Gatuanyaga). Cowpeas in particular are eaten by game.

II. <u>Supplementary dams</u>

The construction of small dams by harambee groups, possibly aided by Food for Work, or by bulldozer, would have a beneficial effect in many ways (water and fish, p. 92). These dams are also very helpful in the supply of water for people and livestock during the arid seasons, as the water courses dry up. Piped water is still not available, but one project with Japanese technical aid is planned for Ithanga in 1978/79. Presently there are only three small dams near Ithanga, but they are not used for raising fish. Supplementary irrigation from these reservoirs would have beneficial effects at low cost.

5.2.4 Proposals for the areas of fourth priority

I. Perennial cultivation of cash crops

From the climatological viewpoint, the best land use in this area would be to concentrate on coffee and other perennial crops. In this area of high relief perennial crops are to be preferred over annual crops. Temperature conditions are good for coffee and the moisture supply is sufficient (Fig. 36, 37). Coffee-berry disease will not be a major problem as the climate is relatively dry which fact restrains dispersion. Irrigation is not feasible in this elevation. Mulching is favourable, especially for the conservation of soil moisture.

Apart from coffee, some other perennial crops are suitable: passion fruits have a ready market at the factory of Kenya Fruit Processors in Thika, the price to the producer rose from -.5o Ksh per kg 1977 to 1.5o in 1978. Papayas might be used to obtain papain and the fruits are also good fodder for pigs. Where wind protection is available, oranges of good quality can be grown, for instance the Washington navel breed. Young plantings of coffee, passion fruits or orange trees should be given soil protection (against overheating and intensive rainfall) by interplanting with beans which would also give an early yield.

II. Supplementary food supplies

As food crops, maize var. 511 and beans will be the main crops, but they should be supplemented. More cultivation of bananas, which grow well here, is advisable. Potatoes have been tried, but the results have been poor so far (yields of about 2o bags/ha according to official sources). Using the right techniques and varieties, considerably higher yields can be obtained (personal communication HOLLER). Blight resistant varieties and fungicides are necessary. Food supplies for the cattle can

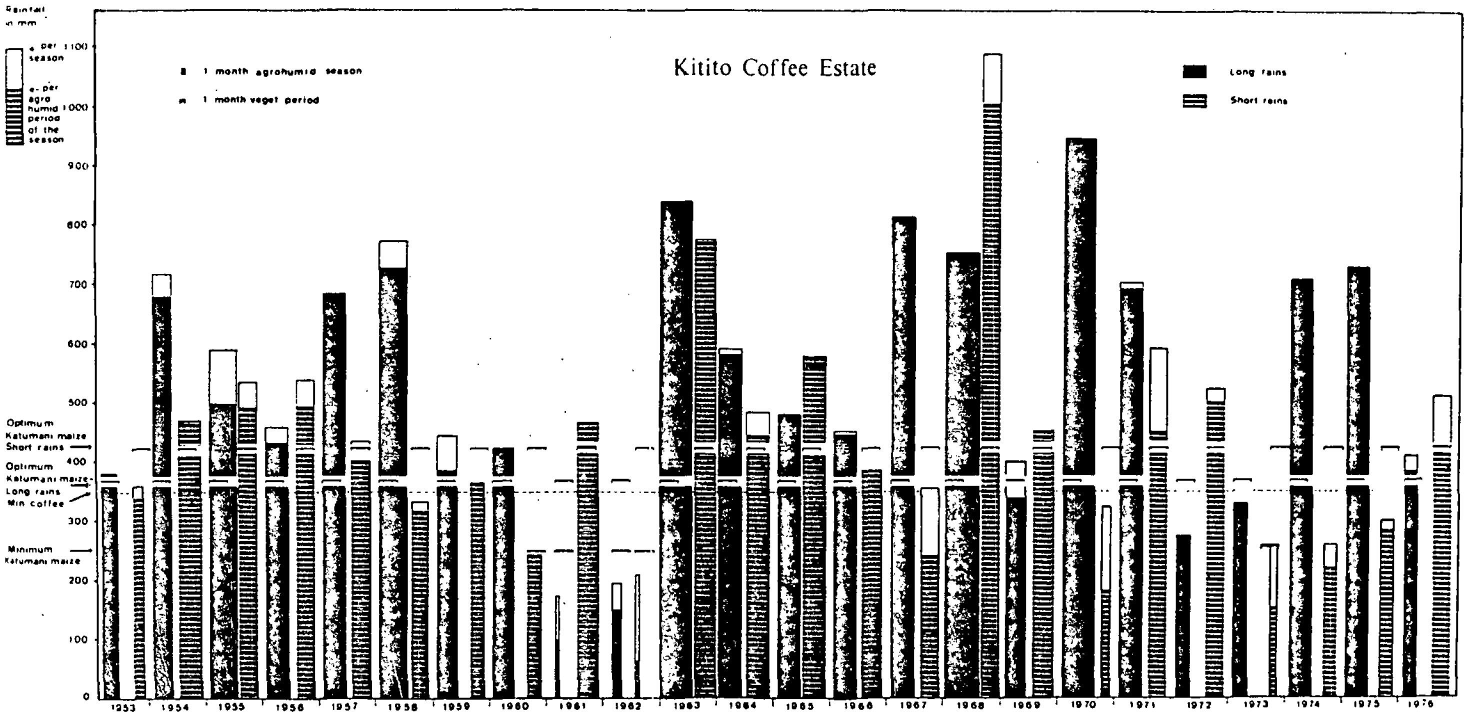

Fig. 36 Seasonal rainfall amounts at the most typical station of the fourth priority area, compared to the water needs of suitable grain crops and coffee

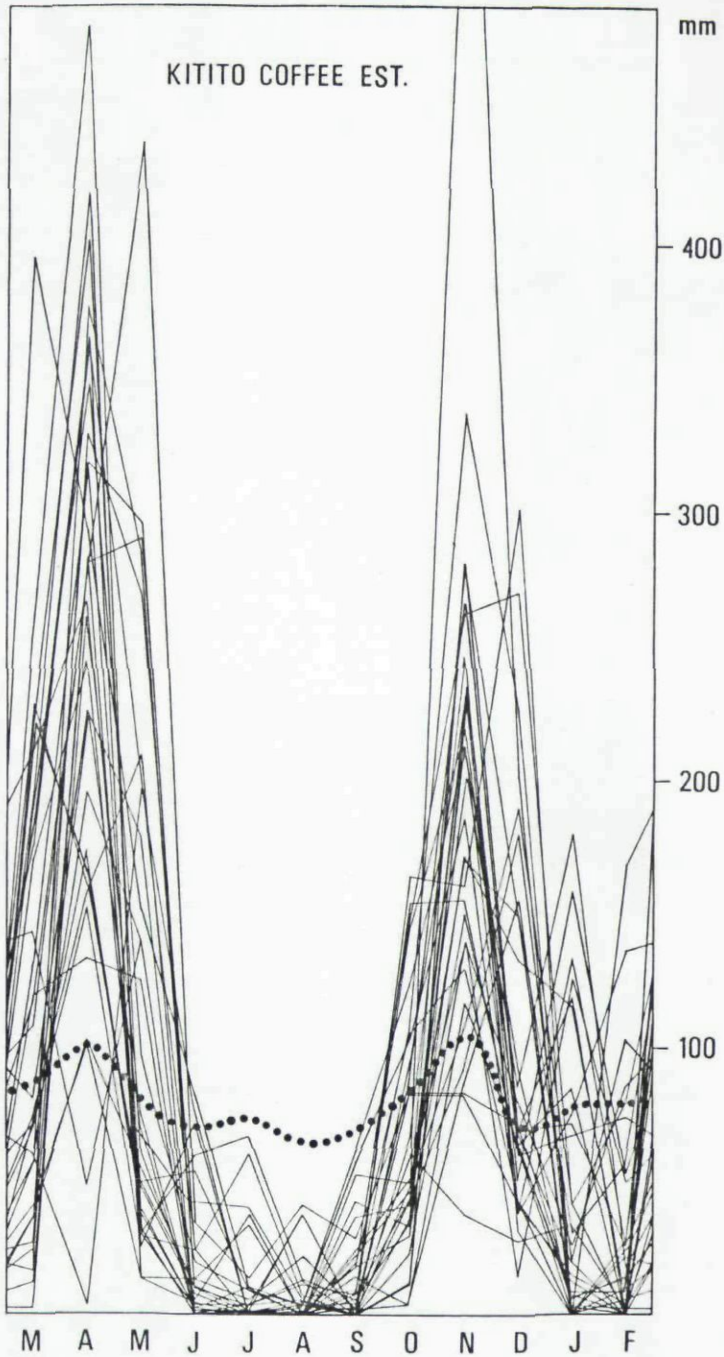

Fig. 37 Water requirements of Coffea arabica compared to the rainfall curves in the fourth priority area

Plate 13 : Experimental wine cultivation at the Nat. Hort. Research Station near Thika

Various wine varities grow relatively well with some supplementary irrigation.

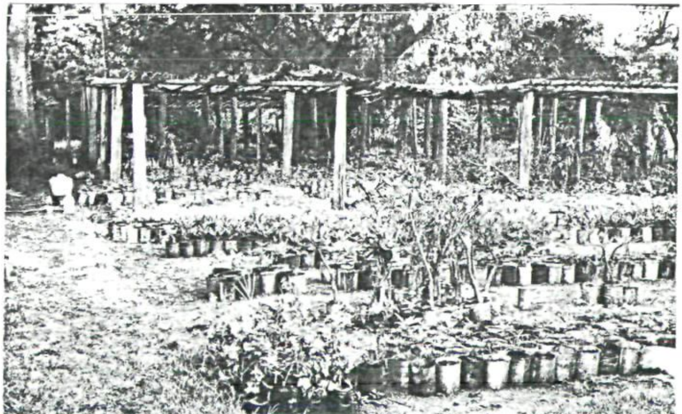

Plate 14 : Tree nursery at the Nat. Hort. Research Station near Thika

Although the young trees are cheap, they are not sold in the Haraka Settlement Schemes, because the nursery is too far away. Small secondary nurseries for sale-days in the Schemes are therefore necessary.

Plate 15 : A settler and his family in Munyu

Here, the main problem of the future is demonstrated very clearly - contrary to the theory that the number of children decreases with rising living standards. This is a rather successful settler, who enjoys a good income from his employment at a firm in Thika.

be improved by cultivating napier grass. Steep slopes should not be used, as at present, for the cultivation of maize, but they should be reforested.

6. Conclusion

Though development aid would have most effect in both semi-humid areas of higher potential (mpz and shpz), the population of these areas only need limited support in the form of a fertilization-, tree-planting-, fodder-cultivation- and cattle-improvement-programme. In the low and very low potential zones, however, considerable amounts of development aid are urgently required to prevent famines and further destruction of the natural resources. Priority should be given to the matuta-system with water harvesting (runoff agriculture, Fig. 27), because it reduces crop risks and prevents further destruction of the soil. The introduction of undemanding crops such as Indian barley, barbed millet from West Africa, dwarf-sorghum from Texas and buffalo gourds from Arizona should be promoted. But with all the help it is unavoidable that the mistake of creating farms which are too small for these semi-arid areas is corrected by resettling part of the population. Therefore development aid should be combined with the creation of new settlement areas near Lamu where the surplus population can find a new home.

The large number of children that many farmers have is alarming (Plate 15). The pressure on the land is intensified by this factor. Here is a possibility to introduce a comprehensive development aid project by creating old age support systems which would abrogate the need to have many children. To pay settlers over 65 years of age a monthly pension of 5o Shillings would cost very little at the present and later about 3oo ooo Shillings per year. This amount would probably save much more money which would be necessary to prevent famine from an exploding population.

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APPENDIX TO REPORT ON AGROCLIMATE OF SETTLEMENT SCHEMES EAST OF THIKA

EXAMPLE OF VERY LOW POTENTIAL ZONE

STATION: YATTA B 2 VET. STATION (NR. 9137076)

RAINFALL, IN MM, FOR PROBABILITIES

MONTH	2 OUT OF 3 YEARS LIMIT		4 OUT OF 5 YEARS LIMIT		YEARS
	LOWER	UPPER	LOWER	UPPER	OBSERVED
01	10.00	26.00	0.00	34.00	21
02	2.00	16.00	0.00	43.00	21
03	23.00	83.00	8.00	110.00	21
04	72.00	127.00	49.00	183.00	20
05	14.00	43.00	2.00	57.00	20
06	0.00	0.00	0.00	6.00	20
07	0.00	0.00	0.00	2.00	20
08	0.00	0.00	0.00	4.00	20
09	0.00	0.00	0.00	3.00	20
10	8.00	41.00	2.00	57.00	20
11	145.00	199.00	64.00	217.00	20
12	33.00	56.00	23.00	87.00	20
PERIOD I (MARCH-MAY)	153.00	213.00	97.00	310.00	20
PERIOD II (JAN-DEC)	392.00	497.00	349.00	577.00	20

NOTE: LIMITS WERE COMPUTED FROM THE LORENZ - CURVE USING LINEAR SMOOTHING.

EXAMPLE OF LOW POTENTIAL ZONE

STATION: KANGUNDO KITHIMANI D.O. (NR. 9137074)

RAINFALL, IN MM, FOR PROBABILITIES

MONTH	2 OUT OF 3 YEARS LIMIT		4 OUT OF 5 YEARS LIMIT		YEARS
	LOWER	UPPER	LOWER	UPPER	OBSERVED
01	11.00	38.00	3.00	66.00	25
02	6.00	27.00	3.00	57.00	25
03	41.00	112.00	10.00	142.00	25
04	105.00	180.00	77.00	203.00	25
05	17.00	83.00	9.00	99.00	25
06	0.00	8.00	0.00	14.00	25
07	0.00	0.00	0.00	9.00	25
08	0.00	0.00	0.00	5.00	25
09	0.00	5.00	0.00	15.00	25
10	22.00	49.00	19.00	67.00	25
11	45.00	202.00	80.00	242.00	25
12	36.00	53.00	25.00	95.00	25
PERIOD I (MARCH-MAY)	236.00	315.00	173.00	371.00	25
PERIOD II (JAN-DEC)	492.00	607.00	434.00	695.00	25

NOTE: THE LIMITS WERE COMPUTED FROM THE LORENZ - CURVE USING LINEAR SMOOTHING.

EXAMPLE FOR THE MEDIUM POTENTIAL ZONE

STATION: MITUBIRI CHUI ESTATE (NR. 9137053)

RAINFALL, IN MM, FOR PROBABILITIES

MONTH	2 OUT OF 3 YEARS LIMIT LOWER	2 OUT OF 3 YEARS LIMIT UPPER	4 OUT OF 5 YEARS LIMIT LOWER	4 OUT OF 5 YEARS LIMIT UPPER	YEARS OBSERVED
01	5.00	39.00	2.00	53.00	27
02	5.00	18.00	2.00	26.00	27
03	55.00	133.00	83.00	87.00	27
04	68.00	239.00	161.00	88.00	27
05	54.00	89.00	24.00	37.00	27
06	4.00	19.00	0.00	23.00	27
07	2.00	6.00	2.00	12.00	27
08	1.00	9.00	0.00	12.00	27
09	0.00	11.00	0.00	15.00	25
10	33.00	62.00	24.00	87.00	27
11	22.00	180.00	98.00	204.00	27
12	45.00	83.00	34.00	30.00	27
PERIOD I (MARCH-MAY)	303.00	462.00	259.00	511.00	25
PERIOD II (JUN-DEC)	566.00	716.00	515.00	.00	25

NOTE: THE LIMITS WERE CALCULATED FROM THE LORENZ - CURVE UDING LINEAR SMOOTHING.

EXAMPLE FOR THE SEMI - HIGH POTENTIAL ZONE

STATION: HITUBIRI KITITO COFFEE EST. (NR. 9037016)

RAINFALL, IN MM, FOR PROBABILITIES

MONTH	2 OUT OF 3 YEARS LIMIT		4 OUT OF 5 YEARS LIMIT		YEARS
	LOWER	UPPER	LOWER	UPPER	OBSERVED
01	10.00	41.00	3.00	85.00	31
02	8.00	28.00	3.00	58.00	31
03	67.00	157.00	40.00	97.00	31
04	188.00	291.00	156.00	346.00	31
05	51.00	142.00	34.00	197.00	31
06	6.00	16.00	3.00	31.00	31
07	2.00	7.00	0.00	13.00	31
08	2.00	6.00	0.00	13.00	31
09	4.00	18.00	0.00	27.00	31
10	44.00	85.00	32.00	107.00	31
11	147.00	225.00	112.00	247.00	31
12	63.00	92.00	44.00	157.00	31
PERIOD I (MARCH-MAY)	299.00	403.00	260.00	434.00	31
PERIOD II (JAN-DEC)	743.00	927.00	640.00	972.00	31

NOTE: THE LIMITS WERE COMPUTED FROM THE LORENZ - CURVE USING LINEAR SMOOTHING.