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Agro-Ecological Zones of the Tropics, with a Sample from Kenya

by Ralph Jätzold and Horst Kutsch*

The World Conference on Alimentation 1981 held in Novisad, Yugoslavia, warned that, unless some far-reaching decisions are made, the numbers of the hungry will double, to reach 1 000 000 000 by the year 2000.
The increasing land pressure in developing countries requires optimal use of natural potential. This can be shown by agro-ecological zones. These are primarily climatic zones variated by soils. The FAO did a rough zoning for continents (3). We try a more differentiated system for large scale maps, to give advice in Districts and smaller areas on the real spot of action. Farm models calculated by the agro-economists in our team show what is economical within the ecological framework, considering current prices, farm scales, land tenure, infrastructure, traditions etc.

1. Method of the Agro-Ecological Zonation

The **base** of the determinations of agro-ecological zones are **temperature, water supply and length of growing periods** (FAO, 3). The **zone groups** are **temperature belts** according to the upper limits of leading crops in Kenya: Cashew and coconuts for the lowlands, sugar cane and cotton for the lower midlands, Arabica coffee for the upper midlands (previously already called highlands, but midlands is used also for their central importance in many countries), tea for the lower highlands, pyrethrum for the upper highlands. Above there is high-altitude rough grazing land, called tropical alpine (or here afro-alpine) vegetation. The threshold values are annual mean temperatures (Tab. 1), but supplemented by limiting factors for many crops like mean minimum temperature, frost etc.
The **main zones** are based on the probability of meeting the temperature and **water requirements** of the main leading crops (Tab. 1). Therefore we developed an extended model of water balance according to climate-crop-soil relationships calculating climatic **yield probabilities**:

- Evaluation of effective rainfall year to year in 10-days periods (decades)
- Use of coefficients for crop water requirements (= kc) according to FAO (1). Calculation of decadic values for kc by a new formula set according to H. Kutsch and H.J. Schuh (6).

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Tab. 1. Agro-ecological Zonation of the Tropics (Method Jaetzold), adapted for Kenya. Coloured copy see back cover.

TABLE I: AGRO-ECOLOGICAL ZONES OF THE TROPICS[1]

Belts of Z. \ Main Zones	0 (perhumid)	1 (humid)	2 (subhumid)	3 (semi-humid)	4 (transitional)	5 (semi-arid)	6 (arid)	7 (perarid)
TA Tropical Alpine Zones Ann. mean 2-10° C	Glacier Mountain swamps	II. Sheep Zone I. Cattle-Sheep Zone						High altitude deserts
UH Upper Highland Zones Ann. mean 10-15° Seasonal night frosts		Sheep-Dairy Zone	Pyrethrum-Wheat Zone	Wheat-Barley Zone	U. Highland Ranching Zone	* U. H. Nomadism Zone[4]		
LH Lower Highl. Zones Ann. mean 15-18° M. min. 8-11° norm. no frost	Forest Zones	Tea-Dairy Zone	Wheat/Maize[2] - Pyrethrum Zone	Wheat/(M)[2]- Barley Zone	Cattle-Sheep-Barley Zone	L. Highland Ranching Zone	* L. H. Nomadism Zone[4]	
UM Upper Midland Zones Ann. mean 18-21° M.min. 11-14°		Coffee-Tea Zone	Main Coffee Zone	Marginal Coffee Zone	Sunflower-Maize[3] Zone	Livestock-Sorghum Zone	U. Midland Ranching Zone	U. Midland Nom. Zone[4]
LM Lower Midland Zones Ann. mean 21-24° M. min. >14°	*	L. Midl. Sugarcane Zone	Marginal Sugarcane Zone	L. Midland Cotton Zone	Marginal Cotton Zone[6]	L. Midland Livestock-Millet Zone	L. Midland Ranching Zone	L. Midland Nom. Zone[4]
L Lowland Zones **IL** Inner Lowland Z. Ann. mean >24° Mean max. >31°	*	* Rice-Taro Zone	* Lowland Sugarcane Zone	* Lowland Cotton Zone	* Groundnut Zone	Lowland Livestock-Millet Zone	Lowland Ranching Zone	Lowland Nom. Zone[4]
CL Coastal Lowl. Z.[5] Ann. mean >24° Mean max. <31°	*	* Cocoa-Oilpalm Zone	Lowland Sugarcane Zone	Coconut-Cassava Zone	Cashewnut-Cass. Zone	Lowland Livestock-Millet Zone	Lowland Ranching Zone	Lowland Nom. Zone[4]

1) Inner Tropics, different zonation towards the margins. The T for Tropical is left out in the thermal belts of zones (except at TA), because it is only necessary if other climates occur in the same country. The names of potentially leading crops were used to indicate the zones. Of course these crops can also be grown in some other zones, but they are then normally less profitable.
2) Wheat or maize depending on farm scale, topography, a.o.
3) Maize is a good cash crop here, but maize also in LH 1, UM 1-3, LM and L 1-4;
4) Nomadism, semi-nomadism and other forms of shifting grazing
5) An exception because of the vicinity of cold currents are the tropical cold Coastal Lowlands cCL in Peru and Namibia. Ann. mean there between 18 and 24°
6) In unimodal rainfall areas growing periods may be already too short for cotton. Then the zone could be called Lower Midland Sunflower-Maize Zone.
* Not in Kenya

Tab. 2. Agro-ecological Subzonation

TABLE II: SUBZONES ACCORDING TO GROWING PERIODS FOR ANNUAL CROPS

Formula	Cropping seasons	Lengths of growing periods[1] in at least 6 out of 10 years
p	Normally permanent	More than 364 days
vl	Very long	285 - 364 days
vl/l	Very long to long	235 - 284 "
l/vl	Long to very long	215 - 234 "
l	Long	195 - 214 "
l/m	Long to medium	175 - 194 "
m/l	Medium to long	155 - 174 "
m	Medium	135 - 154 "
m/s	Medium to short	115 - 134 "
s/m	Short to medium	105 - 114 "
s	Short	85 - 104 "
s/vs	Short to very short	75 - 84 "
vs/s	Very short to short	55 - 74[2] "
vs	Very short	40 - 54[3] "

Additional information: ur = unimodal rainfall, br = bimodal r., tr = trimodal r.
i = intermediate rains (at least 5 decades more than 0.2 E_O)[4]
( ) = weak performance of growing period (most decades less than 0.8 E_O)
\+ = Distinct arid period between growing periods
– = No distinct arid period between growing periods
f = full, i.e. no subdivision of grow.periods, for inst. fm means 115-174 days

1) Growing period = life of annual plants from seed to physical maturity. Figures show the time in which rain and stored soil moisture allow evapotranspiration of more than 0.4 E_O (in medium soils of at least 60 cm depth), enough for most crops to start growing. During main growing time they need more, of course (>0.8 E_O).
2) Lowlands and lower midlands, in UM, LH and UH 65-74 days
3) Lowlands, in LM 45-54 days, in UM 50-64 days, in LH and UH 55-64 days
4) That means moisture conditions are above wilting point for most crops

- Use of actual (reduced) evapotranspiration of crops (ET_{crop}) and their interpretation according to FAO (2). The corresponding ky-values (= effect of water stress on yields) lead us to the yield probabilities in relation to optimum yields in the following order:
  at least and above 80% of optimum (very good yields)
  60–80% of optimum (good yields)
  40–60% of optimum (fair yields)
  20–40% of optimum (poor yields)
  Another outprint "probability of total crop failure" is provided for ky below 0.2.

Most agro-ecological zones are defined by good yield expectations for their leading crops, marginal zones (see Tab. 1) by fair to poor yield expectations (depending on soils).

These values are given for the three main soil texture classes according to their **mean** (unless detailed records per layer of soil were reported) water holding capacity (light soils with 6 mm per 10 cm layer of soil, medium soils with 15 mm per 10 cm layer of soil and heavy soils with 25 mm per 10 cm layer of soil). The maps are for medium soils but the crop lists refer also to occuring other texture groups and if necessary to profile depth.

Within the different altitude zones are used different lengths of growing periods of the same crop according to their range of altitude.

For a quick calculation the zones could be parallelised with a (reduced)[1] precipitation/evaporation-index, > 0.8 = humid[2], 0.65–0.8 subhumid, 0.5–0.65 semi-humid, 0.4–0.5 transitional or subarid, 0.25–0.4 semi-arid, 0.15–0.25 arid, < 0.15 perarid, but there are differences according to the influence of the length and intensity of arid periods on crops (esp. perennials), which is considered by the computer programm too. The names in the system of the main zones (Table I)[3] are to some extend selected by the needs of Kenya, a project financed by the German Agency for Technical Cooperation (GTZ), Eschborn, and supported by the German Agricultural Team (GAT), Nairobi. In other countries it might be necessary to adapt it to the leading regional crops there.

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[1] Generally we estimate effective rainfall in East Africa roughly at 90% of that measured (10% loss due to seepage and inadequate rainfall to reach the roots). Of course, on slopes the run-off, even on unsaturated soils is important (more than 35%) but this loss can be eliminated by anti-erosion control.

[2] Not 1.0 because the average evapotranspiration of most perennial crops is only 0.8 of the evaporation of a water surface.

[3] The names in the zones are that of potentially leading crops there. Of course they can be grown also in some other zones:
Maize in zones: LH 1–3; UM 1–4; LM 1–4; L 2–4
Hybrid Maize in zones: LH 1–3; UM 1–3; LM 1–3
Wheat in zones: UH 2–3; LH 2–4
Rice unirrigated in zones: IL and CL 1–3; LM 1–2
Rice irrigated in zones: IL and CL 1–6, (7); LM 1–6, (7)
Sorghum in zones: UM (1–3), 4–5; LM (1–3), 4–5; L (1–3), 4–5
Finger Millet in zones: LH (1–3); UM (1–3), 4; LM (1–3), 4, (5); L (1–3), 4 (5)
Groundnuts in zones: LM (1–2), 3–4; L (2–3), 4
Cotton in zones: LM (2), 3–4; L (2), 3–4
( ) means that in this zone the crop is normally not competitive to related crops (f.i. sorghum to maize). Livestock is possible in all zones; decreasing stocking rate from 1–7.

The main zones are divided into **subzones** by the length of growing period, given in a 60% probability[4] that means the given number of days will be surpassed in at least 6 out of 10 years (Tab. II). A second water balance program gives us the lengths of potential growing periods for a "normal" crop, in our case following the crop-water requirements curve starting with a kc-value of 0.4 at least, going up to 1.0 and ending with 0.4 (Fig. 1). Rhizospheric development is included up to 60 cm of 80% root complex in at least 6 decades. Calculations are related to medium soils. Figures are also available for heavy and light soils, if demanded to the program. The computer prints decadic values, firstly the year to year distribution of actual kc-values, then the probabilities of surpassing the defined kc-thresholds shown in Fig. 1. By this, phases with more or less secure water supply can be differentiated.

For each subzone an ecological land use potential is set up. The selected crops and varieties (according to the length) are tested by the first program for calculation of yield expectations. It compares the water requirement curves of nearly all important crops, given by FAO (1) and (2), newly calculated by us for Kenyan varieties, with all rainfall occurrences in Kenya from 1926 to 76 by decades and their effects on the water supply in the 80% root zone for three soil groups and three plant population densities.

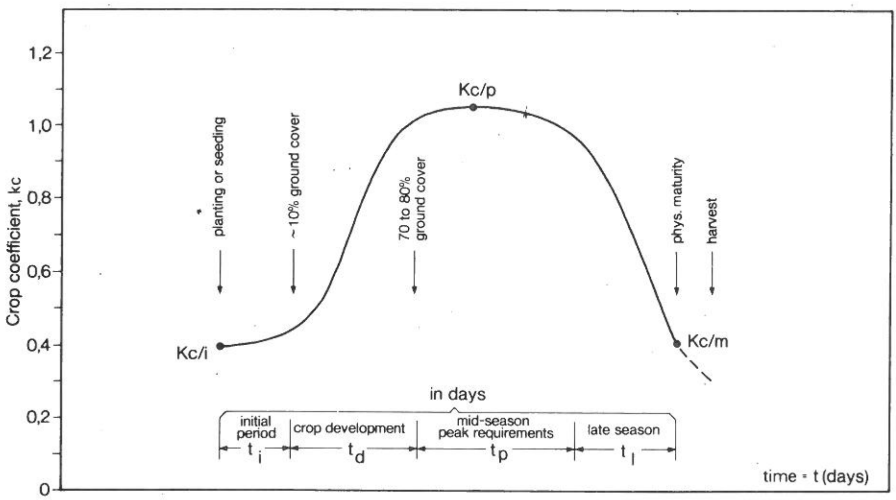

Fig. 1. Normal curve of kc-values (based on FAO (1), p. 39). (For further explications see text)

[4] This 60% probability corresponds to the lower limit of forecast-security in agro-consulting in most of the developing countries

Decade:	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Year 1.	0	1	0	2	3	0	3	3	3	2	2	3	2	0	0	0	0	0
2.	1	0	0	1	2	3	3	3	3	3	3	3	3	2	1	0	0	0
3.	0	0	1	0	2	2	2	3	3	3	3	3	3	2	1	1	0	1
4.	1	0	1	1	2	0	3	3	3	3	2	2	2	2	0	1	0	0
5.	0	0	1	1	2	3	3	3	3	2	1	0	1	0	1	0	1	0
6.	0	1	0	2	3	0	3	3	3	2	2	3	2	0	0	0	0	0
7.	1	0	0	1	2	3	3	3	3	3	3	3	3	2	1	0	0	0
8.	0	0	1	0	2	2	2	3	3	3	3	3	3	2	1	1	0	1
9.	1	0	1	1	2	0	3	3	3	3	2	2	2	2	0	1	0	0
10.	0	0	1	1	2	3	3	3	3	2	1	0	1	0	1	0	1	0
a. s. o. ↓			↓ PROB$_1$=60 PROB$_5$=40	↓ P_1=80 P_5=20		↓ P_5=40	P_4 = 80 - 100					↓ P_5= 20		↓ P_5=40	↓ P_5=40			

Fig. 2. Example for a computer outprint of the year to year distribution of (actual) water supply of a "normal" crop. Values for medium soils, i.e. 15 mm of mean water holding capacity per 10 cm layer of soil. (For further explications see text)

2. Methods of Calculation

The main aspect of our water balance model for defined crop stands in the use of **calculated** kc- and root development values per decade. The introduction of increasing soil water ressources by root development leads us to a more **dynamic** water balance model as required recently by Franquin/Forest (4). The available soil moisture, per decade also, is estimated in regard of the „Mehrschichtbodenfeuchtemodell" by Koitzsch (5) that enables us to calculate with different water holding capacities in a given root zone. If these detailed values were not available, we used uniform water holding capacities over the total root zone.

Some specific conventions were to be made:

- The **reference for crop coefficients** (= kc-values) is Penman evaporation (E_0), calculated for representative stations in Kenya by Woodhead (8) using the altitude adaption of McCulloch (7). For stations lacking calculated E_0 we used interpolated values.
- We modified the **normal curve for kc-values** of the FAO (1) according to the agroclimatological situation of Kenya. Therefore, the initial crop coefficient (= kc/i) is generally about 0.4 regarding the mean daily Penman evaporation of 5 to 6 mm and the mean frequency of significant rainfalls of about 1 every 3 days at the begin of a rainy season. The kc/p-value represents peak crop water requirements, kc/m means water requirements at physical maturity (see Fig. 1).

- The leading parameter for the estimation of yield expectations is the **(actual) crop water supply**. It is calculated as ratio of available moisture (rainfall + soil moisture) to given (= potential) crop water requirements per decade. Following definitions of this ratio are made. The numbers correspond to an internal program codification:
  "0": < 0.2 (dying period for most crops), "1": 0.2 to 0.4 (survival period, esp. for most perennial crops), "2": 0.4 to 0.8 (normal water supply, whereby the range 0.4 to 0.6 could be described as subnormal and tending more or less to the survival period, esp. when peak water requirements), "3": > 0.8 (optimum water supply).

The year to year distribution of crop water supply gives us an approximate feature of the **length of the growing period** for a "normal" crop. "Normal" means here, that water supply intends mathematically the general curve of crop water requirements (Fig. 1) within the interval of kc = 0.4 (initial period and also begin of phys. maturity) and kc ≅ 1.0 (peak water requirements). Now, the water supply curve established year by year allows us to calculate different probabilities (P):

- Probability for the best start (P ⩾ 60%) of seeding, defined by a water supply in the prephase of at least "1". In our example (Fig. 2) this probability (P_1) is 60% in the 3rd decade and 80% in the 4th.
- Probability for a selected and defined length of a growing period, irrespective of when the decades start. In our example we can select a length of 10 decades (without prephase) over all years and define a water supply of at least "2" in the initial decade and "2" or "3" in the following decades with no deficiency (= "0"). This pattern occurs in only 4 of the 10 years shown (2nd, 3rd, 7nd and 8nd year, decade 5 to 14, P_2 = 40%).
- Probability for a selected and defined length of a growing period as a function of a defined initial decade. In our example we can select a length of 11 decades over all years and define the 5th as the initial decade and the 4th decade as pre-phase; we can also define "2" or "3" in the following decades with, possibly, only one deficiency (= "0"). This occurs in 4 of the 10 years shown (P_3 = 40%).
- Probability per decade of a given water supply threshold. In our example we can define the threshold as "3". We then obtain a probability sequence (P_4) which gives us some idea of more or less reliable seasons with the given water supply threshold. In our example a relatively reliable season includes decades 7, 8 and 9 with P_4 = 80–100%.
- Probability for eventual lacks (water supply = "0") within a defined growing period.
  In our example the probability (P_5) of a lack (= "0") is given in several decades, mostly between the 12th and the 15th decade.

From the given water supply feature (Fig. 2) we may deduce therefore a very short, but rather exact view:

- Best time for **sowing** or **planting** in the 4th decade,
- Relatively secure situation in **optimum water supply** from the 7th to the 9th decade,
- Growing period until phys. maturity normally to 14th decade or to the 15th in case of crops more adapted to drier conditions in their maturity,
- Short **dry periods** (not more than 10 days) more frequent up from the 12th decade.

An example for a computer outprint of the year to year distribution of (actual) water supply of a "normal" crop is given in Fig. 2.

With these results we are able to find for each agro-ecological subzone **a potential set of crops** whose growing periods and water requirement cycles roughly coincide with those of the "normal" crop. Then they are tested by the first program to obtain yield probabilities.

This program contains water consumption curves of more than 45 crops resp. varieties allowing us to combine different potential agro-ecological patterns in the

form of a model ("scenarium") that gives a quick answer to the question of the suitability from the point of view of crop water requirements and yield response to water for each subzone (see example Embu).
With our programs we will also be able to provide information for **genetic research**, to breed for defined areas varieties with an appropriate feature of water consumption and root development.
Finally the total program, established as a set of independent moduls compatible to all IBM systems and with a complete user manual, can be ordered as a software package from the authors.

3. A Sample: The Embu District

As a sample we have selected the Embu District in Kenya (Fig. 3) because it reveals a profile from wet and cool zones on a high tropical mountain (Mt. Kenya) passing temperate well watered zones with fertile soils on its footslopes down to hot and dry zones on infertile and dissected areas. The ecological lands use potentials are showing in average yield expectation classes for each rainy season the annual crops in the following order: Cereals, pulses, tubers, cash crops, vegetables. After that the perennial crops as well as finally the pasture and forage are estimated, but the mentioned restrictions and other factors including labour should be always considered when selecting actual crops from these potentials.

Embu District
Agro-Ecological Zones

TA = *TROPICAL-ALPINE ZONES*

TA I + II = *Trop.-Alpine Moor- and Heathlands*
Here National Park
Limited grazing potential

UH = *UPPER HIGHLAND ZONES*

UH O = *Forest Zone*
Too wet, steep, and too important as a catchment area, therefore not cleared.
Bamboo thickets.
Forest Reserve

LH = *LOWER HIGHLAND ZONES*

LH O = *Forest Zone*
The same like UHO but many valuable timbers. Forest Reserve

LH 1 = *Tea-Dairy Zone*
(see Diagram Embu Forest station)

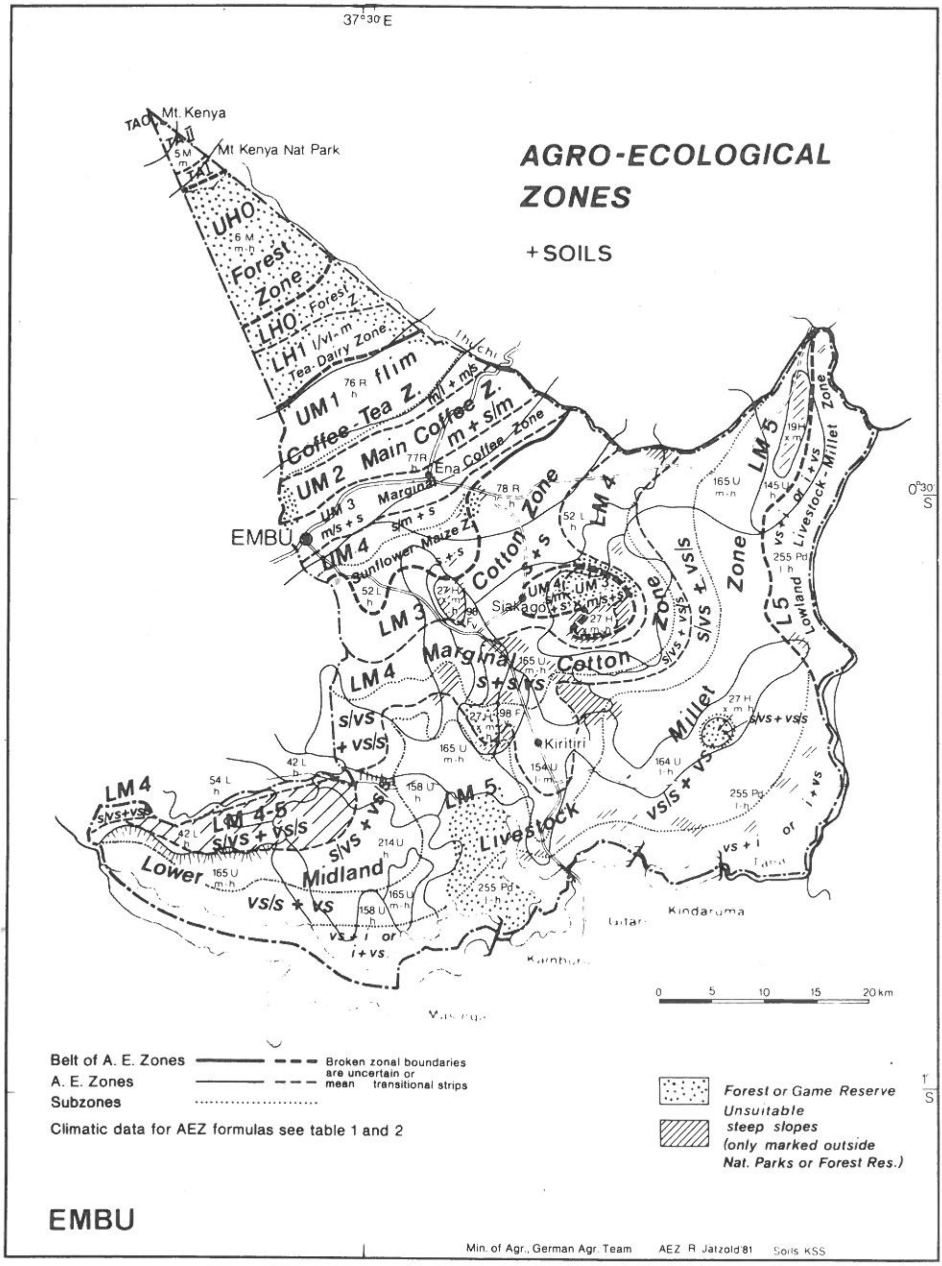

Fig. 3. Embu-District on the slopes of Mt. Kenya as a sample of agro-ecological zonation, surprinted over a soil map (colours see folded map in back cover)

I/vl ⌐ m = Tea-Dairy Zone with a long to very long cropping season followedbyamediumone[1]

Very good yield potential (av. over 80% of the optimum) 1st rains, start norm. mid March: Peas; cabbages, lettuce 2nd rains, start norm. mid Oct.: Peas

Good yield potential (av. 60–80% of the optimum)
1st rains: Potatoes (eF-July); carrots, leek, kales, endive
2nd rains: Potatoes; cabbages, carrots, kales
Whole year, best planting time mid March: Tea (high quality); loquats

Fair yield potential (av. 40–60% of the optimum)
1st rains: Late mat. maize like H 611; beans (two times, 2nd end Jy-N)
2nd rains: Beans; leek, lettuce
Whole year: Pyrethrum (too wet); plums

Grassland & forage
~0.5 ha/LU on sec. pasture of Kikuyu grass, suitable for grade dairy cows; clover for higher productivity

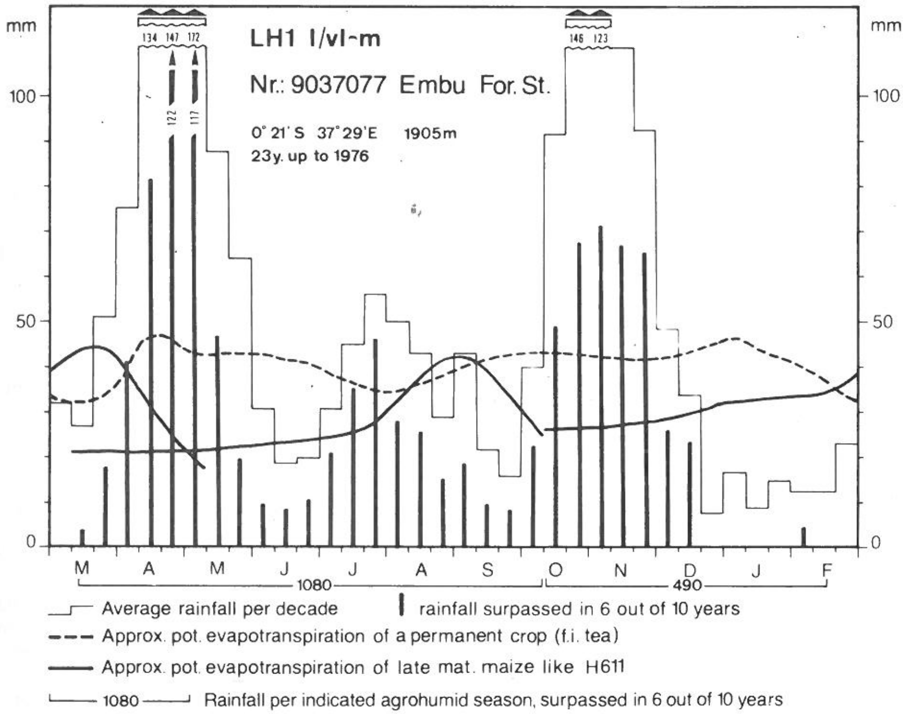

Fig. 4. Rainfall and water requirement diagram of the Tea-Dairy Zone on the slopes of Mt. Kenya

[1] On medium soils; on heavy soils permanent cropping possibilities. Given potential refers to predominating heavy red loams.

UM = *UPPER MIDLAND ZONES*

UM 1 = *Coffee-Tea Zone*

UM 1 flim = Coffee-Tea Zone with a fully long cropping season, intermediate rains, and a medium one

Very good yield potential
1st rains, start norm. mid March: Sweet potatoes; cabbages, kales
2nd rains, start norm. mid Oct.: Beans (Aug.-D./J.)
Whole year, best planting time mid March: Passion fruit, black wattle

Good yield potential
1st rains: Maize H 612, 613, 614, 622 & 632, finger millet; potatoes; late mat. sunflower like Kenya White; onions
2nd rains: Sweet potatoes; e. mat. sunflower like 252; cabbages (Aug.-D.), kales, onions, tomatoes
Whole year: Tea, Arabica coffee; bananas, yams, mountain pawpaws, loquats, avocadoes, passion fruit

Fair yield potential
1st rains: Beans; tomatoes
2nd rains: M. mat. maize like H 511 & 512 (S.-Jan.), late mat. H 612–14 (Aug.-F.), high alt. sorghum (Aug.-F.), finger millet, Meru foxtail millet (Jy.-O.); potatoes (Aug.-D.)
Whole year: Citrus, taro

Grassland & forage
0.5–0.6 ha/LU on sec. pasture of Kikuyu grass; down to about 0.15 ha/LU feeding Napier grass, banana stems and leaves, sweet potato vines, maize stalks

UM 1 m/l + m/s = Coffee-Tea Zone with a medium to long and a medium to short cropping season
Very small, potential see Meru District

UM 2 = *Main Coffee Zone*

UM 2 m + s/m = Main Coffee Zone with a medium and a short to medium cropping season[2]
(See Diagram Embu Agr. Res. St.)

Very good yield potential
1st rains, start norm. mid March: Sweet potatoes; m. mat. sunflower like Hybrid S 301 A
2nd rains, start norm. mid Oct.: Beans (S./O.-Jan./F.)
Whole year, best pl. time mid March: Loquats, mountain pawpaws

Good yield potential
1st rains: M. mat. maize like H 511 & 512; beans; potatoes; cabbages, kales, tomatoes, onions
2nd rains: E. mat. maize like Katumani comp. B, Meru foxtail millet, e. mat. sorghum like 2KX17; sweet potatoes (Aug./S.-Jan.); e. mat. sunflower like Hybrid S 345 (< 1500 m); kales, cabbages, onions, tomatoes
Whole year: Arabica coffee; bananas, citrus, avocadoes, passion fruit

[2] On medium soils; on heavy soils there is a long to medium and a medium to short cropping season. Given potential refers to predominating heavy red loams

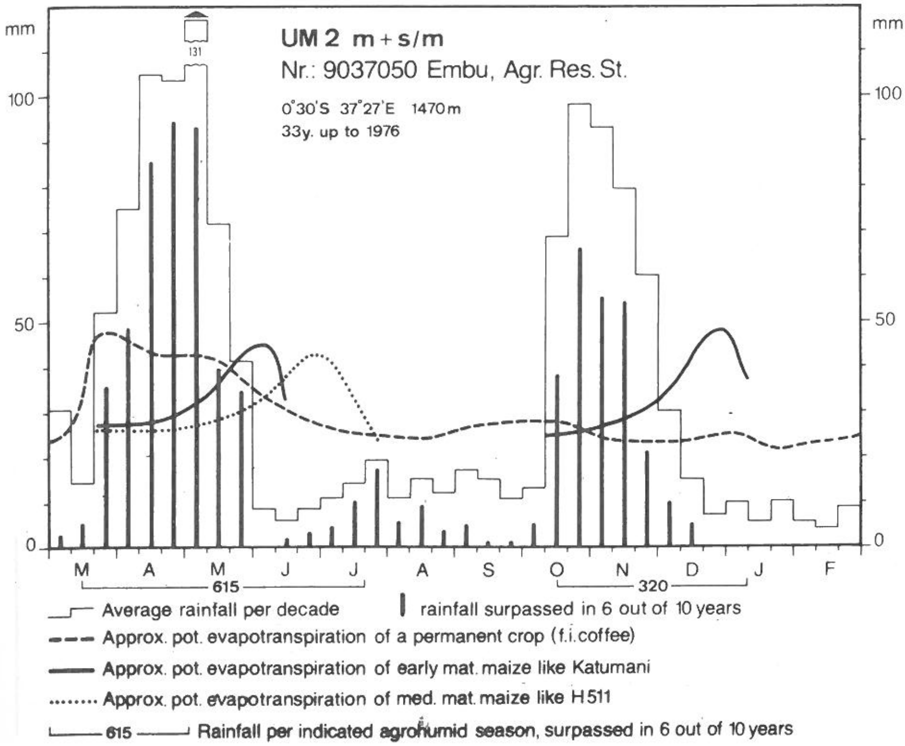

Fig. 5. Rainfall and water requirement diagram of the Main Coffee Zone on the slopes of Mt. Kenya

Fair yield potential
2nd rains: M. mat. local maize (Aug./S.-J./F.), finger millet; e. mat. potatoes
Whole year: Cassava, sugar cane (lower and wet places)

Grassland & forage
0.6–1.0 ha/LU on sec. pasture of star grass (Cynodon dactylon); down to about 0.2 ha/LU feeding Napier or Bana grass with banana leaves and others

UM 3 = *Marginal Coffee Zone*

UM 3 m/s+s = Marginal Coffee Zone with a medium to short and a short cropping season[3]
(see Diagram Embu, Distr. Office)

Good yield potential
1st rains, start norm. end March: Katumani maize & H 511 (~60%); e. mat. sorghum e. mat.; sunflower like Issanka (< 1500 m); onions, cabbages, early mat. beans

[3] On medium soils; on heavy soils first cropping season has a medium length, higher places even medium to long. Given potential refers to predominating heavy red loams.

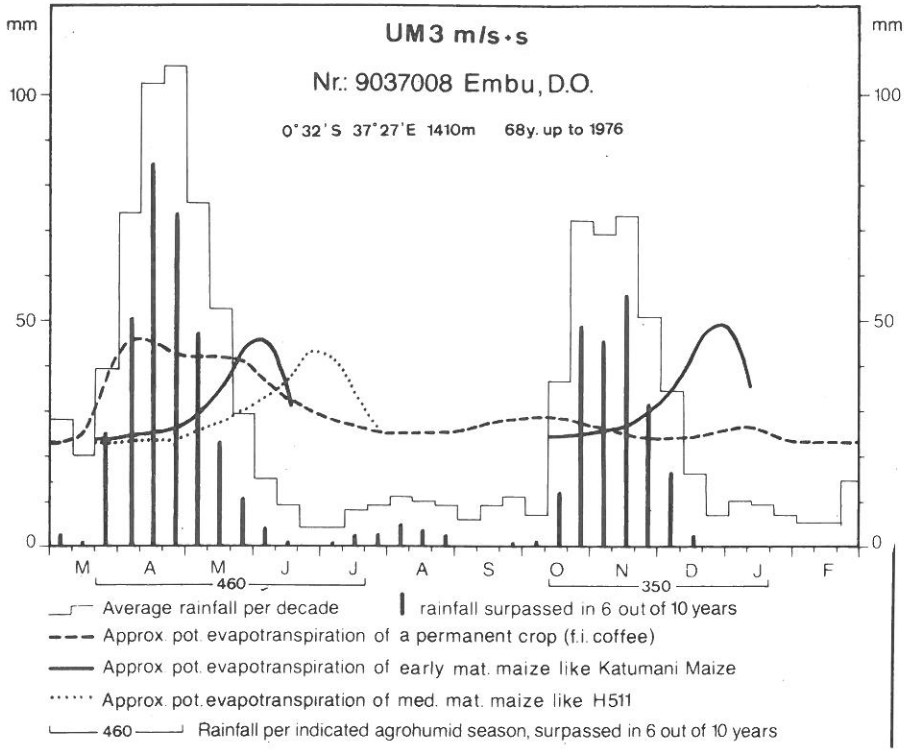

Fig. 6. Rainfall and water requirement diagram of the Marginal Coffee Zone on the footslopes of Mt. Kenya

2nd rains, start norm. mid Oct.: Meru foxtail millet; sunflower Issanka
Whole year: Pineapples, best planting time end March

Fair yield potential
1st rains: Maize H 512, e. mat. finger millet; m. mat. beans, sweet potatoes; kales, tomatoes
2nd rains: Katumani maize, e. mat. sorghum like Serena; e. mat. beans; cabbages, kales, tomatoes
Whole year: Arabica Coffee (lower places poor, there add. irrigation profitable), bananas (lower places poor) avocadoes, citrus, pawpaws, cassava

Grassland & forage
0.7–1.1 ha/LU on sec. high grass sav. with Zebra grass (Hyparrhenia rufa) predom; down to 0.23 ha/LU feeding Napier or Bana grass and others

UM 4 = *Sunflower-Maize Zone*

UM 4 s/m+s = Sunflower-Maize Zone with a short to medium and a short cropping season

Good yield potential
1st rains, start norm. end March: Katumani maize, e. mat. sorghum like 2KX17; mwezi moja beans; e. mat. sunflower like Issanka

2nd rains, start norm. mid Oct.: v.e. mat. maize like Dryland composite; Sunflower Issanka
Whole year, best pl. time end Oct.: Sisal, pineapples

Fair yield potential
1st rains: Maize H 511, finger millet, Meru foxtail millet; dolichos beans; sweet potatoes, virg. tobacco; tomatoes, onions, cabbages
2nd rains: Katumani maize, mwezi moja beans (50–60%)
Whole year: Cassava, castor

Poor yield potential (marginal)
2nd rains: E. mat. sweet potatoes
Whole year: Bananas, citrus, mangoes, pawpaws

Grassland & forage
0.8–1.2 ha/LU on high grass sav. with Zebra grass (Hyparrhenia rufa) predominant; down to 0.26 ha/LU feeding Bana grass, siratro (Macroptilium atropurpureum), horse tamarind (Leucaena leucocephala) a.o.

UM 4 s+s = Sunflower-Maize Zone with two short cropping seasons

Crop potential like UM 4 s/m+s, but maize H 511, 512 not recommended any more except on very suitable soils. Stocking rates 0.8–1.5 ha/LU

LM = *LOWER MIDLAND ZONES*

LM 3 = *Cotton Zone*

LM 3 s+s = Cotton Zone with two short cropping seasons[4]

Very good yield potential
2nd rains start norm. mid Oct.: E. mat. proso millet like Serere I

Good yield potential
1st rains, start norm. end March: Dryland comp. maize[4], ratoon of e. mat. sorghum like 2KX 17, e. mat. bulrush millet (awned var.), e. mat. foxtail millet like 1Se 285; e. mat. beans, cowpeas, chick peas on h. black soils, green grams; e. mat. sunflower like Issanka
2nd rains: E. mat. sorghum like 2KX 17, e. mat. bulrush millet; green grams, cowpeas, pigeon peas (O.-S.); dwarf sunflower
Whole year, best planting time end Oct.: Sisal, castor like C-15

Fair yield potential
1st rains: Katumani maize[4]; dolichos beans (50–60%), groundnuts in light soils, e. mat. soya beans; sweet potatoes; virginia tobacco; tomatoes, onions
2nd rains: Dryland comp. maize (50–60%), Katumani maize; dolichos beans, mwezi moja beans; cotton bimodal var. (end S./O.-Aug.), sunflower Issanka
Whole year: Cassava, pineapples, mangoes, Macadamia nuts

Poor yield potential
2nd rains: Virg. tobacco; e. mat. sweet potatoes
Whole year: Citrus

[4] On medium soils; on heavy soils first cropping season has a short to medium length. Given potential refers to medium soils, heavy ones occur especially in Northeastern parts. There H 511 fair and Katumani maize good 1st rains, cotton good 2nd to 1st rains

Grassland & forage
0.8–1.5 ha/LU on high grass savanna with Zebra grass (Hyparrhenia rufa) predominant, down to 0.28 ha/LU feeding Bana grass, Siratro (Macroptilium atropurpureum), horse tamarind (Leucaena leucocephala) a.o.

LM 4 = *Marginal Cotton Zone*

LM 4 s+s/vs = Marginal Cotton Zone with a short and a short to very short cropping season
Potential like LM 3 s+s but cotton marginal (except on very suitable soils) and stocking rates a little bit lower

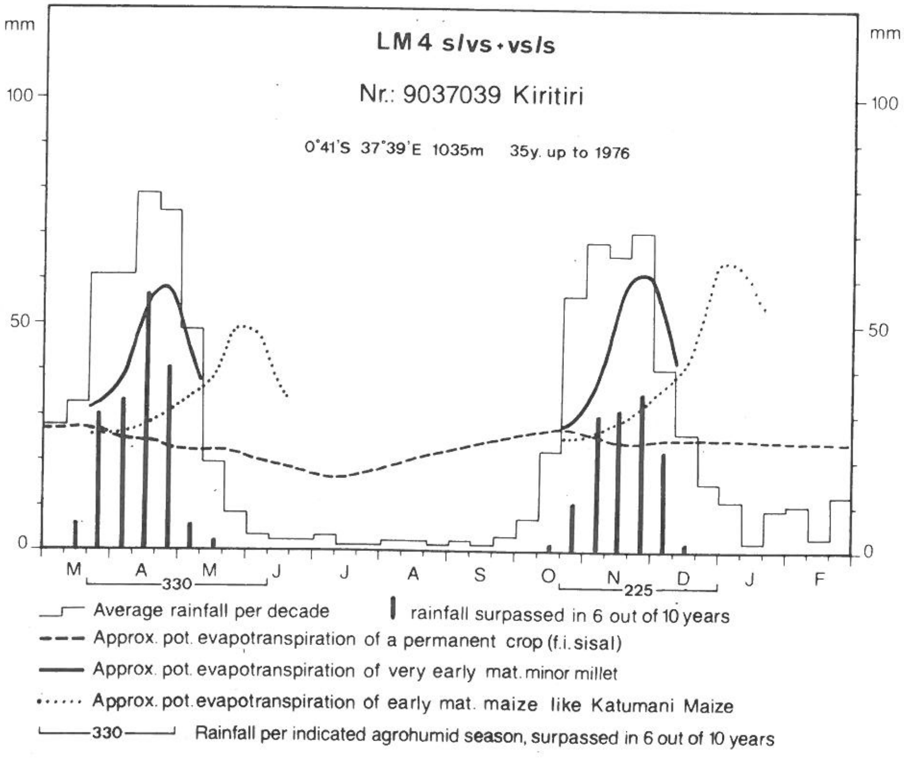

Fig. 7. Rainfall and water requirement diagram of the Marginal Cotton Zone on the foodplateaus of Mt. Kenya

LM 4 s/vs + vs/s = Marginal Cotton Zone with a short to very short and a very short to short cropping season
(See Diagram Kiritiri)

Good yield potential
1st rains, start norm. end March: Katumani maize on drained deep black soils (~ 60%), Dryland comp. maize on medium red soils (~ 60%), e. mat.

bulrush millet, e. mat. proso millet like Serere I, e. mat. foxtail millet like 1Se 285; cowlike Serere I, e. mat. foxtail millet like 1Se 285; cowpeas; v. e. mat. dwarf sunflower
2nd rains, start norm. end Oct.: E. mat. proso and foxtail millet, moth beans
Whole year: Buffalo gourds (Cucurbita foetidissima)[7] and Marama beans (Tylosema esculentum)[7] on sandy soils; castor, Jojoba (deep soils)

Fair yield potential
1st rains: Dwarf sorghum (50–60%); mwezi moja beans, chick peas (on heavy black soils), black and green grams (50–60%), e. mat. soya beans, dolichos beans; v.e. mat. bambarra groundnuts (in light soils); sweet potatoes
2nd rains: Dryl. comp. maize on heavy soils (40–50%), dwarf sorghum (50–60%), e. mat. bulrush millet; dwarf sunflower; pigeon peas (O.-S.)
Whole year: Sisal (50–60%), cassava

Poor yield potential (marginal)
1st rains: Finger millet
2nd rains: Cotton bimodal var. (end S./O.-Aug.); sweet potatoes, Dryland comp. maize (nearly 40% on medium soils, 30–40% on light soils
Whole year: Macadamia nuts

Grassland & forage
1.5–3 ha/LU on mixed medium grass savanna with red oats grass (Themeda triandra) predominant; if degraded well improvable by saltbush (Atriplex nummularia) and horse tamarind as palatable shrubs; additional forage: Barrel medicago, Mauritius beans, moth beans

LM 5 = *Lower Midland Livestock-Millet Zone*

LM 5 s/vs + vs/s = Lower Midland Livestock-Millet Zone with a short to very short and a very short to short cropping season
Small transitional strip. Crop potential like LM s/vs + vs/s, but Dryland comp. maize only fair, and 2–3 ha/LU

LM 5 vs/s + vs = Lower Midland Livestock-Millet Zone with a very short to short and a very short cropping season

Good yield potential
1st rains, start norm. end March: E. mat. foxtail millet like 1Se 285 (~60%), e. mat. proso millet like Serere I, moth beans (~60%)
2nd rains, start norm. end Oct.: E. mat. proso millet like Serere I
Whole year: Buffalo gourds[7] and Marama beans[7] on light soils, Jojoba (in valleys)

Fair yield potential
1st rains: Dwarf sorghum (50–60%), e. mat. bulrush millet (bird rejecting awned var.); bl. and green grams, cowpeas, chickpeas (on h. bl. soils), v. e. mat. bambarra groundnuts (on light soils); dwarf sunflower
2nd rains: E. mat. foxtail. millet like 1 Se 285, dwarf sorghum (50–60%): dwarf sunflower (40–50%); bl. and green grams, cowpeas, moth beans, chickpeas (on h. bl. soils)
Whole year: Sisal, castor C-15

Poor yield potential
1st and 2nd rains: Dryland comp. maize

Grassland & forage
> 3 ha/LU on mixed short grass savanna with Buffel grass (Cenchrus ciliaris) & Horsetail grass (Chloris roxburghiana) predom: saltbush best palatable shrub for re-establishing pasture on overgrazed and eroded places

LM 5 vs + i or i + vs = Lower Midland Livestock-Millet Zone with a very short cropping season and intermediate rains or vice versa[5]
Small, potential see Kitui District, but it is nearly like L5 vs+i or i+vs

L = *LOWLAND ZONES*

L 5 = *Lowland Livestock-Millet Zone*

L 5 vs+i or i+vs = Lowland Livestock-Millet Zone with a very short cropping season and intermediate rains or vice versa[5]

Good yield potential
1st or 2nd rains[5]: E. mat. proso millet
Whole year: Buffalo gourds[7] & Marama beans[7] on sandy soils, ye-eb nuts (Cordeauxia edulis)[6]

Fair yield potential
1st or 2nd rains[5]: V. e. mat. foxtail millet, dwarf sorghum (40–50%), e. mat. bulrush millet (40–50%); green grams, moth beans (50–60%), cowpeas for leaves; dwarf sunflower, v.e. mat. bambarra groundnuts (sandy soils)
Whole year: Sisal (40–50%), castor, Jojoba (deep soils, better in valleys)

Grassland & forage
> 4 ha/LU on short grass bushland with Horsetail grass predominant; saltbush best palatable shrub for re-establishing pasture

Soil Distribution, Fertility and Major Characteristics

Mt. Kenya forms the northwestern corner of the district. Going to the Southwest, the topography becomes more plain and the underlying volcanic bedrock gives way mainly to different types of gneisses of Basement System. The soils occur in broad southwest-northeast running zones and they are mainly heavy (h), in the upper middle parts, mainly medium to heavy (m-h), in the lower middle parts and light to heavy (l–h) in the lower parts. Some "Inselbergs" have stony soils (x).
On Mt. Kenya mountain soils of units 5 M and 6 M occur. Normally soil unit 6 M is very suitable for tea cultivation. On the lower parts volcanic footridge soils of units 76 R, 77 R and 78 R have a moderate to high or high fertility.
Footplateau soils (42 L, 52 L, 54 L) are situated in the southwestern part of the district. They have a low to moderate natural fertility.
The soil units 145 U and 165 U occupy the uplands. They are partly associated with hill complexes (19 H) and have a low to moderate fertility. Also on uplands but with a better fertility, the soil units 158 U and 214 U are found.
On the surrounding uplands East and West of Siakago poor soils of hills (27 H), footslopes (98 F) and related uplands (145 U, 164 U) occur.
The dissected erosional plains in the southeastern and very eastern part of the district carry the soil unit 255 Pd with a low fertility.

[5] At least one of these seasons will be long enough to give success with the mentioned crops in 6 or more years out of 10.
[6] From Somalia
[7] Supposed only, still experimental

SOILS ON MOUNTAINS AND MAJOR SCARPS

Soils developed on olivine basalts and ashes of major older volcanoes

5 M
m[1] = imperfectly drained, shallow to moderately deep, dark greyish brown, very friable, acid humic to peaty, loam to clay loam, with rock outcrops and ice in the highest parts (dystric Histosols, lithic phase; with Lithosols, rock outcrops and ice)

6 M
m-h = well drained, very deep, dark reddish brown to dark brown, very friable and smeary, clay loam to clay, with thick, acid humic topsoil; in places shallow to moderately deep and rocky (humic Andosols, partly lithic phase)

SOILS ON HILLS AND MINOR SCARPS

Soils developed on basic igneous rocks (serpentinites, basalts, nepheline phonolithes; older basic tuffs included)

19 H
x, m = well drained, very shallow to moderately deep, very dark brown, firm, stony and rocky, clay loam (Lithosols; with verto-luvic Phaeozems, lithic phase and Rock Outcrops)

Soils developed on undifferentiated Basement System rocks, predominantly gneisses

27 H
x, m-h = complex of excessively drained to well drained, shallow, dark red to brown, friable, sandy clay loam to clay; in many places rocky, bouldery and stony and in places with acid humic topsoil (dystric Regosols; with Lithosols, humic Cambisols lithic phase and Rock Outcrops)

SOILS ON PLATEAUS AND HIGH-LEVEL STRUCTURAL PLAINS

Soils developed on Tertiary basic igneous rocks (olivine basalts, nepheline phonolites; older, basic tuffs included)

42 L
h = well drained, very deep, dark reddish brown to dark brown, friable to firm, slightly cracking clay; in places with humic topsoil (verto-eutric Nitosols; with mollic Nitosols)

52 L
h = well drained, very deep, dark red, very friable clay (nito-rhodic Ferralsols)

54 L = see: MURANGA DISTRICT SOILS

SOILS ON VOLCANIC FOOTRIDGES

Soils developed on Tertiary basic igneous rocks (basalts, nepheline phonolites; basic tuffs included)

76 R
h = well drained, extremely deep, dark reddish brown to dark brown, friable and slightly smeary clay, with acid humic topsoil (ando-humic Nitosols; with humic Andosols)

77 R
h = well drained, extremely deep, dusky red to dark reddish brown, friable clay, with acid humic topsoil (humic Nitosols)

78 R
h = well drained, extremely deep, dusky red to dark reddish brown, friable clay; with inclusions of well drained, moderately deep, dark red to dark reddish brown, friable clay over rock, pisoferric or petroferric material (eutric Nitosols; with nito-chromic Cambisols and chromic Acrisols, partly pisoferric or petroferric phase)

SOILS ON FOOTSLOPES

Soils developed on colluvium from undifferentiated Basement System rocks

98 F
v = complex of well drained, deep to very deep, dark reddish brown to dark yellowish brown soils of varying consistence and texture, in places gravelly and stratified (ferralic Arenosols; with ferralo-chromic, orthic Luvisols)

SOILS ON LOWER MIDDLE-LEVEL UPLANDS

		Soils developed on intermediate igneous rocks (andesites, etc.)
145 U h	=	well drained, very deep, dusky red to dark red, friable clay (nito-rhodic Ferralsols)
		Soils developed on quartzites
154 U l-m	=	complex of somewhat excessively drained to well drained, shallow to very deep, dark reddish brown to yellowish brown, loose to friable, loamy sand to sandy clay loam; in places rocky and stony (ferralic Arenosols; with orthic Ferralsols, Acrisols a.o.; partly lithic and stony phase)
		Soils developed on Basement System rocks rich in ferromagnesian minerals
158 U h	=	well drained, very deep, dark red, friable to firm, clay (nito-rhodic Ferralsols)
		Soils developed on undifferentiated Basement System rocks
164 U l-m	=	well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay; in many places with topsoil of loamy sand to sandy loam (ferralo-chromic/orthic/ferric Acrisols; with Luvisols and Ferralsols)
165 U m-h	=	well drained, moderately deep to deep, dark red to yellowish red, friable, sandy clay loam to clay (rhodic and orthic Ferralsols; with ferralo-chromic/orthic/ferric Acrisols)

SOILS ON UPLAND-PLAIN TRANSITIONAL LANDS

		Soils developed on gneisses rich in ferromagnesian minerals
214 U h	=	complex of well drained to imperfectly drained, shallow to very deep, dark red to black, friable to firm, cracking clay; in places sodic (pellic Vertisols, with vertoeutric Nitosols, verto-eutric Planosols and orthic Solonetz, partly lithic phase)

SOILS ON DISSECTED EROSIONAL PLAINS

		Soils developed on undifferentiated Basement System rocks
255 Pd l-h	=	well drained, shallow, dark red to yellowish red, stony loamy sand to clay (chromic Cambisols, paralithic and stony phase; with ferralic Arenosols, lithic phase)

[1] Soil texture-classes

h	= heavy
l	= light
m	= medium
x	= stony or bouldery
v	= varying texture
m-h	= medium to heavy
m, h	= medium and heavy (e. g. abruptly underlaying a topsoil of different texture)

Soil description from Kenya Soil Surgey: Exploratory Soil Map and Agro-climatic Zone Map of Kenya, Scale 1: 1 000 000 Rep. E_1, Nairobi 1982. See this map also for colours; symbols simplified here. Introduction modified from Siderius, W.: Simplified Soil Maps of some Districts in Kenya. KSS, Misc. Soil Paper M 19, 2nd impr. Nairobi 1979

4. Summary

The aim of reducing the fundamental danger of hunger in the Third World can be achieved through well-adapted agricultural development, and this step by step. One of these steps is the system of "Agro-Ecological-Zones (AEZ)" that determines on the base of natural factors agro-ecological zones as zones of accurately defined potential land use. The results of AEZ-calculations allow for locally differentiated agro-consulting at district level. If other relevant factors are included, it is possible to calculate farm models also. The F.A.O. zoning system (3) does not seem to be exact enough for such a large scale. Therefore a more detailed (differentiated) system had to be developed beginning with the so-called "main zones". These are determined by mean, minimum, and, if necessary, maximum temperatures and by the yield probability according to crop water requirements of the most important crops and also for pasture and forage. The "sub-zones" are determined according to a 60% probability factor of the length of the growing period (in decades), which is important for the right choice of crop varieties.
This article tries to show how complex the land use potential of a district can be, using the example of the Embu-District which covers the humid region from Mt. Kenya until the arid Tana-Basin.

Zusammenfassung

Als Grundlage einer auch kleinräumlich differenzierten Agrarberatung auf Distriktebene ist die Abgrenzung von agro-ökologischen Zonen als Zonen potentieller Landnutzung von den natürlichen Standortfaktoren her sehr gefragt. Auf dieser Basis können unter Berücksichtigung der anderen Faktoren Betriebsmodelle kalkuliert werden.
Die Zonierungsweise der FAO (3) erwies sich für solch große Maßstäbe als zu ungenau. Ein differenziertes System mußte daher geschaffen werden. Die Hauptzonen werden nach der Mitteltemperatur, den Minima, wo erforderlich auch den Maxima, und der Wahrscheinlichkeit der Befriedigung von Verdunstungsansprüchen von wichtigen Kultur- und Weidepflanzen unterschieden. Die Subzonen werden nach der 60%-Wahrscheinlichkeit der Länge der Vegetationszeit (in Dekaden) bestimmt, was für die Sortenwahl entscheidend ist. Am Beispiel des Embu-Distrikts, der vom Mt. Kenya bis ins trockene Tanabecken reicht, wird gezeigt, wie unterschiedlich das Landnutzungspotential eines Distrikts sein kann.

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