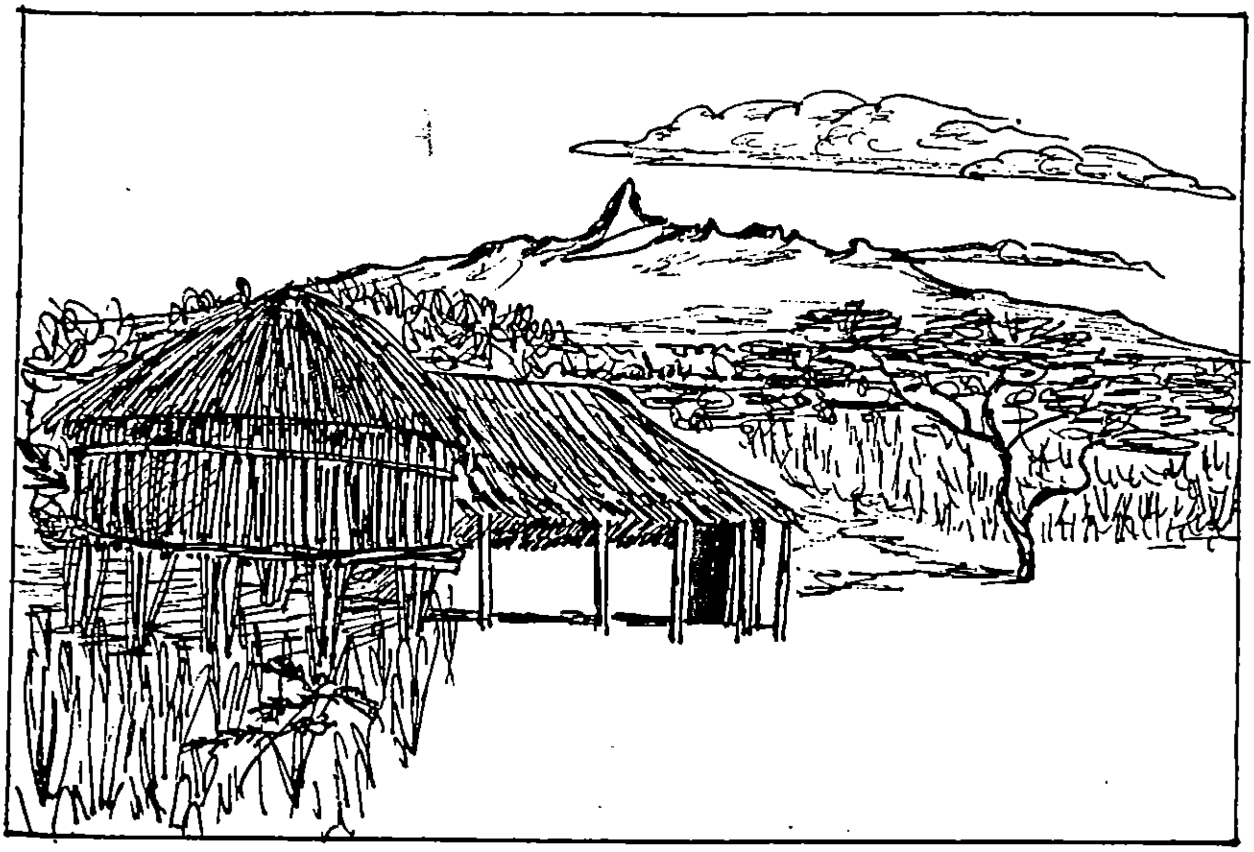
AN ECOLOGICAL SUITABILITY CLASSIFICATION, FOR THE CEREALS OF THE CHUKA AREA, KENYA



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PREFACE

The present report is written in the framework of my post-graduate studentwork, which I carried out from November 1985 till June 1986 at the Training Project in Pedology (T.P.I.P.) in the Chuka area, Kenya.

It contains the results of my research work, an investigation of the yields of maize, bulrush millet and sorghum, resulting in an ecological suitability classification of the area for these cereals, the staple food for the major part of the population in this area. Besides it gives some general information on geology, vegetation and agriculture in the area and information about the excursions made during my stay.

The main reason for the strong emphasis on the research work in this report is the fact that it required all my attention and I needed even more than the available time to complete it.

ACKNOWLEDGEMENT

First of all I want to take the opportunity to express my gratitude to the people of the Chuka area, giving me the opportunity to do my fieldwork and being of a great help during that period of fieldwork; in spite of the fact that they know from experience that this kind of study will not contribute in any direct or indirect way to the solution of their daily problems. The contrast of their daily problems, often concerning the food provision, and my actual work argues the legitimate character of this kind of work.

Furthermore I want to express my gratitude to all the fellow workers of the T.P.I.P., especially Alfred Odupa Arunga for his work in the laboratory, Ndwiga Mbarire for being my driver during my recovery of a motor accident and last but not least Jane Njoki Mbogo being my daily interpreter and companion during ten weeks of fieldwork.

I am grateful to Dr. Ir. T. de Meester and Ir. D. Legger in their function of principal of the project, giving advice and being responsible for the available project facilities during my stay in Chuka, Kenya.

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LIST OF ABBREVIATIONS

AEG Agro Ecological Group
KMD Kenya Meteorological Department
KSS Kenya soil Survey
LC Land Characteristic
LQ Land Quality
LU Land Unit
LUT Land Utilization Type
NAL National Agricultural Laboratories
T.P.I.P. Training Project in Pedology

GLOSSARY

Bembe local name for maize
Githeri plate of cooked beans and maize mixed with bean leaves
Mwere local name for bulrush millet
Nufia local name for sorghum
Shamba kiswahili word for cultivated field
Ugali maize/sorghum porridge
Uji millet/sorghum porridge

1. INTRODUCTION

1.1. Choice of the institute

During the last year's course, 1984-1985, I was very much concerned with qualitative and quantitative land evaluation. I wrote in cooperation with Hoogerbrugge (1985) for the qualitative land evaluation course a small report on crop requirements and maize-bean inter cropping in the Chuka area, Kenya. The Training Project in Pedology (T.P.I.P.) of the Department of Geology and Soil Science, Agricultural University Wageningen was still looking for a student in tropical agronomy who wanted to be engaged in land evaluation. As I was looking for a possibility to carry out my studentswork somewhere in the tropics, the decision was easily made.

1.2. Background of the T.P.I.P.

The Chuka project (April 1985-May 1986) is the third phase of the Training Project in Pedology) of the Agricultural University Wageningen in Kenya. Previous phases were the Kisii project (1973-1979) and the Kilifi project (1979-1982). All the activities of the T.P.I.P. are carried out in close consultation with the cooperating agency, the Kenya Soil Survey (KSS), part of the National Agricultural Laboratories (NAL) of the Ministry of Agriculture at Nairobi.
The objectives of the project are:

a. to produce a reconnaissance soil map (1:100.000) of the Chuka and Ishiara mapsheets, both scale 1:50.000, of the Survey of Kenya, together with a detailed report and a land evaluation to assess the suitability of a number of land uses.

b. to train post-graduate students of the University of Wageningen, the Netherlands, in soil science, agronomy, vegetation and agricultural economics. The training consist of graduate students-work (5-6 months period) as well as research work for Msc-thesis.

The selection of the project area took place in full cooperation with the KSS. The funds for the project are provided by the Agricultural University Wageningen, the Netherlands.

1.3. Objectives of the study

In general the underlying study deals with the first project objective as far as it concerns the land evaluation and of course the second project objective.
The specified objective of this study is:

> to produce an ecological suitability classification of the area for the cereal crops, within the framework of land evaluation, based on data of climate, soil, crop performance and the crop requirements.

The suitability classification will be carried out on reconnaissance scale (1:100.000). The intention is to make a description and to draw a map, of the different suitability classes with the main constraints for the three cereal crops, maize, millet and sorghum.

The procedure is two fold:

On one hand data on climate, soil and crop requirements are gathered to compare the land qualities with the crop requirements. This method provides a suitability classification, which can be called theoretical and is based on natural factors like climate and soil without any interference of man.

On the other hand data on crop performance are gathered. These data provide information of the suitability of the land under the actual circumstances of the climate, the soil and the level of input and farmmanagement. This practical method will show the differences in farmmanagement and input level. Besides the yield levels of the crops under the actual different environmental circumstances are estimated.

The combination of this theoretical and practical method gives the possibility to compile an ecological suitability classification partially based on apparent constant factors like climate and soil, and on the actual growing circumstances of the crop during the second rainy season 1985/1986.

The actual situation of crop performance will change every season due to climatological variation, change in soil conditions and variation in farmmanagement and input level. So the final result of this work is just an indication of the suitability of the different sites in the area for maize, millet and sorghum.

1.4. Project area and choice of the survey area

The project research area is located in Eastern Province, on the south-eastern footslopes of Mount Kenya, just south of the equator (latitudes 0 15'S and 0 30'S, longitudes 37 30'E and 38 00'E), see fig. 1.1. It comprises the Chuka (122/3) and the Ishiara (122/4) mapsheets of the Survey of Kenya. The area measures 55,50 km from east to west and 27,75 km from north to south. The project area is intersected by the borders of three districts, viz. Embu district south of Thuchi river, Meru district north of Thuchi river and Kitui district east of Tana river, see map 1. (reference map), Appendix A.

For the soil mapping, -description and land evaluation, the area is divided in two from east to west going sample strips, see Fig. 1.2. and map 1. One in the South (sample strip A) on the border of Embu district along the road Rukuriri, Kanyuambora, Ishiara, Ciangera and Katama up to Mumoni forest. The other one in the North (sample strip B) along the road Gachima, Chuka, Kaanwa, Kanjuki, Kathwana and Materi crossing Tana river just north of Kierera forest.

The survey area, where the ecological suitability classification will be carried out, encloses all parts where cereal crops are cultivated. This means the whole area except of those parts, which are covered by forests. The fieldwork, gathering data on crop performance, was only carried out in the sample strips A and B.

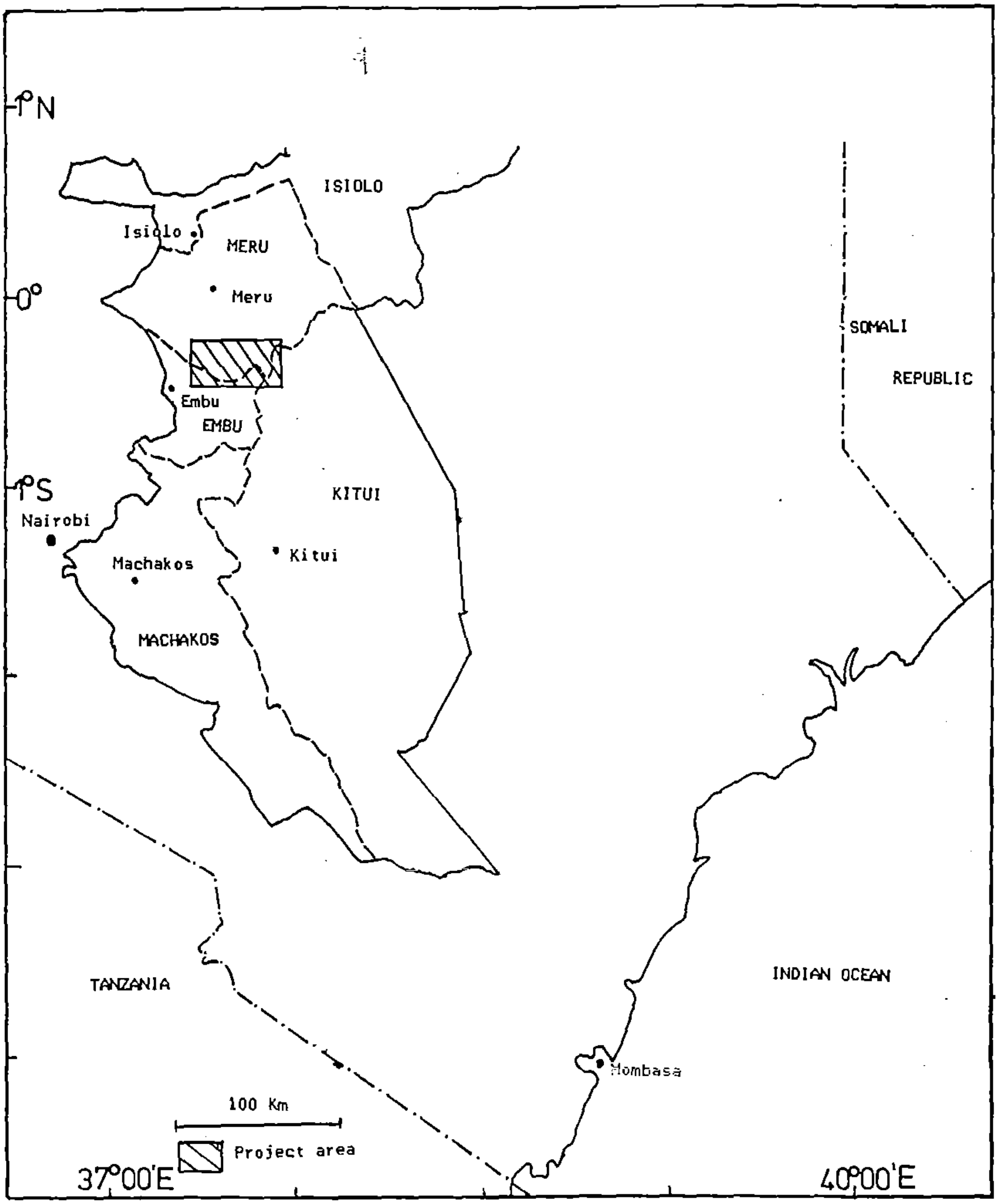


Fig 1.1. Map showing the location of the project area in Eastern Province.

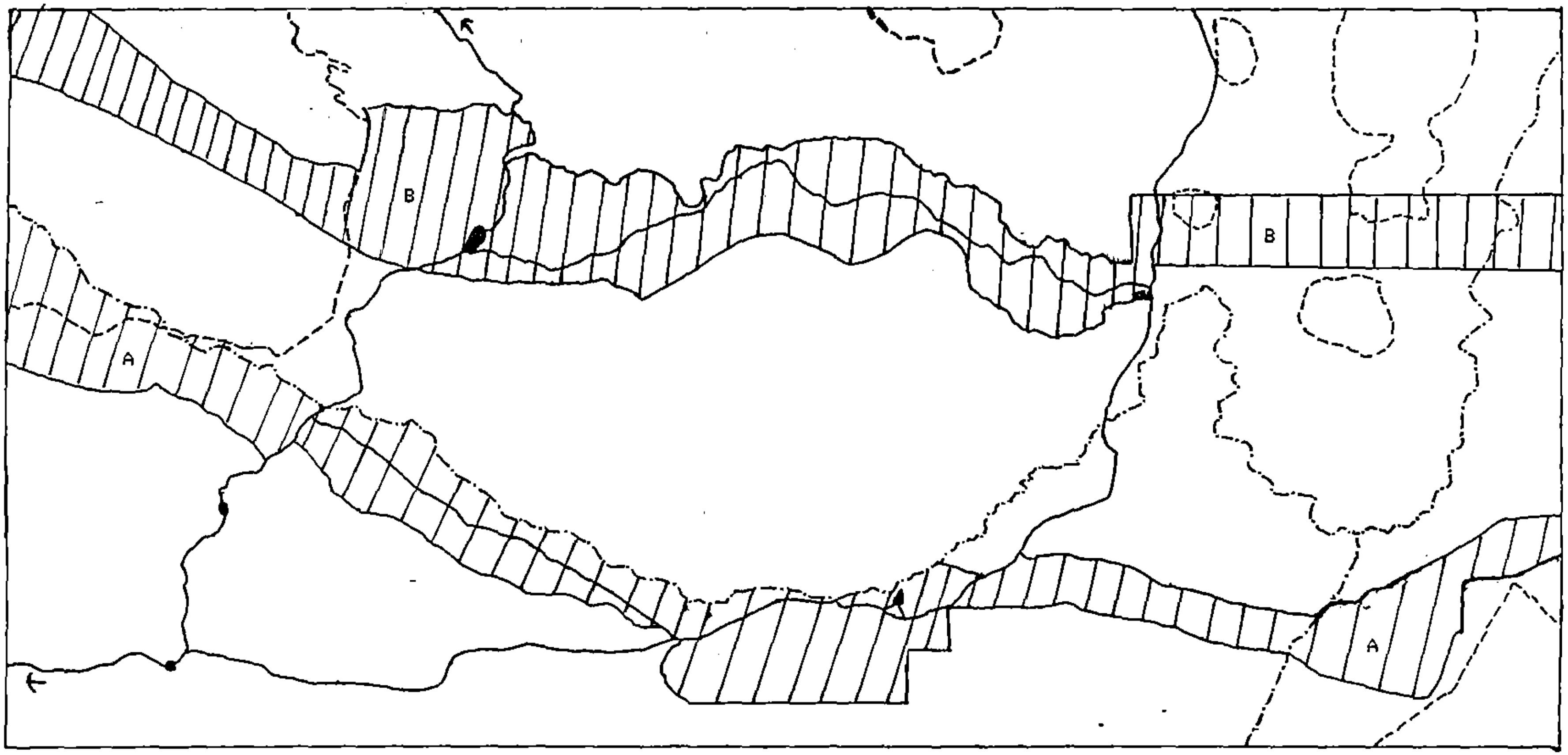


Fig. 1.2. Map of the project area showing the both sample strips.

Road

Forest boundary

River/district boundary

Sample strip

10 Km

2. DATA COLLECTION AND METHODOLOGY

2.1. Collection of climatological data

It appeared that not very many climatological data, concerning the project area, were immediately available. The farmmanagement handbook of Kenya (Jaetzold and Schmidt, 1983) provides some data on rainfall and temperature. Besides the agro-climatic zone study of Braun (1982) is very useful. In spite of these two data sources the available figures were not sufficiently reliable for this study and neither for the final project report. So after selection of all the weather stations in the project area (25) and all the stations within a distance of about 9 km (00 05') of the project area (24), the Kenya Meteorological Departement (KMD) at Nairobi was requested to provide figures over the last thirty years, concerning rainfall, temperature (mean, minimum and maximum), evaporation and radiation. The KMD provided data on temperature for only two stations and data on rainfall for nearly all the stations, but only 24 of the 49 stations having more or less complete data of ten consecutive years.

In addition to these two sources, visits to local stations were made to obtain supplementary data, especially of the last growing seasons.

A map of the annual average rainfall and a map of the mean annual temperature were compiled, see paragraph 3.2. For the compilation of these maps the data of Jaetzold, the local stations and the most important data of the KMD were used. Statistical treatment of the data was necessary before the maps could be compiled.

2.2. Collection of data on soils

A semi-detailed soil survey (scale 1:25.000) in the both sample strips A and B (Legger, 1987) as well as a reconnaisance survey (scale 1:100.000) of the whole project area (de Meester, 1987) were carried out.

The crop performance figures are principally related to the characteristics of the soil mapping units of the reconnaissance survey. The soil mapping units of the reconnaissance survey are also the starting point of the final suitability classification. So land characteristics and land qualities concerning the different soil mapping units were derived from the legend of the soil map and the profile descriptions of the soil pits. By gathering these land characteristics and land qualities, the different soil mapping units will be classified according to their suitability for maize, millet and sorghum.

2.3. Collection of data on crop requirements

Already in May 1985 a report was written, in the framework of qualitative land evaluation, on the crop requirements of some crops occurring in the Chuka area, Kenya (Hoogerbrugge & Ooms, 1985). One of the conclusions of that report was that the available, used literature was not sufficiently specific. Better results would be achieved by gathering crop requirements of local varieties in the Chuka area.

As far as possible crop requirements of specific varieties have been gathered at Embu Agricultural Research Station. Table 6.1. shows the crop requirements and is compiled using this locally gathered information and the general literature (Acland, Jaetzold, Purseglove and Landon). For the requirements, optimum values as well as limiting ranges have been established.

2.4. Methods and data collection on crop performance

2.4.1. Introduction

The main purpose of this part of the study was to gather as much as possible data on crop performance and yield levels of maize, millet and sorghum on different equally distributed sites in the both sample strips A and B. Yield variations are mainly due to variations in climate, soil and the differences in farm-management and input level.

Only for maize and millet quantitative crop measurements were carried out. Considering sorghum no quantitative crop measurements were carried out, because sorghum is mainly occurring as individual plants in stands of millet. Only in a very small part of the area and just on a few shamba's, sorghum was found in pure stands. It appeared, during later field observations in the first rainy season, that sorghum is cultivated abundantly during this period compared to its occurrance during the second rainy season. Qualitative measurements are carried out for all these cereals.

2.4.2. General methods

There are many ways to estimate yields. The first distinction can be made between subjective and objective methods.

Subjective methods concerns estimations and are usually not very precise. For example, when a farmer is asked at a certain time and place his opinion about the yield expectations. Objective methods involve measurements of some characteristics of the crop in the field. The crops are sampled in a systematic way. The yields are taken home, weighed and the results are computed using statistical methods. They provide exact estimates with known statistical errors, but their design and implementation is useful, but costs a lot of time.

Another distinction is made between qualitative and quantitative methods. In the first case only an indication is given of yield or crop performance. This is always subjective. On the other hand quantitative methods give exact figures on yield. These may be of a subjective or objective character.

2.4.3. Measurements in the field

For the collection of data on crop performance it is important to get as much as possible reliable data in a short period, the harvesting season. To achieve this a two fold procedure is used:

*The comprehensive sample sites:

At 35 sites actual yield measurements are carried out. This is an objective method. An area of 10 m^2 of maize or millet is harvested. Some important factors are counted or measured:

-the number of plant pits in the 10 m^2

-the number of maize ears/millet heads in the 10 m^2

-a figure is given for the overall crop performance (scoring), see below

-every ear/head is given a figure for its performance (scoring)

-only for maize the length (l) and the circumference (c) of the ear with husks are measured.

-a short interview is done, to get some information of the growing circumstances, the farm-management and the input level. During the interview the farmer is also asked, to give his yield expectation. This is a subjective method. For the questionnaire see appendix B.

The harvested maize ears are all labelled and the millet heads are put in a bag according to their score. Everything is taken home to be weighed.

*The non-comprehensive sample sites:

For both maize and millet, as much as possible data are gathered by estimation on a large number of sites, the non-comprehensive sample sites. The target figure is to sample for both maize and millet together about 300 sites. At these sites just the undermentioned factors are estimated or measured:

-the number of plant pits/m^2

-the number of ears/heads of each considered plant pit

-a figure is given for the overall crop performance (scoring)

-every ear/head is given a figure for its performance (scoring)

-only for maize the length (l) and the circumference (c) of the cob with husks are measured.

The farmer was asked to give an estimation of the expected yield.
For these measurements the non-comprehensive sample site form is used, see also Appendix B.

Scoring

Scoring is a way to give an indication of crop performance. It is an subjective qualitative method. Individual plants or stands of a certain crop are given a figure according to their performance. This is called visual evaluation or scoring.

For scoring five values are used: 1.very good crop
2.good crop
3.average crop
4.poor crop
5.very poor crop

The score is determined by comparing with the average. Scoring for overall crop performance takes into account both yield per plant and plant density. Scoring can also be done for plant density. In this case the plant density is evaluated on basis of plant pits per area, this is done by counting the number of plant pits in a certain area. Usually squares of about 9 m^2 were made using 3 big steps in two directions.

The relation between the comprehensive and non-comprehensive sample sites.

* Millet

By scoring for the individual plants and measuring the actual yields per plant at the comprehensive sample sites, the scores of the individual plants can be related to the grain yields by calculation. In this way a relation can be found between the different scores of the millet heads and the corresponding grain yield. Knowing the number of heads/ m^2 and the average yield/head, the yield per acre can be calculated for all the non-comprehensive sample sites. By calculating the correlation coefficient (R^2) one gets an idea of the accuracy of the method.

* Maize

From other studies (Hesselmark, 1978) it is known that there is a close relationship between the size of a maize ear and its grain yield. The relation of a maize ear and its grain yield is roughly of the shape:

$y=a+b(l*c)$. l=length over which grains can be felt
c=circumference in the middle of the ear

The ear is measured with the husks. This method can only be used for biological healthy, not damaged, not rotting, grain filled and regular ears.

All these calculations and their results are described in chapter 5.

2.4.4. The sampling procedure

2.4.4.1. Sampling of the sites

A. The comprehensive sample sites.

The yield levels of maize and millet vary strongly at various sites in the area. So the selection of the comprehensive sample sites is very important and requires a good procedure. Before this selection procedure was established, some criteria were drawn up:

- the sites should be equally distributed over the both sample strips, because of possible differences between the sample strips.
- the sites should be equally distributed over the sample strips from east to west, because of the climatic variation in that direction.
- as far as possible the most occurring cultivated soil mapping units should be sampled.
- selection of shamba's on the transition of different soil mapping units. Special attention will be paid to differences within these shamba's.
- selection of the sites on basis of differences in farm-management and input level.

Farm-management and input level have a very strong influence on crop performance. Variations in management and input level may give a few times higher yields on two in a different way treated shamba's located at the same site. This factor may be very disturbing in the harvest results. On the other hand the variation in farm-management and input level will show what the effect of these two factors can be under the same natural circumstances.

B. The non-comprehensive sample sites.

These sites were selected at random. Driving or walking along the roads in both sample strips, shamba's or homesteads were chosen on the left or right side of the road after every few hundred meters.

The comprehensive sample sites were selected on basis of the mentioned criteria during the first field days in December and January, see the time table (Appendix C). Besides the selection of these sites much attention was paid to the shape of maize ears and millet heads in connection with the necessary visual evaluation (scoring) during harvesting time. Also the development stage of the crops at different sites in the area got some attention. Farmers were asked when they expected to start harvesting. A lot of time was saved by selecting and investigating in advance.

Intercropping is very common in the area. Besides there is a felling prohibition for trees. Where possible purely cropped treeless shamba's were sampled to avoid all kinds of interaction between various crops and trees, which occur in the same shamba. This is taken into consideration for both the comprehensive and the non-comprehensive sample sites. The combinations of crops occurring in one shamba differ also a lot in the area, because of the ecological variation. On the other hand the occurring cropping patterns should be the starting point of all the measurements.

2.4.4.2. Sampling within the shamba

Within the chosen sample sites, the differences in crop performance and soil were taken into consideration. The sampled piece in a shamba has to reflect the performance of the whole shamba. For that reason it is very important to pay attention to the differences in crop performance within a shamba. In shamba's we find good and poor patches, differences in crop performances, due to conservation practices (e.g. trashlines and terraces), land preparation and fertility. Also the slope may play an important role as well as stoniness and rockiness. All these factors are very important in the selection of the exact piece of a shamba which will be sampled.

For the harvesting at the comprehensive sample sites, a rope of 10 m was used. The plant pits within a half a meter on both sides of the rope were sampled. For the non-comprehensive sample sites the surveyer walked in a straight line through the shamba. All the pits on this line were sampled. The rope or line method was used to meet the variation in crop performance within the shamba. The above mentioned factors, possibly causing differences in crop performance, were taken into account when laying down the rope or walking through the shamba. At every non-comprehensive sample site about 100 heads were evaluated or 30-35 maize ears were measured.

2.4.5. Organization of the fieldwork

The fieldwork was carried out by only one team of two persons. One who did the visual evaluation of the millet and the measurements of the maize. This is usually done by the one and same person to avoid too much variation in the figures of the evaluation and the measurements, especially for the evaluation which is a very subjective method. When this is done by the same hand, all the figures contain the "same" deviation. The other person was acting as interpreter for carrying out the interviews.

The fieldwork had to be carried out in the whole area starting at Tana river valley in the second week of January and finishing near Mount Kenya forest at the end of February. All those weeks a car was available for the work. The first weeks a lot of time, about 30-50% was lost by driving all the way down to the areas near Tana river. Approaching Mount Kenya day by day, more time became available to do the measurements. In spite of several attempts it appeared to be impossible to find a solution for this consuming transport problem.

2.4.6. Laboratory methods

All the harvested millet heads and maize ears were taken home. The millet heads were kept, according to their harvest number and their score number, in groups on a rack outside under a roof for about one week. They had sunshine for about two hours a day. The decision of drying the millet heads under a roof was made, because there seemed to be too much danger of bird damage. After one week of drying the millet heads were taken away, and the different groups of one harvest were put into an oven for half an hour at a temperature of 113 °C. This was done to get out the grains more easily. After drying the number of heads per scoring group was counted and the weight of every group was fixed. Further every group was put in a closed bag and beaten with a stick. Next the millet was winnowed in the wind and weighed afterwards. So the average grain weight of the different scoring groups is known.

For maize the labelled ears were also dried outside on the rack for about one week. Because of stealing (20%) the maize ears of the next harvests were taken inside and dried in the oven for 4 hours at 113 °C. After that they were weighed, the grains were taken off the ears to be weighed. So the grain weight and size of every harvested ear was known.

3. THE PHYSICAL ENVIRONMENT

3.1. Introduction

The environment is determined by several factors, like climate, geology, relief, soil, vegetation and man. Besides their static and dynamic influence on the environment to a certain extent, there are all kinds of interactions between those factors influencing the environment.

So the present landscape developed in history, due to all kinds of processes concerning the mentioned factors. Further development of the landscape will depend on the way these processes take place in the future. Depending on the population density and -growth, the influence of man will increase or decrease.

The actual physical environment of the project area will be described using some of the most important factors.

3.2. Climate

3.2.1. Rainfall

3.2.1.1. Average annual rainfall

In the project area, located on the windward side of Mt. Kenya, there is a strong variation in the average annual rainfall, see Fig 3.1. This is mainly due to the effects of altitude and relief. Moving to the higher and colder western parts, the rainfall is strongly increasing according to the altitude. The rainfall is decreasing approaching Tana river in the lower and warmer eastern part of the area. The contrast is well shown in Fig 3.1. The rainfall varies from 2400 mm at 2150 m in the north-western part to 550-700 mm in the south-eastern part near Tana River.

The rainfall is to a certain extent influenced by local relief. This results at some places, for example Kijege forest and Kibiro hills, in a relatively high average annual rainfall. The area in the south-eastern part with its very low average annual rainfall is affected by Mumoni forest (1750 m). It is lying in the rainy shadow of this forest.

3.2.1.2. Distribution of the rainfall during the year(s)

The rainfall is not equally distributed throughout the year, see Fig 3.2. The distribution of the rainfall is bimodal for the whole area.
The first long rainy season from March up to May and the second short rainy season lasts from October up to December. April and November are the months with the highest amount of rainfall. The distinction between long and short is due to the amount of rain and in the wetter areas the first season appears to be longer than the second one. This is also correlated with the length of the growing seasons.

Fig 3.3. shows the rainfall zones for the both rainy seasons, based on 60% reliability. This means that these amounts are exceeded in 6 out of 10 years.

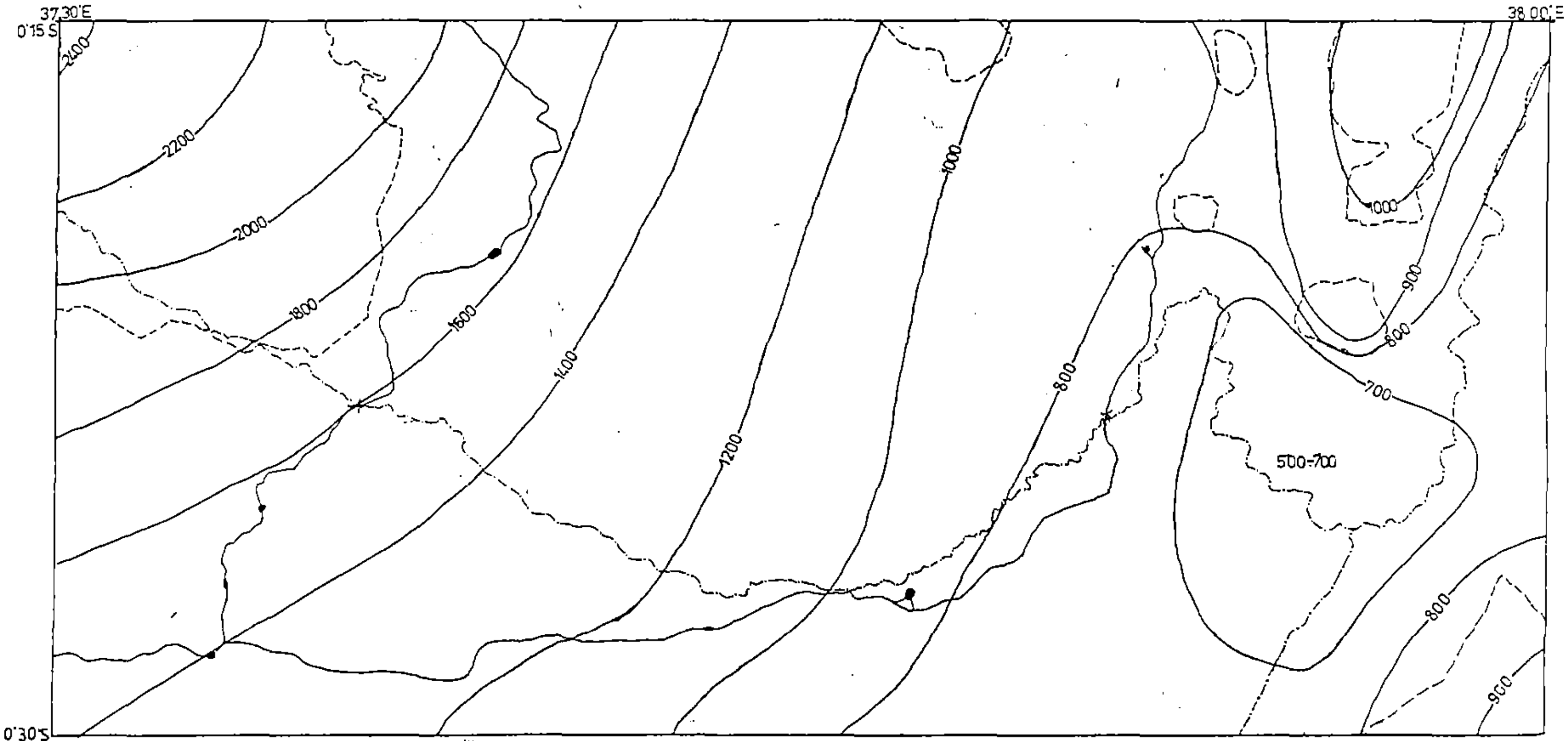
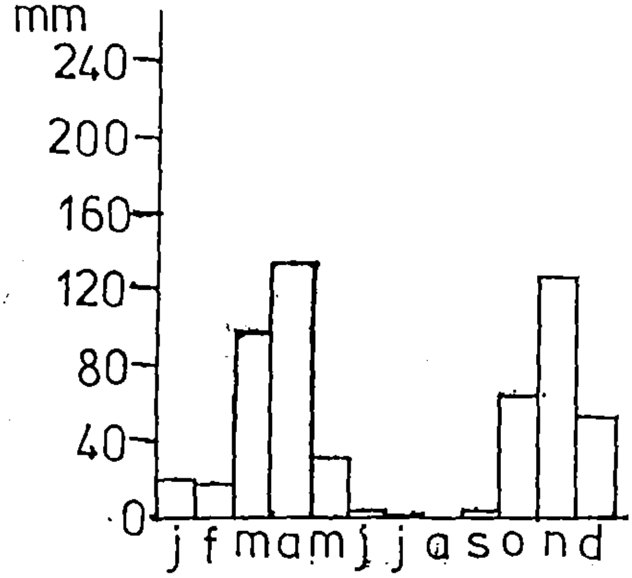


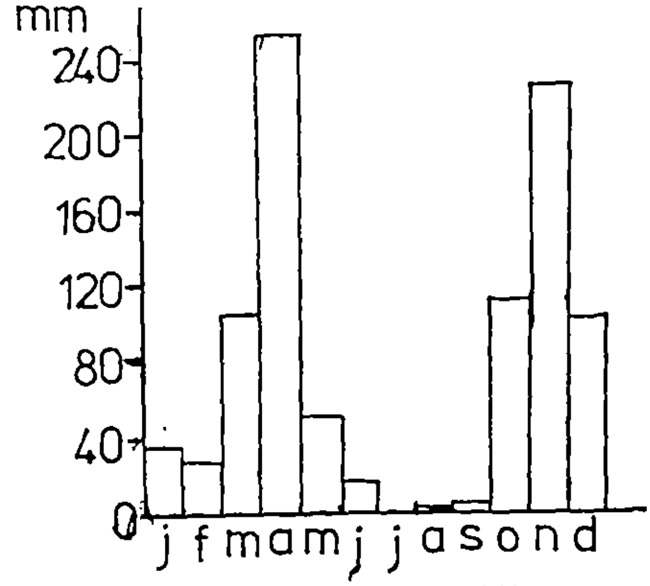
Fig. 31. The rainfall zones

SYMBOLS:
- road with village
- forest boundary
- river/district boundary
- isoheyt (mm)

Fig. 3.2. The rainfall distribution at certain spots in the area.



9037232, Karua Mutonga
0 22'S 37 54'E, alt. 701 m



9037187, Chiokarige D.O.'s office
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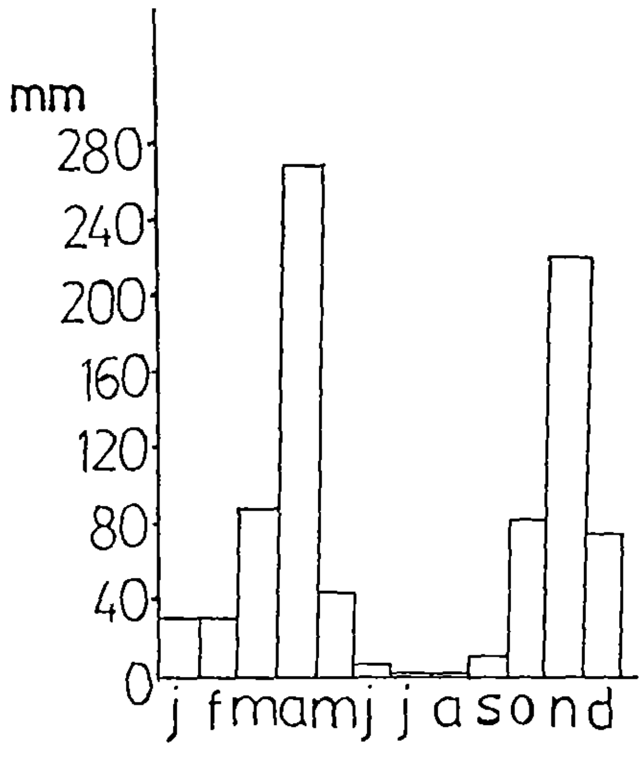

9037161, Embu Ishiara
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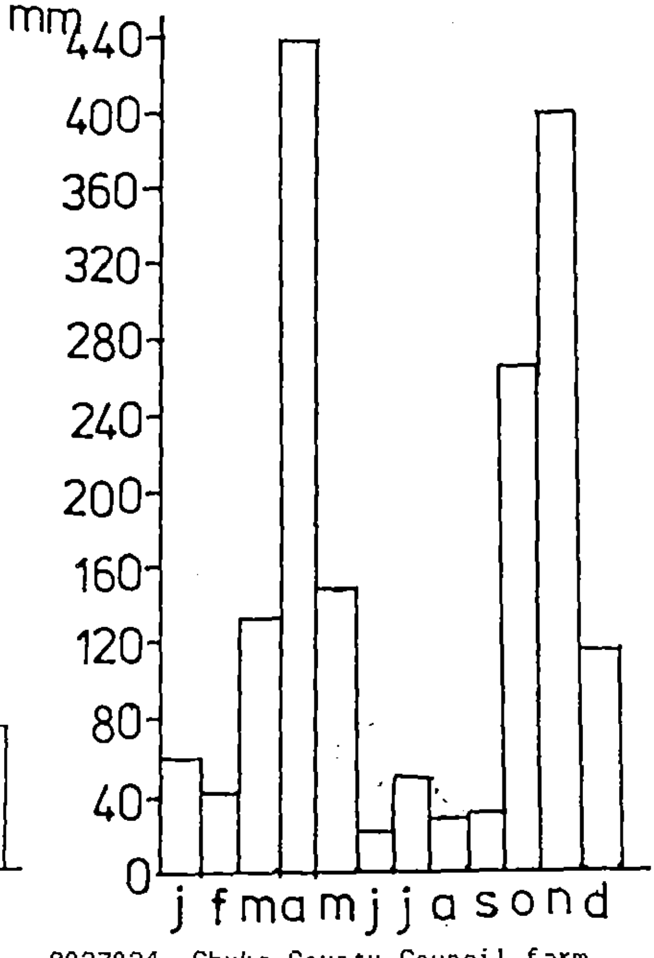
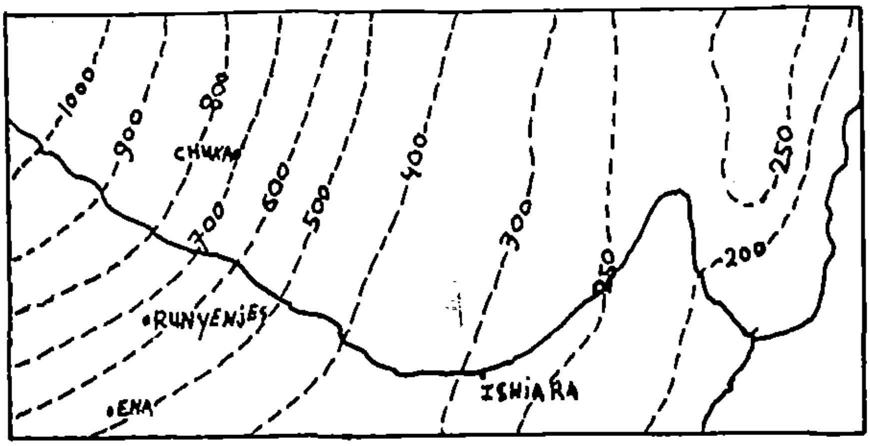
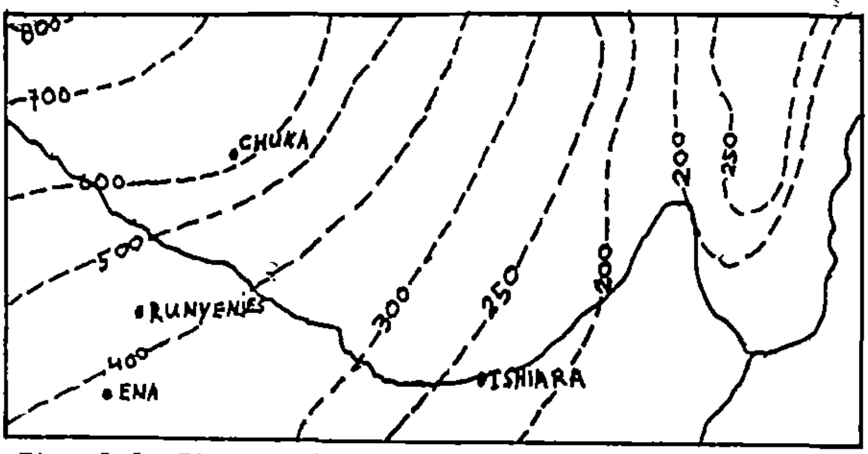


9037034, Chuka County Council farm
0 20'S 37 38'E, alt. 1496 m



First rainy season.



Second rainy season.

Fig. 3.3. First and second rains in the project area (60% reliability).

The dry spells between the two rainy seasons are divided in a short dry period, January and February, and a long dry period from June to September In the western wetter parts there is still some rain during those "dry" periods, while the eastern parts are characterised by dry periods without any rain at all. The rain during the "dry" periods in the wetter areas prolongs the growing season nearly till the onset of the next rains.

Table 3.1. shows the rainfall figures of the stations from Fig. 3.2. based on data of 10 to 15 consecutive years. This table gives also figures with 60% reliability. The standard error of all the annual rainfall data for these stations varies very strongly. If the standard error of the annual rainfall figures of a station is compared to its annual average rainfall, it appears that the standard error for the stations further to

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Karua Mutonga	Av.	19	17	95	133	31	4	1	0	4	64	125	52	545
	60%	0	0	28	95	8	0	0	0	0	33	88	35	287
Chiokarige	Av.	36	29	103	251	50	15	0	3	6	115	222	105	935
D.O.'s office	60%	2	0	54	194	31	0	0	0	0	48	136	59	524
Embu, Ishiara	Av.	31	31	87	268	45	8	3	3	11	81	221	74	863
	60%	3	7	41	216	22	0	0	1	3	32	160	46	531
Chuka County	Av.	58	42	133	435	147	23	47	27	31	265	386	115	1709
Council farm	60%	13	10	75	384	92	7	14	13	13	143	268	69	1101

Table 3.1. Rainfall figures (mm) of the four station from Fig. 3.2.

the east is relatively larger. So this means that there is a stronger variation in the annual rainfall in the drier areas. Both reliability of rainfall and distribution during the year are especially very important for farming in those dry areas.

Besides, especially in the eastern part, the intensities of rainfall are very high. It is not exceptional that the majority of the rain falls in a few days, during a few hours. These intensities are very erosive, especially affecting areas with poor vegetation.

3.2.2. Temperature

Also the temperature shows a strong east-west tendency. A low and warm part in the east and higher and cooler part in the west.

In general temperature is correlated with altitude, but it is important to use a specific relation, adapted to the project area to appoint the temperatures in the area. To meet the lack of data requested at the KMD, all the temperature data of 22 stations, mentioned in Jaetzold (1983), were used to find a correlation between altitude and temperature. Those 22 stations were selected, because they are located on the windward side of Mt. Kenya, the first higher area on the African continent, following the winds coming from the Indian Ocean. A correlation for altitude and mean annual temperature was found: T=28,9-6,51A. A=Altitude in km.
T=temperature in ^{o}C

The correlation coefficient (R^2) was 0,95. The temperature map, Fig 3.4. showing the different zones is based on this correlation. The temperature zones as drawn in Fig 3.4. are given in Table 3.2. The mean maximum and minimum temperatures are derived from the mean annual temperature after processing the data from those 22 stations to find a certain correlation for the different temperatures.

zone	mean annual temperature ^{o}C	mean maximum temperature ^{o}C	mean minimum temperature ^{o}C
I	24-30	30-37	18-23
II	22-24	28-30	16-18
III	20-22	26-28	14-16
IV	18-20	24-26	12-13
V	16-18	21-24	11-12
VI	14-16	19-21	9-11

Table 3.2. The temperature zones

3.2.3. Average annual potential evaporation

The average annual potential evaporation (Eo) varies from 1200 to 2000 mm in the north-western part of the area and from 1650 to 2300 mm in the eastern part of the area (Braun et al, 1982).

The ratio r/Eo of the average annual rainfall (r) and the average annual potential evaporation can be derived from these figures and the figures in the previous paragraphs. This ratio r/Eo varies from 80% in the north-western parts to 25-40% in the eastern parts of the area. Higher ratios appear in the mountaineous area.

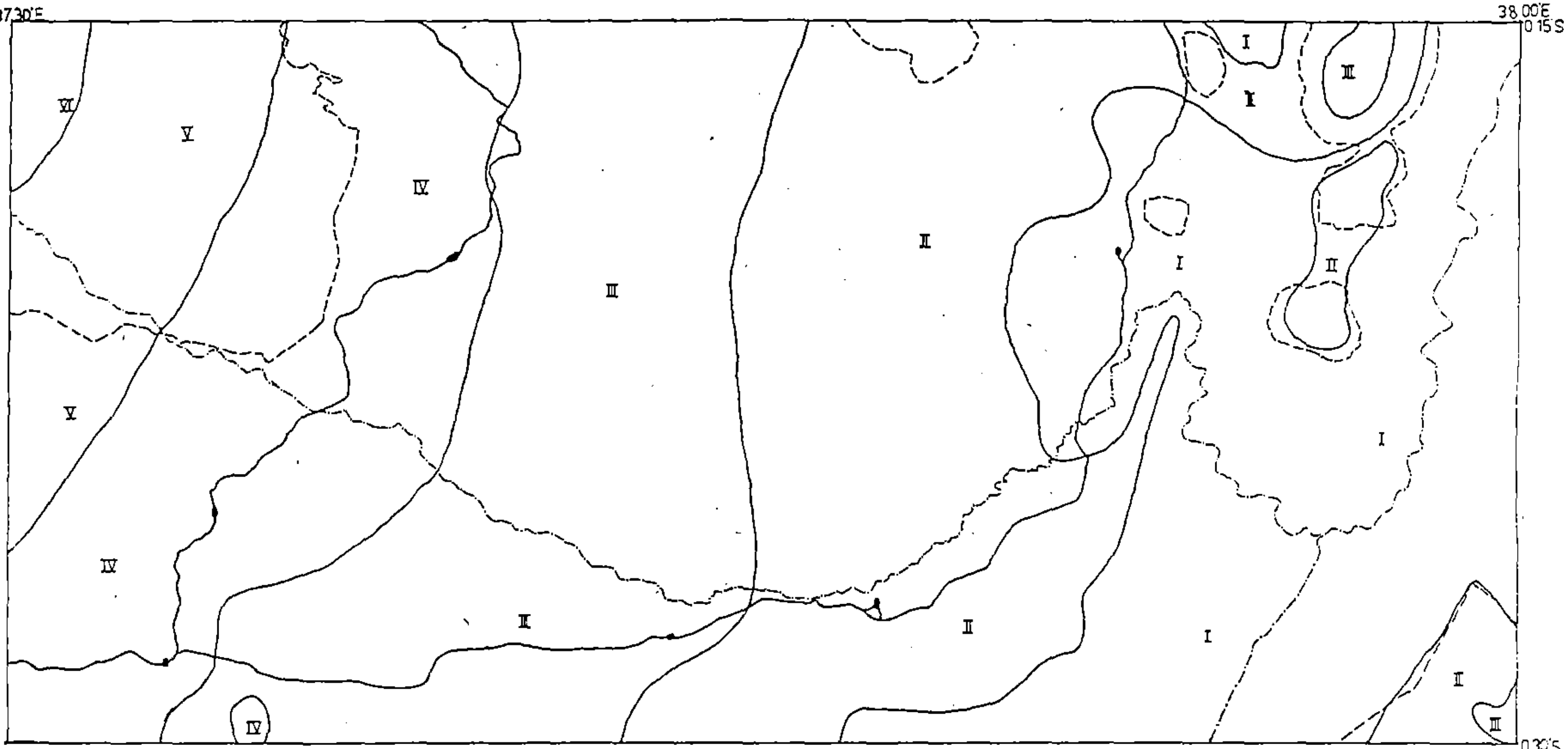


Fig. 34 The temperature zones

SYMBOLS: road with village
forest boundary
river/district boundary
/I/ temperature zone

3.3. Geology

The Basement System rocks (belonging to the Mozambique Belt) form the floor on which all the other rocks of the area lie. These rocks are composed of heterogenous migmatic gneisses, granulites and schists of varied complex.

During the Miocene these Basement System rocks had formed a peneplain which became covered by volcanics from Mt. Kenya during the Tertiary. The majority of these volcanics are so called lahars; consolidated mud flows which form the slopes of the volcano, enbedding all kind of volcanic rocks in a matrix of pyroclasstic material.

Parts of the Basement System which are not covered by volcanics have undergone various erosion cycles and form now the Uplands, Hills and Mountains. Most hills and mountains are intrusive rocks which have been injected in the consolidated sediments. These hills and mountains are formed due to their relatively high resistence against erosion.

Some hills are build up from the same rocks as their surroundings. They have been protected against erosion by a cover of more resistent volcanic material (lahar), which now has been eroded away.

The gneisses which form the main part of the Basement System rocks are in general rich in minerals like hornblende and biotite. The weathering of these minerals releases lots of iron from the crystal lattices. This iron gives the soils developed on these gneisses a deep red colour. Soils developed on the granitoid gneisses, which contain more quartz have a lighter orange colour because of the lower amounts in ferro-magnesian minerals and higher amounts of quartz.

During the Pleistocene the Nyambeni volcanoes were active. One of the elongated olivine basalt flows produced by these volcanoes filled the former bed of the Mutonga river. Since then this ancient riverbed is protected against erosion by the volcanics. This caused an inversion of the landscape by erosion, so at the present the basalt form the higher parts in the landscape. An example of the pleistocene basalts is the plateau on which Materi is situated.

3.4. Geomorphology

The project area can be divided in two distinct geomorphological units; the volcanic deposits of Mt. Kenya in the west and the Basement System in the east of the area.

Mt. Kenya which is the remnant of a tertiary volcano, has a relative flat profile. The western part of the area comprises the eastern part of the Mt. Kenya slopes up to 2100 m. These slopes are classified as Mountain Footridges.

The mountain footridges are strongly dissected by perennial streams and rivers, descending from the mountain. The major streams, Nithi, Tungu and Naka have cut gorges in the volcanics; the Major Valleys. The smaller valleys which dissect the mountain footridges are not seperated from the higher parts of the foodridges as another geomorphological unit. They form a part of the footridges as a unit with parallel higher and lower parts.

The volcanic depressions situated in the volcanic deposits are classified as Bottomlands. These are elliptical shaped, concave depressions which mostly have no outlet. In the rainy season water accumulates in these depressions, causing small lakes or swamps.

The Basement System forms dissected, rolling landscape, classified as

Uplands. These uplands are remains of the Basement System rocks. The higher isolated parts of these uplands with slopes of 30% or more, but with a heigth less than 300 m are called Hills. The parts of the Basement System with steep slopes and a heigth of more than 300 m are called Mountains.

Another landform is formed by the remnants of the river terraces which are called alluvial Plains if they are recognizable as terraces because of their flat topography and their alluvial deposits. Most of the terraces remains are too strongly dissected to be called alluvial plain.

The village of Materi is situated in a flat part, which is called a Plateau, built up of basalts and bordered in the west by a small scarp.

The last landform distinguished in the project area are the Footslopes. The footslopes border some of the hills and mountains in the eastern part of the area and are formed by colluvial materials from these mountains and hills.

3.5. Soils

3.5.1. Some aspects of soil genesis

Characteristics of soils have been formed under influence of several soil forming processes, which are strongly interacting. These processes are characterised by the combined action of soil forming factors like climate, parent material, landform, drainage, biological activity and man.

Climate and parent material are the most important factors influencing the soil formation in the project area. In the volcanic materials in the western part, a sequence can be found of the degree of leaching with decreasing rainfall. This results in highly leached Nitosols in the west to Acrisols at the lower footridges.

With the decrease of rainfall to the east, the temperature increases, which has a strong influence on the formation of an A-horizon. The complete sequence is than humic Nitosol, humic Acrisol, dystic Acrisol and chromic Acrisol.

In the eastern part the rainfall is much less and the soils are slightly leached chromic Luvisols. In this dry and warm area an A-horizon is absent or badly developed. The degree of leaching occurring in these Luvisols must be explained by leaching during the rainy season when rainfall is slightly higher than evaporation or a much wetter climate in the past.

Parent material mainly determines the difference between volcanic and non-volcanic soils Within the Basement its influence is relatively more important than on the volcanic deposits of Mt. Kenya. On granitoid gneisses more sandy soils develop, while on gneisses rich in ferromagnesian minerals more clayey soils develop.

The landform is also important. The scarp of the plateau as well as the small ridges in the Basement System suffer from a lot of erosion due to their shape. This gives a strong juvenation of the soils.

The low infiltration in the relatively compact Luvisols and their sensitivity for sealing of surface layers, causes a lot of run off, sometimes resulting in excessive erosion.

Another factor in the soil formation, especially in the east part of the area is the presence of man and his activity. The practice of shifting cultivation with a short fallow period and overgrazing causes a lot of erosion. This erosion reduces the natural fertility and causes a constant rejuvenation of the landscape.

At the deposits of Mt. Kenya only the cultivation on very steep slopes gives erosion. The erosion hazard is not very large because of high infiltration and vegetation cover.

3.5.2. General properties of the soil

Between the soils developed on lahar and those developed on Basement System rocks is a clear distinction. The soils on lahar are in general well drained, very deep, dark red to dark reddish brown, very friable to friable, clay (mainly humic NITOSOLS).

The valleybottoms, about 10% of the footridges, are in general well to poorly drained, deep to very deep, dark reddish brown, friable, clay (humic NITOSOLS, humic and gleyic ACRISOLS).

The soils developed in the uplands developed on lahar are in general well drained, deep, dark reddish brown, friable to firm, clay (mainly humic, ferric and chromic ACRISOLS).

The soils developed on the Basement System rocks are somewhat excessively to well drained, moderately deep to deep, dark red to dark reddish brown, friable to firm, sandy clay to clay (orthic and chromic LUVISOLS).

The acidity of the soils decreases with altitude. The higher parts of the footridges have a pH of about 4.0 which increases to about 5.0 at the lower footridges. In the LUVISOLS a pH of 7.0 to 8.0 is not uncommon.

3.5.3. Systematics and nomenclature of the soil mapping units

The broadest category of the legend is based on geomorphology. These land types were subclassed by the parent material on which the soils are developed. The third entry in the legend are the soil characteristics.

The following letters were used in the soil mapping units symbols:

Physiography

M mountains and major scarps
H hills and minor scarps
R mountain footridges
B bottomlands
L plateaus
U uplands
P plains
V major valleys

Geology (parent material)

B basic and ultrabasic rocks
G granitoids and granits
P (un)consolidated pyroclasstic rocks
F gneisses rich in ferromagnesian materials
Q granitoid gneisses
U undifferentiated gneisses
I phonolites
A non recent alluvial sediments of various origin
X different parent materials

Soil characteristics

C	complex	p	moderately deep
h	humic topsoil (>1% organic C)	1,2	general subdivision

3.6. Vegetation and land use

There are many differences in vegetation, due to environmental circumstances and human influences.

Fig. 3.5. shows the ecological zones in the area. These zones are distinguished on basis of color differences on a satellite photo from January 1982 and field observations. The main criterium interpretating the satellite photo was the red color intensity, reflecting the amount of biomass.

In the very wet north-western part (zone 0) mountaineous rain forest, characterized by Podocarpus milijaniformis, can be found and secundary forest at places where the original forest has been cut for timber wood.

Moving down to the less wet parts of the forest it changes slowly into the abundantly with tea cultivated shamba's (zone Ia).

The zones Ib and IIa are characterized by the cultivation of coffee and lots of food crops, like maize, beans, bananas and mangoes. A lot of trees, like Erythrina abyssinica, Croton megalocarpus and Grerillea robusta, have been planted between the permanently cultivated plots. Remnants of the original rain forest (Newtoia buchanani the "mukui") can still be admired, especially in the valleys.

More to the east we find a plateau which is characterized by the cultivation of cotton, maize, pigeon pea and sisal. Some parts are also left fallow as Combretum savanna. This is a major East African savanna type and characterized by various broad leaved Combretum species which give it an orchard appearance.

Zone IIIa and b form the transition to semi-arid circumstances in the east part of the area. Zone IIIa is characterized by a more water requiring vegetation.

In the uplands, the lower semi-arid part of the area (zone IV, V and VI), we find a vast area of Acacia Commiphora bushland, which differs from place to place in the amount of covering the soil. This depends principally on the grazing intensity and the length of the fallow period after the cultivation of millet and sorghum. Zone VI is the driest part of these uplands due to the rainy shadow of Mumoni forest. The mountains and hills in the east part of the area are covered with a thick bush and forest, because in the past measures were taken to prevent that these places were used for cultivation and charcoal making.

3.7. The zone concept

The previous paragraphs show that the area is characterized by a strong zonation, concerning all kinds of environmental variables, especially rainfall and temperature. These variables can't be influenced by the individual farmer, but those variables influence the cropping pattern and farming system very strongly in this area.

A team of the KSS (Braun, 1982) made an agro-climatic classification of Kenya based on a combination of soil moisture availability (r/Eo), see

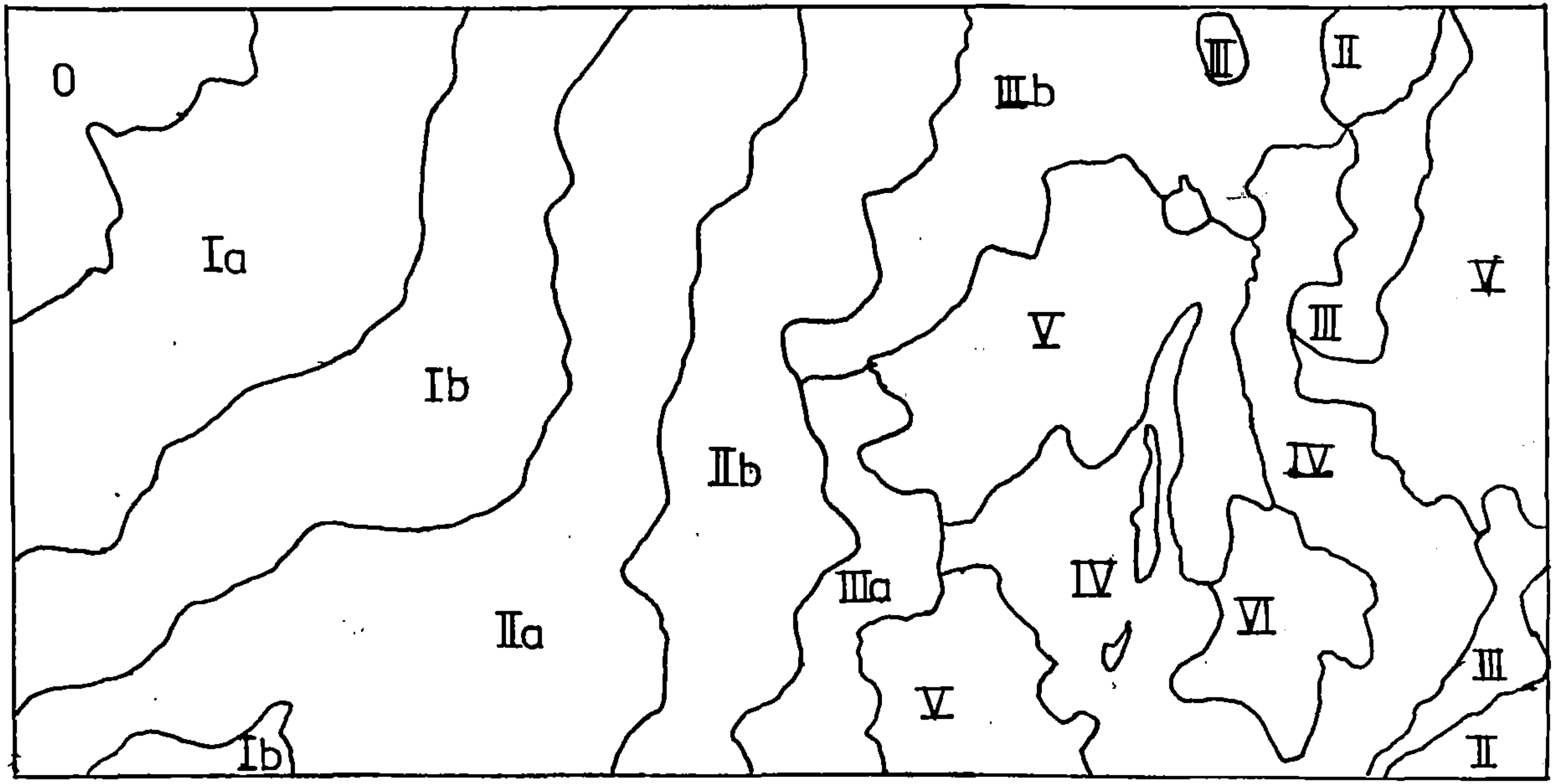


Fig. 3.5. Ecological zones

Table 3.3. and Fig.3.6., and temperature (Table 3.2. and Fig. 3.4.). Besides Braun calculated probabilities of moisture deficit (the chance that rainfall < 2/3 r/Eo). Furthermore he gave probabilities of crop failure for maize. His work resulted in undermentioned soil moisture availability zones, also giving the chance of failure of maize in the different zones.

Zone	r/Eo(%)	Classification	Risk of failure adapted maize
I	>80	humid	extremely low (0-1%)
II	65-80	sub-humid	very low (1-5%)
III	50-65	semi-humid	fairly low (5-10%)
IV	40-50	semi-humid/semi-arid	low (10-25%)
V	25-40	semi-arid	high (25-75%)
VI	15-25	arid	very high (75-95%)
VII	<15	very arid	extremely high (95-100%)

Table 3.3. The soil moisture availability zones of Braun.

Another team (Jaetzold, 1983) also determined zones in the area based on rainfall, temperature and the pattern of crop occurrence. The so called agro-ecological zones. The agro-ecological zones are shown in Fig. 3.7. The codes in the different zones are explained in Table 3.4.

UH Upper Highland zone	LH0=Forest
LH Lower Highland zone	LH1=Tea-diary zone
UM Upper Midland zone	UM1=Coffee-tea zone
LM Lower Midland zone	UM2=Main coffee zone
IL Inner Lowland zone	UM3=Marginal coffee zone
	LM3=Cotton zone
Subscribt:0=per-humid	LM4=Marginal cotton zone
1=humid	LM5=Livestock-millet zone
2=sub-humid	IL5=Livestock-millet zone
3=semi-humid	
4=transitional	
5=semi-arid	

Table 3.4. Explanation of the agro-ecological zones.

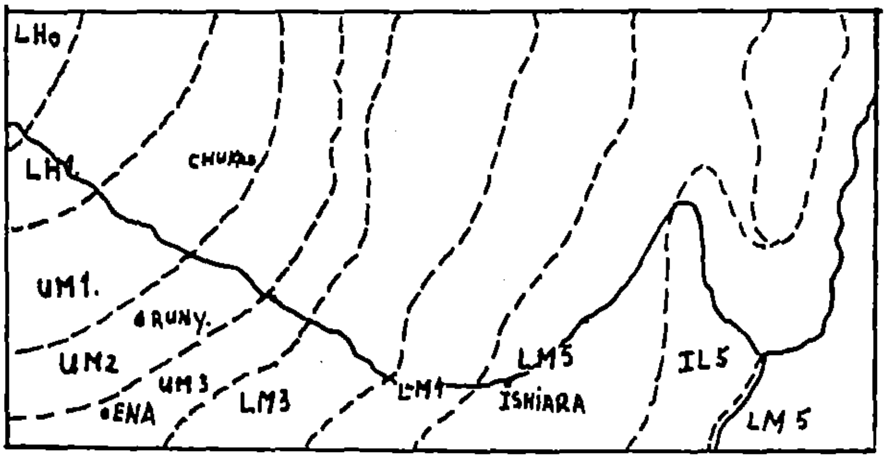


Fig. 3.7. Map showing the agro-ecological zones in the project area.

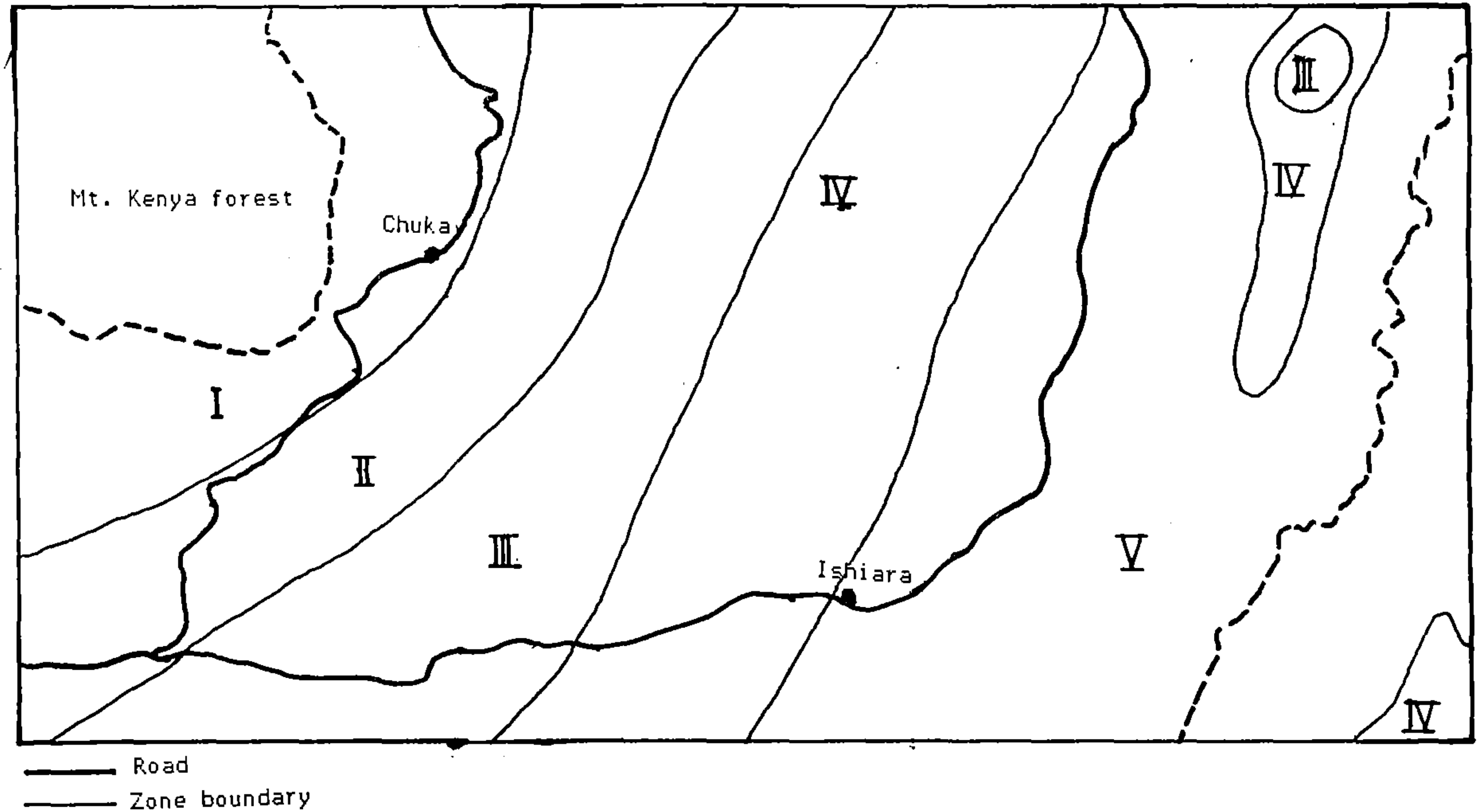


Fig. 3.6. The soil moisture availability zones of Braun.

The name agro-ecological zone suggests an ecological suitability for the crops in those zones. This is not correct and it would be better to call these zones agro-climatological zones, because the classification is only based on climatical data and field observations concerning the occurrence of crops and is not related to other ecological factors than climate.

4. THE CEREAL CROPS AND THEIR CULTIVATION

4.1. Introduction

In the Chuka area Maize, Bulrush millet and Sorghum are the generally grown cereal crops. The cereals are mentioned in order of importance, starting with maize. The added map 1. (Appendix A) shows the occurrence of the different cereals. These cereals are the staple food for the population in this area. The crops are not grown for any other purpose.

Maize is the most popular one of the three. This is mainly due to its high yielding potential in ecological suitable areas. Besides it is not damaged by birds, it is seldom seriously damaged by pests and diseases, it doesn't require much labour in cultivation and processing and a lot of people find maize more palatable than the other cereals.

4.2. Maize
Zea mays, Bembe

4.2.1. Varieties

A large number of cultivars of maize is found all over the world, belonging to different grain types. There is a strong heterozygosity, because maize is a cross-pollinating crop. It is doubtful whether any two seeds in the same ear have the same genotype, because of open pollination. So cultivars names have less meaning than for example in the case of self-pollinating crops or vegetatively propagated crops (Purseglove, 1972).

All maize which is grown in the project area is of the flint grain type. The type of cultivars which are grown depends on the variation in the local conditions.

In the lower parts of the area only Katumani Composites are grown. Katumani Composites are bred by growing a number of varieties of diverse genetic composition on the same shamba, giving them the possibility of free interpollination. Improvement is possible by continual selection. An advantage is that farmers can use the seed after selection, for many successive years. Katumani Composites are short maturing varieties, maturing in 4 months when they are grown between an altitude of 1200 and 1500 m. They are grown in areas with a short rainfall duration. In the project area they are found below 1000 m, that means east of longitude 37 44'E.

In the higher parts of the area, west of longitude 37 44'E, only hybrids are grown. Hybrids are bred by crossing inbred lines or varieties under conditions of controlled pollination. The bred hybrids are indicated by three figures. The first figure indicates the approximate altitude at which the crop has been bred: 6 for Kitale (6000 feet) and 5 for Embu (5000 feet). The second figure indicates the type of hybrid: 1 for varietal hybrid (when a variety is used as one of the parents) and 2 or 3 for a classical hybrid (when inbred lines are used as the parents). The last figure is a serie number. The classical hybrids give the best results between 1200 and 1500 m, while varietal hybrids are suited to altitudes of 1500 m.

The Embu hybrids are suitable for areas with a medium rainfall duration of 3,5 to 4 months. They mature in about 5 months. The hybrids 511, 512 and 513 are grown on nearly every shamba in the area above 1000 m. Sometimes they are mixed.

The Kitale hybrids are bred for higher areas with a long wet season of at least 5 months. They mature in about 6-8 months. The exact growing period depends on the altitude at which they are cultivated. On just a few non-comprehensive sample sites near the border of Mount Kenya, the hybrid 612 was found.

The hybrids give higher responses than local varieties, but they require higher input- and management levels. Without good management and a high level of input growing hybrids is a waste. Fresh seed is required every season. Second generation seed will result in a variable population and low yield levels. Only very few farmers are still growing local varieties. Yellow maize was found on one non-comprehensive sample site. It was imported from the United States of America and for the first time grown during the first rainy season of 1985. The performance till now was quite good, according to the farmer.

4.2.2. Field operations

The timing of the field operations for maize will vary from site to site, mainly due to the variation in climate and soils within the area. For the timing of the field operations, see Fig. 4.1. The cultivation calender of maize.

```
    harvesting                    harvesting
    _______                       ________

we &hu      weeding & husbandry             weeding & husbandry
____        ___________________             ________________

          planting                        planting
          ______                          _____

     preparation                    preparation
     ______                         _______
|____|____|____|____|____|____|____|____|____|____|____|____|
  Ja   Fe   Ma   Ap   Ma   Ju   Ju   Au   Se   Oc   No   De
```

Fig. 4.1. The cultivation calender of maize.

Land preparation

The land preparation is carried out in March just before the onset of the first rains and in September and October before the second rains. The preparation is always performed by hand, using a (forked) jembe or a panga, see Fig 4.2., the cultivation tools. The main activities are, removing crop rests of the last season, weeding and turning and loosening the topsoil to get a good seedbed. Only one out of twelve farmers stated to mix the topsoil with mulch during the preparation. Sometimes lines are made to sow the maize. If maize is planted on ridge these ridges will be a remain of the tobacco cultivation the previous season.

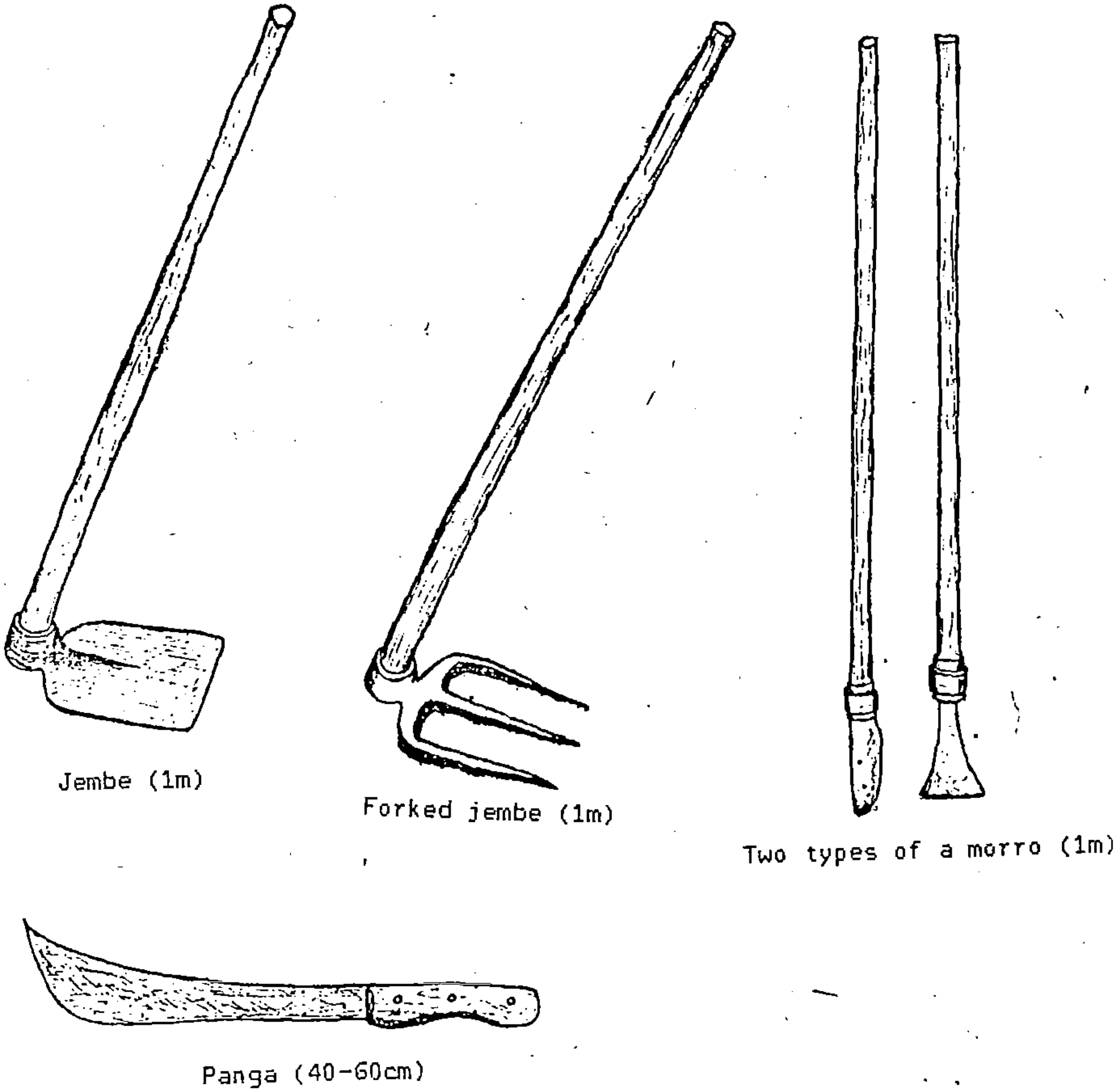


Fig. 4.2. The cultivation tools.

Planting, seeding and fertilizing

Just before the onset of the rains in March and October the seeds are put manually into the soil. Usually holes are made instead of lines. Two seeds are put in every hole, which will result in one or two stalks. The row spacing varies between 70 and 100 cm; the intra row spacing varies between 40 and 60 cm. Eight out of twelve farmers applied manure and five out of twelve used chemical fertilizer (20N-20P or 20N-10P-10K). It is impossible to give any exact indication about the applied quantities; some farmers applied one hand of manure in every plantpit. The manure or chemical fertilizer is mixed with the soil in the plantpit before seeding. Next the seeds are covered by a layer of topsoil varying in thickness (2,5-10 cm) depending on the soil moisture content.

Weeding

Weeding is performed twice every season by using a panga. The first time 2 weeks after the onset of the rains. The second weeding is done 8 weeks after the onset of the rains.

Crop protection.

Earthworms are the greatest pest to the maize in this area. These worms attack the rootsystem of the maize, especially during rainy seasons, when they are moving up from the deeper subsoil to the wet topsoil. When it is getting drier they withdraw again in the deeper subsoil. All the farmers complained about these worms.

Beside worms, the stalkborer (Busseola fusca) is the worst pest. Larvae eat the upper parts of the leaves and penetrate to the centre of the plant. They and the later generations feed on the growing point and the later developing ears.

On some shamba's white leaf blight (Helminthosporium turcicum) is observed. Symptoms are oval, grey, paperly lesions on the leaves. This disease didn't seem to be very severe. There appears to be a certain degree of resistence in particular varieties. Farmers didn't have any complaints about the occurrence of this disease.

Conservation practices and rotation

Six of the twelve farmers took some measures to protect the soil. Making trashlines is very common, but also grass- and stonelines were found in some shamba's. Even terraces were build by some farmers.

Most farmers grow maize continuously on the same shamba. Just some of them practise kind of rotation. Most common are rotations of maize, beans and pigeon pea. The shamba's are never left fallow for one or more seasons in the area were maize occurs.

4.2.3. Harvesting

Maize is physiologically mature, that means no accumulation of dry matter any more, when the moisture content is about 35%. It is left on the field to whither completely and harvested at a moisture content of 19 to 20%, because at this stage it can safely be stored at the cob. Maize is harvested manually during the months July and August at the end of the first season and for the second season during January and February. Sometimes the maize is harvested in stages. This depends on the regularity of maturing and on the need of food of the farmer and his family. The stalks are used as food for the cows or left on the field for trashlining.

4.2.4. Processing

The cobs are dried on a floor in the sun after the husks have been taken of. Further they are stored in a crib/cradling an elevated store with wired netting. Another procedure is that all the grains are taken of the cobs immediately after harvesting to dry them in the sun. When they are dry they will be stored in a bag.

The majority of the maize is grind into flour for making "ugali". The grains may also be cooked and mixed with beans to "githeri". Some of the maize which is not completely dry is roasted and eaten on the cob.

4.3. Bulrush millet

Pennisetum typhoides, Mwere

4.3.1. Varieties

Bulrush millet has a number of cultivated types. Some authors (Purseglove, 1972) consider all those types as a single collective species, while others indicate them as different species. Four different types are cultivated in this area. All the types are early maturing and of local origin. The types can be subdivided in a group without and a group with bristles. The one with bristles is less liable to bird damage. The different types of millet heads are shown in Fig. 4.4.

Just the last fifteen years some breeding programmes are started at Serere in Uganda. Some important selection criteria in the breeding programs of millet are: high yielding, disease resistence, early and medium maturing and the presence of bristles.

4.3.2. Field operations

Due to the strong climatic variation in the area and the consequent differences in growing period in the east and west part of the with millet cultivated area, there is also a variation in the timing of the field operations. For the timing of the field operations, see Fig 4.3. The cultivation calender of millet.

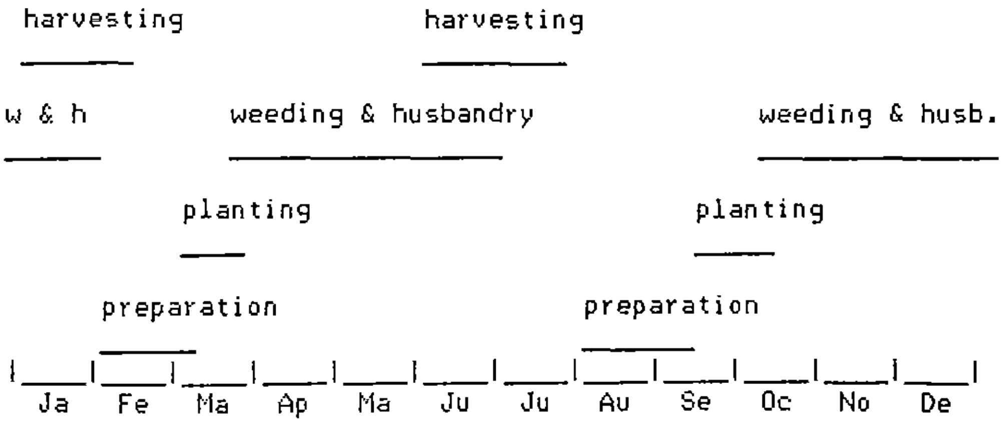


Fig. 4.3. The cultivation calender of millet.

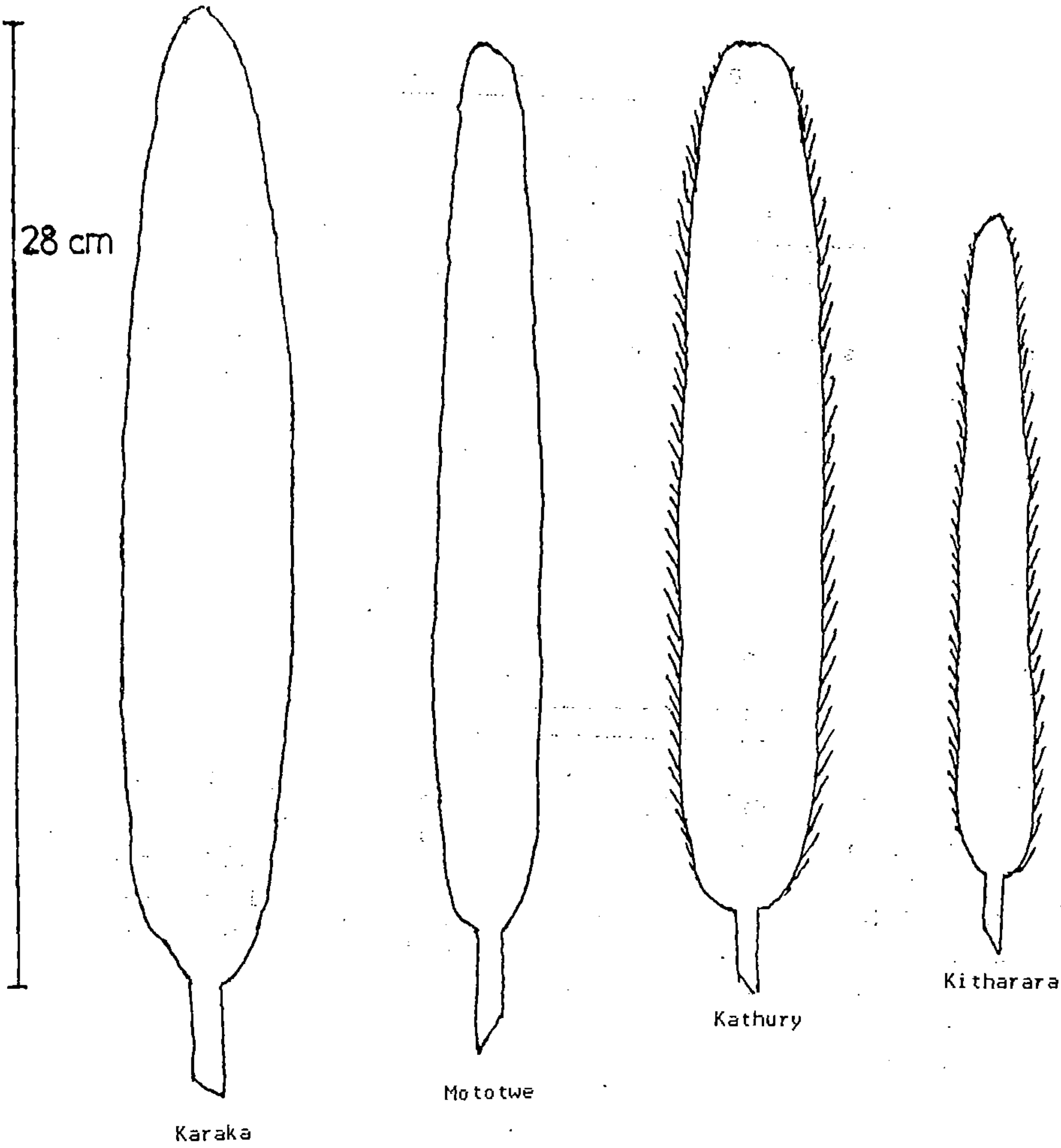


Fig. 4.4. Four types of millet heads occurring in the project area.

Land preparation

The soil preparation exists of removing crop rests or mulching, weeding, loosening the soil and eventually the construction of trashlines or stonelines. For the soil preparation a panga, a morro or a (forked) jembe is used, see Fig. 4.2. Also a plough is often used especially in the drier areas between longitude 37 45'E and 37 52'E. In this area the majority of the shamba's is ploughed. This is mainly due to the favourable physiography, the size of the shamba's, the absence of stones or rocks and the availibility of cattle. The soil preparation is carried out immediately after the harvest from the beginning of February till the first week of March and from the beginning of August till half September.

Planting, seeding and fertilizing

Bulrush millet is planted during both rainy seasons, there is no preference for the first or second rains. Planting is done in March before the first rains and in September and October before the second rains. The farmers select their seed from their own stock. For the planting of millet a hole is made with a panga or morro. About five seeds are put in every hole. The plant density (pits/m^2) varies from 1,5 to 3,5. Expressed in heads/m^2, we see a variation between 7 and 18 heads/m^2. The spacing of millet is very irregular, it is never planted in rows, and principally cropped in pure stands. Just some cropping combinations were found on a few shamba's :

millet-green gram
millet-cotton
millet-sorghum
millet-maize

About 50% of the farmers applied manure, which is mixed with the soil in the planting hole before adjoining the seed. None of the farmers used any kind of chemical fertilizer. About 25% of the shamba's are not fertilized or mulched at all.

Weeding

The weeding is carried out two times during every growing period. The first weeding 2-4 weeks after the onset of the rains and the second one after 8 weeks.

Crop protection

Monkeys, birds, especially Quelea, and worms are the greatest pests to the millet. Monkeys only occur in the area east of longitude 37 52'E. Fourteen out of sixteen farmers complained about damage caused by birds. The crop is during daylight permanently protected by a person who chases the eating birds by throwing stones and shouting. Also bow and arrow are often used to chase them. The introduction of millet types with bristles may reduce the damage caused by birds.

Also worms are a severe threat, namely all the farmers complained about it. During the first weeks of the rains the worms move up from the subsoil and attack the young roots of the plants. Some farmers applied crop rotation to avoid too much damage. None of the farmers complained about any other disease. There are no chemicals used at all.

Conservation practices and rotation

On more than 50% of the shamba's a kind of soil conservation practice is carried out. Most common is the use of trashlines along the contour lines and mulching. These two practises have a very sharp effect on the crop performance, especially in the drier areas, due to the extra conservation of water. For example, the crop performance is is much better and the estimated yields are about three times higher along trashlines. Also measures like the construction of terraces, grass- and stonelines are taken, but these are very few.

In the east part of the area, east of longitude 37 52'E, shifting cultivation is still very common, farmers occupying a piece of land for a short period to leave it again for a fallow period. In this region the land is still communal. Moving to the west the land is permanently occupied and private property. Millet is grown continuously on the same shamba. Only a strong crop rotation is found in the wetter areas, which are suitable for a larger number of crops.

4.3.4. Harvesting

Harvesting is done when the millet has completely dried on the field. In June and July for the first season and from the beginning of January till half February for the second season. The majority of the millet shamba's show a strong irregularity, irregularity between individual plants as well as between patches within the shamba. Due to the irregularity and the need of food of the farmer, the millet heads are harvested in stages. The millet heads are cut off with a knife by the women and taken home in big bags. The stalks remain on the field and are eaten by the cows, used as mulch or for trashlining during the next season.

4.3.5. Processing

The millet heads are dropped on a prepared floor at the homestead. Then they are beaten with a stick to get out the grains. After that the millet is winnowed. Nearly all the millet is made into "uji". To prepare "uji" the grains are rubbed on a stone joining water and cooked afterwards. Some people also like to make beer of it.

4.4. Sorghum

Sorghum bicolor, Nufia

Sorghum occurs in only a small part of the project area, see map 1. (Appendix A) and even in this part the number of shamba's covered by sorghum is quite small. Very few shamba's are pure cropped. It does occur on quite a lot of shamba's as a few individual plants of different varieties between the other crop(s). Because of the occurrence at a small scale and the wide range in varieties it was not really relevant to evaluate the crop performance and to do harvest measurements. It should be remarked that sorghum, especially the type with open panicle, is cultivated abundantly during the first rainy season in contrast to its occurrence during the second season when the measurements were carried out.

4.4.1. Varieties

It seems to be impossible to recognize all the cultivated sorghums as one species Sorghum bicolor. Snowden (1936) examined 3000 specimen of all over the world cultivated sorghums and found 31 species, 157 varieties and 571 forms. All the species cross easily and a wide range of genetic characteristics can occur in a large number of combinations. Still, according to some authors, the species boundaries are too vague and there are all kinds of intermediates, so it is preferable to group all the cultivated sorghums into one single species: Sorghum bicolor (Purseglove, 1972).

All the sorghums cultivated in the project area are grain sorghums, principally cultivated for their grains. The subdivision of the cultivated sorghums is based on the shape of the panicle and the colour of the grains. They can be distinguished in:

a. Compact, goose-necked panicles. The type is called milo and contains white or red/brown grains. It has its origin in North Africa.

b. Compact, erect, cylindric panicles. These ones are called hegari. The plant, especially the panicle, has a chalky appearance. The grains are white or red. This one has also its origin in North Africa.

c. Open panicles with white to yellow or red grains. The cultivation lasts two seasons; after the second rainy season the plants are ratooned to flower the first rainy season.

The different groups are shown in Fig. 4.6.

The first two groups occur principally east of longitude 37 45′E, see map 1. The third group occurs sporadicly west of longitude 37 45′E. These small sites are not indicated on the map. The different sites of occurrence is due to the prefered growing conditions of the different sorghums.

4.4.2. Field operations

There is much variation in the timing of the fieldoperations for sorghum, because of the strong distribution of different varieties over the area. There won′t be so much variation in the timing of the field operations of the two compact sorghums, see Fig 4.5. The cultivation calender of sorghum.

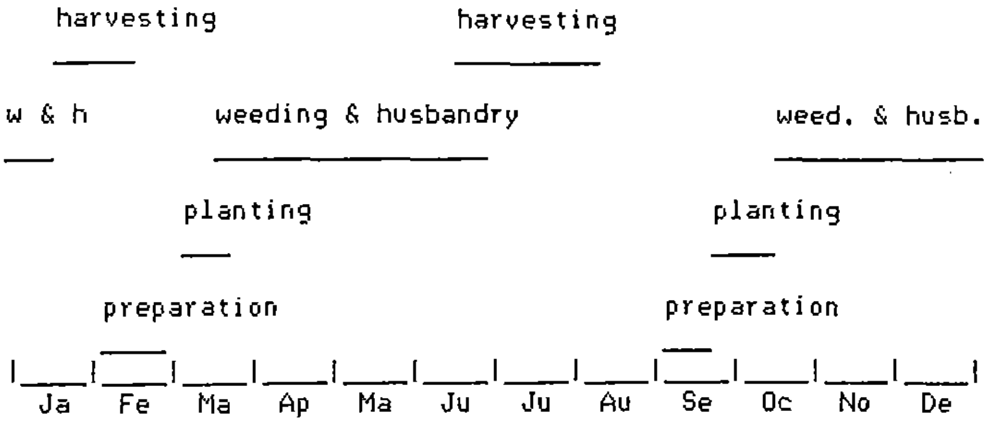


Fig. 4.5. The cultivation calender of the compact sorghums.

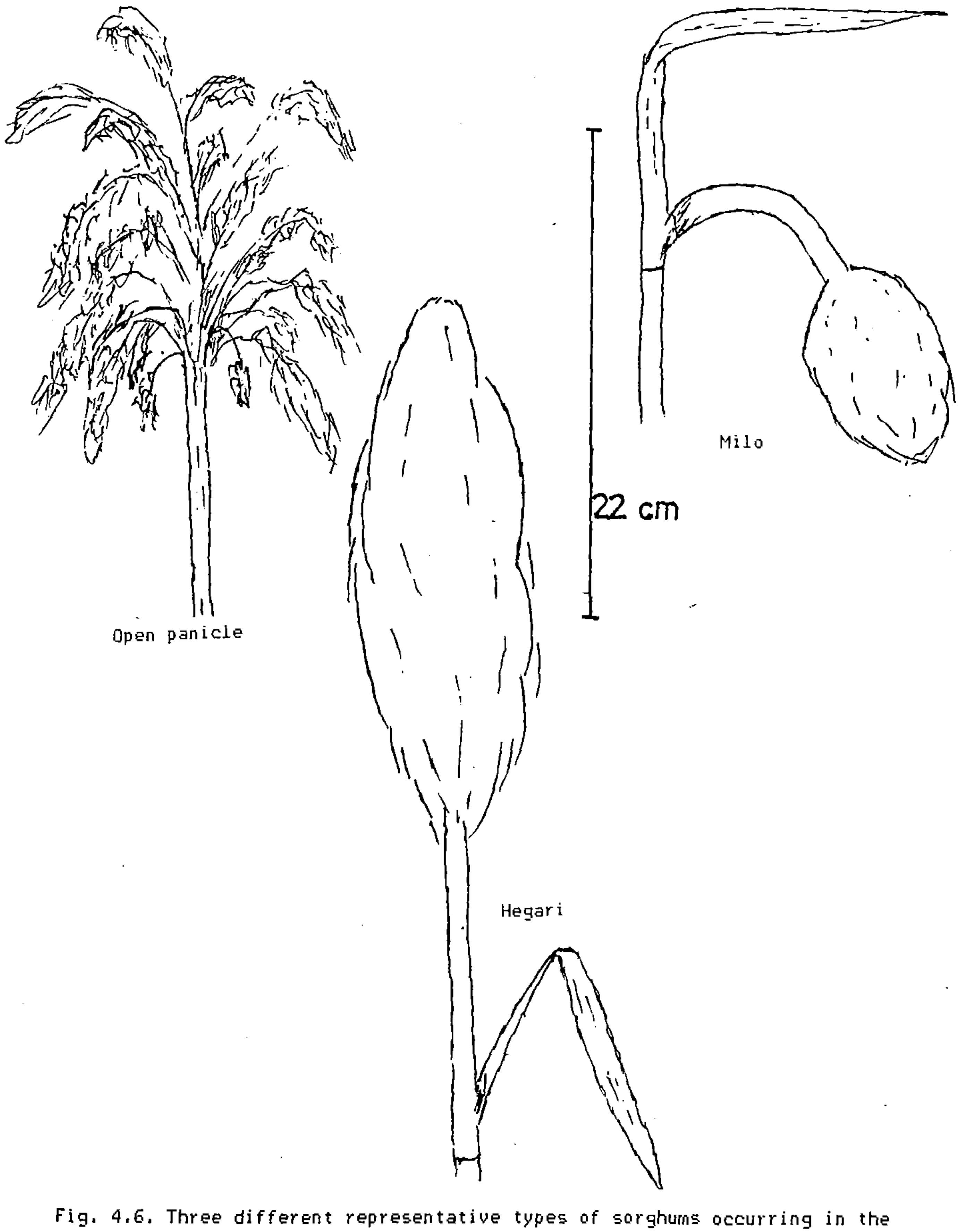


Fig. 4.6. Three different representative types of sorghums occurring in the project area.

Land preparation

The land preparation is performed in either Februari or September. The preparation exists of weeding, loosening and turning the soil. It is carried out with a panga, jembe, morro or a plough. See fig. 4.2.

Planting, seeding and fertilizing

The planting is done as early as possible, just before the onset of the rains. Sorghum responds well to early planting. Planting of the compact types is done during both rainy seasons. Some farmers stated to prefer the second rainy season, because the rainfall is lower and the rains are less reliable. Drought occurring during this period seldom harms the sorghum. The open panicle type is principally planted during the second season. The ratooning is carried out at the end of the short dry period, half March.

Sorghum is seldom purely cropped. Usually a lot of individual plants are found on a shamba, mixed with another, dominating, crop. Especially in the lower areas it is mixed with millet.

The farmers in the lower areas select their seed themselves, just selecting the biggest and healthiest ones. Sometimes they buy them on the local market. The planting holes are made with a panga or a morro. The spacing is usually very irregular.

Some farmers applied manure, chemical fertilizer isn't applied at all.

Weeding

Weeding is performed two times during a growing season. The first one two or three weeks after emergency and the second one after about eight weeks.

Crop protection

Birds is one of the main causes of crop loss. Quelea quela aethiopica, which occurs in large numbers in East Africa, is the most severe one. One method of protecting the sorghum is by chasing the birds, but this requires a lot of labour. There are several kinds of resistance against birds, for example: growing varieties with bitter seed but those are not very palatable, growing goose-necked varieties which are only attacked at the upside of the panicle or growing varieties with glumes and awns.

Sorghum is also attacked by all kinds of fungal diseases, especially anthracnose (Coletotrichem) and leaf blight (Helminthosporium). Besides Sorghum is attacked by all kinds of insects. Crop protection is a very neglected subject.

Conservation practices and rotation

The majority of the shamba's are trashlined. Sometimes stonelines are build instead of trashlines.

Crop rotation is seldom carried out. This is also due to the fact that the land is just suitable for a very small number of different crops.

4.4.3. Harvesting

Harvesting is done by the wives of the farmers in three stages during the months Januari and Februari for the second season, and during the period

June-August for the first season. The panicles are cut with a knife or broken off by hand. The stalks are used for trashlining during the next season.

The open panicle types are ratooned at the end of the short dry season. The advantage is that they have many tillers (10-30) at the end of next season.

4.4.4. Processing

The sorghum is dried in the sun, trashed and winnowed. Next it is grinded coarsely in a trunk or between two stones to make "ugali" or "uji". Further the sorghum is fermented, because people think non fermented sorghum is very unpalatable.

5. HARVESTS, CROP PERFORMANCE; RESULTS AND DISCUSSIONS

5.1. Maize

5.1.1. Relationship between ear size and grain yield

The existence of this correlation between ear size and grain yield is well known from literature (Hesselmark, 1978). Now it is necessary to appoint the relation for this specific situation.

In total 12 maize harvests were carried out at the comprehensive sample sites. Inaccurate administration and the disappearance of several maize ears of the drying rack during the first week, made that only 8 of the 12 harvests could be used for analysis, because the data of the other 4 harvests were considered to be unreliable.

There may be small differences in the exact correlation for the different harvests, due to different soil mapping units and varieties. In spite of that all the ears of those 8 harvests, of different varieties and on different soil mapping units, were put together for analysis. From literature it is well known that this procedure is more often used. So a total of 8 harvests, containing 154 ears was used for analysis. Irregular ears and not completely filled ears were left out of consideration.

Two simple linear regression equations to describe the relation between ear size (lxc in cm^2) and grain yield per ear (W in g) are known and tested for analysis:

a. $W=a+b(l\times c)$
b. $W=a+b_1 l+b_2 c$

After computing all the data, the first equation appeared to give a little bit better correlation coefficient, $R^2=0,97$, than the second equation. Deviations are due to thicker layers of grains or husks, irregular ears or empty places on the ears. And besides to measurement errors. The relation given after analysing is:

$$W=-6,59+0,39(l\times c) \qquad R^2=0,97$$

All the combinations of l and c, and W were put in a diagram, see Fig 5.1. Different statistical values as a result of the statistical analysis are given in Table 5.1.

$\overline{W}=96.9$ g	$S_W=49,0$
$\overline{lxc}=263,5$ cm^2	$S_{lxc}=107,5$
n=154	$R^2=0,97$

Standard error of the linear regression $S_W=24,9$

Table 5.1. Some statistical values of the analysis.

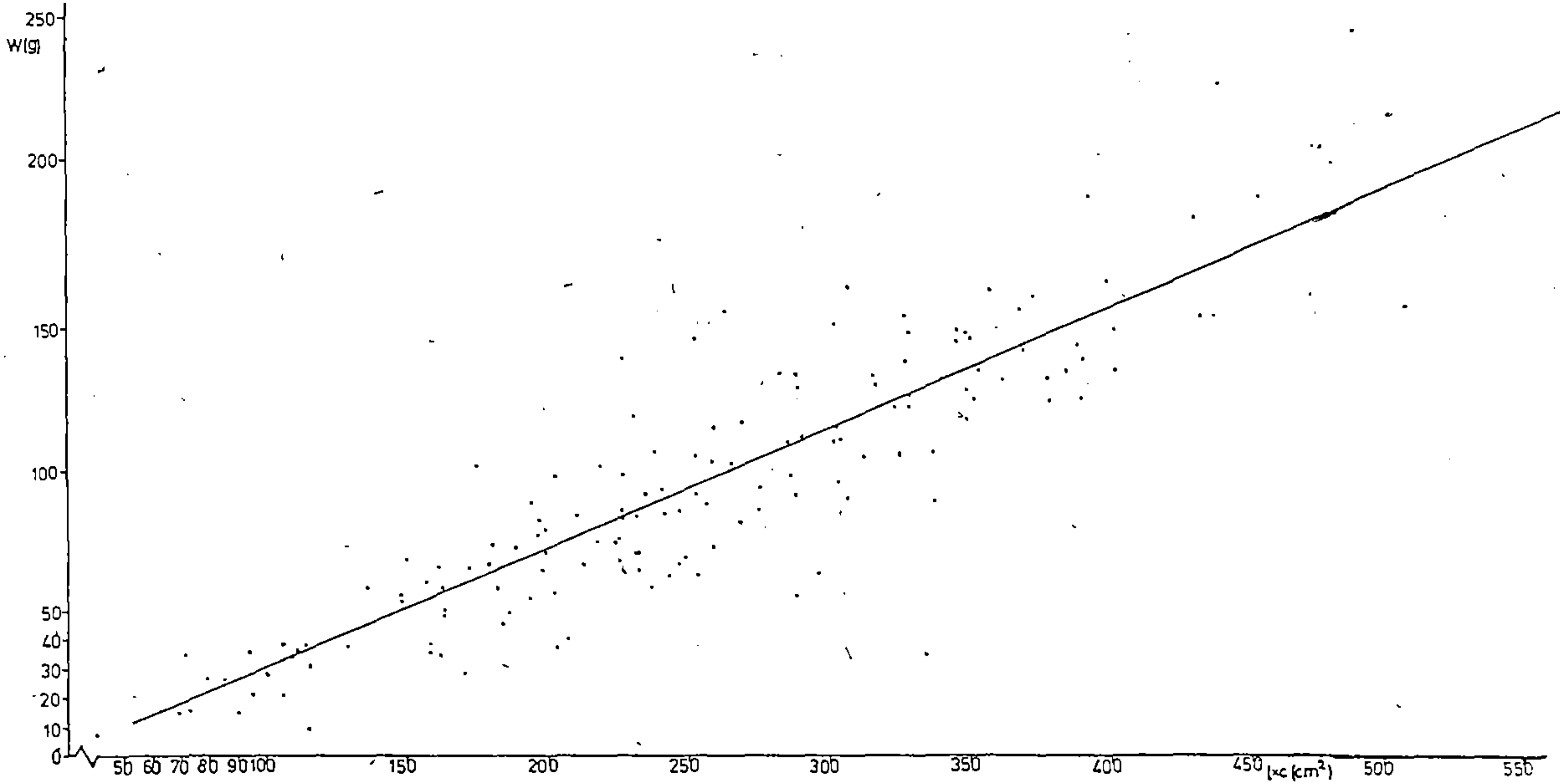


Fig. 5.1. Diagram of W against Ixc

Those 8 harvests were taken on 5 different soil mapping units, quite equally distributed within the both sample strips. The harvests contained three different varieties: Katumani Composite B and the hybrids 511 and 512.

In view of the different soils, the climatic variation and the harvested varieties, there doesn't seem to be so much variation in the ear sizes. Both the standard error of the linear regression and the correlation coefficient are quite reasonable. The correlation coefficient varies a bit with variety and soil mapping unit, but this doesn't seem to be significant.

Also scores were given for crop performance of the individual plants as well as for the overall crop performance. These scores were after all not taken into account for the calculation of the relation, because the data of ear sizes are much more reliable in contrast with those scores of crop performance.

5.1.2. Maize yield data

The results of the 12 harvests, 7 in sample strip A and 5 in B, are given in Table 5.2. All the 12 harvests represent just 6 soil mapping units. Just some of the in advance selected shamba's have finally been harvested, for the same reasons as in the case of millet, see paragraph 5.2.3.

No. site	Location	Reconnais.	Plantd. ears/m^2	Yield Kg/ac.	Kg/ha.	Variety	Yield expect. farmer Kg/ac.
A-6	99496-3601	LVC	2,2	426	1065	Katum.	180
A-9	99498-3564	LP1	2,6	367	918	511/512	375
A-10	99522-3524	UP1h	1,9	649	1623	511/512	275
A-11	99567-3447	RP1h	1,5	375	938	512	90
A-12	99534-3492	RP1h	2,6	1093	2733	?	450
A-13	99547-3475	RP1h	3,0	1283	3208	512	720
A-14	99556-3464	RP1h	2,7	616	1540	511	540
B-6	99656-3636	U1PC	2,2	988	2470	Katum.	75
B-9	99654-3620	U1P2p	2,8	624	1560	Katum.	720
B-11	99664-3594	U1P2p	2,8	853	2133	?	270
B-13	99651-3582	U1P2p	2,3	1043	2608	512	180
B-14	99640-3554	RP1h	1,2	306	765	512	90

Table 5.2. Results of the maize harvests

For the non-comprehensive sample sites, on 81 shamba's the maize ears were actually measured. The average ear weight of the measured ears at a certain site was appointed by using the average ear size (lxc) and the described correlation. The obtained average ear weight was multiplied with the plant density (ears/m^2). So, an estimation of the yield in Kg/ac. could be calculated. All the data of the non-comprehensive sites can be found in Appendix D. A selection classified to soil mapping unit an AEZ of Jaetzold can be found in Appendix F.

As far as has been checked, the rains have been quite good in the western part during the second rainy season of 1985. They can be compared with the average rainfall. There is a very strong yield variation between shamba's at the same spot. Sometimes the lowest yields are about 20% of the highest yields at the same soil mapping unit.

The yields vary between neglectable at some spots near Ishiara to more than 2000 Kg/ac. at a site near Kigumo. Acland (1971) gives average yields of 1350 Kg/ac., while Jaetzold (1983) mentions levels of 1400 kg/ac. for Katumani and values of 2000 Kg/ac. for the hybrids 511/512. These indicative yields are obtained under circumstances of manuring, fertilizing and the application of chemicals.

The yield differences between different soil mapping units is due to the differences between those units, eventually climatic variation and differences in farm-management and input level. The already mentioned yield differences within the same soil mapping units, located at about the same spot, are very strong and only due to the variations in management and input level. This factor is very disturbing in the crop performance results. So, it is impossible to draw any conclusion on the effects of soil and climate on basis of these crop performance data.

Farm-management and input level prove to be very important. In the case of maize, the extent of manuring, fertilizing and the protection of the crop (eventually the application of chemicals) will play a very important role. Besides of course other practices, like soil preparation, weeding, rotation, soil conservation practices, etc.

5.2. Millet

5.2.1. Relationship between plant density, score and yield

The actual yield measurements, carried out at the comprehensive sites, have to be related to the according scores given during the harvesting. For every harvested shamba, the plant density (number of heads/m^2) was determined. Besides the average score per millet head for a harvested area was determined.

The average score of all the millet heads at a certain site was determined by multiplying the score and the number of heads having that score for every score group. Than the total of these five groups was added and divided by the total number of heads, so the average score per head is obtained. The lower the average score, the better the average performance per head. The higher the score, the more worse the performance. This treatement of the figures was carried out, supposing that there would be a relation between the average score per head and plant density, and the yield.

The plant density (b) in heads/m^2 was divided by the average score per head (c). So a productivity factor b/c was created, expressed by plant density and average score per head. The higher the value of b/c, the higher the plant density and/or the lower the score. That means a good performance of millet. A low value means a low plant density and/or a high score, so a poor performance of millet. The calculation of the b/c values and the yields of 14 harvests, see Table 5.3. gave the simplest linear regression of the shape:

$$y=a+bx$$

So the data, yield (y) in Kg/ac. and the b/c in heads/m^2 values were put in a diagram see Fig 5.2., which shows the relationship. The calculation gave the linear regression:

$$y=-120,7 + 139,7b/c \qquad n=14 \qquad R^2=0,97$$

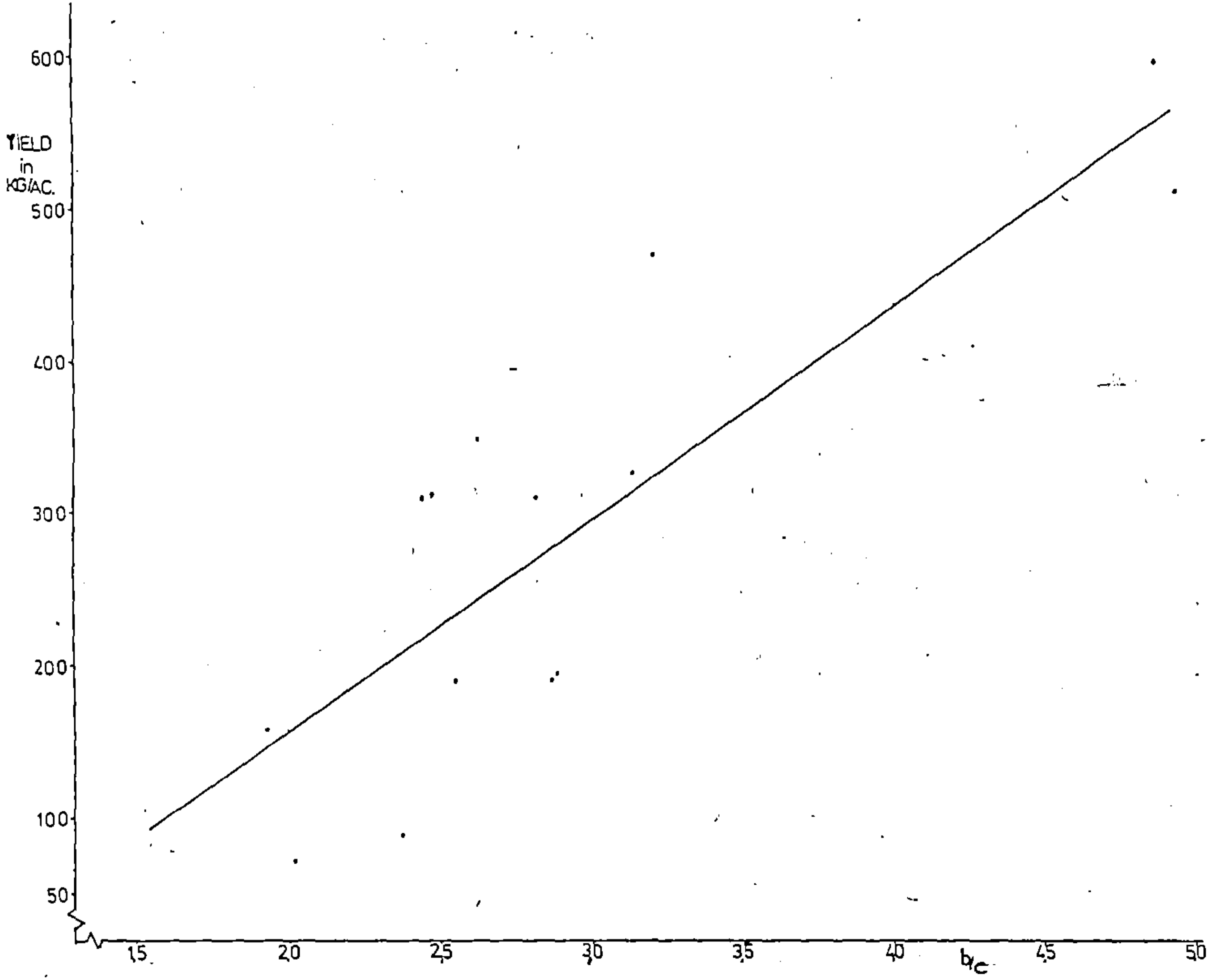


Fig. 5.2. Diagram showing the relation between b/c and the yield of millet.

Table 5.4 shows some statistical figures for the evaluation of this linear regression.

In view of the small amount of harvest data and the lack of information about previous analysis of yield data of millet, this method of analysing the available data must just be seen as an attempt in search of reliable relation to estimate millet yields based on the gathered data. The correlation coefficient of R^2=0,97 is high, but the standard error of the linear regression is quite large, for a good reliability of the estimated harvests. More and larger investigations would probably lead to much better relationships, based on the same principle.

No. site	Location	Reconnais.	Pl.dens. heads/m^2	av. score	b/c	Yield Kg/ac	Kg/ha	Exp.farmer Kg/ac.
A-2	99495-3757	U2F2p	8,4	3,55	2,37	88	220	180
A-3	99514-3727	U2F2p	9,9	3,89	2,55	191	478	90
A-4	99515-3701	U2FC2	7,7	3,99	1,93	158	395	135
A-5	99503-3674	U2FC2	9,9	3,55	2,79	514	1285	36
A-7	99495-3592	LP1	10,3	3,66	2,81	310	775	514
A-8	99493-3554	LP1	10,8	3,45	3,13	327	818	1440
B-1	99625-3788	U2QC1	7,2	3,56	2,02	71	178	-
B-2	99617-3773	U2QC1	10,7	3,72	2,88	195	488	90
B-3	99624-3736	U2F1	8,5	3,48	2,44	310	775	135
B-4	99629-3703	U2F1	8,9	3,40	2,62	349	872	54
B-5	99637-3678	U2F1	10,8	3,37	3,20	465	1163	1080
B-7	99650-3631	U2F2p	17,4	3,57	4,87	575	1438	150
B-8	99654-3618	U1P2p	8,8	3,56	2,47	312	780	90
B-10	99666-3605	U1P2p	10,7	3,74	2,86	190	475	-
B-12	99651-3582	U1P2p	17,6	3,56	4,94	511	1278	720

Table 5.3. Results of the millet harvests.

$\overline{Y}$=289,4 Kg/ac. S_Y=152,4

$\overline{b/c}$=2,94 $S_{b/c}$=0,91

n=14 R^2=0,97

Standard error of the linear regression: S_Y=83,9

Table 5.4. Some statistical figures of the calculation.

5.2.2. Scoring

As already described in paragraph 2.4.3. scoring is a very subjective method in doing harvest estimations. There is a strong variation in the weight of different heads belonging to the same scoring group. The strong variation in the weigths is mainly due to the fact that it was my first experience in scoring of crops. On the other hand it is impossible to avoid variation in weigths, because you have to cover a whole range of weights of millet heads with just five scoring groups. But the extent of overlap between the weights of the diifferent groups, gives an indication of the quality of the scoring procedure in the field. Table 5.5. gives some figures on the scoring of the millet. The maximum and minimum values give an indication of the overlap.

Scoring group	1	2	3	4	5
Average weight	20,47 g	15,87 g	9,38 g	3,96 g	1,19 g
Maximum weight	30,09 g	27,11 g	12,71 g	6,06 g	2,80 g
Minimum weigth	15,03 g	8,27 g	4,20 g	2,11 g	0,28 g
Standard error	4,40	5,55	2,80	1,25	0,82

Table 5.5. The different values of the scoring groups.

Scores for overall crop performance have also been given, taking into consideration the density of heads and the performance of the individual heads. This appeared to be even more difficult than scoring for individual heads. That is why these figures are not taken into consideration and not mentioned in the report.

5.2.3. Millet yield data

A number of 15 millet shamba's was harvested on 6 different soil mapping units, 6 in sample strip A and 9 in B, quite equally distributed over the area in which millet occurs, see map 1. The harvesting results of those 15 shamba's are mentioned in Table 5.3. Not all the in advance selected shamba's could be harvested in the end, due to all kinds of reasons. Sometimes farmers were not found at home or didn't give permission in the end or the shamba didn't appear to be so suitable to be harvested. Another very large problem met during the first field days was, that most farmers had already started harvesting the millet near Tana river. The reason for harvesting in a very early stage, when the crop is not yet completely ripe, is food shortage. So we were too late, in spite of all the investigation in advance. Harvesting started about one week earlier, than farmers had stated, resulting in "running after the harvests" during the first weeks. That is the reason why just a small amount of non-comprehensive sample sites actually was estimated (see Appendix E). In spite of that quite a lot of shamba's were visited just to ask the yield of that season. Just at 44 sites the millet heads were actually evaluated and the plant density counted to get an estimation of the yield. All the data of the non-comprehensive sample sites can be found in Appendix E. A selection of the actually evaluated shamba's can be found in Appendix G.

In the first place the total amount of rain during the last growing season has been less than in average years in the eastern part of the area, according to what farmers stated. Next to the total amount of rainfall, the distribution and the onset of the rains are very important, especially in the case of millet.

In spite of the rain shortage, as farmers stated, the crop performance was good. Remarkable is, that there is a strong difference between shamba's at the same spot. Some of them have a neglectable harvest, while others give very good yields. The yields vary between neglectable and 600 Kg/ac. Acland (1971) gives average values of 180 Kg/ac. and 680 Kg/ac. under optimal circumstances. Jaetzold (1983) gives values of 800 Kg/ac. under circumstances of good husbandry (application of manure, chemical fertilizer and chemicals for crop protection). So the yield estimations for this area appear to be quite high, especially when there was really shortage of rain last season. A systematical mistake couldn't be discovered in the measurements/evaluation neither in the data processing.

Yield differences between soil mapping units are due to differences in soil properties, climate , farm-management and input level. Yield differences within soil units are caused by differences in management and input level, when those units lie within a short distance of each other.

Talking about farm-management and input level there are a lot of factors which play an important role and affect the crop performance. For example the clearing or history of cropping and, especially for millet, the date of planting and other practices like weeding, soil conservation and water conservation. Special attention has to be paid to the chasing of birds and monkeys one of the worst threats to the development of a good crop. The effects of diseases seems to be limited.

If we look at the estimations in Appendix E, the farm-management and input level appear to be very confusing, which makes it difficult or impossible to distinguish different soil mapping units, concerning their suitability for millet just on basis of crop performance figures.

5.3. Sorghum

For sorghum no harvests were carried out, neither any measurements have taken place. Some farmers were asked to estimate the expected yield. The estimations varied from 45 Kg/ac. to 180 Kg/ac. Comparing the estimations of the farmers with the actual yields in the case of maize and millet, the estimations appeared to be very unreliable. Probably this is the same in the case of sorghum. Jaetzold (1983) gives average yields under circumstances of good husbandry of about 1600 Kg/ac. depending on the chosen variety.

A general impression is, that the crop performance of sorghum in pure stands is much better than when it is intercropped with millet.

5.4. Field work and labour input

Much of the time spend during the weeks of fieldwork, see time table Appendix C, was lost by driving to the far areas near Tana river.

The actual harvesting and interviewing on maize and millet shamba's lasted usually about one and a half hour. The evaluation on the non-comprehensive sample sites lasted usually a half an hour to three quarters of an hour.

During the weeks of fieldwork, 10 hours a day during 6 days a week was spent in the field. Arriving home another three quarters of an hour were spent to store the harvested heads or ears and to do some administration of the measurements of that day.

The field work in the sample strip B is not completely carried out up to the forest border of Mount Kenya, because of illness of myself. Sample strip A was much further completed, but not fully to the forest border. By losing time for recovery again a situation of "running after the harvests" arose. A lack of data, which is shown in the Appendices was the inevitable effect.

Anyway, after all the area appeared to be too large to do thoroughly crop investigations in such a short period by only one team operating from one residence.

6. LAND EVALUATION

6.1. Introduction

Land evaluation is the process of assessing land performance when used for a specific purpose. This process involves the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and compare promising kinds of land use in terms applicable to the objectives of the evaluation (FAO, 1976).

A land evaluation, of the actual situation in a certain area, is generally carried out in two stages, namely an ecological analysis followed by a socio-economic analysis. The present evaluation is just an ecological land evaluation of the Chuka area.

6.2. The land evaluation procedure

6.2.1. Different stages of an ecological land evaluation

A. Selection of the LUTs.
At an early stage in the land evaluation procedure the specific kinds of land use are well defined. The relevant Land Utilization Types (LUTs) are identified and described.

B. Determination of the requirements of the relevant land uses.
Each crop has the same basic needs for good performance. The level of certain requirements, not only to survive but also for optimum production, is very diverse for different crops. So when a Land Unit (LU) is under consideration, it depends on the demanding crop(s) if that land unit is very suitable for the crop(s) or if it is less suitable.

C. Determination of the Land Units (LU), their Land Qualities (LQ) and Land Characteristics (LC).
A land unit is an aggregation of one or more soil mapping units occurring in one agro-ecological zone and possessing the same land quality rating. Land characteristics often don't affect the land suitability in an indisriminate way, therefore they are aggragated to clusters called land qualities. These land qualities cover the requirements of land use and influence the suitability more or less independently of each other.

D. Compilation of the conversion tables.
The conversion tables for different LUTs are compiled on basis of the crop requirements, the land quality rating and the different defined suitability classes. So the resulting conversion tables give the different land quality ratings for the distinguished suitability classes. On basis of these tables every land unit can be classified according to its land quality ratings for a certain LUT.

E. The process of matching and suitability classification.
Matching is the process of comparing the requirements of a LUT with the attributes (land qualities) of a land unit. This is done by using

conversion tables, comparing the ratings of the land units with the ratings in the tables. So the suitability class is fixed for that land unit and the most limiting land quality for that land unit can be determined. So a list of all the classified land units is made.

- Since this land evaluation is on an ecological basis, translation of the suitabilities to an overall land evaluation, taking into account the socio-economic circumstances, will give quite a different picture of suitabilities.

- The final suitability classification is just a picture of the actual situation. So any change in the given environmental circumstances or improvement carried out by man will change the suitability of the different land units.

- Intercropping systems are not considered as such. The normative yields are based on monocultures. The normative yields will have to be adapted for such intercropping systems. In this case normative yields are used, taking the interference between the different crops in intercropping systems for granted.

6.2.2. Description of yields, classes and technology levels

Normative yields refer to outputs (in Kg/ha. or Kg/ac.) obtained by farmers under optimal ecological conditions and a certain specified technology level. It has to be remarked that normative yields are related to optimal ecological conditions and a certain technology/management level and not to an "optimal" technology/management level. So normative yield is always related to a specified technology level.

Description of the different land suitability classes:

S_1 Ecologically highly suitable: land with no or slight limitations for the sustained cultivation of a given crop. Yields are 76-100% of the normative yield.

S_2 Ecologically moderately suitable: land with moderate limitations for the sustained cultivation of a given crop. Yields are 51-75% of the normative yield.

S_3 Ecologically poorly suitable: land with severe limitations for the sustained cultivation of a given crop. Yields are 26-50% of the normative yield.

N Ecologically not suitable: Land having limitations which appear so severe as to preclude any possibility of succesful sustained use for a certain crop. Yields are 0-25% of the normative yield.

Description of the suitability subclasses. These classes reflect the main limitations within the main classes as described above.

m=moisture availability	o=oxygen availability
t=temperature zone	e=resistence to erosion
n=nutrient availability	s=hindrance by stoniness and rockiness

Description of the technology levels.

Two levels of technology are usually distinguished in land evaluation. These two levels give different normative yields under the same ecological circumstances. The levels are defined and described depending on the actual situation in the area under consideration.

6.3. The land evaluation procedure for the actual situation

6.3.1. Description of the different stages in this situation

The land evaluation will be carried out on basis of the final reconnaissance soil survey of the area and the gathered climatological data (rainfall and temperature, paragraph 3.2.1. and 3.2.2.).

The classification will be carried out according to the proposals for rating of land qualities, 2nd approximation (Braun, 1977). For additional data the 3rd approximation of Weeda, which is not completely compiled yet, was already used.

A. Selection of the LUTs.
The LUTs to be evaluated in this report are defined as single crops. The cultivation of maize, bulrush millet and sorghum is distinguished. These cereals are cultivated in the area at small scale subsistence farms under varying levels of technology/management, but in general the level of technology is low.

B. Determination of the crop requirements of the cereals.
The crop requirements of the cereals are gathered and put in Table 6.1.

Crops Crop requirements	Maize	Millet	Sorghum
Rainfall per growing season	Variety: Katum. 260-450mm H511/12 500-750mm	220-400mm distribution!	320-590mm
Temperature	30°C (10-35°C)	30-35°C -	24-30°C (15-35°C)
pH	6,0-7,0 (5,0-8,0)	5,5-7,0 (5,0-8,0)	5,5-6,5 (5,0-8,5)
Drainage	Well	Well	Moderately well to well
Texture	loam silt, loams light to medium	loams light to medium	medium to heavy
Heigth	0-2900m	0-1200m	0-1500m
Remarks	no drought no frost no waterlogging	drought resistant no frost no waterlogging	drought resistant no frost

Table 6.1. Crop requirements of the cereals.
Note: (....) ranges of the crop requirements.

Optimum values required for optimum crop performance as well as ranges, the extremes for any still "valuable" performance, are gathered. It should be remarked that even poor performance, giving yield levels below 50 Kg/ac, is considered to be valuable and cannot be neglected.

Beside the mentioned requirements, the heigth is a quite important factor to grow these cereals. The crops are not found in higher or lower located areas than the figures do indicate.

Crops require much more than just the mentioned requirements. Considering these crops it is necessary for a good performance to cultivate them at soils which are not too much eroded and don't show too many signs of stoniness and rockiness. Since the land preparation and weeding is done by hand on nearly all the shamba's, a certain degree of stoniness and rockiness is acceptable as long as foothold for the crops is sufficient and the individual crop performance is not really stunted. At a lot of sites the individual crop performance is not stunted, but by stoniness, rockiness and erosion problems the overall performance of the crop may be reduced by for example lower plant densities. So this will lead to a lower classification, because the classes are related to yield per area. Also a small degree of erosion is acceptable in the cultivation, but it will affect the final classification. So for good overall performance of a crop in the field is much more required than the tabled requirements.

C. Determination of the land qualities.

The land qualities will be selected for the classification of the soil mapping units in the different climatological zones for the cultivation of the cereals in the area. The selection of land qualities is based on two criteria: the relevance of the land quality for the Chuka area and the available data concerning a certain land quality.

The considered land qualities are:

- -available moisture zone
- -availability of moisture storage capacity
- -available temperature zone
- -availability of nutrients, only pH
- -availability of oxygen
- -erosion hazard
- -presence of stoniness and rockiness
- -absence of overgrazing

* Availability of water

The availability is thought to be dependent of the climate characteristic (moisture zone) and the soil characteristic (moisture storage capacity.

- moisture zone

The moisture zone is determined by the ratio r/Eo, the average annual precipitation (r) and the average annual potential evaporation (Eo). With this ratio it is possible to make an estimation of the amounts of days per year with full moisture, according to: amount of days full moisture = 100/0.8 x r/E_0. The agro-climatic zone map of the KSS (Braun et al., 1982) distinguishes 7 zones for moisture availability, see Table 6.2. The need for continuous moist period is not regarded. Considering the bimodal rain distribution the moisture requirements may be hard to meet, especially in the drier zones.

zone	r/Eo.100%	amount of days full moisture	description
I	>80	365	humid
II	65-80	297-365	sub-humid
III	50-65	228-297	semi-humid
IV	40-50	182-228	semi-humid/arid
V	25-40	114-182	semi-arid
VI	15-25	68-114	arid
VII	<15	0-68	very arid

Table 6.2. Moisture availability zones (Braun et al., 1982).

-moisture storage capacity

The soil characteristic factor consists of the total productive available moisture (TPAM in mm) and the hindrance to root development. Since there are no reliable pF-data available, the TPAM has to be estimated from Table 6.3. This table is based on correlation between available moisture and respectively clay content and soil depth. The rating for the soil moisture storage capacity is given in Table 6.4.

depth (cm)		TEXTURE LS	SL	SCL	SC	C
25	very shallow	8	10	14	20	28
50	shallow	15	20	28	40	55
80	moderately deep	24	32	44	64	88
120	deep	36	48	66	96	132
150	very deep	45	60	83	120	165
180	extremely deep	54	72	99	144	198

Table 6.3. TPAM for different soil depth and textures.

Rating		TPAM (mm)
1	very high	160-200
2	high	120-160
3	moderate	80-120
4	low	40-80
5	very low	<40

Table 6.4. Rating of the soil moisture storage capacity.

The rating has to be adjusted when there is too much hindrance to root development. This is not appropriate to this evaluation.

* Available temperature zone

A distinction is made between temperature zones as shown in table 6.5.

zone	mean annual temperature °C	mean maximum temperature °C	mean minimum temperature °C
I	24-30	30-37	18-23
II	22-24	28-30	16-18
III	20-22	26-28	14-16
IV	18-20	24-26	12-13
V	16-18	21-24	11-12
VI	14-16	19-21	9-11

Table 6.5. Temperature zones.

These zones are compiled according to the relation between altitude and temperature as mentioned in paragraph 3.2.2.

* Availability of nutrients
Since there is a lack of chemical soil data, it was decided only to consider pH for this land quality. The rating for pH is derived from the 3rd approximation of Weeda. Table 6.6 gives the ratings for pH.

Rating		$pH-H_2O$	
1	high	5,6-7,2	
2	moderate	4,6-5,5	7,3-8,0
3	low	4,0-4,5	8,1-9,0
4	very low	<4,0	>9,0

Table 6.6. $pH-H_2O$ ratings.

* Availibility of oxygen
The rating for the availability of oxygen is given in Table 6.7. The oxygen availability is only in danger in the bottomlands. These are flooding during the rains.

Rating		Soil drainage class
1	high	Well to excessively drained
2	high	Moderately well drained
3	moderate	Imperfectly drained
4	low	Poorly drained
5	very low	Very poorly drained

Table 6.7. Rating of oxygen availability.

* Erosion hazard
The erosion hazard is taken into account being an important soil degrading factor, strongly influencing the agricultural production. The only erosion data which are available from the reconnaissance soil survey have a qualitative character, indicating the kind of erosion and the gravity. So in this case the ratings from the 2nd approximation couldn't be used.

It was decided to downgrade with one class all those soil mapping units which would be classified as S_1 or S_2 in the case of moderate sheet, rill or/and gully erosion.

* Presence of stoniness and rockiness
The reason why stoniness and rockiness are put in the list of land qualities is that this quality will influence the yield per area strongly. The different classes are distinguished on basis of yield per area. As already said in the paragraph about crop requirements, stoniness and rockiness won't stunt the individual crop performance and it is neither a hindrance for the cultivation under the actual conditions, but the yield level/area of a certain crop is affected.

Rating	Stoniness/Rockiness		Description
1	<0,01%	2%	Non
2	0,01-1%	10%	Fairly
3	1-3%	10-25%	Stony/Rocky
4	3-15%	25-50%	Very strong
5	>15%	>50%	Exceedingly

Table 6.8. Rating of stoniness and rockiness.

* Absence of overgrazing
The presence of overgrazing is considered to be a land quality affecting the ecological suitability. From the available information it appeared to be very difficult to interpret the level of overgrazing and the consequence for the reduction in productivity. Anyway the land quality is considered as far as possible.

* Other land qualities
Other land qualities like the hazard of salinity and alkalinity, absence of natural vegetation and possibilities of mechanisations are not considered.

The first one of these land qualities is not considered to be relevant for this area, because of the absence of salinity and alkalinity. The second one is not relevant in the case of ecological land evaluation, because the presence of natural vegetation has nothing to do with the ecological suitability of land. The essential problem in the case of present natural vegetation is the necessary clearing of the land before it can be cultivated, which requires a lot of human power. Perhaps is the ecological suitability of a piece of land which has been covered with a dense vegetation for several years even higher than an area which has been covered with vegetation during a short period and with a low density.

The land quality possibilities for mechanisation is left out of consideration as there are no possibilities for mechanisation in the (near) future. The actual way of preparing the land is already described in chapter 4. This actual situation won't be liable to change very much in the near future in spite of possible changes in technology level.

D. The conversion tables.

The conversion tables for the three LUTs are shown in table 6.9.

MAIZE

LQ / Class	A	B	C	D	E	F	G	H
S_1	I-II-III	1-2-3	I-II-III IV	1	1	1	1	1
S_2	IV	4	V	2	1	2	2	1
S_3	IV	4	VI	2	2	3	3	2
N	V	5	VII	3	3-4	4-5	4-5	3-4

MILLET

LQ / Class	A	B	C	D	E	F	G	H
S_1	III	3	I	1	1	1	1	1
S_2	IV	4	II	2	2	2	2	1
S_3	V	5	III	2	2	3	3	2
N	I-II	5	IV-V-VI	3	3-4	4-5	4-5	3-4

SORGHUM

LQ / Class	A	B	C	D	E	F	G	H
S_1	I-II-III	1-2-3	I-II-III	1	1-2	1	1	1
S_2	IV	4	IV	1	3	2	2	1
S_3	IV	4	IV	2	4	3	3	2
N	V	5	V-VI	3	4	4-5	4-5	3-4

Explanation of the columns: A = Available moisture zone
B = Availability of moisture storage capacity
C = Available temperature zone
D = Availability of nutrients, only pH
E = Availability of oxygen
F = Erosion hazard
G = Presence of stoniness and rockiness
H = Absence of overgrazing

Table 6.9. The conversion tables for the three LUTs.

The tables are compiled according to the crop requirements and the land quality ratings as already described in paragraph 6.2.1.D. Some remarks should be made about the land qualities moisture zone, moisture storage capacity and temperature zone. In consequence of all the different varieties of maize as well as of sorghum, the land qualities of those two crops in the conversion table are uprated. All those varieties are adapted to different optimum temperatures and so to different altitudes where they are cultivated. Because of this temperature adaptation these varieties are each highly suitable under a certain range of temperature. It is just a matter of chosing the most adapted variety.

The adaptation of maize varieties to different temperatures and the application of those varieties by farmers, causes that also the rating for available moisture zone can be adapted, because the different varieties are also characterized by different water requirements. Varieties adapted to lower temperature require more water during their longer growing period.

Also the rating for moisture storage capacity can be adapted, so that more varying levels of moisture storage capacity are still highly suitable. This was possible because there is, except of the bottomlands, no risk of flooding and enough available oxygen for root development.

E. The process of matching and the final classification can be found in the next paragraph 6.4.

6.3.2. Description of yields and technology levels

To appoint the normative yields for maize and bulrush millet, all the land evaluation units (combination of soil mapping unit and a certain moisture/temperature zone) were classified. Comparing the different classes with the obtained harvest estimations, it appeared that there is not any significant yield level difference between different classes. So, as already suggested in paragraph 2.4.4. farm-management as well as input level are very disturbing factors. The classes don't give any significant difference if we just consider the yield levels. The classified land evaluation units (N, S_3, S_2) give yields of 860-920 Kg/ac. for maize and 290-310 Kg/ac. for millet.

It seems, considering the yield estimations, most reasonable to appoint the normative yields at 2000 Kg/ac. for maize and at 800 Kg/ac. for millet under technology level I. For sorghum a yield level of 1600 Kg/ac. under technology level I seems to be reasonable, see paragraph 5.3.

Description of the technology levels.
There is a wide variation in actual technology levels in the area. This wide variation of levels will be joined to one to be desribed level I. Besides this level a level II will be defined. These levels are only described for the three LUTs.

Level I
This level is locally developed by farmers and characterized by its wide variation for each crop and also between the three crops.

Some farmers apply manure for millet and sorghum. Most farmers apply manure and/or chemical fertilizer for the cultivation of maize. Seed is usually selected from farmers' stock, but some farmers buy hybrid seed. Crop protection is limited to chasing of birds and monkeys for sorghum and millet and spraying with DDT at some places against stalk borer in maize. Land preparation is mainly carried out by hand with panga, jembe or morro. Sometimes ox-traction is used for ploughing. Conservation practices are limited to trash-, stone- and grasslines.

Level II
Under this level farmers will apply inputs like seed, fertilizer and chemicals. Land will be protected against degradation and water conservation will play an important role, especially in the east part of the area.

6.4. The final classification

The area is finally classified according to land evaluation units. A land evaluation unit consist of a soil mapping unit, according to the final reconnaissance soil survey of the area, and an agro-climatic zone. The agro-climatic zone consists of a moisture zone and a temperature zone.

Table 6.10. shows all the final classes with the limiting land qualities for all the land evaluation units for the three occurring cereals.

In spite of upgrading and evaluating according to a for Kenya adapted land quality rating system the final classes are quite low if we consider the yields. The results of the classification should be approached with excessively much care. It is even better to rely on general data concerning the physical environment, like climate, and field observations, because of the doubtful reliability of the results of the classification according to this system for this specific area.

Soil mapping unit	Classification of the land evaluation units		
	Maize	Bulrush millet	Sorghum
MBp	N m/s	N s	N m/s
MGC	N s	N s	N s
HIC	N m, S_3 m/s	S_3 m/s	N m, S_3 m/s
HBC	S_3 m/s	S_3 m/s	N m, S_3 m/s
HPC			
HGC			
HQC	N m/s	N s	N m/s
HUC	N m	S_3 m/s	N m
RP1h	S_2 t/n	N t, S_3 t	N t, S_3 t/n
RP3	S_3 t	N t	N t
LP1	S_2 n, S_3 m	S_3 t	S_3 m/n
LP2p	N m	S_3 m/s	S_3 m
LPC	N/S_3 m	S_3 m/t/s	S_3 m/s
LB	N m, S_3 m	S_2 m/t/n, S_3 m	N m, S_3 m/n
U1IC	$S_{2/3}$ m	S_2 m/t	$S_{2/3}$ m
U1P1h	S_2 n	N m, S_3 t	S_3 t/n
U1P2p	S_2 n, S_3 m	S_2 m/t/n, S_3 t	S_3 m/n
U1PC	N/S_3 m	N t, S_3 t, S_2m	N/S_3 m/t
U2Q1p	N m	S_3 m	N m
U2Q2p	N m	S_3 m/e/s	N m
U2QC1	N m	S_3 m	N m
U2QC2	N m	S_3 m	N m
U2QC3	N m	S_3 m	N m
U2F1	N m, S_3 m/e/s	S_3 m/e/s	N m, S_3 m/e/s
U2F2p	N m, S_3 m/e/s	S_3 m/t/e/s	N m, S_3 n/e/s
U2F3P	N m, S_3 m/e	S_3 m/e	N m/e, S_3 m/e
U2FC1	N m/s, S_3 m/s	N, S_3 m/t/s	N m/s, S_3 m/s
U2FC2	S_3 m/e/s	S_3 e/s	S_3 m/e/s
U2UC	N m	S_3 m/e	N m
U2XC	N m/s	N s	N m/s
U2Ap	N m, S_3 m/e	S_3 e	N m, S_3 m/e
PPC	S_3 m/s	S_3 s	S_3 m/s
BPC	N flooding	N flooding	N flooding
V1PC1	S^3, S^2 m/n	N m, S^3 m, S^2n	N t, S^3 m,S^2 n
V1XC2			
V2P	S^3_3 m, S^2 m/n	S^3_3 t	S^3_3 m, S^2 m/n
V2PC	S^3 m/s	S^3 m/t/s	S^3 m/s, S^2 m
V2XC			

Table 6.10. Classification of the land evaluation units for the cereals.

7. ASPECTS OF AGRONOMY

7.1. Introduction

Due to the many distinct differences in climate and soils in the project area, there is a zonation of different kinds of land use on a short distance, see Table 7.1. the agricultural land use in 1982 for different crops and Table 7.2. the Agro Ecological Groups. In general a clear shift in importance of different crops and sources of income can be observed going from west to east. After some general aspects concerning the farming all the different groups, according to the Agro-Ecological Groups, see table 7.2., will be considered.

-grains			44%
of which	-maize	83%	
	-millet/sorghum	17%	
-pulsus			23%
of which	-beans	93%	
	-pigeon pea	5%	
	-cowpeas	2%	
-tubers			4%
of which	-English potatoes	88%	
	-sweet potatoes	10%	
	-cassave	2%	
-other crops			10%
of which	-cotton	63%	
	-bananas	27%	
	-sunflower	9%	
	-tobacco	1%	
-permanent crops			19%
of which	-coffee	71%	
	-tea	28%	
	-mangoes	1%	

Table 7.1. Agricultural land use (1982) expressed in percentages for different crops.

7.2. General aspects of farming

7.2.1. Farming systems

As already described in chapter 3, there are all kind of variables, like climate, concerning the farming which can't be influenced by the individual farmer. These environmental variables belong to the farming system in that sense that they determine the space within which it can function. So the variables determine how much the farming system can vary. Within this space the actual farming system is determined by the decision the farmer makes, considering the ecological, economical and social/cultural circumstances as well as the objectives of his household.

Agro Ecological Group (AEG)	Agro Ecological Zone	Characteristics
A. Forest	LH0	Trees
B. Tea-coffee-dairy	LH1 UM1	Tea, diary Coffee, tea
C. Coffee-maize-beans	UM2 UM3 UM4	Coffee (Main, Jaetzold) Coffee (Marginal, Jaetzold) Mango, sunflower
D. Cotton-maize-mango pigeon pea	LM3 LM4	Cotton (Main), tobacco Cotton (Marginal), tobacco
E. Millet-livestock	LM5 IL5	Livestock, millet Livestock, millet

Table 7.2. Agro Ecological Groups.

The actual ecological differences cause a variation in the complexity of the farming system. This complexity is mainly determined by the subsystems of the farming system, especially the number of elements of these subsystems and their interactions, see Fig. 7.1. So the more elements from different subsystems are represented in a farming system, the more complex it is. When the farming system is more complex the farmer is less dependent, because he can rely on quite a number of elements. So complexity is a kind of risk avoidance.

SUBSYSTEMS		
Crops	Livestock	Off-farm income
Tea, Coffee, Cotton Tobacco Maize, Millet, Sorghum Cowpeas, Pigeon peas Green grams, Cassave Beans, Bananas Mango, Papaya	Cattle Goats Sheep Poultry	Forestry Employment Beekeeping Marketing foodcrops Charcoal making

Fig. 7.1. The elements of the subsystems.

If we consider the area, the middle section seems to be quite complex, because all kind of food crops and some cash crops can be cultivated. Besides cattle are kept and a lot of other activities are possible, like beekeeping and charcoal making. Moving to the east or the west you see that the farming systems become less complex. For example in the AEG B where only the performance of tea is very good, cattle are kept and some jobs in forestry are available. The same near Tana river where only millet is doing quite well and some grazing and browsing is found. So the sustainable basis is less secure in these areas, especially near Tana river where rainfall is very unreliable and a lot of erosion occurs, which increases the risk of crop failure.

7.2.2. Objectives of the household

The main objective of the household is to cover their needs as well as possible. Their needs can be subdivided in some linked objectives which are all very important:

- provision of food and basic necessities
- meeting social obligations
- maintaining or improving status
- safeguarding future

All the means and resources are applied as well as possible to get the maximum profit.

Farming in the area can generally be characterized as rainfed small scale subsistence farming. There are no large farms in the area and only one small irrigation scheme near Ishiara. There is some variation in the orientation to the market. This is related to the possibility of growing cash crops, but generally the farming has still a dominating subsistence character. In the first place the production of foodcrops gets most attention. If there are means which remain they can be allocated for the production of cash crops. The social obligations are very important to survive within or as a society. This is especially in such a small society undescribable important. As in every society maintaining and improving status is important for individuals as well as for the whole household. The fourth objective is an all comprising objective which is linked with all the other ones. The sequence of the objectives has of course nothing to do with their importance.

7.2.3. Population

The project area is intersected by the borders of the three districts Embu, Meru and Kitui.

The population density shows an east-west tendency. The mountaineous areas are highly populated, while the drier less potential areas have a quite low population density. In the rural areas the population density varies from 400-700 persons/km^2 in AEG C to about 20 persons/km^2 near Tana river in AEG E. The critical figure of 1 ha/household (Jaetzold, 1983) is found on a few spots in the area. In all the three districts the sizes of the households don't differ very much and count 5 to 7 persons. The available land per household amounts 1,2-1,5 ha. in the densely populated areas (AEG C) to about 25 ha. in the thinly populated areas (AEG E).

Kenya has one of the fastest growing populations. The growing rate in certain parts of this area nearly reaches 4% per year. With an unchanging growth rate in the future, the population will be doubled within 20 years. If there is no outlook for the young people to move to other parts of Kenya, so there will arise an increasing pressure on the land and probably an increasing amount of unemployed people. Without any measures of the government, this growing problem will lead to a catastrophe.

7.2.4. Land

Concerning the governmental landregistration, the area can be subdivided in two parts. West of Kaanwa and Ishiara all the land is subdivided and registrated, while east of these villages all the land is still free for settling. Considering the fast growing population the eastern part can be seen as a real settling area. The problem of land scarity will lead to the subdivision of the still free area.

7.2.5. Labour

Nearly all the work on the land is carried out manually. Most of the labour is supplied by the household itself. Different kinds of labour are available and their contribution to the work on the farm varies.

Most of the work is carried out by the adults (over 18) of the household. The contribution of the children concerns principally activities like herding and collecting water or firewood. Besides their additional help is needed during the peak periods, like harvesting maize or picking coffee. The availibility of children labour is reduced by the emphasis on education. In parts of the area where less children attend school their contribution to the farming will be larger.

The use of casual labour is not often found, mainly due to the cash constraints of the household.

In some places of the area you can find a traditional form of reciprocal labour. Friends, neighbours or relatives cooperate with each other to meet individual labour constraints during peak periods. The obligation of this traditional form of labour involves reciprocation and the provision of food and drinks during the work.

7.3. Decription of the agro-ecological groups

AEG B. Tea-coffee-dairy

LH1 Tea-dairy zone

This zone is characterized by the abundant cultivation of tea, the main activity. The area is not quite suitable for tea in the sense that it gives good quality, but the amount of rainfall is too small to produce large quantities of tea. The tea is collected and processed by the Kenya Tea Development Authority (K.T.D.A.), see also paragraph 8.3.

Besides the cultivation of tea, as a source of income, manydairy cows are kept in zero grazing units or on pastures. These cows are also used for the traction of ox-carts. Cows in zero grazing units are fed by: Kikuyu grass, Napier grass, Nadi Setaria or Rhodes grass which are principally growing on the sides of roads and shamba's.

A third source of income are the off-farm jobs, for this zone especially jobs in the forestry, which plays an important role in this area. The forest boundary of Mt. Kenya is moving up, because the tea cultivation is still expanding.

The food crops are of second importance in this area and only a very few crops are performing quite good. Besides maize, the main crops are potatoes, carrots and cabbages. Table 7.3. shows the occurrence of the most important crops in the different agro ecological groups. The performance of maize is very poor in this area, mainly due to the low level of pH. The cultivated varieties are adapted to the heigth.

"Crops"/AEG	B	C	D	E
Tea	+	-	-	-
Coffee	+	+	-	-
Cotton	-	-	+	+
Tobacco	-	-	+	-
Maize	+	+	+	-
Millet	-	-	+	+
Sorghum	-	+	+	+
Beans	+	+	+	-
Pigeon pea	-	+	+	+
Cow pea	-	+	+	-
Green gram	-	-	+	+
Potatoes	+	+	-	-
Cassave	-	+	+	-
Vegetables (carrots, cabbage)	+	+	-	-
Bananas	+	+	+	-
Sunflower	-	+	+	-
Napier	+	+	+	-
Dairy	+	+	+	-
Extensive grazing	-	-	-	+

Table 7.3. Occurrence of the most important crops in the different agro ecological groups.

UM1 Coffee-tea zone

In this zone the importance of tea is decreased and coffee is more and more cultivated going down mountain. All the coffee which is cultivated is Coffee Arabica, of different varieties like, K7, SL28 and SL34. The coffee is generally grown on steep slopes, in pure stands with an average plant density of 1325 trees/ha. The soil under these coffee trees is protected against erosion by terraces, grasslines and mulching. The coffee shamba's are manured. Beside manuring diammonium phosphate (DAP) or calcium ammonium nitrate (CAN) are applied as chemical fertilizers. Weeding is carried out two times a year. The most prevalent disease is coffee berry disease caused by the fungus collectoridium coffeanum and leafrust (Hemeleia vastatrix). These diseases are widespread and most threatening in the wetter parts of the area and during the rainy seasons. Spraying of the coffee trees is common.

The average yield of coffee is 5500-7000 kg/ha. each year. The yields in this area are much higher than the national average yields which are 4500-5000 kg/ha. The picking of coffee is done every 10-14 days during the harvesting seasons, which last from April till the end of June and from October till half December. The picking of coffee requires more than 50% of the labour available for the cultivation of coffee. After picking the coffee is immediately brought to the factory, otherwise the quality will diminish too much. After inspection of the beans to check if there are no diseased, unripe or overripe berries included, the berries are squeezed so that the skins are expelled. Then the parchment coffee is led into an "Aagaard" pre grader. The coffee passes through a flow of water and the beans are selected according to their weigth. The immediately sinking beans belong to the first grade. The floating beans are selected on basis of their weight in second and third grade. After fermentation in separated tanks the coffee berries are spread on drying tables to dry in the sun till the skin is dry. During that drying period the beans are again inspected and the bad ones are taken out. Then they are put between two plastic layers to dry another three weeks before the coffee is put in bags to be traded. The duration of drying is strongly depending on the weather conditions.

Also in this area a lot of dairy is kept for traction and as a source of income (milk) just like in the tea-dairy zone except of the fact that there is no pasture. The animals are kept in zero grazing units. The presence of off-farm jobs is strongly depending on the presence of a village (Chuka) or a factory (Rukuriri) in the neighbourhood.

In this area more food crops appear like bananas, papaya and yams. Also maize and beans are quite common, especially maize being a favourite food crop. However its performance is poor.

AEG C. Coffee-maize-beans

UM2 and UM3 The main and marginal coffee zone.
Coffee has substituted tea in this zone as the only cash crop. The distinction between main and marginal coffee zone is based on the differences in yield and quality. The yields in the marginal coffee zone are much higher, but the quality of the coffee in the main coffee zone is much better.

These are the zones of the abundant cultivation of maize and beans. The good to very good performing maize is intercropped with all kinds of beans. Also sorghum with open-panicles can be observed in this area. Besides there are lots of bananas, papaya, cassave, cowpeas and pigeon peas. In the lower and wetter parts, for example the bottomlands or the seasonal rivers, sweet potatoes and sugar cane are cultivated. At sites which are the whole year wet even arrow root can be found. Dairy and cows for traction are also in this area present in zero grazing units.

AEG D. Cotton-maize-pigeon pea-mango

LM3 The main cotton zone
Cotton is the most important cash crop in this zone. Beside cotton there is still some coffee present, but the coffee disappears when you move down to the eastern parts. Beside the cultivation of cotton as a cash crop tobacco is increasingly grown.

Different cultivars of cotton are cultivated in monoculture (67%) as well as intercropped with bulrush millet and pigeon pea. Cotton is usually planted during the second season and growing on during the subsequent first season. The performance of cotton is good in this area. The cotton is harvested in several picking sessions during the two harvest periods. The first harvest is about to 1/3 of the second harvest. The total average annual harvest is 200-225 Kg/ac. The cotton is collected by the Cotton Lint and Seed Marketing Board, visting the farmers four times every year. The board differentiates two grades of cotton which have to be separated by the farmer. The board provides the farmers with seed, fertilizer and chemicals.

Tobacco is already quite common in this area, but of less importance than cotton, due to its introduction only a short time ago. Two varieties of tobacco can be distinguished: a local variety and a high yielding variety (Virginia). Tobacco is a two seasonal crop. The extent of fertilizing, crop protection etc. depends strongly on the orientation to the market. So a strong variation in management and input level can be observed.

The harvest takes place two times each year, during the periods January-March and July-October. Yields of more than 700 Kg/ac. are reached. the average yields are about 400 Kg/ac. and about 1,5 times higher in sample strip A than in sample strip B. After the tobacco has been harvested the leaves are flue cured in well ventilated barns. All the leaves are hanging on sticks in the barns and are left there to yellow under high humidity circumstances, so the ventilation holes are closed and water is spread on the floor. The yellowing takes about one day. The next stage is fixing and drying. First the temperature is raised to 49°C by heating the pipe system and the ventilation holes are opened for a good air flow. Then the holes are closed to raise the temperature to 71°C for some time. These two processes overlap and are finished after three to four days when the midribs can easily be broken. There are about 25 grades of tobacco. Most of the tobacco is sold on the local market. The introduction of the tobacco started in the second part of the sixties. At the moment the development of the tobacco cultivation is very strong, caused by the involvement of the British American Tobacco (BAT) company.

Beside the mentioned cash crops there are two other important sources of income, charcoal burning and beekeeping. The charcoal is sold to traders, while the honey often is sold on the local market. Mango trees are widespread in this area and all the mangoes remaining after the consumption by the household is traded.

In this zone the importance of maize is slightly diminishing, while the cultivation of bulrush millet becomes more and more important moving down to the east. Beside these foodcrops cassave, pigeon peas, cowpeas and all kinds of beans are quite common.

LM4 The marginal cotton zone

In this zone cotton is beside some tobacco the main cash crop. Beside that charcoal making and beekeeping are very common practices giving the farmer a cash income. Some people also have cattle and goats for grazing and browsing in the bush, but this is of less importance compared to the both livestock-millet zones.

In this zone the importance of maize is strongly decreasing and more and more bulrush millet is cultivated instead just, like the increasing amount of with sorghum cultivated shamba's. Going to the eastern parts the importance of mango trees and paw paw is diminishing because of the rain shortage. Other foodcrops are pigeon peas and green grams.

Another characteristic of this zone is the cultivation of sunflower in monocultures. The seeds of the flower are used as chicken food, the stalks are useful to protect the soil.

AEG E. Livestock-millet

LM5 Livestock-millet zone

In this zone bulrush millet is the main foodcrop which is principally cultivated in monocultures. On some wet spots maize is cultivated, giving reasonable yields, but in general this area is not suitable for growing maize. The land is, due to the lesser population density not permanently occupied. Just after quite many years a new piece of land is cleared for cultivation.

Beside the cultivation of bulrush millet, green grams and pigeon peas are found as foodcrops, intercropped with the millet. Sorghum is also found in this zone in monocultures as well as intercropped with millet.

Cotton is also found in this zone, but it is not widespread, however some attempts have been made recently to expand the marginal cotton zone to the east. The performance of cotton is in general quite poor.

Grazing and browsing as well as charcoal making are the main practices which provide the farmer with some cash income in this zone.

Erosion is one of the biggest problems in this area, caused by the intensive showers in combination with the sparse vegetation and sealed surface layers. The cultivated shamba's are protected by trash- and stone-lines. So the possibilities for cultivation of food crops and the possibilities of other sources of income are limited in this area.

Near Ishiara at the Thuchi river a small irrigation scheme is found The availiblity of water gives the possibility to grow very good maize, bananas, mangoes and paw paw in this area. Also the common crops like millet and sorghum are performing much better under irrigation.

IL5 Livestock-millet zone

Also in this zone bulrush millet is the main foodcrop, mainly cultivated in monocultures. Since the land is communal, free for settling, and abundantly available the practice of shifting cultivation is very common. The shamba's are cultivated for about four seasons, followed by a fallow period of about four years. The fallow period is already too short to guarantee suffucient recovery of the natural fertility. The increasing pressure on the land will aggravate this problem.

On few shamba's the millet is intercropped with sorghum, green grams and in a very few cases the recently introduced cotton, which is performing very poor due to water shortage.

Besides the dependence of the cultivation of millet, a lot of grazing and browsing occurs in the bushland. The property of cattle or goats is next to charcoal making one of the sources of income in this area.

As regard the erosion problem this area can be compared with the LM5 zone.

8. EXCURSIONS

8.1. Introduction

Beside visits to institutes like Kenya Meteorological Department at Nairobi and Embu Agricultural Research Station for the gathering of data, just two excursions were made: one to Mwea rice irrigation and one to the tea factory at Rukuriri.

8.2. Mwea irrigation scheme

The fifth of March an excursion was made to Mwea, a large irrgation scheme in Kirinyaga district, Central Province. This irrigation scheme is started in the colonial period, long before the independence of Kenya on 12 December 1963. During the colonial period some irrigation schemes were set up, in for this purpose suitable areas. Prisoners of war were transported to these areas by the English rulers to work in those schemes. Mwea is the largest irrigation scheme, remaining from that period. Compared to the other schemes it is still doing very well.

The irrigated area of about 5000 ha is located at an altitude of about 1160 m. The total annual rainfall is about 900 mm and has a bimodal character. The first rainy season lasts from half March till the end of May, while the second one starts in October and lasts till the end of December. The mean annual temperature is 21,6 ^{o}C. This area is classified by Jaetzold as marginal cotton zone (LM4).

The soils are developed on high level structural plains. The area is flat (0-2%). The soils can be divided in Nitosols (well drained, very deep, dark reddish brown to dark brown, friable to firm, slightly cracking clay) and Vertisols (imperfectly drained, very deep, dark grey to black, firm to very firm, bouldery and stony, cracking clay). Those soils have a moderately to high fertility.

The area is divided in units of 4 acres. The units are alloted to farmers from outside the irrigated area on basis of two criteria. The person in question has to be landless and also jobless to get the possibility to rent a unit. It is forbidden to subdivide a unit, so children of the farmer will probably have to leave the scheme to look somewhere else for a job or for land. This rule is meant to avoid the splitting of the units to uneconomical pieces of land. In spite of that there is a lot of enthousiasm to get a unit. This is due to the high average net income of about 12000 Ksh a year. Every year about 5% of the farmers is leaving their rented land for all kind of reasons. Some of them are forced to leave, because they don't behave as they should. The average size of a household is six persons. Compared with the surrounding area there is more land available per person and per household.

In the area are some collection/distribution points. At these points inputs are supplied and harvests are collected after the growing season. Mainly rice is cultivated in the area, but only once a year. There is no possibililty to grow two crops a year if one of them is rice. In spite of that President Moi has ordained to grow two rice crops a year. Beside rice also a lot of maize is grown, especially on the Nitosols because of the better drainage. The irrigated maize is much higher yielding than the maize cultivated in the surrounding areas. At the moment some experiments are taking place with vegetables, like aubergine and peppers.

The rice is sown in August on sowing beds. After about 6 weeks it is transferred to the fields. During March the majority of the rice is harvested. The farmers are paid according to the produced quantity and quality. There is a local research station which concentrates on rice research. All the harvested rice is locally processed and packed. The rice is only sold in Kenya.

8.3. The tea factory at Rukuriri

The 17th of April the teafactory at Rukuriri, located in the Chuka area (99587-3383) was visited. The factory is located in the tea-zone near the border of Mount Kenya forest at an altitude of 1660 m. The factory was founded in 1981 and opened in 1984. Tea is grown throughout at this altitude, in spite of the fact that the area is not very suitable, because the amount of rain (1700-2000 mm) is considered to be too small for a very good crop performance. The area is indicated as marginal for tea cultivation. The lack of rain is mainly affecting the quantity of tea production and not the quality.

About 3000 farmers, having together 5000-10000 acres of tea, deliver it to this factory for processing. The factory wants to expand, because the acreage of tea is still expanding in the direction of the forest border which is still moving up.

The maximum production capacity of the factory is 60.000 Kg of green leaves in 24 hours. This level of production is only possible for one or two days. The level of production which can be continued for some time is limited to 32.000 Kg of green leaves a day. Usually the processing is going on till the daily intake of green leaves is all converted into tea. This may last 24 hours during the peak days.

Collection of tea

The tea which has been picked in the morning is brought to the factory ,stored in bags, during the afternoon. Those bags are collected at certain collection points in the area and taken to the factory by a lorry. Arriving at the factory the tea is weighed in the bags and than taken to big boxes, the beginning of processing.

The average daily intake of tea during the week of the visit was 11.032 Kg. Every day the intake of leaves is given a value called, leaf count (0-100%). It is an indication of the quality of the leaves. A figure of 100% is given when the leaves are picked as it should be, two leaves and a shoot.

Processing

After weighing the tea is put in big boxes to wither for about 24 hours. During very cold days wasted heat from the factory is applied by a fan to stimulate the withering of the leaves. A watercontent of 62-64% after the withering is the best to continue processing.

After withering, the leaves are taken from the boxes and led to a chopping machine. First the leaves are chopped in quite big pieces. Next the pieces of tea leaves are chopped in three steps, resulting in very small fine pieces. The ones we are used to buy, but still green and of a high watercontent.

The chopped tea is put in a small wagon and fermented for one and a half hour. For this fermentation only warm air is applied. During this process the green colour of the leaves turns into the well known dark black colour. The stage of fermentation is being checked by the temperature of the leaves. So no chemicals or any other matters are applied to this tea.

After fermenting, the tea passes a machine which breaks the balls, that means, that the small pieces which stick together because of the high watercontent are loosened.

Further the tea is dried for 20 minutes in four stages. The first stage is at 104 ^{o}C. For the next three stages the temperature is reduced during every transition to the next stage. The maximum drying temperature is 104 ^{o}C, otherwise the tea would get burnt.

The dried tea is selected by a machine, resulting in four different qualities/grades. Two of them are subdivided in A and B:

1. Pecco fanning A PF1.
   B PF1. pool
2. Pecco dust PD
3. Broken pecco A BP1.
   B BP1. pool
4. Dust D

The primary qualities, like PF1 (Kenya Black Tea) are all export qualities and exported to countries like Sudan and Somali. The tea is packed in wooden boxes, which are covered at the inside with aluminium to protect the tea against contamination. The secondary qualities, like D, are send to Kericho, the most important tea production centre of Kenya, and packed by Ketepa to sell it at the national market.

Quality

Every hour a sample is taken from every grade of tea. It is prepared and tasted according to special lines of sight for the tasting of tea. When something is wrong, they will rectify. The optimal watercontent after the production of tea is 2,5-3,2%.

Also samples from picked tea are taken to keep the leaf count on a high level. Sometimes pieces of the picked tea are too thick so that dehydration is hampered.

The quality of the final tea is mainly influenced by the quality of the picked pieces and the way of processing. The farmers are paid according to delivered quantity and quality.

9. REMARKS, DISCUSSIONS AND RECOMMENDATIONS

Considering the yield estimations of the cereals (chapter 5), it appears that these estimations are just an indication of the reached yield levels and showing the variation in yield levels. It strikes that the variation in yield levels is very sharp, especially at the same site in spite of the expectation that the yield levels would vary strongly at different sites in the area due to the ecological variation. Notwithstanding ecological differences between certain sites for the cultivation of a cereal, the farm-management and input level appear to be the most important factor for a good performance.

The estimated yield levels (Appendix D and E) are quite high. This is mainly due to the "low" temperature, compared to the optimal growing temperature, which prolongs the grain filling period, especially for maize at the higher located sites.

Considering the data of the yield levels and the field observations, I tend to say that sample strip A in the western part, west of longitude 37'46 E, is more suitable for maize cultivation than the same part in sample strip B. The eastern part, east of longitude 37'43 E, of sample strip B appears to be more suitable for the cultivation of millet compared to the same part of sample strip A. These differences are caused by the actual condition, like fertility and erosion, of the soils.

As already said in paragraph 6.3.2. there is no significant difference between the classes N, S_3 and S_2 if these are compared on basis of the estimated yield levels. So, if a classification is carried out on basis of theoretical data concerning the physical environment and it appears that there is no significant difference between the suitability classes when making field checks by estimating yield levels, than the used land evaluation procedure should be discussed. The results of this land evaluation are quite striking (in the sense of comparing the classes to the actual estimated yields), especially if we realize that the operated procedure is based on a for Kenya adapted land evaluation system and even this had to be adapted by me for several land qualities to get reasonable results. Reasonable in the sense of reflecting reality if we consider the estimated yields. If the system hadn't been adapted almost the whole area would have been classified as not suitable. So, what is the sense of this land evaluation?

A system for land evaluation can not be universal. The way of thinking of the actual in general operating land evaluation is based on productivity. That means high production levels on small pieces of land. The expression of normative yields in Kg/ac. or Kg/ha reflects that "productivity" thinking. A land evaluation system based on that principle is not everywhere under all circumstances applicable. As already mentioned in paragraph 6.3.1., a certain site may be very suitable for sustained cultivation and giving very good crop performance within a certain farming system, but in the mean time it is considered not to be suitable according to the actual operating land evaluation system, which is based on principles of productivity. That is the problem for this area, the application of a not suitable land evaluation system.

It is important to check every land evaluation system in the sense of its applicability in an involuntary area before actually using it. So field checks should be made to check if the operated land evaluation system reflects the real situation. Eventually the system should be adapted will it not loose its meaning.

In the case of the Chuka area, the question is posed what the exact purpose of this land evaluation is. In whose interest is this land evaluation, being an important part of the project activities, carried out. The owners of those small scale subsistence farms know already for years from history and experience which are the most suitable crops and what farming pattern they prefer.

Beside it is often said that land evaluation overshadows the interest and the daily problems of the local population. Some general striking aspects, concerning farming and the daily life of the population, didn't get much attention neither of the project nor of the Kenyan government. The sometimes revolting situation, still being survived by the population, made the field work very hard.

Carrying out my field work I was often approached by farmers, especially in the eastern part of the area where only food crops were cultivated. Those farmers mainly dependent on a few food crops were never visited by extension officers, while farmers cultivating cash crops like, tea, coffee, cotton and tobacco were surrounded with lots of attention. There are special boards for all these cash crops, providing farmers with inputs, giving information and collecting the harvests. So, the cultivation of food crops is a strongly neglected subject, especially affecting those people who are mainly dependent on a very few food crops.

Beside some farmers stated, being the last thing they would do, that they didn't have enough food to feed themselves. Due to the food shortage at the end of the dry period, I had to run after the harvests during the first days of my field work, notwithstanding my investigations in advance to appoint the beginning of the harvesting period.

Farmers often stated that my work didn't contribute in any way to the solution of their pinching agricultural problems. For who or what are you working in such a situation, writing a report on land evaluation. Gathering data for the evaluation in an area having severe constraints for sustainable crop production, like water shortage and soil degradation. Beside that all the cereal crops in the area were attacked by worms being a great problem for the farmers, who did't get any attention for problems like this.

Concluding I would like to say that the still high population growth of about 4% per year will lead to severe problems in this area.

In the highlands, because all the land is divided, so a higher food production under better management will be necessary. Than the question is if the food production can keep up with the population growth. Much attention should be paid to a lot of different crops and agricultural practices like fertilizing, mulching and the responsible application of admitted chemicals as far as necessary.

In the lowlands much attention should be paid to restrain soil degradation, especially soil erosion. Beside that measurements should be taken in cooperation with farmers, which will lead to necessary water conservation in the area, resulting in higher and more well-balanced yield levels of bulrush millet to guarantee that this area will stay livable in the future if the population growth decreases.

So a lot of attention should be paid to the cultivation of food crops on a sustainable basis. Anyway, considering the whole area, the population growth is the most threatening problem, which will probably be solved in disaster, if there won't be any concrete change in this actual already degrading eco-system.

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Appendix B: Questionnaire.
Non-comprehensive sample site form.

COMPREHENSIVE SITE

number site:

date 1.
2.

name murīmi:

location, -coördinates:
-elevation:

A GENERAL DATA

* CLIMATE, -rainfall, average: mm (annual)
  first season: mm (6 out of 10 years)
  second season: mm (6 out of 10 years)
  -temperature, mean annual: °C
  -quality of the second rains (total, distribution, beginning)

* DESCRIPTION OF THE SOIL MAPPING UNIT
  -parent material:
  -macro-relief:
  -erosion:
  -rockiness/stoniness:
  -soil, general

  ,colour
  ,texture
  ,structure
  ,consistence
  -chemical properties:
  -diagnostic properties:
  -classification:

* CROPS,

Crop	Yes/No
Maize	
Millet	
Sorghum	
Coffee	
Cotton	
Tea	

B SHAMBA SPECIFIC DATA

* NO SHAMBA,

* SPECIES,

	Maize	Millet	Sorghum
, variety			
, date of sowing			
,date of expected harvest			
,expected yield			

* OTHER CROPS,

species	%	expected yield	remarks

* TREES ,SHRUBS,

species	number	remarks

* DRAWING OF THE SHAMBA, see the other side (size, shape, cropping pattern, et

* PRESENCE OF WEEDS, -% covering
  -frequency of weeding

* DAMAGE, -birds
  -monkey 's

* ROTATION, 1.
  -MANURE 2.
  3.
  4.

* CLEARING:

* SOIL PREPARATION:

* CONSERVATION PRACTICES,

-terraces	
-grass-lines	
-stonelines	
-trashlines	
-mulch	

* LAND, -communal
  , -rented
  , -private

* MANAGEMENT LEVEL, INPUT:

  -fertilizer,

	quantity	kind
manure		
chemical		
mulch		

  -seed, own
  bought

  -chemicals,

kind	quantity

* REGULARITY OF CROP GROWTH, -regular
  -irregular,
  -overall
  -poor-good patch

COMPREHENSIVE SAMPLE SITE

-number site:

-crop:

-area:

-plant density:

-score overall performance:

-patch:

Nr. ear /head	Plant nr.	Plant [illegible]	Score per plant	l(cm)	c(cm)	lxc(cm^2)	W(g)	Remarks

NON COMPREHENSIVE SAMPLE SITE

- number site:
- date:
- location:
- crop:
- soil mapping unit:
- plant density:
- score for overall performance:

Nr. ear /head	Plant nr.	Plant pit	Score per plant	l(cm)	c(cm)	lxc(cm^2)	w(g)	Remarks

Appendix C: Time table

First phase: PREPARATION

Subject:	wk.1 24/11	wk.2 01/12	wk.3 08/12	wk.4 15/12	wk.5 22/12	wk.6 29/12	wk.7 05/01
Orientation	------	------					
Proposal			---	-			
Selection sites			--	- --	--	-- --	-
Visit Embu Agric. Station				-			
Questionnaire							
-preparation					--		
-field check						-	
-multiplication							-
Motor accident							----

Second phase: FIELDWORK

Subject:	wk.8 12/01	wk.9 19/01	wk.10 26/01	wk.11 02/02	wk.12 09/02	wk.13 16/02	wk.14 23/02
Fieldwork	------	------	-----	------	----	--	--
Trip Mt. Kenya					--	-	
Illness						--	--
Trip Marsabit							--

Third phase: REPORT WRITING

Subject:	wk.15 02/03	wk.16 09/03	wk.17 16/03	wk.18 23/03	wk.19 30/03	wk.20 06/04	wk.21 13/04	wk.22 20/04
Fieldwork	--	-						
Exc. Mwea	-							
KMD/Nairobi	---	-		---				
Analysis and tabulation		----	------	---				
Exc. Rukuriri							-	
Writing					-----	-------	- -	-----
Drawing							- - -	

Subject:	wk.23 27/04	wk.24 04/05	wk.25 11/05	wk.26 18/05	wk.27 25/05	wk.28 01/06	wk.29 08/06	wk.30 15/06
Holiday	------	------	------	--- -	------			
Writing				--		-------	------	
Departure								-

Appendix D: Yield estimations of maize at the non-comprehensive sample sites.

Explanation of the undermentioned columns:

A = Observation no.
B = Location in the area.
C = Semi-detailed soil mapping unit (note: original soil survey).
D = Reconnaissance soil mapping unit (note: original soil survey).
E = Plant density in ears/m^2.
F = Average ear weight (g).
G = Estimated yield in Kg/ac.
H = Yield expectation farmer in Kg/ac.
I = Score for overall crop performance.
J = Remarks.

A	B	C	D	E	F	G	H	I	J
A-01	99516-3692	UFrs/AC	UFaer/BC	0.00	0.0	0	150	0	
A-02	99521-3691	UFrs/AC	UFaert/C	0.00	0.0	0	80	0	
A-03	99510-3685	UFr/AB	UFaer/BC	0.00	0.0	0	180	0	
A-04	99507-3656	AAr/A	UAer/AC	2.31	122.2	1127	999	1	20N-20P
A-05	99500-3627	VVCV/EF	VVepst/F	0.00	0.0	0	90	0	
A-06	99499-3619	LVMp/AB	LVpst/AC	0.00	0.0	0	80	0	
A-07	99500-3618	LVMp/AB	LVpst/A	0.00	0.0	0	90	0	50% millet
A-08	99504-3614	LVMp/AB	VVepst/F	0.00	0.0	0	125	0	
A-09	99503-3607	LVMp/AB	LVbms/AB	0.00	0.0	0	0	4	
A-10	99502-3605	LVMp/AB	LVbms/AB	0.00	0.0	0	0	5	
A-11	99504-3607	LVMp/AB	LVbms/AB	2.27	66.2	601	0	3	
A-12	99489-3581	LVr-LVm/AB	LVc/AB	0.00	0.0	0	0	4	
A-13	99497-3598	LVr-LVm/AB	LVc/AB	3.78	66.4	1004	540	4	
A-14	99497-3597	LVr-LVm/AB	LVc/AB	1.91	98.6	754	360	4	
A-15	99496-3596	LVr-LVm/AB	LVc/AB	2.36	44.0	324	180	5	
A-16	99495-3594	LVr-LVm/AB	LVc/AB	2.86	89.1	1020	55	4	
A-17	99492-3594	LVr-LVm/AB	LVc/AB	1.70	114.3	778	0	3	50% cotton
A-18	99490-3582	LVr-LVm/AB	LVc/AB	2.62	77.0	827	300	3	
A-19	99489-3581	LVr-LVm/AB	LVc/AB	2.80	76.2	853	180	3	
A-20	99488-3581	LVr-LVm/AB	LVc/AB	4.58	106.3	1948	180	3	
A-21	99487-3575	LVr-LVm/AB	LVc/AB	0.00	0.0	0	240	0	
A-22	99491-3568	LVr-LVm/AB	LVc/AB	5.58	68.8	1520	180	3	
A-23	99490-3567	LVr-LVm/AB	LVc/AB	2.72	49.3	537	180	3	
A-24	99497-3559	LVr/AB	LVc/AB	5.87	63.2	1483	360	3	
A-25	99498-3559	LVr/AB	LVc/AB	2.40	52.6	506	720	4	50% cot/p.p
A-26	99500-3559	LVr/AB	LVc/AB	3.95	38.9	615	0	3	50% cotton
A-27	99499-3557	LVr/AB	LVc/AB	2.19	45.8	402	135	3	50% cotton
A-28	99504-3555	LVr/AB	LVc/AB	2.88	67.8	781	180	3	
A-29	99501-3554	LVr/AB	LVc/AB	3.03	76.8	932	180	2	ex tob. cul
A-30	99492-3554	LVr/AB	LVc/AB	3.48	98.6	1373	360	2	50% cowpea
A-31	99492-3553	LVr/AB	LVc/AB	2.90	56.9	660	45	3	
A-32	99504-3552	LVr/AB	LVc/AB	3.55	52.6	748	150	3	
A-33	99507-3547	LVr/AB	LVc/AB	3.44	71.4	982	0	3	50% cotton
A-34	99506-3547	LVr/AB	LVc/AB	0.00	0.0	0	480	0	
A-35	99505-3545	LVr/AB	LVc/AB	0.00	0.0	0	0	2	
A-36	99507-3545	LVr/AB	LVc/AB	4.77	53.4	1018	540	3	
A-37	99513-3533	LVhn/AB	LVc/AB	2.20	104.1	916	360	2	
A-38	99517-3527	VVCV1/EF	VVt/DE	3.26	72.9	950	180	2	
A-39	99515-3527	VVCV1/EF	VVt/DE	5.77	87.9	2028	900	1	

A-40	99523-3518	LVhn/AB	UVhn/AB	4.40	47.6	837	90	4	
A-41	99525-3515	BVr/AB	UVhn/BC	2.09	109.1	912	270	1	
A-42	99524-3514	VVCV1/EF	UVt/DE	2.55	84.6	863	540	3	
A-43	99527-3510	VVCV1/EF	UVh/BC	2.36	61.5	581	360	3	
A-44	99527-3505	LVhn/BD	UVhn/BC	1.98	119.9	949	360	1	
A-45	99527-3504	LVhn/BD	UVhn/BC	2.82	108.0	1218	360	2	
A-46	99528-3503	LVhn/BD	UVhn/BC	4.00	79.1	1266	180	4	
A-47	99529-3501	LVhn/BD	UVhn/BC	2.55	90.1	919	315	2	
A-48	99531-3500	VVCV1/EF	VVt/DE	4.12	29.9	492	90	3	
A-49	99530-3496	LVhn/BD	RaVn/AB	4.04	99.9	1614	270	2	
A-50	99533-3495	LVhn/BD	RaVn/AB	2.54	130.2	1223	0	2	
A-51	99534-3494	LVhn/BD	RaVn/AB	3.14	100.9	1267	235	2	
A-52	99531-3494	LVhn/BD	RaVn/AB	4.40	110.3	1941	180	2	
A-53	99537-3489	LVhn/BD	RaVn/AB	3.23	66.2	856	450	3	
A-54	99537-3488	LVhn/BD	RaVn/AB	3.37	70.5	950	720	3	
A-55	99539-3487	RaVn/AB	RaVn/AB	3.09	83.8	1035	720	3	
A-56	99538-3486	RaVn/AB	RaVn/AB	2.76	69.5	768	180	3	
A-57	99541-3481	RaVn/AB	RaVn/AB	2.84	77.6	883	240	3	
A-58	99543-3477	RaVn/AB	RaVn/AB	0.00	0.0	0	160	0	
A-59	99548-3474	RaVn/AB	RaVn/AB	3.91	93.0	957	450	2	
A-60	99551-3468	BVr/AB	RiVn/AB	1.60	67.4	431	45	4	
A-61	99554-3466	RiVn/AB	RiVn/AB	2.78	83.8	933	450	3	
A-62	99555-3465	RiVn/AB	RiVn/AB	2.50	110.9	1109	540	2	
A-63	99555-3466	RiVn/AB	RiVn/AB	0.00	0.0	0	0	3	
A-64	99558-3462	RiVn/AB	RiVn/Ab	2.09	73.3	612	720	3	
A-65	99599-3459	RiVn/DF	RiVn/AB	3.02	46.3	560	240	4	
A-66	99561-3458	RiVn/DF	RiVn/AB	0.91	88.2	320	90	2	50% beans
A-67	99563-3457	RiVn/BD	RiVn/AB	4.00	90.5	1448	270	2	
A-68	99654-3454	RiVn/BD	RiVn/AB	4.35	86.9	1511	540	2	
A-69	99567-3442	RiVn/AB	RiVn/AB	2.40	60.0	576	240	3	
A-70	99573-3438	RiVn/DF	RiVn/AB	0.00	0.0	0	0	5	
A-71	99573-3439	RiVn/AB	RiVn/AB	0.00	0.0	0	0	3	
A-72	99578-3427	RiVn/AB	RiVn/DF	3.27	104.7	1369	270	2	
A-73	99585-3418	RiVn/AB	RiVn/DF	1.63	30.1	195	540	3	
A-74	99591-3405	RiVn/AB	RiVn/DF	0.00	0.0	0	360	0	
A-75	99593-3406	RaVn/AB	RaVC2/EF	0.00	0.0	0	90	0	
A-76	99590-3409	RiVn/DF	RiVn/AB	0.00	0.0	0	0	5	
A-77	99590-3410	RaVn/DF	RaVn/AB	0.00	0.0	0	0	4	
A-78	99587-3417	RaVn/DF	RaVn/DF	0.00	0.0	0	360	0	
B-01	99628-3745	UFar/B	UFar/B	0.00	0.0	0	112	0	
B-02	99627-3746	UFar/B	UFar/B	0.00	0.0	0	90	0	
B-03	99614-3719	UFar/B	UFar/B	0.00	0.0	0	120	0	
B-04	99613-3719	UFar/B	UFar/B	0.00	0.0	0	0	4	
B-05	99618-3715	UFar/B	UFar/B	0.00	0.0	0	0	5	
B-06	99627-3708	UFar/B	UFar/B	2.78	112.9	1255	560	3	
B-07	99628-3701	UFar/B	UFar/B	0.00	0.0	0	0	0	
B-08	99648-3660	PAp/AB	PVapt/AB	2.19	99.9	874	180	4	
B-09	99645-3664	UVpr/AB	PVapt/AB	0.00	0.0	0	0	5	
B-10	99653-3639	UFabps/BC	HBpst/EF	0.00	0.0	0	0	3	
B-11	99653-3654	UFaepr/BC	UFaepr/CD	0.00	0.0	0	0	3	
B-12	99654-3658	HBpst/E	UFaepr/CD	0.00	0.0	0	0	5	
B-13	99654-3634	UFabps/BC	UFaepr/BC	3.15	58.2	733	360	4	40% sunfl.
B-14	99648-3626	UVr1/C	UFaepr/BC	2.67	79.1	844	360	4	50% millet
B-15	99647-3623	UVr1/C	UVbpst/BC	3.41	87.5	1195	450	2	
B-16	99654-3615	UVr2/BC	UVr/C	3.64	100.6	1462	540	3	homest. ma

B-17	99657-3613	UVbpst/C	UVr/AB	3.84	70.2	1078	360	3	
B-18	99667-3604	UVepst/BC	UVr/AB	1.52	61.1	373	90	4	60% tobac.
B-19	99667-3602	UVr1/AB	UVr/AB	0.49	91.1	179	90	3	20% beans
B-20	99667-3600	UVepst/BC	UVr/AB	1.71	59.4	407	270	3	50% beans
B-21	99662-3592	UVr2/AB	UVr/AB	1.07	37.7	161	90	3	50% pig. p.
B-22	99658-3588	UVh1/CD	UVr/AB	2.77	53.0	587	360	3	
B-23	99650-3582	UVh1/CD	UVr/AB	3.58	47.4	679	450	3	
B-24	99665-3598	UVr2/AB	UVr/AB	4.61	45.4	836	500	4	25% millet
B-25	99663-3597	UVr2/AB	UVr/AB	3.76	103.0	1553	235	2	50% millet
B-26	99660-3588	UVr1/AB	UVr/AB	3.78	74.8	1132	180	2	
B-27	99661-3591	UVr2/AB	UVr/AB	0.00	0.0	0	0	5	
B-28	99652-3583	UVh1/CD	UVr/AB	2.53	64.9	637	0	3	
B-29	99657-3589	UVh1/CD	UVr/AB	0.00	0.0	0	360	0	
B-30	99653-3583	UVh1/CD	UVr/AB	3.52	99.1	1395	450	2	
B-31	99653-3583	-	UVbpst/BC	0.00	0.0	0	450	0	
B-32	99647-3578	UVh1/B	UVr/AB	3.59	61.1	877	135	3	50% pig. p.
B-33	99647-3569	UVhr/AB	UVh/BC	0.00	0.0	0	0	2	
B-34	99646-3567	UVhr/AB	UVhn/BC	0.00	0.0	0	0	2	
B-35	99644-3567	UVhr/AB	UVhn/BC	7.45	53.3	1589	360	3	
B-36	99647-3566	UVhr/AB	UVhn/BC	3.89	61.8	963	285	3	
B-37	99645-3557	RiVps/DF	UVhn/BC	1.58	39.3	249	90	4	50% cotton
B-38	99640-3557	RiVps/DF	UVhn/BC	3.12	31.8	396	45	5	
B-39	99645-3555	UVhn/AC	UVhn/BC	4.20	12.4	208	90	5	
B-40	99638-3554	RiVps/DF	UVhn/BC	0.00	0.0	0	270	0	
B-41	99637-3552	RiVps/DF	UVhn/BC	0.00	0.0	0	70	0	
B-42	99630-3556	RiVps/DF	UVhn/BC	0.00	0.0	0	360	0	
B-43	99632-3548	RiVps/DF	UVhn/BC	0.00	0.0	0	160	0	
B-44	99632-3540	RiVn3/AC	RiVhn/BC	0.00	0.0	0	495	0	
B-45	99631-3539	RiVn3/AC	RiVhn/BC	0.00	0.0	0	225	0	
B-46	99631-3537	RiVn3/AC	RiVhn/BC	0.00	0.0	0	225	0	
B-47	99622-3530	RiVn3/AC	RiVhn/BC	0.00	0.0	0	120	0	
B-48	99627-3528	RiVn3/AC	RiVhn/BC	0.00	0.0	0	135	0	
B-49	99623-3523	RiVn3/AC	RiVhn/BC	0.00	0.0	0	540	0	

Appendix E: Yield estimations of millet at the non-comprehensive sample sites.

Explanation of the undermentioned columns:
A = Observation no.
B = Location in the area.
C = Semi-detailed soil mapping unit (note: original soil survey).
D = Reconnaissance soil mapping unit (note: original soil survey).
E = Plant density in heads/m^2.
F = Average score of the heads.
G = Estimated yield in Kg/ac.
H = Yield expectation farmer.
I = Score for overall crop performance.
J = Remarks.

A	B	C	D	E	F	G	H	I	J
A-01	99483-3794	UUCE/B	UFQep/B	0.00	0.00	0	0	5	
A-02	99483-3792	UUCE/B	UFQep/B	0.00	0.00	0	0	5	
A-03	99483-3785	UUes2/DE	UFCes/D	0.00	0.00	0	60	4	
A-04	99482-3784	UUes2/DE	UFCes/D	0.00	0.00	0	60	4	
A-05	99482-3778	UUes2/CD	UFCes/D	0.00	0.00	0	5	5	
A-06	99485-3768	UQes2/BC	UQep1/BC	0.00	0.00	0	180	4	
A-07	99488-3753	UFes/BC	UFap1/BC	14.06	3.84	391	20	3	
A-08	99483-3750	UFas/BC	UFap1/BC	8.72	3.80	200	0	5	
A-09	99499-3747	UFn/A	UFap1/BC	16.00	3.44	529	0	3	
A-10	99506-3740	UFC/AB	UFap1/BC	7.61	3.96	148	60	4	
A-11	99507-3739	UFC/AB	UFap1/AB	12.05	3.97	303	60	4	
A-12	99508-3738	UFC/AB	UFap1/BC	8.87	3.82	204	90	4	
A-13	99507-3726	UQPs/AC	UFaert/C	13.94	3.83	387	180	3	
A-14	99518-3710	UQPs/AC	UFaert/C	10.67	3.92	259	45	4	
A-15	99517-3702	UCV/BD	UFart/BC	14.34	3.56	442	72	3	
A-16	99520-3701	UFC/AB	UFaert/C	7.47	3.95	189	40	4	
A-17	99518-3693	UFr/AB	UFaer/BC	11.28	3.83	291	45	4	
A-18	99521-3689	UFrs/AC	UFaert/C	0.00	0.00	0	40	5	
A-19	99521-3691	UFrs/AC	UFaert/C	0.00	0.00	0	70	5	
A-20	99516-3692	UFrs/AC	UFaer/BC	0.00	0.00	0	180	4	
A-21	99516-3694	UFPs/AB	UFaer/BC	0.00	0.00	0	0	5	
A-22	99514-3693	UFr/AB	UFaer/BC	0.00	0.00	0	50	5	
A-23	99489-3653	UACV/B	UFaer/BC	0.00	0.00	0	0	5	pl too late
A-24	99515-3694	UFes1/AB	UFaer/BC	0.00	0.00	0	45	0	
A-25	99496-3655	UFer3/B	UAer/AC	0.00	0.00	0	0	5	pl too late
A-26	99497-3654	UFer3/B	UAer/AC	10.44	3.96	248	67	3	pl too late
A-27	99483-3657	UQpr/BC	UFaer/BC	13.13	3.95	343	135	4	
A-28	99515-3685	UFrs/AC	UFaert/C	7.90	3.20	224	60	2	
A-29	99512-3685	UFPs/AB	UFaer/BC	0.00	0.00	0	180	3	
A-30	99510-3685	UFr/AB	UFaer/BC	0.00	0.00	0	22	5	
A-31	99511-3686	UFr/AB	UFaer/BC	0.00	0.00	0	90	4	
A-32	99507-3656	AAr/A	UAer/AC	9.35	3.32	273	0	1	
A-33	99500-3627	VVepse/F	VVCV/F	0.00	0.00	0	135	0	
A-34	99499-3619	LVMp/AB	LVpst/A	0.00	0.00	0	90	3	
A-35	99500-3618	LVMp/AB	LVpst/A	0.00	0.00	0	90	0	
A-36	99504-3614	LVMp/AB	VVepst/F	0.00	0.00	0	135	0	
A-37	99503-3607	LVMp/AB	LVbmp/AB	0.00	0.00	0	180	0	
A-38	99502-3605	LVMp/AB	LVbms/AB	0.00	0.00	0	160	4	
A-39	99489-3581	LVr-LVm/AB	LVc/AB	0.00	0.00	0	90	0	

A-40	99490-3582	LVr-LVm/AB	LVc/AB	19.40	3.87	579	0	3	
A-41	99495-3594	LVr-LVm/AB	LVc/AB	12.27	3.78	333	180	3	
A-42	99487-3575	FQst/BC	LVc/AB	6.20	3.69	114	225	3	
A-43	99493-3553	LVr/AB	LVc/AB	12.30	3.75	338	180	4	
A-44	99518-3527	UUCV1/EF	UVt/DE	7.94	3.69	180	180	3	
A-45	99495-3594	LVr-LVm/AB	LVbms/AB	0.00	0.00	0	540	0	
A-46	99490-3567	LVr-LVm/AB	LVc/AB	0.00	0.00	0	90	0	
A-47	99497-3559	LVr/AB	LVr/AB	0.00	0.00	0	100	0	
A-48	99509-3536	LVhn/BD	LVc/AB	0.00	0.00	0	180	0	
A-49	99515-3527	VVCV/EF	VVt/DE	0.00	0.00	0	320	0	
A-50	99505-3548	LVr/AB	LVc/AB	0.00	0.00	0	180	0	
A-51	99506-3547	LVr/AB	LVc/AB	0.00	0.00	0	180	0	
A-52	99504-3552	LVr/AB	LVc/AB	0.00	0.00	0	360	0	
A-53	99504-3555	LVr/AB	LVc/AB	0.00	0.00	0	180	0	
A-54	99499-3558	LVr/AB	LVc/AB	0.00	0.00	0	270	0	
A-55	99500-3558	LVr/AB	LVc/AB	0.00	0.00	0	80	0	
B-01	99652-3861	UUes/BC	UUes/BC	0.00	0.00	0	45	5	
B-02	99647-3850	UUes/CD	UUes/CD	0.00	0.00	0	60	4	
B-03	99650-3849	UQ1/DE	UUes/CD	0.00	0.00	0	50	0	
B-04	99654-3849	UUes/CD	UQs/DE	0.00	0.00	0	150	0	
B-05	99613-3845	-	UUes/CD	0.00	0.00	0	10	0	
B-06	99617-3843	-	UUes/CD	0.00	0.00	0	45	0	
B-07	99649-3810	UFep/BC	HGes/EF	8.58	3.78	196	72	3	
B-08	99660-3807	HQPT/E	UQes/D	8.46	3.57	210	0	3	
B-09	99650-3808	UFep/BC	HGeps/EF	16.24	3.22	584	180	2	
B-10	99643-3793	UUPT/CD	UAac/BC	17.20	3.63	541	180	2	
B-11	99618-3797	-	UQes/D	4.01	3.49	40	210	3	
B-12	99647-3797	UFs/CD	UQes/D	11.26	3.59	318	0	3	
B-13	99618-3789	-	UQes/D	6.71	3.40	155	60	3	
B-14	99621-3786	UFs/C	UQaes/CD	6.60	3.46	146	180	3	
B-15	99625-3787	UFCp/C	UQaes/CD	0.00	0.00	0	90	0	
B-16	99624-3786	UFCp/C	UQaes/CD	11.22	3.78	294	65	4	
B-17	99633-3784	UFs/C	UQaes/CD	12.13	3.84	320	180	3	
B-18	99618-3786	-	UQaes/CD	0.00	0.00	0	90	0	hea.erosion
B-19	99618-3785	-	UQaes/CD	0.00	0.00	0	15	0	
B-20	99629-3783	UFs/C	UQaes/CD	11.49	3.17	386	60	3	
B-21	99626-3775	UFs/CD	UQaes/CD	10.67	3.79	273	180	4	
B-22	99634-3755	UFs/CD	UFes2/D	9.10	3.84	210	90	4	
B-23	99638-3747	UFp1/C	UFar/AB	9.54	2.85	347	180	2	
B-24	99628-3745	UFrp/BC	UFaer/BC	0.00	0.00	0	112	0	
B-25	99627-3746	UFrp/BC	UFar/AB	0.00	0.00	0	90	0	
B-26	99635-3742	UFrp/BC	UFar/AB	16.67	3.90	476	72	3	
B-27	99622-3743	UFrp/BC	UFar/BC	0.00	0.00	0	135	0	
B-28	99636-3743	UFps/B	UFar/BC	9.67	3.83	232	45	3	
B-29	99619-3727	HFprst/DE	HFprst/DE	0.00	0.00	0	80	0	
B-30	99615-3715	UFar/B	UFar/BC	0.00	0.00	0	120	0	
B-31	99618-3726	UFar/B	UFar/B	0.00	0.00	0	75	0	
B-32	99617-3725	UFprst/CD	UFar/B	10.44	3.90	253	68	3	
B-33	99618-3715	UFar/B	UFar/B	0.00	0.00	0	30	0	
B-34	99613-3719	UFar/B	UFar/B	0.00	0.00	0	60	0	
B-35	99614-3719	UFar/B	UFar/B	0.00	0.00	0	120	0	
B-36	99614-3722	UFar/B	UFar/B	0.00	0.00	0	180	0	
B-37	99616-3723	UFar/B	UFar/B	0.00	0.00	0	25	0	
B-38	99620-3715	UFar/B	UFar/B	0.00	0.00	0	180	0	
B-39	99617-3713	UFar/B	UFar/B	0.00	0.00	0	45	0	

B-40	99623-3707	UFar/B	UFar/B	0.00	0.00	0	180	0
B-41	99625-3705	UFar/B	UFar/B	7.62	3.55	179	0	3
B-42	99626-3708	UFar/B	UFar/B	0.00	0.00	0	90	0
B-43	99626-3700	UFar/B	UFar/	0.00	0.00	0	90	0
B-44	99626-3704	UFar/B	UFar/B	7.84	3.38	203	120	3
B-45	99627-3691	UFar/AB	UFar/B	0.00	0.00	0	45	0
B-46	99626-3693	UFar/AB	UFar/B	0.00	0.00	0	90	0
B-47	99627-3698	UFar/B	UFar/B	9.71	3.44	273	180	2
B-48	99634-3696	UFar/B	UFar/BC	0.00	0.00	0	180	0
B-49	99629-3693	UFar/B	UFar/BC	9.47	3.26	285	180	2
B-50	99625-3678	UFar/BC	UVepst/B	0.00	0.00	0	30	0
B-51	99633-3679	UVepst/AB	UFar/	0.00	0.00	0	90	0
B-52	99630-3688	UFar/AB	UFar/B	0.00	0.00	0	45	0
B-53	99630-3688	UFar/AB	UFar/B	0.00	0.00	0	45	0
B-54	99631-3684	UFar/B	UFar/B	0.00	0.00	0	90	0
B-55	99648-3660	UVpr/AB	UAap/B	7.58	3.73	163	90	3
B-56	99645-3664	UVpr/AB	PVapt/AB	0.00	0.00	0	90	0
B-57	99647-3664	UVpr/AB	PVapt/AB	0.00	0.00	0	90	0
B-58	99653-3642	UFabps/BC	Hbpst/EF	12.75	4.18	305	70	4
B-59	99654-3658	HBpst/E	UFaepr/CD	0.00	0.00	0	100	0
B-60	99647-3623	UVr1/C	UVr/C	10.67	3.45	311	180	3
B-61	99654-3618	Uvr1/C	UVr/C	13.06	4.22	311	60	4
B-62	99657-3616	UVh2/BC	UVbpst/BC	16.19	3.43	535	240	2
B-63	99654-3615	UVr2/BC	UVr/C	16.00	3.61	498	120	2
B-64	99670-3602	UVr1/AB	UVr/AB	0.00	0.00	0	180	0
B-65	99667-3600	UVr1/AB	UVr/AB	0.00	0.00	0	180	0
B-66	99665-3590	UVr1/AB	UVr/AB	13.75	3.62	410	180	3
B-67	99663-3597	UVr1/AB	UVr/AB	11.69	3.00	424	540	1
B-68	99657-3586	UVh1/CD	UVr/AB	0.00	0.00	0	180	0
B-69	99653-3588	-	UVbpst/BC	0.00	0.00	0	450	0
B-70	99661-3591	UVr2/AB	UVr/AB	0.00	0.00	0	180	0
B-71	99660-3593	UVr2/AB	UVr/AB	0.00	0.00	0	90	0
B-72	99661-3591	UVr2/AB	UVr/B	0.00	0.00	0	180	0
B-73	99662-3592	UVr2/AB	UVr/AB	0.00	0.00	0	80	0
B-74	99647-3578	UVh1/B	UVbpst/BC	0.00	0.00,	0	90	0

Appendix F: Selection of the yield estimations of maize, classified according to their occurrence on different soil mapping units, in AEZ and the sample strips A and B.

Sample strip A:

AEZ	Reconnaissance	Yield (Kg/ac.)	Number of observ.
LM5	UFaer/BC	neglectable	2
LM5	UFaPrt/C	neglectable	1
LM5	UAer/AC	1127	1
LM4	LVbms/AB	514	2
LM4	LVc/AB	903	11
LM3	LVc/AB	947	11
LM3	VVt/DE	1489	2
LM3	UVhn/AB	837	1
LM3	UVhn/BC	781	2
LM3	UVt/DE	863	1
UM4	UVhn/BC	987	5
UM4	VVCV1/DE	492	1
UM3	RaVn/AB	1207	8
UM2	RaVn/AB	883	1
UM2	RiVn/AB	846	13
UM1	RiVn/AB	1106	2
UM1	RiVn/AB	195	1

Sample strip B:

AEZ	Reconnaissance	Yield (Kg/ac.)	Number of observ.
LM5	UFar/B	1255	1
LM4	PVapt/AB	874	1
LM4	UFaepr/BC	733	1
LM3	UFaepr/BC	844	1
LM3	UVr/C	1043	2
LM3	UVbpst/BC	1091	2
LM3	UVr/AB	786	15
LM3	UVhn/BC	681	5
UM3	RiVhn/BC	306	1

AEZ	Yields in Kg/ac. Sample strips A	B	Average
LM5	282(4)	1255(1)	476(5)
LM4	843(13)	804(2)	838(15)
LM3	980(17)	812(25)	860(42)
UM4	905(6)	-	905(6)
UM3	1207(8)	306(1)	1107(9)
UM2	849(14)	-	849(14)
UM1	802(3)	-	802(3)

Note:(..) number of observations.

Appendix G: Selection of the yield estimations of millet classified according their occurrence on different soil mapping units, in AEZ and the sample strips A and B.

Sample strip A:

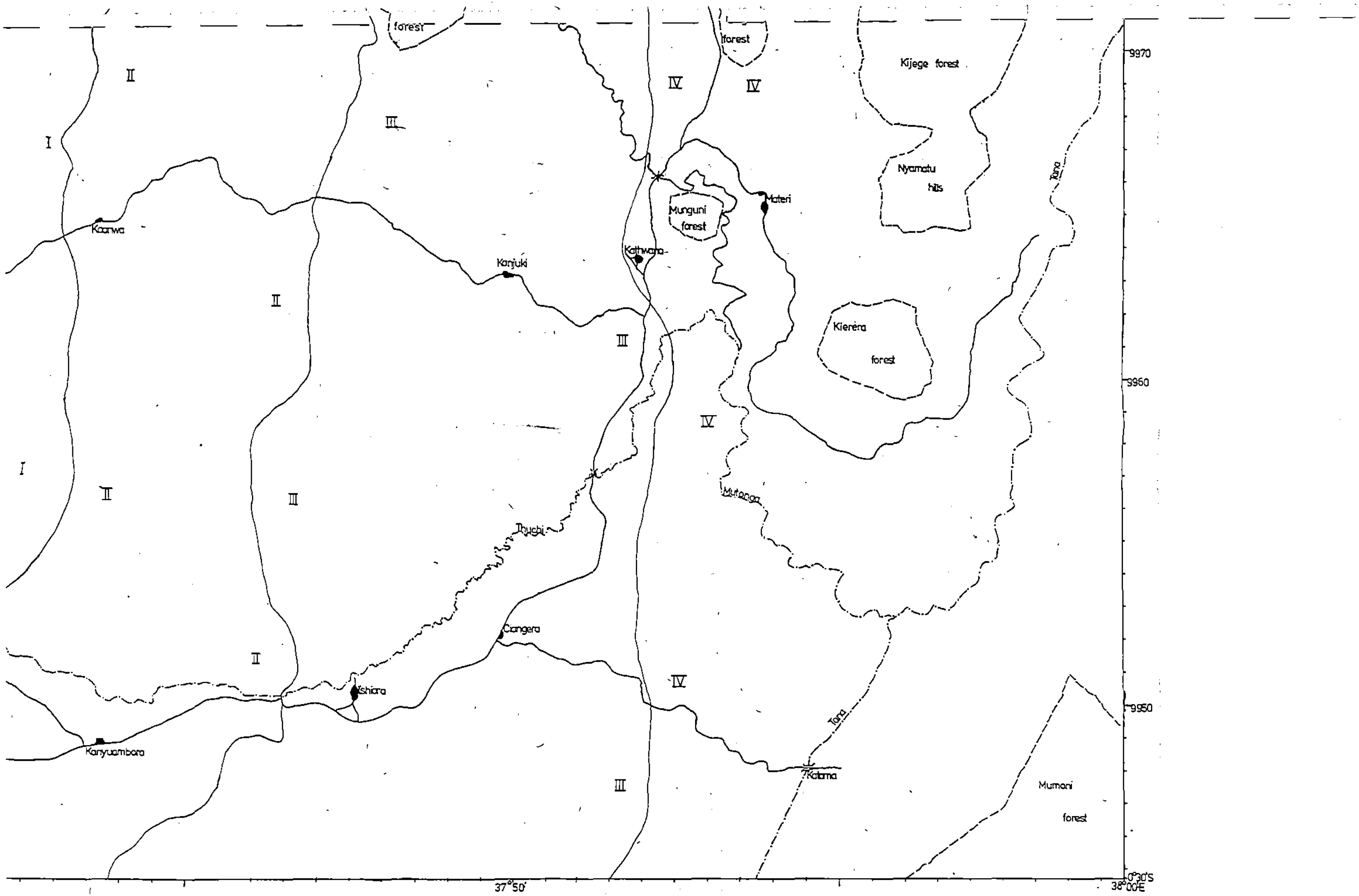
AEZ	Reconnaissance	Yield (Kg/ac.)	Number of observ.
LM5	UFap1/BC	254	8
LM5	UFap1/AB	303	1
LM5	UFaert/C	257	4
LM5	UFaert/BC	442	1
LM5	UFaer/BC	383	3
LM5	UFaer/C	189	1
LM5	UAer/AC	261	2
LM3	LVc/AB	334	6
LM3	UVt/DE	180	1

Sample strip B:

AEZ	Reconnaissance	Yield (Kg/ac.)	Number of observ.
IL5	UQaes/CD	273	2
LM5	HGeps/EF	390	2
LM5	UQes/D	165	6
LM5	UQaes/CD	333	3
LM5	UAac/BC	541	1
LM5	UFes2/D	210	1
LM5	UFar/AB	412	2
LM5	UFaepr/BC	575	1
LM5	UFar/B	287	3
LM5	UFar/BC	271	2
LM4	UFar/BC	285	1
LM4	UAap/B	163	1
LM4	HBpst/EF	305	1
LM3	UVr/C	373	2
LM3	UVr/AB	371	3
LM3	UVr/BC	312	1
LM3	UVbpst/BC	535	1

AEZ	Yields in Kg/ac. Sample strips		
	A	B	Average
IL5	-	273(2)	273(2)
LM5	283(20)	301(21)	292(41)
LM4	-	251(3)	251(3)
LM3	312(7	387(7)	350(3)

Note:(..) number of observations.



forest
forest
Kijege forest
9970
II
I
III
IV
IV
Nyamatu
hills
Tana
Munguni
forest
Materi
Kaanwa
Kanjuki
Kathwana
II
III
Kierera
forest
9960
IV
I
II
III
Mutonga
Thuchi
Ciangera
II
IV
Ishiara
Tana
9950
Kanyuambora
Katama
III
Mumoni
forest
0°30'S
37°50'
38°00'E

MAP 1. THE OCCURENCE OF THE CEREALS