Ministry of Agriculture

National Agricultural Laboratories

Fertilizer Use Recommendation Project (Phase I)

Final Report

Annex III

Description of the First Priority Sites in the Various Districts

Volume 5

Busia District

District No.: 5

Nairobi, June 1987

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Fertilizer Use Recommendation Project (Phase I)

Project Team

Team of Consultants[1])		Professional Staff from NAL[2])
	Project Coordination	
H. Ströbel (ed.) Project Coordinator		G.Hinga Director NAL S.W.Nandwa Counterpart Coordinator
	Agro-Climatologists	
R. Jätzold R. Rötter		J.W. Onyango
	Soil Scientists / Surveyors	
R.F. van de Weg E.M.A. Smaling		F.N. Muchena C.K.K. Gachene J.M. Kibe
	Soil Chemists	
P. Pietrowicz		J.N. Qureshi P.O.S. Oduor
	Agronomists	
A.Y. Allan		J.O. Owuor
	Data Processing	
H. Mayr R. Dölger A. Muliro		R.L. Milikau D.K. Wamae
	Land Surveyors	
R. Rötter		B. Mwangi S. Wataka
	Animal Production	
W. Bayer		

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1) German Agency for Technical Cooperation (GTZ) (German Agricultural Team (GAT))

2) National Agricultural Laboratories

Fertilizer Use Recommendation Project (Phase I)

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Busia District

Please note the following numbering mode of Tables and Maps:
First Number : District Number
Second Number: Trial Site Number
Third Number : Number of Table or Map within Chapter.

Contents of Chapter 5.0:

General Aspects

List of Tables

List of Maps

1. Climate and Soils of the District

Annual average rainfall in Busia District increases from 900 mm at the lake shore to 2000 mm near the border of Kakamega District.
The contrasts in 66% rainfall reliability, i.e. amounts surpassed in 20 out of 30 years, are even higher, in the first rains from 400 to 900 mm (see Map 5.0.1) and in the second rains from 80 to 800 mm (see Map 5.0.2).
In the wetter areas it is difficult to divide the growing seasons, since there is no distinct dry period to separate them (see Figure 5.2.5). The Agro-Ecological sub-zone formula: l - m i (i.e. a long cropping season followed by a medium one and intermediate rains) for instance, expresses one possibility to divide the more or less continuous agro-humid period, provided that second planting is to start at the beginning of September.
The annual average temperature is between 21 and 23°C. Humidity of the air is relatively high, due to the proximity of the lake. For the entire District evaporation is 1800 - 2000 mm per year.

A summary of climatic data is compiled in Table 5.0.1, which can be used as a key to the Agro-Ecological Zones Map 5.0.3.

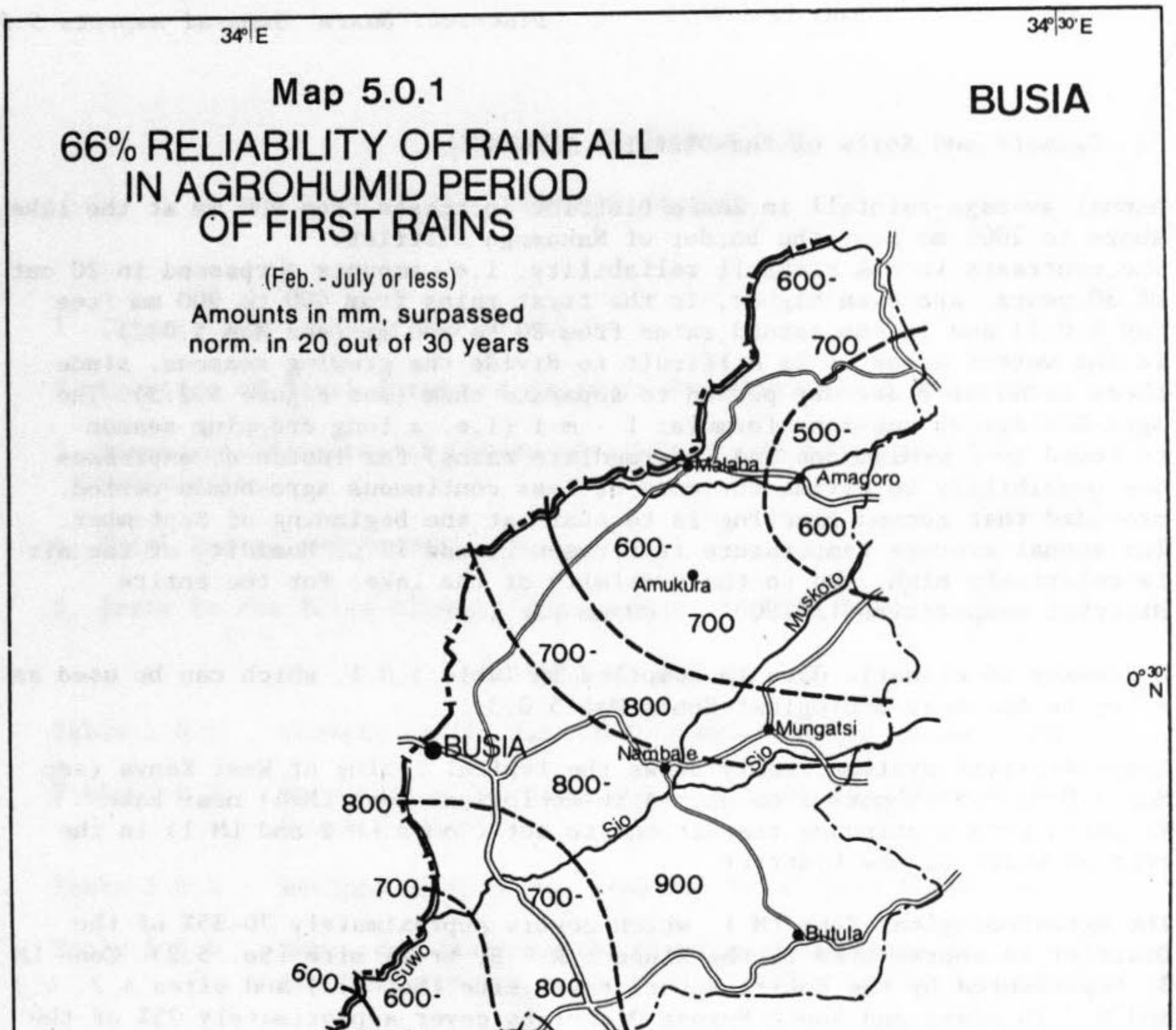
Siaya District systematically shows the typical zoning of West Kenya (see Map 5.0.3) for it goes from dry (Agro-Ecological Zone LM 4) near Lake Victoria with continuous transitions to wet (Zones LM 2 and LM 1) in the central parts of the District.

The Agro-Ecological Zone LM 1, which covers approximately 30-35% of the District is represented by the Alupe A.R.S.S. trial site (No. 5.2). Zone LM 3, represented by the Bukiri-Buburi trial site (No. 5.1) and sites 4.2, 4.3 and 2.3 in Siaya and South Nyanza Districts cover approximately 25% of the District area.
Zone LM 4, which covers only 10-15% of the District area is considered to be marginal for fertilizer trials, as water limitation is the overruling constraint to plant growth.

The soils Busia District are shown on Map 5.0.4.

In the northern and central parts of the District, poor parent materials prevail: granites, sandstones and mudstones. In the southern part intermediate igneous rocks predominate.

Acrisols are by far the most common soil type in the District.


34° E
34° 30' E
Map 5.0.1
BUSIA
66% RELIABILITY OF RAINFALL IN AGROHUMID PERIOD OF FIRST RAINS
(Feb. - July or less)
Amounts in mm, surpassed norm. in 20 out of 30 years
Malaba
Amagoro
Amukura
Muskoto
Mungatsi
Nambale
Sio
BUSIA
Butula
Suwo
Nangina
Sio Port
Hakati
Lake Victoria
Port Bunyala
Nzoia
600
700
500
600
600
700
700
800
800
800
900
700
700
600
600
800
500
500
600
400
400
500
>400
0° 30' N
0°
Broken boundaries are uncertain because of lack of rainfall records
0 5 10 15 20 25 km
Nat. Agr. Labs., German Agr. Team, R. Jaetzold


34° E
34°30' E
Map 5.0.2
BUSIA
66% RELIABILITY OF RAINFALL IN AGROHUMID PERIOD OF SECOND RAINS
(Aug. - Dec. or less)
Amounts in mm, surpassed norm. in 20 out of 30 years
Malaba
Amagoro
Amukura
Muskoto
Mungatsi
Nambale
Sio
BUSIA
Butula
Suwo
Nangina
Sio Port
Sep.-Dec.
Nov.-Dec.
Oct.-Dec.
Lake Victoria
Port Bunyala
Nzoia
100-200
<100
400
500
300
600
700
800
200
0°30' N
0°
Broken boundaries are uncertain because of lack of rainfall records
0 5 10 15 20 25 km
Nat. Agr. Labs. German Agr. Team R. Jaetzold

Table 5.0.1 : Climate in the Agro-Ecological Zones of Busia District

Agro-Ecological Zone	Subzone	Altitude in m	Annual mean temperature in °C	Annual av. rainfall in mm	66 % reliability of rainfall[1] 1st rains in mm	66 % reliability of rainfall[1] 2nd rains in mm	66 % reliability of growing period 1st rains[2] in days	66 % reliability of growing period 2nd rains in days	66 % reliability of growing period Total[3] in days
LM 1 L. Midland Sugar Cane Zone	p or two	1 300 1 500	21.7–20.5	1 800 2 000	800 900	650–800	215 or more	130–150	345–365
	l – m i			1 650–2 000	750–900	550–750	195 or more	120–130	315–325
LM 2 Marginal Sugar Cane Zone	l – (m/s)i	1 200–1 350	22.3–21.4	1 550 1800	650–800	480–650	190 or more	110 120	300–310
	l/m – (s/m)i			1 450 1 550	650 700	550–580	180 or more	105–120	285–300
	l/m – (s/m)			1 420 1 450	600 650	460–480	170 or more	105–115	275–285
LM 3 L. Midland Cotton Zone	m/l – (s)	1 140 1 250	22.7–22.0	1 200–1 420	500 650	400 460	155–175	85 95	240–270
	m/l – (s or s/vs)			1 200 1 450	530 650	300–550	150–170	80– 90	230–260
	m+f(vs)			1 100 1 200	480–530	200–300	135–155	45– 75	
LM 4 Marginal Cotton Zone	(m/s)+i	1 135–1 200	22.7–22.3	900–1 100	<400–480	<100–220	125–135	<45	

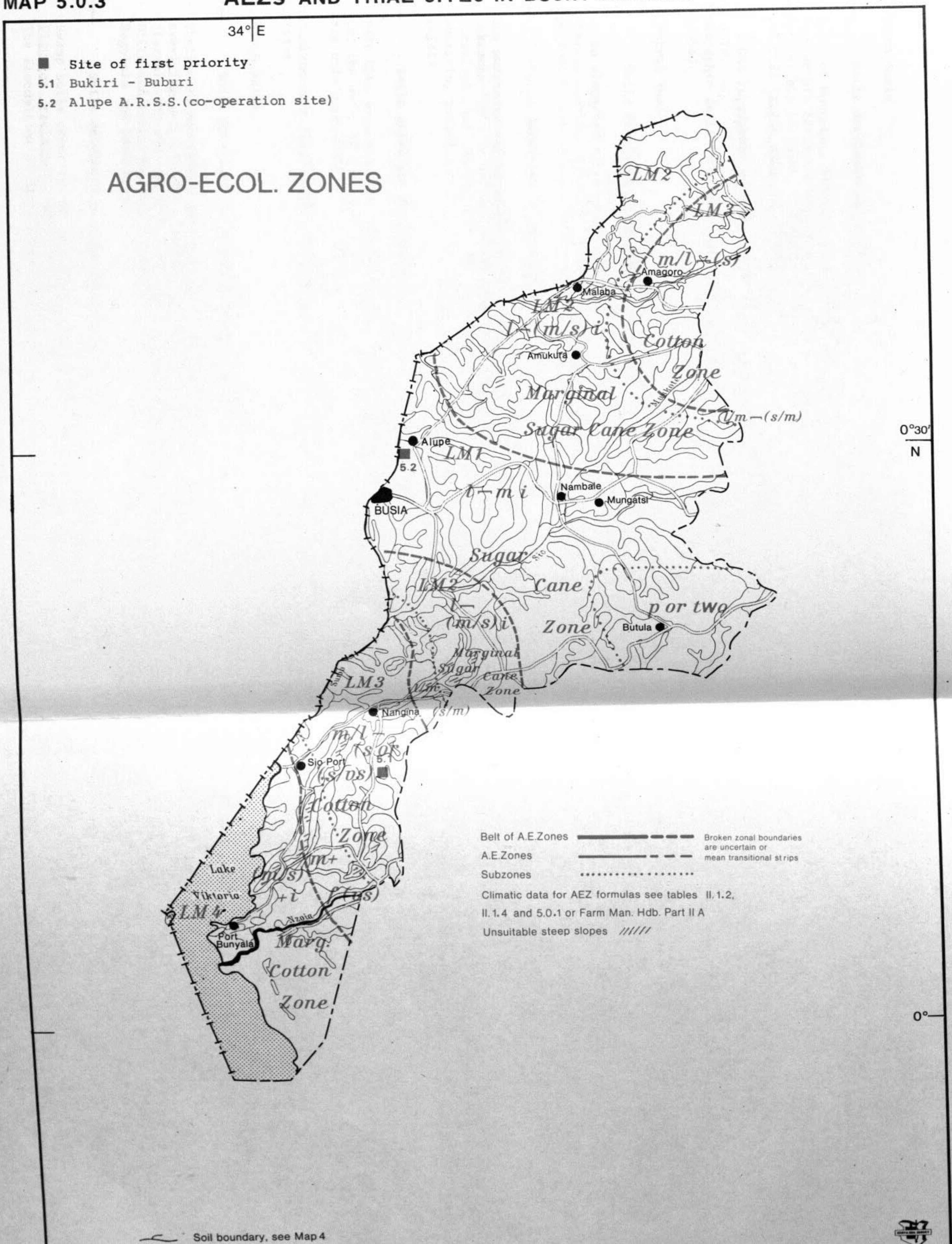
1) Amounts surpassed norm. in 6 out of 10 years, falling during the agro-humid period which allows growing of most cultivated plants

2) More if growing cycle of cultivated plants continues into the period of second rains

3) Only added if rainfall continues at least for survival ($>0.2\ E_o$) of most long term crops

Source: Jaetzold R., and H. Schmidt, eds. (1982): Farm Management Handbook of Kenya, Volume II/A West Kenya, page 27o.

MAP 5.0.3 AEZs AND TRIAL SITES IN BUSIA DISTRICT



FERTILIZER USE RECOMMENDATION PROJECT (1987)

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a. North Busia

--- Soils developed on granites.

- North of Mungatsi, Acrisols are strongly prevalent: deep orthic Acrisols constitute unit UmG2, and shallow to moderately deep orthic Acrisols, overlying petroplinthite, constitute units UmG6 and UlG3 (trial site 7.1. Kakamega District).

Unit UlGA1 represents an association of shallow to very deep orthic Acrisols.
Hydromorphic soils constitute unit PnG1 (gleyic Acrisols and dystric Gleysols)

b. Central Busia

--- Soils developed on sandstones and arkoses.

- In an elongated strip from Busia-Alupe to the east, shallow to deep, (ferralo-)orthic Acrisols and Ferralsols, mostly overlying petroplinthite, are prevalent: units UlS1 (trial site 5.2) and UlSA.

--- Soils developed on mudstones and claystones.

- The mudstones and claystones which occur in large parts of Siaya and Kakamega District extend into Busia District: the soils are rhodic Ferralsols and (ferralo-)chromic and orthic Acrisols, in places overlying petroplinthite (unit UlD2, cf. trial site 4.1. Siaya District)

--- Soils developed on granites.

- Unit UlG1 occurs around Butula and has deep to very deep orthic Acrisols; the soils of the adjacent unit UlG2 have the same classification but are only moderately deep to deep.

Bottomland unit BXC1 covers a considerable percentage of Central Busia District.

c. South Busia

--- Soils developed on intermediate igneous rocks.

- Shallow to moderately deep (ferralo-)chromic and orthic Acrisols, overlying petroplinthite (units UlI2, UlIA) alternate with deep (ferralo-)chromic Acrisols (unit UlI1, trial site 5.1).
- Hills and footslopes are widespread: units HI1 and FI2 (very shallow Regosols and Cambisols).

--- Soils developed on alluvial deposits.

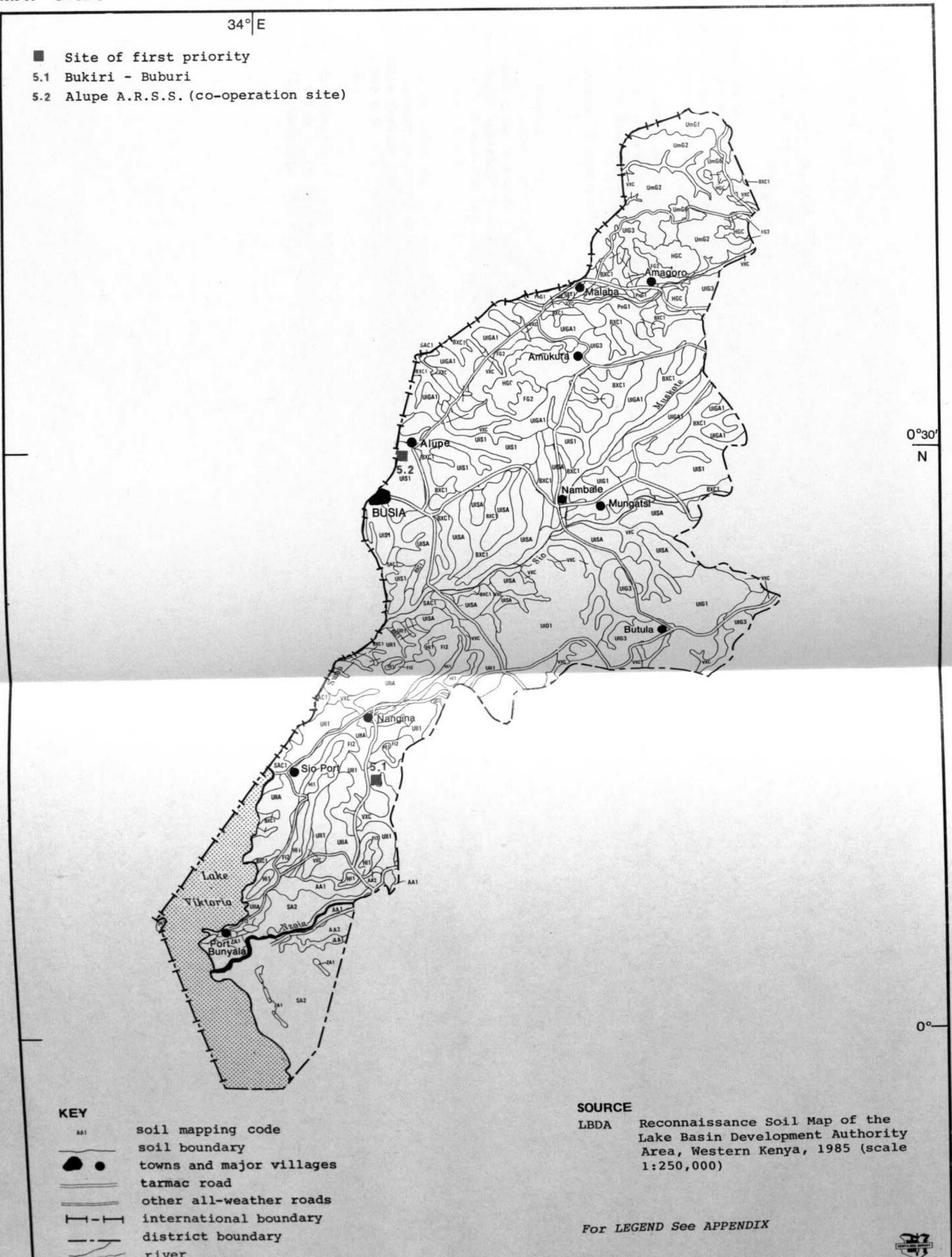
- Swamp soils occur in the very south, unit SA2 (trial site 4.3. Siaya District, reclaimed): humic Gleysols.
- The floodplains of Nzoia river constitute map units AA1 and AA2.

The basic climatic and soil designations referring to trial sites in Busia District are summarized in Table 5.0.2.

Table 5.0.2: Agro-Ecological Zone and Soil Classification of Trial Sites in Busia District

Site No.	Site Name	Agro-Ecological Zone	Soil Classification
5.1	Bukiri-Buburi	COTTON ZONE (LM 3)	ferralo-chromic ACRISOL
5.2	Alupe ARSS	SUGAR CANE ZONE (LM 1)	ferralo-orthic ACRISOL

MAP 5.0.4 SOILS AND TRIAL SITES IN BUSIA DISTRICT



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2. Location of Trial Sites and Criteria for their Final Position

In Busia District, two first priority sites were selected as shown in Map 5.0.3.

Widespread occurrence of termite mounds and appreciable variability with respect to effective soil depth are common features in the rural areas of Siaya, Busia and Bungoma Districts.

Consequently, site selection in these areas proved difficult. The team had to reject many of the trial fields proposed, but did finally manage to find what, under the given circumstances, could be defined as a very appropriate plot between Bukiri and Buburi (5.1).

The site selected is a rectangular plot which is quite even, with good accessibility and a very high demonstration effect as it is situated right beside the Nangina-Sio Port road.

The farmers' fields are also situated beside this road, north and south of the trial plot.

At the somewhat remotely situated Alupe Agricultural Research Sub-Station (5.2), the selection team faced problems.
Although termite mounds could be avoided at the plot eventually chosen, soil depth variability appeared to be high all over the station. A soil depth sketch map for the rectangular trial plot is given in Figure 5.2.8, Sub-Section 3.3.3 of Chapter 5.2.

Both trial sites are close to long-term rainfall recording stations: Site Bukiri-Buburi (elevation: 1220 m) is located 6 km SSW of 08934030, Nangina Catholic Mission Station and the Alupe A.R.S.S. site(elevation: 1170 m) only 300 m W of 08934161 Alupe Cotton Research Sub-Station meteorological station.

The criteria for the final position of the trial sites are listed in Table 5.0.3, which is self-explanatory. Criteria have been rated very good (1), good (2), moderate (3), poor (4) or non-relevant (nr).

Table 5.0.3: Ratings of Criteria Used for Trial Site Selection in Busia District

Criterion	Site number 5.1	5.2
1. Representativeness Agro-Ecological Zone	2	2
2. Representativeness Soils	1	2
3. Representativeness Topography	1	2
4. Adequacy of size and shape of the trial plot	2	2
5. Absence of trees and hedges	1	3
6. Absence of rocks and boulders	1	1
7. Absence of termite mounds	2	2
8. Uniformity of previous land use	2	3
9. Accessibility	2	2
10. Demonstration effect	1	4
11. Proximity to a long-term rainfall station	2	1
12. Availability of storage facilities	3	2
13. Availability of sturdy fences	4	3
14. Availability of housing facilities for T.A.s	2	2
15. Farmer's willingness to cooperate	2	nr
16. Security - theft	3	4
17. Security - intruding animals	3	3
18. Proximity of on-farm trials	1	nr
19. Representativeness of soils at on-farm trials	1	nr

3. Names and Addresses of Government Officers Involved in FURP Activities in Busia District

The names and addresses of the agricultural staff members in the District are listed in Table 5.0.4.

Table 5.0.4: Names and Addresses of Government Officers in the District

OFFICER	SITE	NAME	P.O. BOX	TEL. NO.
DISTRICT				
D.C.		Daniel Omangi*		
D.A.O.		J.L. Kurgat*	28-Busia	
D.C.O.		not met		
D.E.C.		A. Segoria	28-Busia	
DIVISION				
Div. Ext. Officer	5.1	W.Auma	36-Hakati	56-Hakati
Loc. Ext. Officer	5.1	not met		
Technical Assistant	5.1	not met		
RESEARCH STATION				
Officer-in-charge	5.2	N.W. Ochanda*	278-Busia	131-Busia
Agronomist	5.2	G.O. Abayo	278-Busia	131-Busia
Farm Manager	5.2	L.M. Kisuya	278-Busia	131-Busia

* not met during site selection.

Period of site selection in the District: December 1985.

4. Trial Design and Execution Plan, Busia.

(Full details of the methodology for carrying out the trials are shown in Section V of the main report).

The proposed crop sequences in each of the 3 modules, for the 2 Busia trials are:

Site 5.1 Bukiri-Buburi	RAINY SEASONS 1st, Long, March	2nd, Short, Sept
S1 Standard Maize	Hybrid 512	Katumani C.B.
S2 Maize & Cotton	H.622 + BBA 75	Cotton BBA 75
S3 Sorghum, ratooned	Sorghum, Seredo	Ratoon Sorghum

The 1st sequence or module is continuous, pure maize, 2 times per year.
The 2nd is intercropped maize with cotton which is the main crop in the second season.
The 3rd is sorghum planted in 1st rains, ratooned in the 2nd rains.

Site 5.2 Alupe Ag.R.S	RAINY SEASONS 1st, Long, March	2nd, Short, Sept
S1 Standard Maize	Hybrid 622	Hybrid 511
S2 Maize & Beans	H.622 + GLP2 Beans	H.511 + GLP2 Bns
S3 Sorghum, ratooned	Sorghum, Seredo	Ratoon Sorghum

The 1st sequence or module is continuous, pure maize, 2 times per year.
The 2nd is intercropped maize and beans, also 2 times/year.
The 3rd is sorghum planted in 1st rains, ratooned in the 2nd rains.

Each module contains 2 experiments, namely Experiment 1 and Experiment 2.
Experiment 1 is a 4N x 4P factorial, with 2 replications in each module.
Experiment 2 is a 2NP x 2K x 2L x 2 FYM factorial, also with 2 replications in each module.
Each module thus consists of 64 plots, and the total for the 3 modules is 192 plots.
FYM will be applied only to the crops during the first rainy seasons, whereas the mineral fertilizers will be given in both seasons. Where maize and beans are intercropped, the fertilizer will go on the maize. The intercropped beans will not receive any fertilizer directly, but will "scavenge" from the maize, and from residual fertilizer left in the relevant plots after the first trial season.

5. Areas in Busia District Represented by FURP Trial Sites

The aim of FURP Phase I is to select trial sites which, as far as possible, are representative of the agriculturally high and medium potential areas of Kenya. This consideration constituted the backbone for making decisions as to where to establish these FURP trial sites.

Two representativeness maps are drawn per District. One refers to the soils only (Map 5.0.5: Groupings of Soil Map Units), and in the second (Map 5.0.6) Agro-Ecological Units (AEUs) are shown in which, according to the information available, the soils and the climate can be considered homogeneous.

Map 5.0.5 shows the representativeness of FURP trial sites for the Busia District only as far as soils are concerned. Since FURP can only cover major physiographic units (mainly uplands, plateaus and plains), minor units such as hills, flood plains and bottomlands indicated in the Soil Map (Map 5.0.4) and described in the accompanying Legend (cf. Appendix: H-, A- and B-units), are beyond consideration when it comes to representativeness.

The explanation for Map 5.0.5 shows ten generalized "Groupings of Soil Map Units". These groupings have the same or similar soil properties and, as such, represent a specific soil environment typified by one of the FURP trial sites.

The codes in the explanation to Map 5.0.5 refer to a specific trial site (5.1, 5.2, etc.) and to a specific degree of representativeness of soils (A, B+, B-). The combination of both forms a "Soil Representativeness Code". Unit 5.1.A, for instance, covers an area which is highly represented (A) by the trial site Bukiri-Buburi (5.1). Unit 4.1.B+ covers an area which is moderately represented (B) by the Ukwala trial site in Siaya District (4.1), although information on soil properties reveal slightly better conditions in the represented area in the Busia District than at Ukwala itself (B+).

The explanation to Map 5.0.5 also lists those units of the Soil Map (Map 5.0.4) which are considered in the various groupings. This is to exclude the smaller physiographic units, such as VXC and BXC1, which, for cartographic reasons, partly occur as inclusions of units coded A, B+ or B-, instead of unit C, where they actually belong.

A breakdown of soil properties referring to the Groupings of Soil Map Units is given as part of Table 5.0.5.

The soils of Busia District are well represented by the FURP trial sites. This is testified by Map 5.0.5 which shows a high percentage of A-cover (highly representative).

The trial sites of Busia District itself are 5.1 (Bukiri-Buburi) and 5.2 (Alupe ARSS).

Site 5.1 is highly representative for the Acrisols on intermediate igneous rocks in the southern part of the District.

Soil Representativeness Code 5.1.A refers to soil map unit UlIl, in which the site is situated, and Code 5.1.A/B- for the combination of unit UlIl and soil association UlIA, which includes some shallower soils than the soils at the trial site.

Site 5.2 is representative for the Acrisols on sandstones and arkoses in the central part of the District.

The combined Soil Representativeness Code is 5.2.A/B+/C and refers to soil map unit UlSl, in which the site is situated, and UlSA. The shallow and moderately deep soils represent the trial site best and are, therefore, coded 5.2.A. The deep soils are 5.2.B+, and some imperfectly drained soils, which form part of soil association UlSA, are to be coded C.

In the northern and eastern parts of the District, Acrisols are developed on granites. They are highly represented by site 7.1 (moderately deep, ferralo-orthic), site 8.2 (deep, humic) and site 11.2 (very deep, ferralo-chromic) in Kakamega, Nandi and Uasin Gishu Districts respectively.

The part of Yala Swamp belonging to Busia District in the very south can be coded 4.3.A/B- if the area is reclaimed (trial site Yala Swamp Phase 1, Siaya District). Gleysols are 4.3.A: Histosols (peats) are 4.3.B- and non-reclaimed land is coded C.

Busia District is moderately represented (B-cover) by trial site 4.1 (Ukwala, Siaya District) and by sites 4.3, 5.1 and 5.2 in the earlier mentioned combined groupings. Soils of map unit UlDl are generally deeper than those at the Ukwala trial site (4.1.B+).
Groupings which show a combination of codes occur where different soils are given in one Soil Map unit: so-called associations or complexes. Examples are the Groupings 5.1.A/B- with soil association UlIA and 5.2.A/B+/C with soil association UlSA.

Areas which are not represented by any one trial site with respect to soils are coded C. This involves the minor physiographic units, such as BXCl, VXC, SACl, and some hydromorphic soils near Malaba (soil map unit PnGl).

The second representativeness map, Map 5.0.6, shows the integrated representativeness of FURP trial sites involving both soils and climate. The map units are named "Agro-Ecological Units" and represent a specific soil-climate environment, typified by FURP trial sites.

All combinations of the different soil-climate environments occurring in Busia District are shown in the Agro-Ecological Unit Map (Map 5.0.6) and are explained in Table 5.0.5. The codes for the Agro-Ecological Units consist of three parts: site, soil representativeness and climatic representativeness.
Site and soil representativeness are taken from Map 5.0.5. In addition, Map 5.0.6 and Table 5.0.5 indicate the codes which refer to the representativeness of the climatic environment (small letters).

Several degrees of representativeness are given according to the prevailing temperature regime and the rainfall in the agro-humid period of the long rains.

All areas in Map 5.0.6 which are marked with code "a" (highly representative) are within the same temperature belt and receive the same amount of rainfall (+/- 10%) in the agro-humid period of the long rains as the trial site the code refers to.

The map units marked with code "b" (e.g.: b++, b+- ,b+*) are only moderately represented by trial sites. In the AEU 5.2.A.b++, for instance, the soils are highly represented by the Alupe ARSS trial site (5.2.A), but the climate (b++) indicates that this Agro-Ecological Unit belongs to the next warmer temperature belt and receives 10-20% more rainfall than the trial site Alupe ARSS.

Areas which are not represented by any one trial site, i.e. soils and/or climate not represented by any site, are coded 0.

The criteria set for sub-division of the various degrees of representativeness with respect to soils and climate are further elaborated upon in Chapter IV.2 of the main report.

EXPLANATION TO MAP 5.0.6

Soil Codes

= A = highly representative

= B+ = moderately representative
(soils of map unit are slightly more favourable than soils at the trial site)

= B- = moderately representative
(soils of map unit are slightly less favourable than soils at the trial site)

Trial sites

4.1 Ukwala (Siaya District)
4.3 Yala Swamp Phase 1 (Siaya District)
5.1 Bukiri-Buburi (Busia District)
5.2 Alupe ARSS (Busia District)
7.1 Mumias (Kakamega District)
8.2 Chepkumia (Nandi District)
11.2 Turbo (Uasin Gishu District)

Climatic Codes

a highly representative, i.e. same Agro-Ecol.Zones Belt and long rains (+/-10%) as at trial site

b moderately representative

++ = 1 AEZ Belt warmer, long rains 10-20% higher
+* = 1 AEZ Belt warmer, long rains similar (+/-10%)
+- = 1 AEZ Belt warmer, long rains 10-20% lower
-+ = 1 AEZ Belt cooler, long rains 10-20% higher
-* = 1 AEZ Belt cooler, long rains similar (+/-10%)
-- = 1 AEZ Belt cooler, long rains 10-20% lower
*+ = AEZ Belt the same, long rains 10-20% higher
*- = AEZ Belt the same, long rains 10-20% lower
xx = 2 AEZ Belts warmer, long rains 20-30% higher
<u>**xx**</u> = 2 AEZ Belts cooler, long rains 20-30% lower
m = long rains 30-50% higher (more mm)

Areas not represented

0 = not represented by soils and/or climate

For further explanation see Table 5.0.5

MAP 5.0.6 AGRO-ECOLOGICAL UNITS REPRESENTED BY TRIAL SITES IN BUSIA DISTRICT

■ Site of first priority
5.1 Bukiri - Buburi
5.2 Alupe A.R.S.S. (co-operation site)
—— agro-ecological unit boundary

For EXPLANATION see PREVIOUS PAGE and TABLE 5.0.5

KEY
AA1 soil mapping code
soil boundary
towns and major villages
tarmac road
other all-weather roads
international boundary
district boundary
river

SOURCE
LBDA Reconnaissance Soil Map of the Lake Basin Development Authority Area, Western Kenya, 1985 (scale 1:250,000)

For LEGEND See APPENDIX

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Table 5.0.5: Major Soil Properties and Climatic Conditions of the Agro-Ecological Units in the Busia District

Agro-Ecological Unit		Soil properties						Climatic Conditions				
Site Soil No. Code	Climate Code	drainage	eff. depth	nutr. avail.	top-soil	moist. st.cap.	classification	temp.1) mean ann.	temp.1) mean min.	rainfall 66% prob.2)	Agro-Ec. Subzone 3)	Agro-Ec. Zone
4.1. B+	a	w	md-d	l	0	m-h	ch Ac + rh Fe (+ or Ac)	21-24	14-17	640-780	l--(m/s)	LM2
	b*+							21-24	14-17	780-840	l--mi to p or two	LM1
4.3. A/B- (if reclaimed)	b*-	mw-i	d-vd	l	lah	l-m	hu Gl (A) + dy His (B-)	21-24	14-17	430-485	(m/s)+i	LM4
	b*x							21-24	14-17	375-430	(m/s)+i	LM4
5.1. A	b*+	w	md-d	l	0	m-h	ch + fe-ch Ac (A)	21-24	14-17	640-700	l--(m/s)i	LM2
5.1. A/B-	a	w	sh-md	l	0	l-m	ch + fe-ch Ac (+ or Ac + fe Ca) (B-)	21-24	14-17	520-640	m/l--(s)	LM3
	b*-							21-24	14-17	460-520	m+f(vs) to (m/s)+i	LM3-4
	b*x							21-24	14-17	400-460	(m/s)+i	LM4
5.2. A/B+/C	a	w	sh-d	l	0	l-h	or + fe-or Ac (+ or Fe + dy Ca) A: sh-md, B+: d, C: gl Ac	21-24	14-17	765-935	l--mi	LM1
	b*-							21-24	14-17	680-765	l--(m/s)i	LM2
	bx-											
7.1. A	a	w	sh-md	l	0	l-m	or + fe-or Ac	21-24	14-17	830-1010	p or two	LM1
	b*x							21-24	14-17	650-740	l--(m/s)i	LM2
7.1. B+		w	d-vd	l	0	h-vh	or Ac	Not a unit, only for combination in 7.1.A/B+				
7.1. A/B+	a	w	sh-d	l	0	l-h	or + fe-or Ac	21-24	14-17	830-1010	l--mi	LM1
	b*-							21-24	14-17	740-830	l--(m/s)i	LM2
	b*x							21-24	14-17	650-740	l/m--(s/m) to m/l--(s)	LM2-3
8.2. A	b+x	w	d	l	lah	h	hu Ac	21-24	14-17	595-680	l--(m/s)i	LM2
11.2. A	b+*	w	d-vd	l	0	h-vh	or Ac	21-24	14-17	520-640	l--(m/s)i to m/l--(s)	LM2
	b+x							21-24	14-17	700-760	l--mi to p or two	LM1
	b+m							21-24	14-17	760-880	p or two	LM2
11.2. B-	b+*1)	w	sh-md	l	0	l-m	or + fe-or Ac	See Footnote 21-24	14-17	520-640	l--(m/s)i to m/l--(s)	LM2
C		soil not representative										
0		soil and/or climate are not representative										

Key:

Drainage

se somewhat excessive
w well
mw moderately well
i imperfect
p poor

Moisture storage capacity

vh very high > 160 mm.
h high 120-160 mm.
m moderate 80-120 mm.
l low < 80 mm.

Effective soil depth

ed extremely deep > 180 cm.
vd very deep 120-180 cm.
d deep 80-120 cm.
md moderately deep 50- 80 cm.
sh shallow 25- 50 cm.
vsh very shallow < 25 cm.

Nutrient availability

h high
m moderate
l low
vl very low
Specification given in Chapter IV.2 (main report)

Topsoil properties

h humic (base saturation >50 %)
ah acid humic (base saturation <50%)
2 thick (30-60 cm.)
1 thin (<30 cm.)
0 non-humic

Soil classification

Ca Cambisols
Ac Acrisols
Fe Ferralsols
Gl Gleysols
His Histosols

hu humic
or orthic
ch chromic
rh rhodic
dy dystric

fe ferralic
fe-or ferralo-orthic
fe-ch ferralo-chromic
gl gleyic

1) **Temperature (°C)**
(differentiated according to AEZ belts)

2) **Rainfall 66% probability (in mm.)**
-referring to agro-humid period of long rains only;
-for definition of rainfall ranges see explanation to Map ...0.6;
-66% probability means that amount of rainfall will be exceeded in at least 20 out of 30 years.

3) **Agro-ecological Subzone**
-approximative indication only, since subzones are not directly related to amount of rainfall;
-"--" in formula means "followed by";
-for further explanation of subzones see Chapter IV on methodology;
-Agro-ecological zones land subzones are shown in Map ...0.3.

---

1) Unit 11.2.B-.b+* only occurs on Map 5.0.6. On Map 5.0.5, this area is named 7.1.A. The soil are almost similar but the unit is too dry to be represented climatically by site 7.1.

E X P L A N A T I O N   T O   M A P   5.0.6

Soil Codes

= A = highly representative

= B+ = moderately representative
(soils of map unit are slightly more favourable than soils at the trial site)

= B- = moderately representative
(soils of map unit are slightly less favourable than soils at the trial site)

Trial sites

4.1 Ukwala (Siaya District)
4.3 Yala Swamp Phase 1 (Siaya District)
5.1 Bukiri-Buburi (Busia District)
5.2 Alupe ARSS (Busia District)
7.1 Mumias (Kakamega District)
8.2 Chepkumia (Nandi District)
11.2 Turbo (Uasin Gishu District)

Climatic Codes

a highly representative,i.e. same Agro-Ecol.Zones Belt and long rains (+/-10%) as at trial site

b moderately representative

++ = 1 AEZ Belt warmer, long rains 10-20% higher
+* = 1 AEZ Belt warmer, long rains similar (+/-10%)
+- = 1 AEZ Belt warmer, long rains 10-20% lower
-+ = 1 AEZ Belt cooler, long rains 10-20% higher
-* = 1 AEZ Belt cooler, long rains similar (+/-10%)
-- = 1 AEZ Belt cooler, long rains 10-20% lower
*+ = AEZ Belt the same, long rains 10-20% higher
*- = AEZ Belt the same, long rains 10-20% lower
xx = 2 AEZ Belts warmer, long rains 20-30% higher
xx = 2 AEZ Belts cooler, long rains 20-30% lower
m = long rains 30-50% higher (more mm)

Areas not represented

0 = not represented by soils and/or climate

For further explanation see Table 5.0.5

MAP 5.0.6 AGRO-ECOLOGICAL UNITS REPRESENTED BY TRIAL SITES IN BUSIA DISTRICT

34° E

■ Site of first priority

5.1 Bukiri - Buburi

5.2 Alupe A.R.S.S. (co-operation site)

—— agro-ecological unit boundary

For EXPLANATION see PREVIOUS PAGE
and TABLE 5.0.5

0°30' N

0°

KEY

AA1	soil mapping code
	soil boundary
	towns and major villages
	tarmac road
	other all-weather roads
	international boundary
	district boundary
	river

SOURCE

LBDA Reconnaissance Soil Map of the Lake Basin Development Authority Area, Western Kenya, 1985 (scale 1:250,000)

For LEGEND See APPENDIX

0 5 10 15 20 25 km

APPENDIX: LEGEND TO THE SOIL MAP OF BUSIA DISTRICT

1----Explanation of first character (physiography):

H — Hills and Minor Scarps (hilly to steep; slopes predominantly over 16%; relief intensity up to 100 (Minor Scarps) to 300 m (Hills); altitudes up to 2850 m)

F — Footslopes (at the foot of Hills and Mountains; gently undulating to rolling; slopes between 2 and 16%; various altitudes)

U — Uplands
Um Lower Middle-Level Uplands (gently undulating to undulating; slopes between 2 and 8%; altitudes between 1200 and 2200 m)

Ul — Lower-Level Uplands (very gently undulating to undulating; slopes between 2 and 8%; altitudes between 1200 and 2100 m)

P — Plains
Pn Non-Dissected Erosional Plains (very gently undulating to undulating; slopes between 0 and 8%; various altitudes)

A — Floodplains and River Terraces (almost flat to gently undulating; slopes between 0 and 5%; various altitudes; seasonally flooded or ponded)

B — Bottomlands (flat to gently undulating; slopes between 0 and 5%; various altitudes; seasonally ponded)

S — Swamps (almost flat; slopes between 0 and 2%; various altitudes; permanently waterlogged if not reclaimed)

V — Minor Valleys (V or U-shaped valleys; slopes mainly up to 16%, exceptionally up to 30%; width mainly 250-500 m, up to about 1000 m; depth up to about 100 m; various altitudes)

Z — Lake-side Beach Ridges (very gently undulating; slopes between 2 and 5%; altitude approximately 1200m; along Lake Victoria)

2----Explanation of second character (lithology):

A — Recent Alluvial Sediments from various sources
D — Mudstones and Claystones
G — Granites and Granodiorites
I — Intermediate Igneous Rocks (andesites, phonolites, syenites, etc.)
S — Sandstones, Grits and Arkoses
X — Undifferentiated or Various Rocks

3----Soil descriptions

HGC — Complex of:
Somewhat excessively drained, shallow, stony and rocky soils of varying colour, consistency and texture
--- dystric REGOSOLS and RANKERS, with ferralic and humic CAMBISOLS, lithic, rocky and stony phases, LITHOSOLS and Rock Outcrops

HI1 — Somewhat excessively drained, very shallow to shallow, yellowish red to dark reddish brown, stony and rocky, gravelly clay loam to sandy clay; in places moderately deep
--- LITHOSOLS, stony phase, with dystric REGOSOLS and CAMBISOLS, lithic, stony and rocky phases

FG2 Well drained, moderately deep to deep, dark yellowish brown, friable sandy clay; in many places with an acid humic topsoil, rocky and/or stony
--- dystric and humic CAMBISOLS, stony and rocky phases

FI2 Well drained, shallow to moderately deep, dark red to dark yellowish brown, friable, gravelly clay loam to clay; in places stony and rocky; in places over petroplinthite
--- ferralic CAMBISOLS, lithic or petroferric phase, partly stony phase and LITHOSOLS; with Rock Outcrops

UmG1 Well drained, deep, reddish brown, friable, gravelly sandy clay to clay, with an acid humic topsoil
--- humic ACRISOLS, with humic CAMBISOLS

UmG2 Well drained, deep, dark yellowish brown to dark brown, friable sandy clay loam to sandy clay; in places gravelly in the deeper subsoil
--- ferralo-orthic ACRISOLS

UmG6 Well drained, shallow to moderately deep, dark yellowish brown, friable sandy clay
--- orthic ACRISOLS

UlD1 Well drained, moderately deep to very deep, dark red to strong brown, friable clay; in many places shallow over petroplinthite
--- chromic and orthic ACRISOLS and rhodic FERRALSOLS, partly petroferric phases, and dystric phases, with dystric NITISOLS

UlG1 Well drained, deep to very deep, yellowish red to strong brown, friable clay; in places moderately deep, over petroplinthite or rock; in places rocky
--- orthic ACRISOLS; with Rock Outcrops

UlG3 Well drained, shallow to moderately deep, dark yellowish brown to strong brown, friable sandy clay; over petroplinthite; in places very shallow, stony or rocky
--- orthic and ferralo-orthic ACRISOLS, petroferric and partly stony phase, with LITHOSOLS and Rock Outcrops

UlGA1 Association of:
well drained, deep to very deep, dark yellowish brown to strong brown, friable clay loam to clay; in places with an acid humic topsoil; in places stony; on straight side slopes (50%)
--- orthic ACRISOLS, with humic ACRISOLS, partly stony phases
and:
well drained, shallow to moderately deep, dark yellowish brown to brown, friable sandy clay loam; over petroplinthite; in places excessively drained and sandy; on interfluves, convex slopes and near fringes to bottomlands (50%)
--- (ferralo-)orthic ACRISOLS, petroferric phase, with ferralic ARENOSOLS

UlI1 Well drained, deep, red to dark red, friable clay; in places (mainly on interfluves) shallow to moderately deep over petroplinthite
--- chromic ACRISOLS, partly petroferric phase

UlIA Association of:
well drained, deep, strong brown to dark brown, friable clay; on side slopes (50%)
--- orthic ACRISOLS
and:
well drained, shallow to moderately deep, yellowish red to dark reddish brown, friable, gravelly sandy clay to clay; over petroplinthite; in places stony or rocky; on interfluves (50%)
--- orthic ACRISOLS and dystric and ferralic CAMBISOLS, petroferric and partly stony phases; with Rock Outcrops

UlS1 Well drained, moderately deep to deep, dark reddish brown to strong brown sandy clay loam to clay, over petroplinthite; in places shallow
--- orthic ACRISOLS, with orthic FERRALSOLS, partly petroferric phase

UlSA Association of:
well drained, shallow to moderately deep, dark reddish brown to yellowish red, friable sandy clay loam to clay; over petroplinthite; on interfluves (60%)
--- orthic ACRISOLS with dystric CAMBISOLS, petroferric phases
and:
imperfectly drained, moderately deep, dark yellowish brown to reddish brown, mottled, friable sandy clay; over petroplinthite; in places shallow; on lower slopes and fringes to bottomlands (40%)
--- gleyic ACRISOLS, petroferric phase

PnG1 Imperfectly drained, deep to very deep, dark brown to dark greyish brown, mottled, friable to firm clay
--- gleyic ACRISOLS and dystric GLEYSOLS

AA1 Well to moderately well drained, deep, dark greyish brown to yellowish brown, friable, stratified, sandy clay loam to clay; in places mottled, firm clay; in places slightly saline or sodic; on river levees
--- eutric FLUVISOLS, with vertic FLUVISOLS and vertic and eutric GLEYSOLS, partly saline-sodic phases

AA2 Imperfectly to poorly drained, deep, greyish brown to very dark grey, mottled, very firm, saline and sodic, cracking clay; in river backswamps
--- pellic VERTISOLS and vertic GLEYSOLS, saline and sodic phases

BXC1 Complex of:
imperfectly to poorly drained, deep to deep, very dark grey to brown, mottled, firm to very firm, sandy clay to cracking clay, in many places abruptly underlying a topsoil of friable sandy loam to sandy clay loam; in places saline and sodic
--- dystric PLANOSOLS, dystric and vertic GLEYSOLS and pellic VERTISOLS; partly saline-sodic phases

SA2 Very poorly drained, very deep, dark grey to black, half ripe clay, with an acid humic or dystric histic topsoil; in many places peaty
--- humic GLEYSOLS and dystric HISTOSOLS

SAC1 Complex of:
imperfectly to poorly drained, deep to very deep, greyish brown to very dark grey and black, mottled, firm to very firm clay to cracking clay; in places with a saline and sodic subsoil
--- eutric GLEYSOLS and pellic VERTISOLS, partly saline-sodic phase
and:
very poorly drained, deep, dark grey to black, half-ripe clay, with a humic or histic topsoil; in many places peaty
--- mollic GLEYSOLS and dystric HISTOSOLS

VXC Complex of:
well drained, shallow to deep soils of varying colour, consistency and texture (on valley sides)
--- CAMBISOLS, ACRISOLS and FERRALSOLS, partly lithic phases, with Rock Outcrops
and:
imperfectly to poorly drained, deep, mottled soils with predominantly greyish colours, firm consistence and fine textures (in valley bottoms)
--- GLEYSOLS, with VERTISOLS and HISTOSOLS

ZA1 Well drained, very deep, brown to dark yellowish brown, loose, sand to loamy sand, with inclusions of imperfectly drained, greyish brown, friable to firm sandy loam to sandy clay of varying salinity and sodicity
--- cambic ARENOSOLS, with gleyic SOLONCHAKS, partly sodic phase

NOTES

1 mollic Nitisols and chromo-luvic Phaeozems: soils are equally important
2 mollic Nitisols, with chromo-luvic Phaeozems: Nitisols are prevalent
3 in places: in <30% of the area
4 in many places: in 30-50% of the area
5 predominantly: in >50% of the area
6 deeper subsoil: below 80 cm.

Contents of Chapter 5.1:

Detailed Description of Trial Site Bukiri-Buburi

List of Tables[1])

1) See Footnote next page.

List of Figures[1])

1) Numbering mode of Tables and Figures:
First Number: District Number
Second Number: Trial Site Number
Third Number: Number of Table or Figure within Chapter.

1. Geographical and Additional Technical Information

1.1 Final Position of the Trial Site

The position of the site at Bukiri-Buburi is shown in Figure 5.1.1, extracted from Map No. 101/3 - Samia. Its UTM grid coordinates are E 21.2 and N 23.9. The elevation is 1220 m. Further details on the final position are shown in Figure 5.1.2 and the sketch map of the trial plot is to be found in Figure 5.1.3

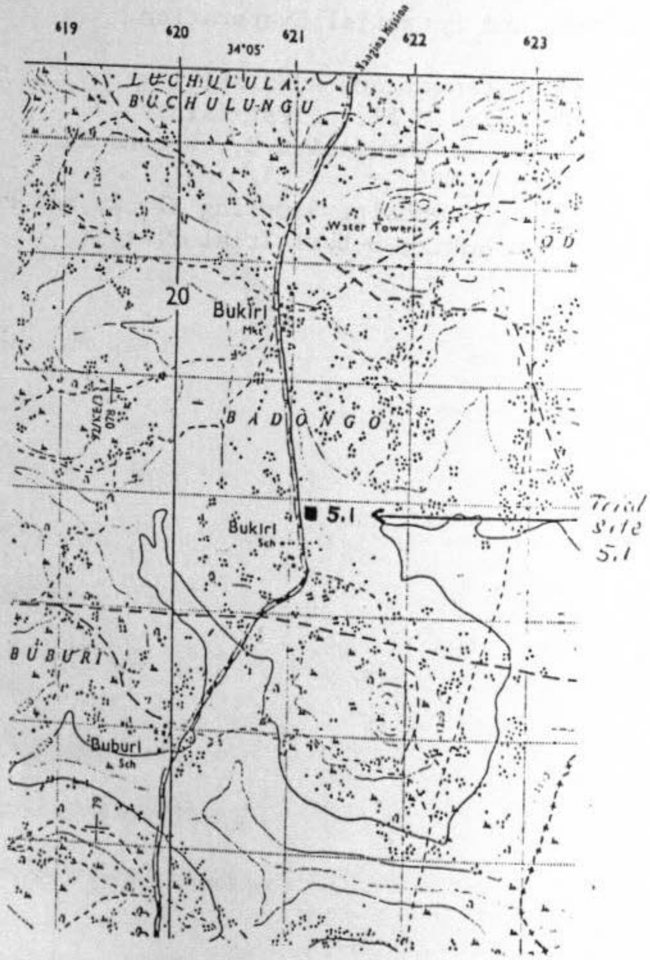


Figure 5.1.1: Demarcation of the Bukiri-Buburi Trial Site on the 1:50,000 Topographic Map

1.2 Sketch of the Trial Site

The location of and the access route to the Bukiri-Buburi site are shown in Figures 5.1.2 and the map of the trial plot in Figure 5.1.3

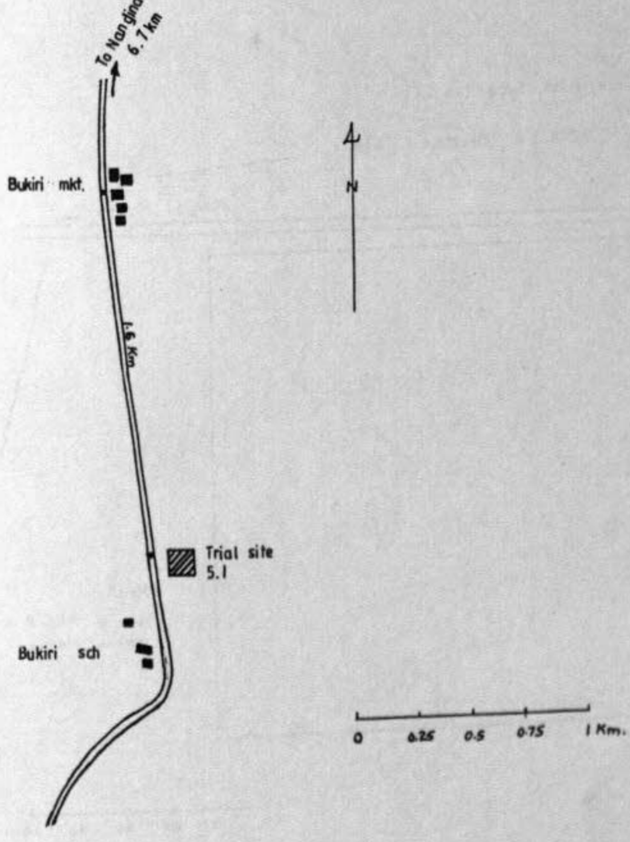


Figure 5.1.2: Access Map to the Bukiri-Buburi Trial Site

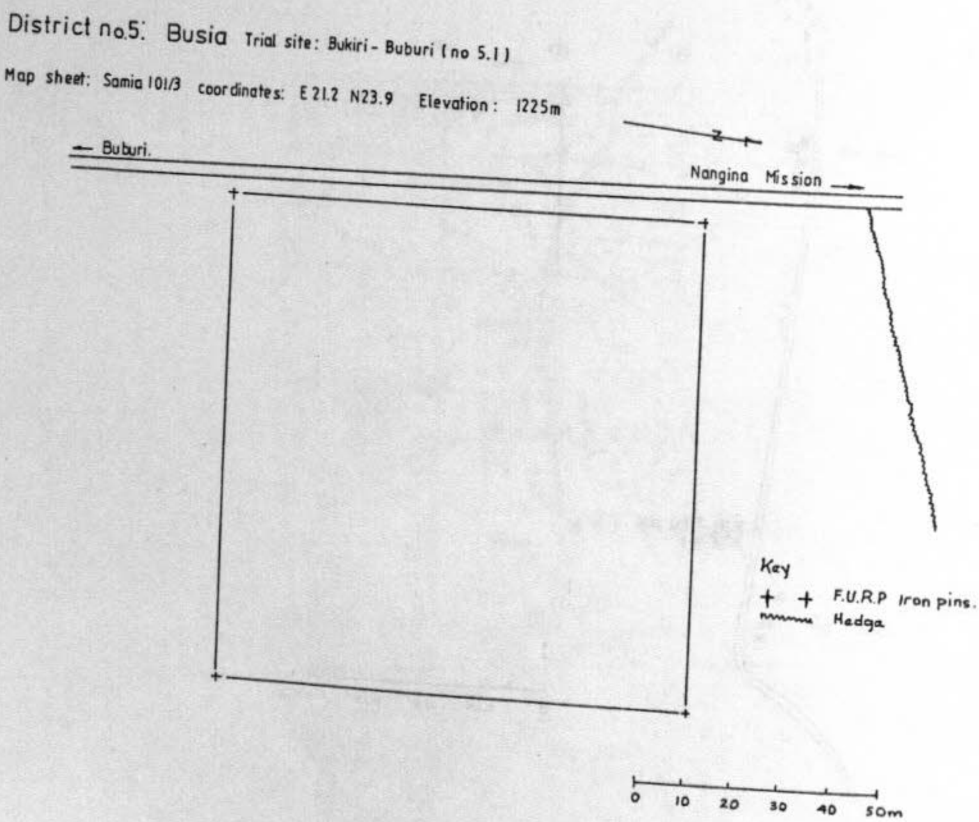


Figure 5.1.3: Map of the Trial Plot, Bukiri-Buburi

The approximate location of the on-farm trials is indicated in Figure 5.1.4.

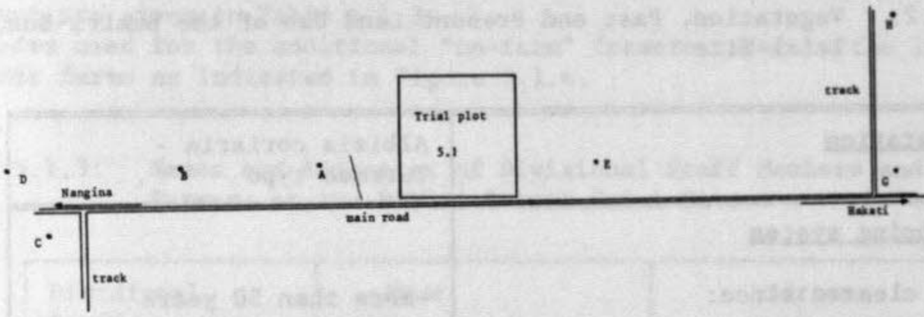


Figure 5.1.4: Location of Farmers' Fields for On-Farm Trials, Bukiri-Buburi

1.3 Physiography

Information on the physiography of the trial site and its surroundings is summarized in Table 5.1.1 below.

Table 5.1.1: Physiography of the Bukiri-Buburi Trial Site

Elevation	1220 m
Landform	lower-level uplands/ planation surface
Physiographic position of the site	convex slope (upper part)
Topography of surrounding country	gently undulating (slopes 2-5%)
Slope on which trial plot is sited	4%
Aspect	E
Microtopography	termite mounds, 2 m wide gully (will be excluded)

1.4 Vegetation, Past and Present Land Use

Information on vegetation and on past and present land use is summarized in Table 5.1.2 below:

Table 5.1.2: Vegetation, Past and Present Land Use of the Bukiri-Buburi Trial Site

Vegetation	Albizia coriaria - Turraea type
Cropping system	
(a) cleared since:	more than 50 years
(b) crops grown:	sugarcane (1975-1983), maize/beans, sorghum, cotton (relay crop), millet
(c) fallow periods:	none
(d) present land use:	maize/beans + cotton
Inputs	
(a) mineral fertilizers:	not applied
(b) organic manure:	first application 1986
(c) means of land preparation:	manual or (hired) tractor
(d) means of weeding:	manual
(e) frequency of weeding:	twice per crop stand
(f) other capital inputs:	knapsack
(g) level of know-how:	low
Produce	
(a) maize	8 bags/acre (90 kg-bags)
(b) beans	3 bags/acre (intercropped)
(c) sorghum	4 bags/acre (60 kg-bags)
Livestock	no information
Remarks	Considerable yield reduction due to termites. High infestation of couch grass. Monkeys are a serious plague to the farmers in the area.

1.5 Names and Addresses of Government Officers from the Division and of Farmers Involved in FURP Activities

Names and addresses of the divisional staff members and of all farmers involved are given in Table 5.1.3.
The codes used for the additional "on-farm" farmers refer to the location of their farms as indicated in Figure 5.1.4.

Table 5.1.3: Names and Addresses of Divisional Staff Members and of Farmers at the Bukiri-Buburi Trial Site

Divisional Staff	Name	Address
D.E.O. L.E.O. T.A.	W. Auma not met not met	Box 36, Hakati
Farmers	**Name**	**Address**
Trial plot	Edward Omalo	Box 1, Funyala
	LOCATION: SUB-LOCATION:	Samia South Buburi
On-Farm trials	**Name**	**Remarks**
5.1.A 5.1.B 5.1.C 5.1.D 5.1.E 5.1.F 5.1.G 5.1.H	Okato Musambira Felix Namude Sedekia Oduke Jared .... Ibrahim Malo Buburi Prim. School Selvano Ogesa Coleta Adourdi	

Period of site selection: December 1985.

2. Climate

2.1 Prevailing Climatic Conditions

2.1.1 Agro-Climatic Classification of the Area Represented by the Bukiri-Buburi Trial Site

The following brief climatic description refers to the existing information:

ACZ : III3 (H.M.H. BRAUN, 1982)[1])

AEZ : LM 3, m/l - (s) (R. JÄTZOLD, 1983)[2])

Next long-term rainfall station: 08934030, Nangina Catholic Mission

Agro-Climatic Zone (ACZ):

Moisture availability Zone III (r/Eo): annual average precipitation is 50-65% of the potential evaporation (Eo).

Temperature Zone 3: mean annual temperature is 20-22°C

Agro-Ecological Zone (AEZ):

LM 3 = Cotton Zone

LM = Lower Midland Zone: mean annual temperature is 21-24°C, mean minimum >14°C

3 = semi-humid; annual average precipitation is 50-65% of the potential evaporation (Eo)

Sub-zone according to growing periods for annual crops (calculated for a "normal" crop in 60% probability)

m/l - (s) = a medium to long cropping season followed by a (weak) short cropping season

---

1) According to H.M.H. BRAUN in: W.G. SOMBROEK et al. (1982): Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, scale 1:1,000,000 - Rep. E1, Nairobi

2) According to R. JÄTZOLD and H. SCHMIDT, eds. (1982): Farm Management Handbook of Kenya, Vol.II/A WEST KENYA - Nairobi and Trier.

Formula	Cropping season	Lengths of growing period (exceeded in 6 out of 10 years)
m/l	medium to long	155 - 174 days
s	short	85 - 104 days

\- = no distinct arid period between growing periods
( ) = weak performance of growing periods (most decades less than 0.8 Eo)

2.1.2 Relevant Meteorological Data for the Bukiri-Buburi Trial Site

In this section a breakdown is given of the following climatic parameters: rainfall, potential evaporation and temperature.

Rainfall:

Rainfall data are obtained from the nearest long-term rainfall station: 08934030 Nangina Catholic Mission (elevation: 1240 m), 6 km NNE of the Bukiri-Buburi trial site (elevation: 1220 m). The data are listed in Table 5.1.4. At the trial site, rainfall amounts are slightly lower: in 20 out of 30 years Bukiri-Buburi gets more than 580 mm during the agro-humid period of the first rains (see Map 5.0.1),and about 450 mm during second rains (see Map 5.0.2). The methods of rainfall data analysis are described in Chapter IV.2.2 of the main report.

Temperature and potential evaporation(Eo):

Temperature data are extrapolated from the Kadenge Yala Swamp Meteorological Station (elevation: 1160 m), 22 km SSE of the trial site. The temperature gradient in this area on average is 0.6°C per 100 m. Potential evaporation (Eo) is calculated using the PENMAN formula, modified by MC CULLOCH (1965). The input parameters employed - windrun, sunshine hours and relative humidity - are obtained from Kadenge Yala Swamp Meteorological Station.

Temperature and evaporation data for the Bukiri-Buburi site are given in Tables 5.1.5 and 5.1.6, and the rainfall pattern and potential evaporation are shown in Figure 5.1.5.

For more detailed information on the methodology of climatic description see Chapter IV.2.2 of the main report.

Table 5.1.4 : Data of the Nearest Long-Term Rainfall Station

Station No.: 08934030
Nangina Catholic Mission
Elevation: 1240 m

Total years for calculation: 19
First year included: 1961
Last year included: 1983

Average annual rainfall: 1459 mm

Rainfall surpassed in 20 out of 30 years (≈66% Probability):

1st rains: 600 mm (beg. Mar. - beg. Jul.)

2nd rains: 470 mm (end Jul. - end Dec.)

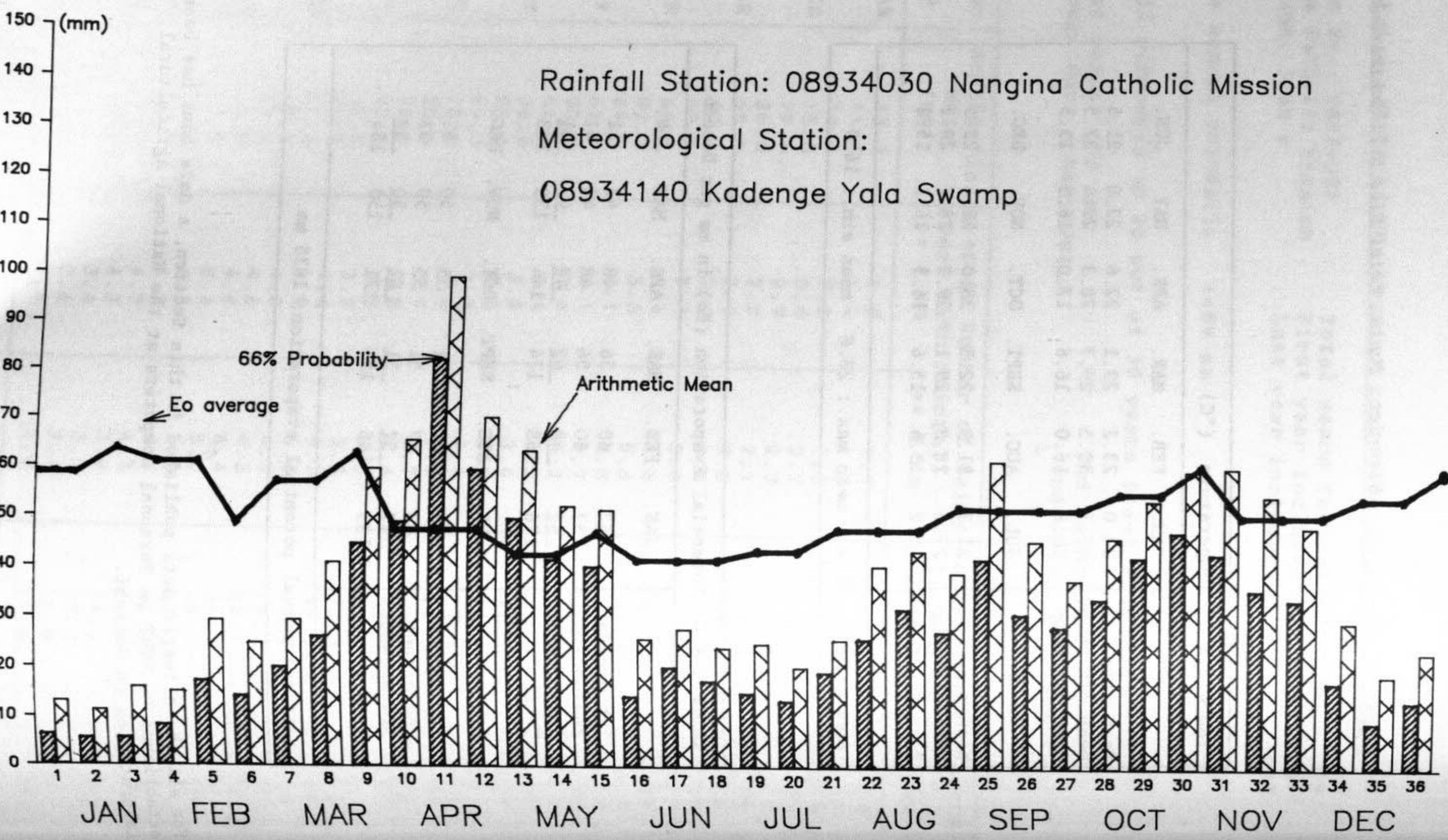
Decades and Month	Arithmetic Mean (mm)	Average Number of Rainy Days with Rainfall >= 1 mm	>= 5 mm	≈66% Probability of exceeding ...mm	Years analized
1 JAN	13.3	1.8	1.7	6.5	19
2	11.4	1.4	1.3	5.8	19
3	16.0	2.2	1.8	5.9	19
4 FEB	15.3	2.4	2.2	8.5	19
5	29.4	2.9	2.7	17.3	19
6	25.0	2.2	2.1	14.3	19
7 MAR	29.5	3.8	3.5	20.1	19
8	40.8	3.6	3.4	26.2	19
9	59.5	5.3	5.0	44.5	19
10 APR	65.3	5.4	4.8	48.8	19
11	98.5	5.8	5.6	81.6	19
12	69.8	6.1	5.8	59.1	19
13 MAY	63.1	6.1	5.7	49.5	19
14	52.0	5.4	5.2	41.4	19
15	51.3	5.4	5.2	40.0	19
16 JUN	26.0	3.2	3.0	14.5	19
17	28.0	3.8	3.5	20.2	19
18	24.3	3.3	3.1	17.6	19
19 JUL	25.2	3.9	3.3	15.2	19
20	20.4	2.9	2.7	13.8	19
21	26.0	2.8	2.6	19.4	19
22 AUG	40.5	3.5	3.5	26.2	19
23	43.5	3.7	3.3	32.0	19
24	39.3	4.4	4.3	27.6	19
25 SEP	61.4	4.9	4.6	41.9	19
26	45.6	4.8	4.5	31.3	19
27	37.9	4.4	4.3	28.7	19
28 OCT	46.3	4.6	4.4	34.3	19
29	53.6	5.4	5.0	42.5	19
30	59.6	6.3	6.0	47.5	19
31 NOV	60.2	4.9	4.6	43.2	18
32	54.6	4.7	4.4	36.1	18
33	48.5	4.3	3.9	34.2	18
34 DEC	31.7	3.4	3.2	19.3	18
35	20.5	2.6	2.4	10.8	18
36	25.4	2.8	2.6	15.4	18

Table 5.1.5: Temperature (°C)						
	JAN.	FEB.	MAR.	APR.	MAY	JUN.
Mean temp.	23.0	23.2	23.1	22.6	22.0	21.5
Mean max.temp.	30.1	30.5	29.7	28.3	27.4	27.5
Mean min.temp.	15.8	16.0	16.6	17.0	16.5	15.5
	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
Mean temp.	21.3	21.9	22.3	23.0	22.4	22.5
Mean max.temp.	27.5	28.3	29.1	29.7	28.7	29.2
Mean min.temp.	15.2	15.4	15.6	16.3	16.1	15.8
annual mean: 22.4 mean max.: 28.8 mean min.: 16.0						

Table 5.1.6: Potential Evaporation (Eo) in mm per Decade:						
	JAN.	FEB.	MAR.	APR.	MAY	JUN.
1st decade	57	60	56	48	43	41
2nd decade	57	60	56	48	43	41
3rd decade	62	48	62	48	47	41
Total:	176	168	174	144	133	123
	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
1st decade	43	47	51	55	50	53
2nd decade	43	47	51	55	50	53
3rd decade	47	52	51	61	50	58
Total:	133	146	153	171	150	164
average annual potential evaporation: 1835 mm.						

For all the climatic data published in this Section, a data bank has been established by FURP on Personal Computers at the National Agricultural Laboratories in Nairobi.

Figure 5.1.5: Rainfall and Potential Evaporation



2.1.3 Crop Suitability from the Climatic Point of View

A summary of the agro-climatic suitability of the most important seasonal crops is given in Table 5.1.7 below. Additional information on other crops, considered suitable from the agro-climatic viewpoint, is given in the Farm Management Handbook, Vol.II/A, West Kenya[1]).

Table 5.1.7: Agro-Climatological Crop List for Bukiri-Buburi

Crop/variety (or place of breeding) e = early m = medium l = late	Av.No.of days to physiol. maturity	Altitudes[2]) according to growing period (m.)	Requirem.of well distributed rainfall [3]) in grow.period (mm.)	Yield potential acc. to water availability [4]) a = 1st rains b = 2nd rains
Maize/m.mat. like H 512	125-160	1000-1800	500-800	a) good
Maize/e.mat. Katumani	85-110	700-1600	260-500	b) fair
Sorghum/ e.mat.Serena	85-110	0 - 1500	220-480	a) good b) good (ratoon.)
Beans/e.mat like Rose Coco (GLP 2)	80-110	700-1800	250-450	a) good b) fair
Cotton	170-210	0 - 1400	550-950	a) good b) good

1) R. JÄTZOLD, and H. SCHMIDT, eds.(1982): Farm Management Handbook of Kenya, Vol. II/A, West Kenya - Nairobi and Trier.

2) Most suitable altitudes; the length of the growing period increases with altitude; growth is also possible beyond the indicated altitude range, as long as the ecological limits have not been reached.

3) Lower figure for fair results, higher for very good results with some corrections due to rainfall distribution, evaporation and run-off losses.

4) Estimated yield potential: very good >80%, good = 60-80%, fair = 40-60% and poor <40% of the expected yield under optimum water availability adapted from R. JÄTZOLD and H. SCHMIDT, eds. (1982): Farm Management Handbook of Kenya, Vol. II/A, West Kenya.

For the most important food crops in the area around the Bukiri-Buburi trial site, the crop coefficients (kc) are shown in Table 5.1.8, differentiated according to decades (10 day periods) of the growing season which is the time between planting or sowing and the physiological maturity. Furthermore, four crop development stages are distinguished in Table 5.1.8.

The crop coefficients for the climatic conditions at the Bukiri-Buburi trial site were estimated on the basis of data obtained from DOORENBOS and PRUITT (1977)[1] and DOORENBOS and KASSAM (1979)[2].

The data on the duration of each of the growing seasons and on the various development stages of each crop were assessed on the basis of local observations made under average climatic conditions.

The crop coefficients estimated for the various decades of the growing seasons were used to estimate the maximum (potential) evapotranspiration (ETm) under the prevailing climate, assuming that water is not a limiting factor for plant growth. For this calculation the following approximative formula was employed:

$$ETm = kc * Eo$$

whereby: ETm= maximum (potential) evapotranspiration
kc = crop coefficient
Eo = potential evaporation (climatic evaporative demand)

In Figures 5.1.6a to 5.1.6b, the ETm-values are used to indicate the estimated maximum water requirements of important food crops for optimum growth. Furthermore, the rainfall data at 66% reliability are shown in each of the Figures 5.1.6a to 5.1.6b to give an indication of the water availability. However, when reading these figures, it must be borne in mind that the actual availability of water for the plants also depends, to a large degree, on factors such as the run-off, the moisture storage capacity of the soil, the deep percolation of water etc.

The placement of the growing seasons of the various crops on the time axis as presented in Figures 5.1.6a and 5.1.6b, was mainly based on the pattern of rainfall, whereby the peak water requirements of the plants should be met by high, reliable rainfall.

Detailed information on the calculation procedures and references are given in Chapter IV.2.2 of the main report. The interpretation of the diagrams mentioned above follows in Section 4 of this volume (Conclusions from the analyses of climate and soils).

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1) FAO (1977): Crop Water Requirements - (= Irrigation and Drainage Paper, 24), Rome

2) FAO (1979): Yield Response to Water - (= Irrigation and Drainage Paper, 33), Rome

Table 5.1.8 Crop development stages 1) and crop coefficients (Kc) 2) for approx. maximum (potential) crop evapotranspiration of the most important seasonal crops grown at Bukiri-Buburi (site no. 5.1)

Crop/ Variety	Number of decades from seeding resp. planting to (physiological) maturity																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
MAIZE	0.5	0.45	0.45	0.57	0.69	0.81	0.93	1.05	1.05	1.05	1.05	1.05	0.96	0.8	0.63									
H512	I	I	I	II	II	II	II	III	III	III	III	III	IV	IV	IV									
MAIZE	0.6	0.65	0.75	0.85	0.95	1.05	1.05	1.05	0.93	0.67	1.05	0.96	0.8	0.63										
KATUMANI	I	I	II	II	II	III	III	III	IV	IV	III	IV	IV	IV										
SORGHUM	0.5	0.45	0.54	0.72	0.91	1.0	1.0	1.0	0.89	0.64														
SERENA	I	I	II	II	II	III	III	III	IV	IV														
BEANS	0.5	0.65	0.76	0.94	1.05	1.05	1.05	0.82	0.49															
GLP 2	I	I	II	II	III	III	III	IV	IV															
COTTON	0.6	0.65	0.65	0.69	0.77	0.85	0.93	1.01	1.05	1.05	1.05	1.05	1.05	1.05	0.97	0.84	0.67	0.52	0.4					
GLP 2	I	I	I	II	II	II	II	II	III	III	III	III	III	III	IV	IV	IV	IV	IV					

1) Crop development stages as defined in chapter IV 2.2 (main report)
I = initial stage II = development stage III = mid season IV = late season
2) Kc = crop coefficient as defined in chapter IV 2.2 (main report)

Figure 5.1.6.a: Water requirements and availability for crop Maize H 512, first rains

Rainfall Station: 08934030
Nangina Catholic Mission

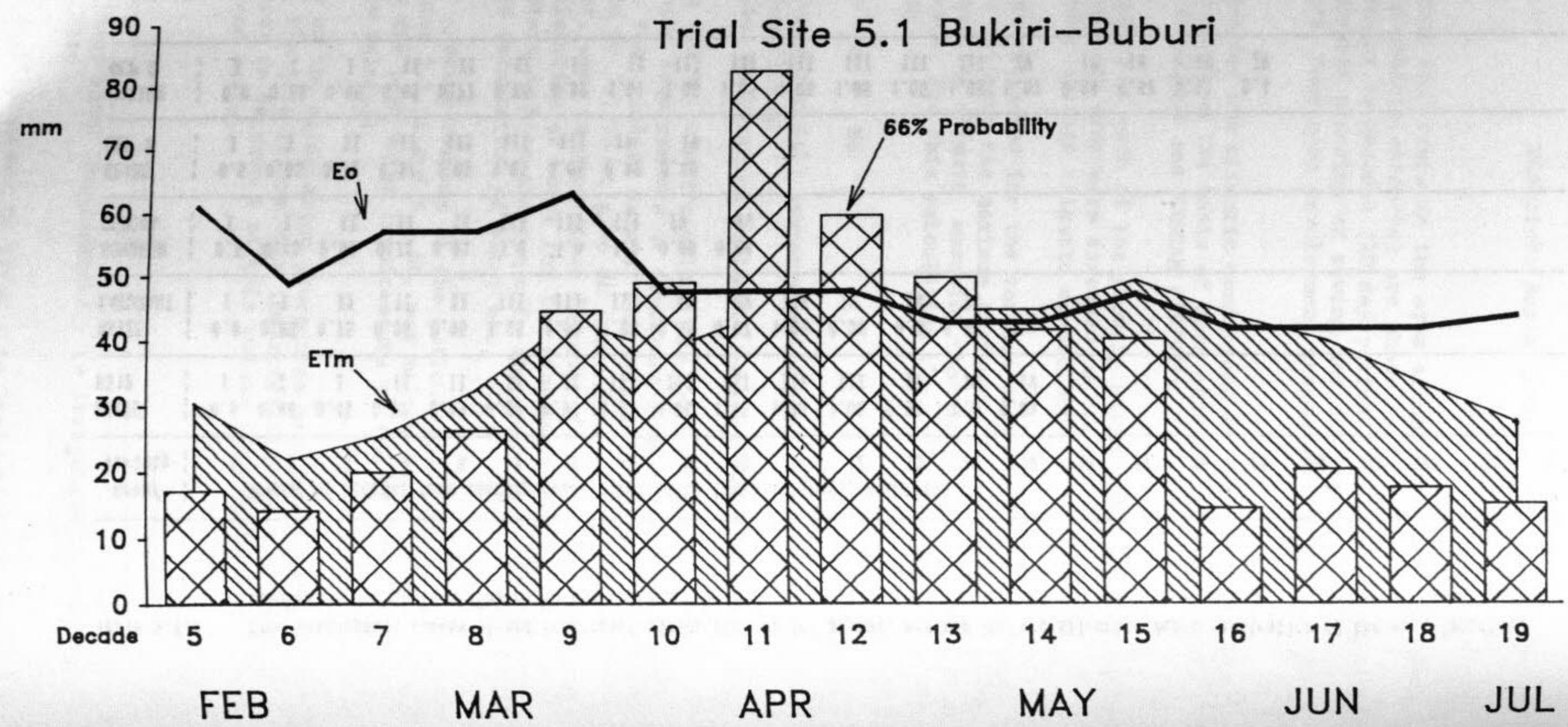
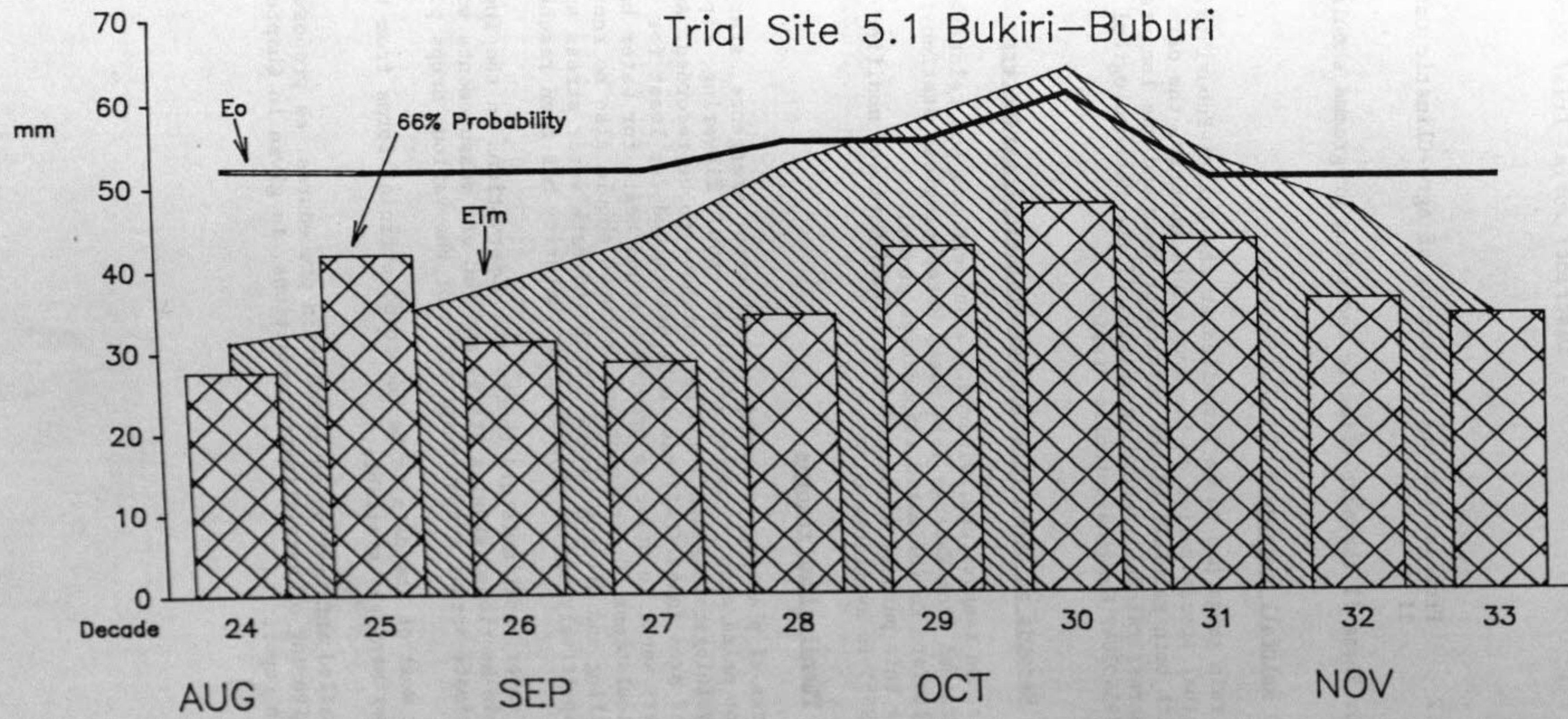


Figure 5.1.6.*b*: *Water requirements and availability for crop Maize, Katumani C.B., second rains*

Rainfall Station: 08934030
Nangina Catholic Mission



2.2 Proposal for the Monitoring of Agro-Climatic Conditions in Phase II

For Phase II the agro-climatic recording programme should include:

1) **Rainfall records:**

A rain gauge has to be installed at the Bukiri-Buburi trial site to measure actual precipitation on the spot. Subsequently, the data can be compared with both rainfall of the particular year and the long-term average of the nearest rainfall-recording station of the Meteorological Department: 0893403042 Nangina Catholic Mission.

2) **Records on other relevant meteorological parameters:**

Data on temperature, windrun, sunshine hours and relative humidity can be obtained from Kadenge Yala Swamp Meteorological Station in order to calculate Eo (climatic evaporative demand).
For this purpose a computerized PENMAN formula, modified by MC CULLOCH (1965) is available on PC.

3) **Phenological records:**

Dates of planting or sowing of each crop, emergence, start of tasselling (for maize crop), budding (for bean crop), flowering, ripeness or physiological maturity and harvest have to be recorded. Additionally, the leaf area index (LAI) has to be determined (at least for the cereal crops) every week, in order to provide a sound basis for water balance calculations. Other important features should also be recorded, above all rolling and wilting leaves, which indicate water stress and wilting point respectively before physiological maturity has been reached.

Moreover, soil moisture checks and observations on rooting depth at the above-mentioned growing stages and run-off measurements would be needed to estimate actual evapotranspiration of the various crops properly.

For most of the data to be recorded, official forms from the Meteorological Department are available.

Detailed information on calculation procedures, as proposed for the monitoring of agro-climatic conditions, is given in Chapter IV.2.2 of the main report.

3. Soils

In this Section, survey and laboratory data concerning the trial site and, more specifically, the soil profile are given. The evaluation of these data is shown in Sub-Section 3.3.

3.1 Survey Data

3.1.1 Brief Soil Description and General Information on the Soil

The brief description of the soils of the trial plot is followed by a rating of relevant soil-related land factors. The classes for these factors have been adapted from Andriesse and van der Pouw (1985) and a key for them is to be found in Chapter IV.2.3 of the main report.

Brief soil description

The soils are deep, dark red in colour, and consist of friable clay. They have a moderate, sub-angular blocky structure and a very high bioporosity is prevalent.

Rating of soil-related land factors

- Parent rock
  - 1 rich: basic igneous rocks
  - 2 moderately rich: intermediate igneous rocks
  - 3 poor
- Drainage
  - 1 (somewhat) excessively drained
  - 2 well drained
  - 3 moderately well drained
  - 4 imperfectly drained
  - 5 (very) poorly drained
- Effective soil depth
  - 1 extremely deep
  - 2 very deep
  - 3 deep
  - 4 moderately deep to
  - 5 shallow
  - 6 very shallow
- Inherent fertility
  - 1 high
  - 2 moderate
  - 3 poor
  - 4 very poor
- Topsoil properties
  - 0 non-humic
  - 1 humic
  - 2 thick humic
  - 1a acid humic
  - 2a thick acid humic

- Salinity	<u>0 non-saline</u> 1 slightly saline 2 saline
- Sodicity	<u>0 non-sodic</u> 1 slightly sodic 2 sodic
- Stoniness	<u>0 non-stony</u> 1 slightly stony 2 stony 3 very stony
- Rockiness	<u>0 non-rocky</u> 1 slightly rocky 2 rocky 3 very rocky
- Consistency (moist)	1 half-ripe 2 loose 3 very friable <u>4 friable</u> 5 firm 6 very firm
- Moisture storage capacity	1 very high <u>2 high</u> 3 moderate 4 low
- Excess surface water	<u>0 none</u> 1 occasional 2 seasonal 3 permanent

3.1.2 Detailed Profile Description and Soil Classification

Detailed information on the various soil properties as they occur in the different horizons of the soil profile is given in Table 5.1.9. The location of the profile near the trial plot is shown in Figure 5.1.7.

The soil profile is classified according to two systems, which are explained in Chapter II.2.2 of the main report.

1. Legend to the Soil Map of the World (FAO-Unesco, 1974), with adjustments according to the Kenya Concept (Siderius and van der Pouw, 1980): <u>ferralo-chromic Acrisol</u>.
2. USDA Soil Taxonomy (Soil Survey Staff, 1975): <u>"ultic oxic" Rhodudalf, very fine-clayey family</u>.

Table 5.1.9: Detailed Profile Description of Trial Plot Bukiri-Buburi

Profile number: 5.1
Date of examination: 10-12-1985
Authors: Gachene/Smaling

Sample No.	Horizon Genetic	Horizon Depth	Horizon Boundary	Colour (Moist)	Mottling	Texture	Cutans	Structure	Biopores	Consistence	Field pH	Concretions	Other Features
5.1.1	Ah	0 - 20	clear irregular	2.5 YR 3/4 dark redd. brown	---	clay	---	weak medium subangular blocky	many v.f. many f. many m. many c.	friable-firm; sl.sticky-sl.plastic	5.6	---	---
5.1.2	Bt1	20 - 35	gradual smooth	2.5 YR 3/6 dark red	---	clay	patchy thin clay	moderate medium subangular blocky	many v.f. many f. many m. many c.	friable-firm; sl.sticky-sl.plastic	5.1	---	---
5.1.3	Bt2	35 - 60	gradual smooth	2.5 YR 3/6 dark red	---	clay	broken moderately thick clay	moderate medium subangular blocky	many v.f. many f. many m. common c.	friable; sl.sticky-sl.plastic	5.5	---	---
5.1.4	Bt3	60 - 100		10 R 3/6 dark red	---	clay	broken moderately thick clay	moderate fine-medium subangular blocky	many v.f. many f. common m. common c.	friable; sticky-plastic	6.0	---	---

Remarks: big termite chambers and worm casts (0-3cm) are common in the Bt1- and Bt2 horizons; extremely high termite activity.
Colour: redd. = reddish
Biopores: v.f.= very fine; f. = fine; m. = medium; c. = coarse
Consistence: sl. = slightly

3.1.3 Soil sampling

Soil samples (profile, composite, farmers' fields, pF rings) are listed in Sub-Section 3.2.
Figure 5.1.7 shows the location of the composite sampling blocks (I to IV) as well as the location of the profile pit.

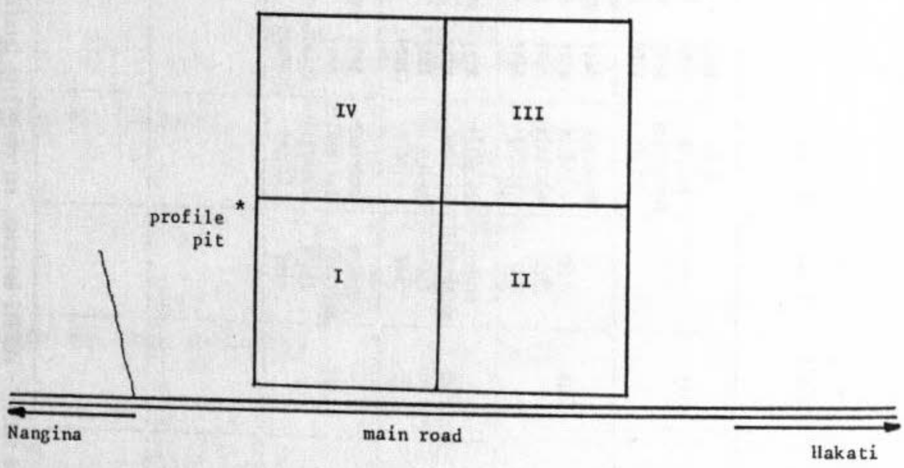


Figure 5.1.7: Location of Composite Sampling Blocks and Profile Pit at the Bukiri-Buburi Trial Plot

3.2 Laboratory Data

The soil samples from the profile and the composite samples from the various blocks of the main trial site and from the farmers' fields were analyzed in the laboratory. The results are compiled in Tables 5.1.10 to 5.1.12. The methodology applied for obtaining these results is described in detail in Chapter IV.2 of the main report.

Table 5.1.10 : Analytical Results (physical and chemical analysis, results on air dry soil basis)
Profile Samples from Trial Site

	Horizon	Depth cm.	Field No.	Lab. No.	> 2 mm. %	Sand %	Silt %	Clay %	Texture Class	pH KCl	pH H2O	Diff. pH	Cond. H2O
1	Ap	0-20	5.1.1	11278/85	--	17	18	65	C	4.8	5.0	0.2	0.00
2	Bt1	20-35	5.1.2	11279	--	13	14	73	C	4.7	5.2	0.5	0.10
3	Bt2	35-60	5.1.3	11280	--	13	14	73	C	4.9	5.4	0.5	0.00
4	Bt3	60-100	5.1.4	11281	--	13	14	73	C	5.1	6.0	0.9	0.01
5													
6													
7													
8													

	Saturation Extract % water	pH	El.Cond.	Na	K	Mg	Ca	Mn	ECEC	Bases %	Al %	Al me./100gm. KCl	H+Al
				me./100gm. AgTU									
1	NA	NA	NA	0.06	1.44	2.30	6.80	0.96	12.0	88.3	2.7	0.32	0.44
2	NA	NA	NA	0.03	0.17	2.15	5.80	0.83	10.2	79.9	1.2	0.12	0.22
3	NA	NA	NA									0.10	0.22
4	NA	NA	NA									0.12	0.24
5													
6													
7													
8													

	Na	K	Mg	Ca	CEC pH8.2	Bases %	Bases+Al me./100gm.	Al %	Org. C %	N %	C/N	P Olsen ppm.	105 deg.C in rel.to air dry
	me./100gm. Acetate												
1	0.21	1.49	3.4	3.9	20.20	44.55	9.32	3.43	1.14	0.16	7.1		0.97
2	0.19	0.25	2.5	3.3	13.00	48.00	6.36	1.89	0.67	0.11	6.1		0.96
3	0.20	0.16	2.6	3.0	14.30	41.68	6.06	1.65	0.45	0.10	4.5		0.97
4	0.19	0.16	2.5	2.0	10.80	44.91	4.97	2.41	0.41	0.10	4.1		0.97
5													
6													
7													
8													

Moisture Retention Capacity

	Horizon	Depth cm.	Vol.% Moisture bar 0 / pF 0	1/10 / 2	1/3 / 2.5	5 / 3.7	15 / 4.2	Avail. Moisture Capacity mm./10cm.	Bulk Dens gm./cc. 105 deg.C
1	Ap	15-20	46.6	35.3	34.0	30.2	29.0	6.3	1.26
2	Bt2	50-55	54.4	39.4	36.7	34.0	28.6	10.9	1.36
3									
4									

NA = not applicable
me./100gm. = milliequivalents per 100 gm. of soil
AgTU = Silver Thio Urea Extraction
Acetate = Bases by Ammonium Acetate of pH 7, CEC by Sodium Acetate pH 8.2
pH and conductivity in suspension 1:2.5 v/v

Tabl 5.1.11 : Analytical Results (chemical analysis, results on air dry soil basis)
Trial Site Composite Samples

	Depth cm.	Block number I	II	III	IV	V	VI	VII	x̄	s	Max. diff.
Lab. No. /85	20	11179	11181	11183	11185						
	50	11180	11182	11184	11186						
Fine earth %	20	100	100	100	100				100	0.00	0.00
	50	100	100	100	100				100	0.00	0.00
Vol.weight gm./cc/	20	1.05	1.05	1.03	1.04				1.04	0.01	0.02
	50	1.01	0.97	1.02	1.03				1.01	0.03	0.06
105 deg.C / air dry	20	0.97	0.97	0.94	0.97				0.96	0.01	0.03
	50	0.97	0.97	0.96	0.97				0.97	0.00	0.01
pH H2O 1/1	20	5.5	5.0	5.6	5.4				5.38	0.26	0.60
	50	5.2	4.7	5.2	5.2				5.08	0.25	0.50
pH H2O 1/2.5	20	7.1	6.3	6.8	5.6				6.45	0.66	1.50
	50	7.0	6.2	6.5	6.4				6.53	0.34	0.80
pH N KCl 1/2.5	20	5.1	4.3	4.7	4.2				4.58	0.41	0.90
	50	4.8	4.9	4.5	4.8				4.75	0.17	0.40
C org. %	20	1.74	1.27	1.48	1.40				1.47	0.20	0.47
N tot. %	20	0.23	0.17	0.22	0.21				0.21	0.03	0.06
C/N	20	8	7	7	7				7.11	0.48	0.90
Mod.Olsen Abs. 260nm	20	187	163	112	136				149.50	32.54	75.00
(1/1000)	50	110	121	113	75				104.75	20.37	46.00
SO4 soluble ppm.	20										
	50										
P Meh.1/5 ppm.	20	10	25	18	16				17.25	6.18	15.00
	50	30	15	15	16				19.00	7.35	15.00
P Olsen ppm.	20	9									
	50	12									
P mod.Olsen ppm.	20	2.50	2.20	1.70	1.80				2.05	0.37	0.80
	50	4.60	3.10	2.20	2.20				3.03	1.13	2.40
P Citric ac. ppm.	20	14									
	50	28									
ECEC AgTU me./100gm.	20	9.8	7.9								
Bases %	20	92	75								
Al%	20	1.2	2.0								
Hp BaCl2 me./100gm.	20	0.10	0.40		0.30				0.20	0.18	0.40
	50	0.30	0.50	0.20	0.30				0.33	0.13	0.30
H & Al KCl me./100gm	20	0.16	0.40		0.20				0.19	0.16	0.40
	50	0.52	1.08	0.28	0.36				0.56	0.36	0.80
Al 3- KCl me./100gm.	20	0.12	0.16		0.12				0.10	0.07	0.16
	50	0.24	0.68	0.08	0.16				0.29	0.27	0.60
Al 3- AgTU me./100gm	20										
Sat.Ext. % H2O	20	not applicable									
	50	not applicable									
Sat.Ext. El.Cond.	20	not applicable									
	50	not applicable									
Sat.Ext. pH	20	not applicable									
	50	not applicable									

Tabl 5.1.11 : Analytical Results (chemical analysis, results on air dry soil basis)
Trial Site Composite Samples

No.		Depth cm.	I	II	III	IV	V	VI	VII	x	s	Max. diff.
1	Lab. No. /85	20	11179	11181	11183	11185						
2		50	11180	11182	11184	11186						
3												
55												
56	Na Meh.1/5 me./100gm	20	0.16	0.16	0.16	0.14				0.16	0.01	0.02
57		50	0.13	0.16	0.14	0.10				0.13	0.03	0.06
58	Na Ag-TU me./100gm.	20	0.07	0.07								
59												
60	K Meh.1/5 me./100gm.	20	0.69	0.65	0.88	1.04				0.82	0.18	0.39
61		50	0.54	0.50	0.46	0.86				0.59	0.18	0.40
62	K mod.Ol. me./100gm.	20	0.81	0.45	0.81	0.94				0.75	0.21	0.49
63		50	0.35	0.23	0.51	0.39				0.37	0.12	0.28
64	K Ag-TU me./100gm.	20	1.04	0.58								
65												
66	Mg Meh.1/5 me./100gm	20	1.80	2.70	3.80	2.10				2.60	0.88	2.00
67		50	2.40	2.40	3.20	1.90				2.48	0.54	1.30
68	Mg mod.Ol. me./100gm	20	2.20	1.82	2.98	2.26				2.32	0.48	1.16
69		50	1.53	1.19	2.17	2.04				1.73	0.46	0.98
70	Mg Ag-TU me./100gm.	20	2.95	2.25								
71												
72	Ca Meh.1/5 me./100gm	20	2.80	1.60	4.00	2.00				2.60	1.06	2.40
73		50	1.60	0.40	2.00	0.80				1.20	0.73	1.60
74	Ca mod.Ol. me./100gm	20	5.00	4.00	6.00	5.00				5.00	0.82	2.00
75		50	4.00	2.00	5.00	5.00				4.00	1.41	3.00
76	Ca Ag-TU me./100gm.	20	5.00	3.00								
77												
78	Mn Meh.1/5 me./100gm	20	0.62	0.98	0.96	1.08				0.91	0.20	0.46
79		50	0.84	0.96	0.80	1.28				0.97	0.22	0.48
80	Mn mod.Ol. me./100gm	20	0.29	0.47	0.38	0.43				0.39	0.08	0.19
81		50	0.27	0.36	0.39	0.43				0.36	0.07	0.16
82	Mn Ag-TU me./100gm.	20	1.18	0.55								
83												
84	Zn HCl ppm.	20	2.00									
85		50	1.50									
86	Zn mod. Ol. ppm.	20	1.00	2.00	2.00	2.00				1.75	0.50	1.00
87		50	3.00	1.00	1.00	2.00				1.75	0.96	2.00
88												
89	Cu HCl ppm.	20	1.20									
90		50	1.50									
91	Cu mod. Ol. ppm.	20	6.00	7.50	7.70	7.60				7.20	0.80	1.70
92		50	6.00	5.40	6.70	6.20				6.08	0.54	1.30
93												
94	Fe HCl ppm.	20	8.0									
95		50	7.5									
96	Fe mod. Ol. ppm.	20	10	15	10	9				11.00	2.71	6.00
97		50	9	10	9	11				9.75	0.96	2.00
98												
99	Fe Oxalate %	20	0.50									
100		50	0.30									
101	Al Oxalate %	20	1.10									
102		50	0.95									

NA = not applicable
me./100gm. = milliequivalents per 100 gm. of soil
Meh. = Mehlich Analysis
mod. Ol. = Modified Olsen Extraction
AgTU = Silver Thio Urea Extraction

Table 5.1.12 : Analytical Results (chemical analysis, results on air dry soil basis)
Farmers' Fields Composite Samples

		Depth cm.	Farmers' fields (code) A	B	C	D	E	F	G	H	Trial site average	$\bar{x}$	s	Max. diff.
1	Lab. No. /85	20	11187	11188	11189	11190	11191	11192	11193	11194				
2	Fine earth %	20	100	100	100	100	100	100	100	100	100	100.00	0.00	0.00
3	Vol.weight gm./cc.	20	1.02	1	1.03	0.97	0.95	0.98	0.96		1.04	0.99	0.03	0.09
4	105 deg. C / air dry	20	0.97	0.97	0.97	0.97	1	1.0	0.97		0.96	0.97	0.01	0.01
5	-----													
6	pH H20 1/1	20	5.9	5.9	5.3	4.8	5.8	5.3	4.5	4.9	5.38	5.31	0.50	1.40
7	pH H20 1/2.5	20	6.7	6.8	7.1	6.2	7.3	6.9	7	6.4	6.45	6.76	0.36	1.10
8	pH N KCl 1/2.5	20	5.1	4.8	4.6	4.9	5.1	4.7	4.7	4.4	4.58	4.76	0.24	0.70
9	-----													
10	C org. %	20	1.32	1.25	1.5	1.19	1.78	1.76	1.19	1.19	1.47	1.41	0.24	0.59
11	N tot. %	20	0.21	0.22	0.19	0.19	0.18	0.17	0.12	0.15	0.21	0.18	0.03	0.10
12	C/N	20	6	6	8	6	10	10	10	8	7	7.93	1.76	4.67
13	-----													
14	Mod.Olsen Abs.260nm.	20	263	142	66	69	73	110	52	75	150	111.06	66.67	211.00
15	-----													
16	P Meh. 1/5 ppm.	20	22.00	19.00	16.00	52.00	27.00	19.00	16.00	14.00	17.25	22.47	11.72	38.00
17	P mod.Olsen ppm.	20	4.00	2.50	3.00	3.80	5.10	5.20	3.20	4.60	2.05	3.72	1.12	3.15
18	-----													
19	Na Meh.1/5 me./100gm.	20	0.10	0.10	0.10	0.14	0.14	0.10	0.16	0.10	0.16	0.12	0.03	0.06
20	-----													
21	K Meh.1/5 me./100gm.	20	0.74	1.12	0.82	0.54	0.74	0.82	0.78	0.56	0.82	0.77	0.17	0.58
22	K mod.Ol. me./100gm.	20	0.26	0.61	0.64	0.38	0.56	0.69	0.67	0.41	0.75	0.55	0.17	0.49
23	-----													
24	Mg Meh.1/5 me./100gm.	20	2.40	1.90	2.00	1.50	1.90	1.80	1.30	1.40	2.60	1.87	0.44	1.30
25	Mg mod.Ol. me./100gm.	20	Trace	Trace	2.30	1.50	2.20	2.80	1.70	1.30	2.32	1.57	1.00	2.80
26	-----													
27	Ca Meh.1/5 me./100gm.	20	4.00	2.40	2.00	Trace	3.60	1.60	0.80	Trace	2.60	1.89	1.44	4.00
28	Ca mod.Ol. me./100gm.	20	7.00	6.00	5.00	3.00	7.00	4.00	3.00	2.00	5.00	4.67	1.80	5.00
29	-----													
30	Mn Meh.1/5 me./100gm.	20	0.96	0.75	0.86	0.62	0.73	0.77	0.58	0.58	0.91	0.75	0.14	0.38
31	Mn mod.Ol. me./100gm.	20	0.23	0.28	0.30	0.27	0.16	0.21	0.26	0.27	0.39	0.26	0.06	0.23
32	-----													
33	Zn mod.Ol. ppm.	20	2.00	1.00	2.10	1.50	1.90	1.20	1.80	2.40	1.75	1.74	0.44	1.40
34	-----													
35	Cu mod.Ol. ppm.	20	6.00	7.50	6.60	5.80	5.40	7.10	6.70	7.80	7.20	6.68	0.81	2.40
36	-----													
37	Fe mod.Ol. ppm.	20	8	10	30	28	24	33	30	46	11.00	24.44	12.61	38.00
38	-----													
39	Hp BaCl2 me./100gm.	20			0.30	0.40		0.40	0.20	0.30	0.20	0.30	0.09	0.20
40	H & Al KCl me./100gm.	20			0.24	0.72		0.44	0.48	1.12	0.20	0.53	0.34	0.92
41	Al KCl me./100gm.	20			0.04	0.72		0.12	0.24	0.04	0.10	0.21	0.26	0.68

NA = not applicable
me./100gm. = milliequivalents per 100 gm. of soil
ppm. = parts per million
Meh. = Mehlich Analysis
Mod. Ol. = Modified Olsen Extraction

3.3 Evaluation of Soil Data

3.3.1 Literature References and Soil Correlation

From 1972 onwards, the Kenya Soil Survey has carried out many soil surveys and site evaluations and, in addition, some surveys were conducted by other agencies.

A complete list of soil survey reports is given in Chapter II.2 of the main report. Those reports that refer to the area in which the trial site is situated are listed below.

Literature references:	
E1	W.G. Sombroek, H.M.H. Braun and B.J.A. van der Pouw (1982). Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980, scale 1:1,000,000.
LBDA	W. Andriesse, and B.J.A. van der Pouw (1985). Reconnaissance Soil Map of the Lake Basin Development Authority Area, Western Kenya, scale 1:250,000.
R8	D.O. Michieka, and J.R. Rachilo (in prep.). Soils of the Busia Area (with map, scale 1:100,000).
P18	J.P.Mbuvi (1975). A Preliminary Report on the Suitability of the Area of Busia District for Sugar Cane Development.

In order to correlate existing information with findings at the trial site, the map units and classification units in the above-mentioned reports have been grouped in Table 5.1.13. Moreover, the FURP soil map unit (Map 5.0.4) and the classification of the soil of the profile at the trial plot are given.

Table 5.1.13: Soil Correlation with Respect to the Bukiri-Buburi Trial Site

Reference	Map unit	Soil Classification
E1	Ul6	Association of dystric Nitisols and ironstone soils
LBDA	UlI1	chromic Acrisols, partly petroferric phase
R8	UIr	chromic Acrisols, partly petroferric phase
FURP	UlI1	chromic and ferralo-chromic Acrisols, partly petroferric phase
Trial plot profile		ferralo-chromic ACRISOL

El mentions unit Ul 6 for both sites 4.2 and 5.1.
LBDA and R8, however, recognize relatively higher levels of soil depletion at site 5.1 (chromic Acrisols vs. eutric Nitisols and chromic Luvisols).

The soils of the trial plot have CEC well below 24 me/100 g. clay and should have the "ferralo-" prefix, according to the Kenya Concept (Siderius and van der Pouw, 1980).

3.3.2 Representativeness

For two reasons, statements about the representativeness of the soils of the trial site should be made with care.
Firstly, soil classification units are mainly based on properties of a relatively permanent nature, i.e. those of the sub-surface horizons and not those of the topsoil.

Secondly, the generally high variability of topsoil properties within short distances is not reflected in relatively small-scale reconnaissance soil maps (1:100,000 to 1:1,000,000).

In this report, soils of a map unit considered to be within the "area of representativeness" must meet the following requirements:

(a) the soil-related land factors must have the same or similar ratings;
(b) soil classification must be the same or similar.

The extent to which all the FURP trial sites are representative of the soils of Busia District is shown in Map 5.0.5: "Groupings of Soil Mapping Units Represented by Trial Sites in Busia District". This map is discussed in Sub-Section 5.0.5.

Distinction is made between <u>high</u> representativeness - code A - and <u>moderate</u> representativeness - code B+ if soil conditions are slightly <u>more</u> favourable than at the trial site and code B- if soil conditions are slightly <u>less</u> favourable than at the trial site. Code C is applied for the remaining parts of the district, where <u>none</u> of the FURP trial sites are representative.

Within Busia District, the Bukiri-Buburi trial site has high and moderate representativeness (5.1.A and 5.1.A/B-) for an extensive area in the southern part of the District. It refers to soil map unit UlI1, in which the Bukiri-Buburi trial site is situated, and soil map association UlIA (see Map 5.0.4). The deep soils have Soil Representativeness Code 5.1.A, the moderately deep soils over petroplinthite are coded 5.1.B-.

The Bukiri-Buburi trial site is also representative for areas outside Busia District, in particular in the westernmost part of Kisumu District (soil map unit UlI1, Grouping 5.1.A), in many parts of Siaya District (soil map unit UlI1, Grouping 5.1.A and, for the very shallow to moderately deep soils of complexes UlIC and UlVC, Grouping 5.1.B-/C), and in the western parts of Kakamega District on deep to very deep soils (Grouping 5.1.B+).

3.3.3 Variability of Soil Properties within the Trial Site

The soils of the trial site are deep throughout the main plot and the farmers' fields.

Fertility parameters show the following ranges for pH-KCl and organic carbon content in the upper 20 cm of the soil:

pH-KCl: composite samples Block II and IV: 4.2-4.3, but Block III 4.7 and Block I 5.1. The profile had a pH-KCl of 4.8. The farmers' fields were in the range between 4.4 (field H) and 5.1 (field A).

organic carbon content: composite samples Block II, III and IV: 1.3-1.5%, Block I: 1.7%. The profile only had 1.1% organic carbon in the topsoil.

The farmers' fields are within the range between 1.2% (fields D, G, H) and 1.8% (fields E and F). Composite Block I is on the "rich" side, whereas the farmer's field H is on the "poor" side.

3.3.4 Fertility Status of the Soil

The criteria applied for the interpretation of the analytical data are outlined in Chapter IV.2 of the main report.

3.3.4.1 Soil Profile

The analytical data of the soil samples taken from the profile pit, situated on the side of the site and close to Blocks I and IV (see Figure 2.3.7) are presented in Table 5.1.10 and are interpreted in the following paragraphs.

The rooting depth of the soil is limited neither by physical nor chemical obstacles in the subsoil. The capacity for plant available water in the upper 100 cm of the profile may roughly be estimated from the pF determination carried out on the Ap and Bt2 horizons and hardly attains 80 mm. The available moisture capacity may thus be rated as low to moderate, which differs from the profile description (texture and structure) and the field estimate that available moisture capacity is high. Although the reported laboratory values for pF 0 and pF 2 seem to be rather low, the overall small portion of medium sized pores is quite typical for these soils.

All horizons down to 60 cm depth have a moderate CEC (pH 8.2) of 14 to 20 me./100 gm. and only the underlying Bt3 horizon shows a low CEC of 11 me./100 gm. The base saturation is moderate (42-48%) and in accordance with the slightly to moderately acid soil reaction.

The Ap horizon is very rich in exchangeable K (1.5 me./100 gm.) while the underlying soil shows only a low K saturation of the exchange complex. In the entire profile Mg shows very high values (>2.5 me./100 gm. by Ammonium Acetate). Ca by Ammonium Acetate is in the low range (2.0 - 3.9 me. /100 gm.), whereas exchangeable Ca by AgTU (Silver Thiourea) is moderate (5.8 -

6.8 me./100 gm.). This difference is due to laboratory performance. The Ca/Mg ratio is narrow. The K/Mg ratio is quite variable, but never close to critical values.

The soil reaction of the upper horizons is in the moderately acid range (pH KCl 4.7 - 4.8), which is favourable for the growth of most plants. Consequently only very low amounts of Al are exchangeable (<0.32 me./100 gm. and <3.4 % of exchangeable bases plus Al in topsoil) which may not affect even sensitive plants.

The organic matter content of the topsoil (profile) is in the medium range; the underlying soil is only slightly humic. Although the topsoil of the trial site itself (see Table 5.1.11, composite samples) has a comparatively high humus content on the whole, it can be described as moderately humic. The N content of the entire solum is moderate, which results in very narrow C/N ratios in the subsoil.

3.3.4.2 Soil Fertility Assessment of Composite Samples

The analytical results for the composite samples from the trial site (depths 0-20 cm. and 20-50 cm.) are presented in Table 5.1.11. Those for the farmers' fields (depth 0-20 cm. only) are shown in Table 5.1.12.

The composite samples were analyzed to assess the chemical fertility status of the soil, with special emphasis on the availability of the important nutrient elements to the plants. The "available nutrients" were estimated by means of two complementary methods, the "Mehlich" diluted double-acid method (NAL routine) and a "modified Olsen" bicarbonate + EDTA extraction.

The interpretation of the analytical data presented is in so far tentative for both methods, as the validity of the applied ratings (ranges for Low, Medium, High) has not yet been verified by field trials in the various regions of Kenya.

The trial site soil samples mostly investigated are within the moderately acid range (pH KCl 4.5-5) with only the extreme values in the topsoil of Blocks I and IV just outside these boundaries (5.1 and 4.2 respectively).

The total N content of these moderately humic soils is moderate to high (around 0.2 %). The moderate to narrow C/N ratios and other prevailing soil properties indicate that N availability is probably low to moderate, varying mainly with humus content, C/N ratio, and soil pH. The UV-absorption of the modified Olsen extract on average indicates a low to moderate N supplying capacity of the soil as well, but for farmers' fields C, D, E, G, and H only a low rate for N release from the soil may be expected.

While the "available" P, as determined by the Mehlich analysis, is mainly in the moderate range (15-30 ppm), the P determined by the modified Olsen method is in the low range (<5.2 ppm) for all samples.

The "available" quantities of K are generally high in the top-soil and moderate in the underlying 20 - 50 cm with considerable variation from place to place.

The "available" amounts of Mg are always in the high range, whereas the Ca levels are generally low to moderate (around 1.8 me./100 gm. Ca [Mehlich] and 4.7 me./100 gm. Ca [mod.Olsen]). Similar to the NH_4-O-Ac exchangeable bases the cations are still adequately balanced with respect to plant nutrition, although Ca is low in comparison to K in the topsoil and the Ca/Mg ratio is particularly narrow.

"Available" Mn, according to both the Mehlich and the modified Olsen analyses, is in the moderate range (0.5-1.2 and 0.2-0.5 me./100 gm. respectively).

According to the modified Olsen method, Zn and Fe are very low and often close or below the, however tentative, deficiency thresholds. Cu seems to be available in moderate amounts. This is confirmed by the ratings for the HCl extractable micro-nutrients determined in Block I of the trial site.

The oxalate extraction for amorphous oxides and hydroxides yielded low amounts of Fe and moderate quantities of Al.

The evaluation of the Mehlich Analysis data according to NAL standards is given in Table 5.1.14.

Table 5.1.14: Evaluation of the Mehlich Analysis Data According to NAL Standards

Parameter	Trial Site	Farmers' Fields
Soil reaction (pH)	Moderately acid	Moderately acid
Acidity (Hp)	Low	Low
Available nutrients		
Sodium	Adequate	Adequate
Potassium	Adequate	Adequate
Calcium	Low to moderate	Low to moderate
Magnesium	Adequate	Adequate
Manganese	Adequate	Adequate
Phosphorus	Low	Low
Total Nitrogen	Moderate	Moderate
Organic Carbon	Moderate	Moderate
C / N Ratio	Favourable	Favourable
Ca / Mg Ratio	Unfavourable	Unfavourable
Ca / K Ratio	Favourable	Favourable
K / Mg Ratio	Favourable	Favourable

Remarks on Trial Site:
Soil reaction is favourable. Positive yield responses to manure, N, P and lime application are expected. Response to K application is unlikely.

Remarks on Farmers' fields:
Same as Trial Site but with unfavourable soil reaction on farms D, G, and F.

3.4 Sampling Programme for Laboratory Analyses during Phase II

3.4.1 Soil Samples

Soil samples will be collected once a year at the beginning of the long rains in February just after ploughing and before the fields are planted. The samples will be taken individually from two depths (0 - 20 cm and 20 - 50 cm) for each replication of the selected fertilizer treatments, and only from the plots in module 2 with maize/cotton mixed cropping.

The treatments to be sampled are:

Trial I:	N0:P0	N75:P0	N0:P75	N75:P75
Trial II:	0	FYM	FYM+NP	NP+K
	lime	FYM+lime	FYM+NP+lime	NP+lime

Farmers' fields: Fields A, B and G are suggested

3.4.2. Plant Samples

Harvest samples from the maize/cotton mixed crop include the individual samples of grain and straw for maize and cotton respectively. Maize samples are collected following harvesting after the first season. Cotton will continue to grow for another season. Thus cotton samples are taken at the time of the cotton harvest after the second season. Samples will be collected separately from each replication of the following treatments:

Trial I:	N0:P0	N75:P0	N0:P75	N75:P75
Trial II:	0	FYM	FYM+NP	NP+K
	lime	FYM+lime	FYM+NP+lime	NP+lime

Farmers' fields: Harvest samples will only be collected from those farmers' fields where soil samples were taken. Individual samples of grain and straw are only required from the maize crop.

3.4.3 Other Samples

From every batch of applied FYM three representative samples will be taken.

4. Conclusions from the Analyses of Climate and Soils

4.1 Moisture Availability

The amount of rainfall, which is surpassed in 20 out of 30 years (i.e. 66% probability), constitutes the basis for estimating moisture availability during the growing periods. Other parameters of the water balance such as moisture storage capacity, run-off, and deep percolation also have to be considered in order to obtain a comprehensive picture of the moisture availability.

For example, the water requirements and the water availability for Maize H 512, first rains, at the Bukiri-Buburi trial site, can be interpreted as follows:
Figure 5.1.6a shows that the maximum water requirements (ETm) of the maize crop are almost in line with the rainfall amounts at the 66% probability level. The ratio of reliable rainfall (i.e. 66% probability) to maximum evapotranspiration (ETm) for maize H 512 is >0.8 for the total length of the growing period of first rains.

Run-off is moderate to low. Although the trial site is located on sloping land (4-5%) and high rainfall intensities occur in April, the water surplus can to a large extent be stored, as the storage capacity is high and the crop also provides adequate ground-cover.

Deep percolation and lateral sub-surface flow could be estimated, but can be omitted, since they are generally very low.

Run-on is likely to occur, as the trial plot is located downslope and very close to the convex-shaped main road. It is estimated that the amounts of run-on offset the losses of run-off.

For the Bukiri-Buburi trial site, the moisture storage capacity is high (i.e. 120 - 160 mm.). Therefore the surplus of water, which is likely to occur in April can to a large extent be stored and can prolong the agro-humid period for 10-20 days during the first rains.

Summarizing the evaluation of the climatic factors, the yield potential from the climatic point of view can, for the maize crop in first rains, be rated good on a "20 out of 30 year" basis.

The crop performance is less favourable in the second rains, as can be seen in Figure 5.1.6b for Katumani maize.

4.2 Nutrient Availability in Relation to Possible Fertilizer Requirement

In all samples analyzed, the N supplying capacity appeared to be moderate. P availability was estimated to be low to moderate. K, Mg and Ca were extracted in appreciable amounts, but K is only moderate in the subsoils.

A shortage of Fe and Zn is suspected on the basis of two different analyses; but this should be verified by trials, because the soil pH supports solubility of these elements. Mn and Cu were extracted in moderate amounts.

Fertilizer applications should first of all consider the most relevant plant nutrients which include N and P, and perhaps also the micronutrients Fe and Zn.

For sustained high yields regular N fertilization will be necessary, either from FYM or green manure or in mineral form. When mineral N is applied regularly, it should be complemented with mulch and other organic amendments in order to protect the topsoil and to ameliorate its humus content. The humus plays an essential role in stabilizing the present weak structure of the topsoil and in preventing applied nutrients from leaching too quickly.

N applications in whatever form should be complemented by P to avoid excessive depletion of the soil. The trials will have to show whether any reasonable response to N can be obtained without P. P may be applied in the form of TSP or finely ground soft rock phosphate (e.g. Hyperphos or from Minjingu). TSP will be more efficient in the year of application. P fixation by the soil should be very low in the Bukiri-Buburi site. The efficiency of P application may be enhanced by the addition of small amounts of fresh FYM to stimulate soil biological activity.

K applications are at the present stage not needed and response to K may not be obtained at least in the first years. The analytical data provide no information on the reserves of K beyond the exchangeable pool. Permanent high applications of mineral N and P might, in the long run, need to be complemented by K. FYM is normally also a good source of K.

If K fertilizer is to be applied, K_2SO_4 should generally be preferred to KCl (both contain 50% K_2O), the SO_4-ion enhances P availability. The form in which K is applied should also take into account crop requirements (e.g. KCl to cabbage, but not to Irish potatoes).

Under the present soil conditions liming is not needed. In the long term, the acidifying effects of the applied mineral or organic fertilizers should be counterbalanced, i.e. approximately 1.8 Kg. of $CaCO_3$ per Kg. of applied N; in the case of CAN, which contains Ca, only about 0.8 Kg.$CaCO_3$ per Kg.N, i.e. 0.2 Kg. lime per Kg. of CAN will be needed. TSP does not contribute substantially to the Ca budget of the soil; soft rock phosphates (30% P_2O_5) contain about 2.7 Kg. $CaCO_3$ equivalents per Kg. of P_2O_5.

If lime is applied in larger amounts, the solubility of P will be reduced and availability of some micro-nutrients may become critical. This applies mainly for Zn, but also Fe, Mn, and Cu availability and plant uptake should be monitored, at least for demanding crops.

4.3 Other Relevant Land Qualities

In addition to an assessment of moisture and nutrient availability, the following land qualities are relevant in the context of fertilizer use:

a) Oxygen availability.
There is no reason to expect any serious inhibition as to exchange of oxygen and carbon dioxide in the soils at the trial site.

b) Rootability.
The soils provide a suitable environment for root development and tuber expansion.

c) Resistance to erosion.
The area around the Bukiri-Buburi trial site has a moderate resistance to erosion. Upon sustained high rainfall in the early growth stages of annual crops, when vegetation cover is scarce, erosion may play an important part in these Acrisols.

d) Ease of cultivation and scope for agricultural implements.
Any type of land preparation is possible without major setbacks on the deep Acrisols of the Bukiri-Buburi trial site.

e) Pests.
Special mention is given to the high infestation of termites in the area which are reported even to feed on living plant tissue, notably on roots. Therefore, stover which is left on the soil after harvesting disintegrates in no time.

5. Trial Design and Execution Plan, Bukiri-Buburi

(Full details of the methodology for carrying out the trials are shown in Section V of the main report.)

Selection of crops for each of the 3 modules.

Site 5.1 Bukiri-Buburi	RAINY SEASONS 1st, Long, March	2nd, Short, Sept
S1 Standard maize	Hybrid 512	Katumani C.B.
S2 Maize & Cotton	Hybrid 512+BBA 75	Cotton BBA 75
S3 Sorghum, ratooned	Sorghum Serena	Ratoon Sorghum

The 1st sequence is thus continuous, pure maize, 2 times/year.
The 2nd is intercropped maize and cotton in 1st rains, with cotton being left after the maize as the sole crop in 2nd rains.
The 3rd is sorghum planted in 1st rains, ratooned in 2nd rains.

Each module contains 2 experiments, namely Experiment 1 and Experiment 2.

Experiment 1 is a 4N x 4P factorial, with 2 replications in each module.
Experiment 2 is a 2NP x 2K x 2L x 2 FYM factorial, also with 2 replications in each module.
Each module thus consists of 64 plots, and the total for the 3 modules is 192 plots.

FYM will be applied only to the crops during the first rains, wheras mineral fertilizers will be used in both seasons. Where maize and beans are intercropped, the fertilizer will go on the maize. The beans will not receive any fertilizer directly, but will "scavenge" from the maize and from residual fertilizer left in the relevant plots after the first season.

Contents of Chapter 5.2:

Detailed Description of Trial Site Alupe

List of Tables[1])

1) See Footnote next page.

List of Figures[1])

1) Numbering mode of Tables and Figures:
First Number: District Number
Second Number: Trial Site Number
Third Number: Number of Table or Figure within Chapter.

1. Geographical and Additional Technical Information

1.1 Final Position of the Trial Site

The position of the site at Alupe A.R.S.S. is shown in Figure 5.2.1, extracted from Map No. 101/1 - Busia. Its UTM grid coordinates are E 24.8 and N 54.5. The elevation is 1170 m. Further details on the final position are shown in Figure 5.2.2 and the sketch map of the trial plot is to be found in Figure 5.2.3

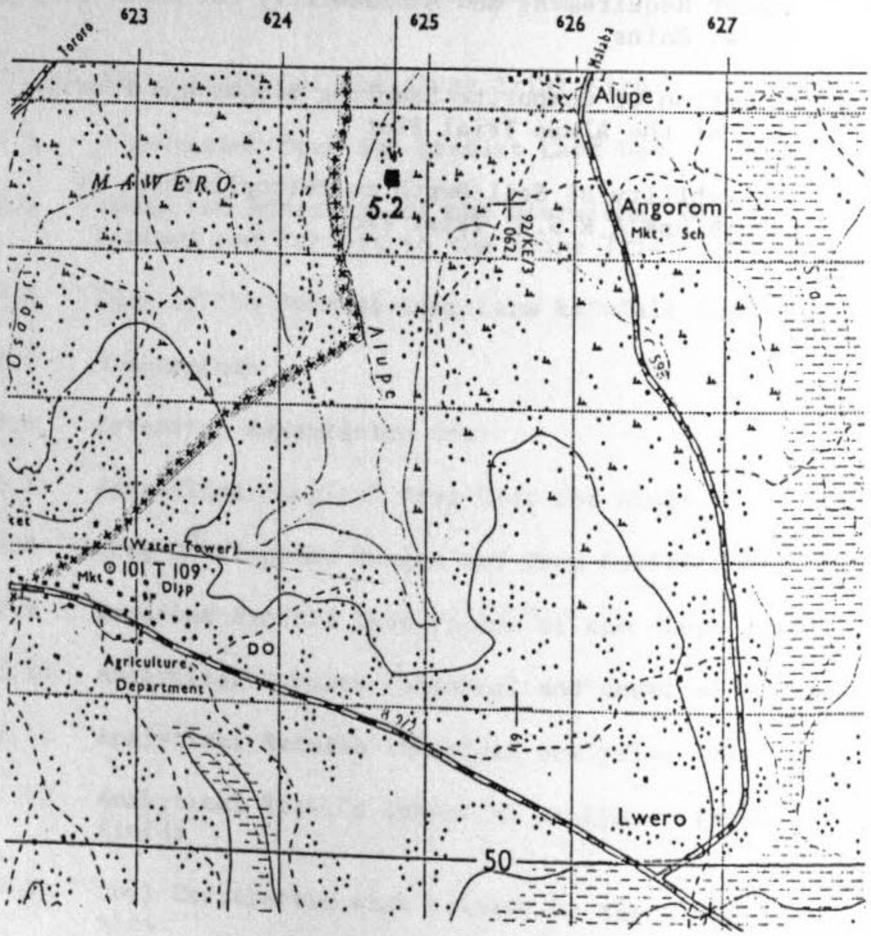


Figure 5.2.1: Demarcation of the Alupe A.R.S.S. Trial Site on the 1:50,000 Topographic Map

1.2 Sketch of the Trial Site

The location of and the access route to the Alupe A.R.S.S. site are shown in Figures 5.2.2 and the map of the trial plot in Figure 5.2.3

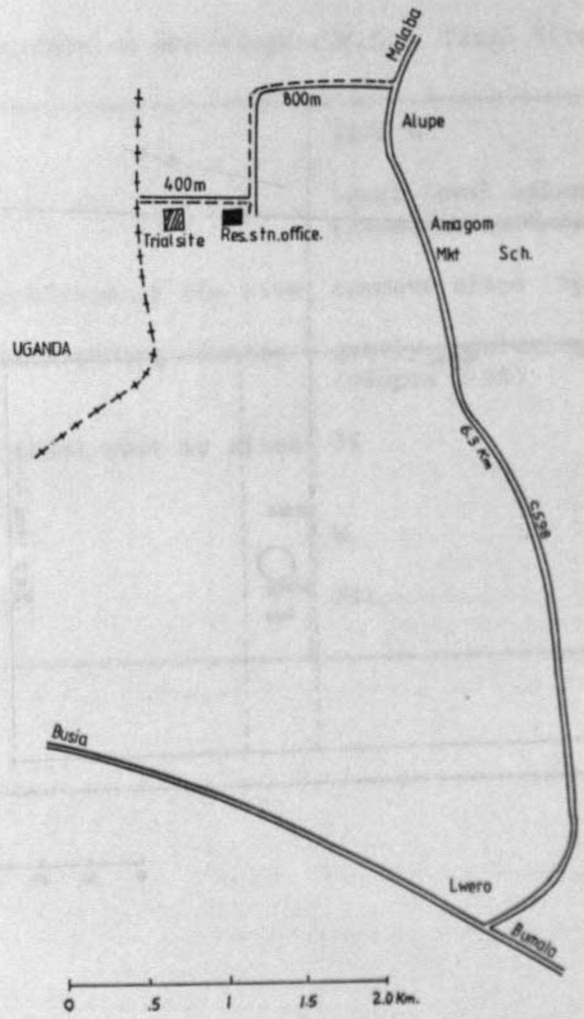


Figure 5.2.2: Access Map of the Trial Site, Alupe A.R.S.S.

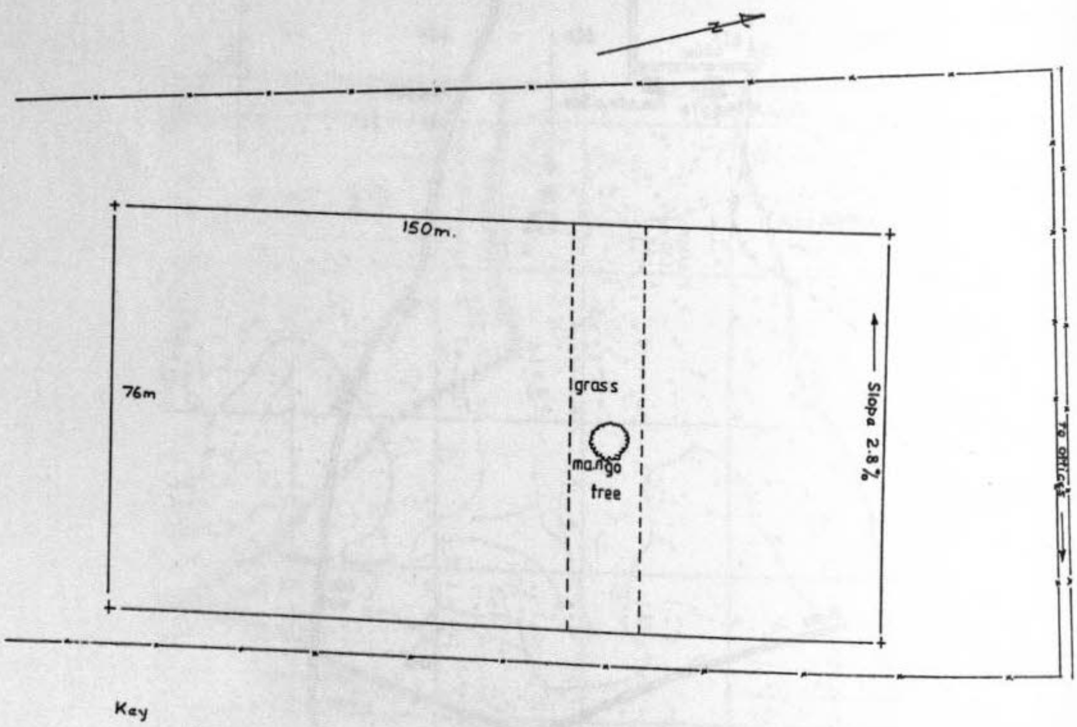


Figure 5.2.3 : Map of the Trial Plot, Alupe A.R.S.S.

As trial site 5.2 is a cooperation site, no farmers' fields were selected. Consequently, Figure 5.2.4 and Table 5.2.3 have been omitted.

1.3 Physiography

Information on the physiography of the trial site and its surroundings is summarized in Table 5.2.1 below.

Table 5.2.1: Physiography of the Alupe A.R.S.S. Trial Site

Elevation	1170 m
Landform	lower-level uplands/ planation surface
Physiographic position of the site	concave slope (upper part)
Topography of surrounding country	gently undulating (slopes 2-5%)
Slope on which trial plot is sited	3%
Aspect	W
Microtopography	Nil

1.4 Vegetation, Past and Present Land Use

Information on vegetation and on past and present land use is summarized in Table 5.2.2 below:

Table 5.2.2: Vegetation, Past and Present Land Use of the Alupe A.R.S.S. Trial Site

Vegetation	Cultivated Albizia-Bridelia with scattered Chlorophora
Cropping system	
(a) cleared since:	
(b) crops grown:	
(c) fallow periods:	
(d) present land use:	
Inputs	
(a) mineral fertilizers:	
(b) organic manure:	
(c) means of land preparation:	
(d) means of weeding:	
(e) frequency of weeding:	
(f) other capital inputs:	
(g) level of know-how:	
Produce	
(a) maize	
(b) beans	
(c) sorghum	
Livestock	
Remarks	

Period of site selection: December 1985.

2. Climate

2.1 Prevailing Climatic Conditions

2.1.1 Agro-Climatic Classification of the Area Represented by the Alupe A.R.S.S. Trial Site

The following brief climatic description refers to the existing information:

ACZ : I3 (H.M.H. BRAUN, 1982)[1])

AEZ : LM 1, l - m i (R. JÄTZOLD, 1983)[2])

Next long-term rainfall stations: 08934105, Busia F.T.C. and 08934161, Alupe Cotton Research Station.

Agro-Climatic Zone (ACZ):

Moisture availability Zone I (r/Eo): annual average precipitation is >80% of the potential evaporation (Eo).

Temperature Zone 3: mean annual temperature is 20-22°C

Agro-Ecological Zone (AEZ):

LM 1 = Sugar Cane Zone

LM = Lower Midland Zone: mean annual temperature 21-24°C, mean minimum >14°C

1 = humid; annual average precipitation is >80% of the potential evaporation (Eo)

Sub-zone according to growing periods for annual crops (calculated for a "normal" crop in 60% probability)

l - m i = a long cropping season, followed by a medium cropping season and intermediate rains

---

1) According to H.M.H. BRAUN in: W.G. SOMBOREK et al. (1982): Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, scale 1:1,000,000.-Rep.El, Nairobi

2) According to R. JÄTZOLD, and H. SCHMIDT, eds. (1982): Farm Management Handbook of Kenya, Vol.II/A WEST KENYA - Nairobi and Trier.

Formula	Cropping season	Lengths of growing period (exceeded in 6 out of 10 years)
l	long	195 - 214 days
m	medium	135 - 154 days

- = no distinct arid period between growing periods

i = intermediate rains (at least 5 decades more than 0.2 Eo) which means moisture conditions are above wilting point for most crops

2.1.2 Relevant Meteorological Data for Alupe A.R.S.S. Trial Site

In this section a breakdown is given of the following climatic parameters: rainfall, potential evaporation and temperature.

Rainfall:

Rainfall data are obtained from the nearest long-term rainfall station: 08934105 Busia F.T.C. (elevation: 1180 m), 3 km S of the Alupe A.R.S.S. trial site (elevation: 1170 m) and recording station: 08934161 Alupe Cotton Research Sub-Station, 300 m E of the trial site. The data are listed in Table 5.2.4. At the trial site rainfall amounts are similar: in 20 out of 30 years Alupe A.R.S.S. gets 840 mm during the agro-humid period of first rains (see Map 5.0.1), and about 620 mm during second rains (see Map 5.0.2). The methods of rainfall-data analysis are described in Chapter IV.2.2 of the main report.

Temperature and potential evaporation(Eo):

Potential evaporation (Eo) is calculated using the PENMAN formula, modified by MC CULLOCH (1965). The input parameters employed - temperature, windrun, sunshine hours and relative humidity - are obtained from Alupe A.R.S.S. Meteorological Station (elevation: 1180 m), 300 m E of the trial site.

Temperature and evaporation data for the Alupe A.R.S.S. site are given in Tables 5.2.5 and 5.2.6, and the rainfall pattern and potential evaporation are shown in Figure 5.2.5.

For more detailed information on the methodology of climatic description see Chapter IV.2.2 of the main report.

Table 5.2.4 : Data of the Nearest Long-Term Rainfall Station

Station No.: 08934105
Busia Farmer s Tr. Centre
Elevation: 1180 m

Total years for calculation: 22
First year included: 1961
Last year included: 1983

Average annual rainfall: 1748 mm

Rainfall surpassed in 20 out of 30 years (≈66% Probability):

1st rains: 850 mm
(beg. Feb. - mid Jul.)

2nd rains: 620 mm
(end Jul. - end Dec.)

Decades and Month	Arithmetic Mean (mm)	Average Number of Rainy Days with Rainfall >= 1 mm	Average Number of Rainy Days with Rainfall >= 5 mm	≈66% Probability of exceeding ...mm	Years analized
1 JAN	21.0	2.2	2.2	9.7	21
2	11.6	1.9	1.8	5.3	21
3	27.6	2.6	2.6	17.2	21
4 FEB	24.0	1.9	1.9	10.9	20
5	34.7	3.4	3.2	22.1	20
6	28.9	2.6	2.5	14.7	20
7 MAR	29.1	3.3	3.1	17.7	22
8	48.1	4.3	4.0	32.4	22
9	60.6	5.0	4.9	43.8	22
10 APR	79.3	5.8	5.6	58.6	22
11	88.4	6.8	6.6	68.0	22
12	81.0	5.8	5.7	61.4	22
13 MAY	99.7	6.6	6.6	83.0	21
14	88.7	6.4	6.4	72.5	21
15	68.4	6.2	6.0	52.8	21
16 JUN	47.9	4.5	4.5	33.6	22
17	43.4	4.3	4.2	24.2	22
18	31.7	3.9	3.7	21.7	22
19 JUL	26.8	2.9	2.7	18.4	21
20	20.2	2.7	2.7	12.2	21
21	35.6	3.5	3.4	21.1	21
22 AUG	40.1	3.7	3.7	27.4	20
23	52.6	4.1	4.0	38.9	20
24	53.6	4.5	4.4	42.0	20
25 SEP	55.6	5.0	4.9	42.8	21
26	43.6	4.8	4.5	35.8	21
27	50.9	5.1	5.0	36.3	21
28 OCT	43.1	4.7	4.6	31.9	22
29	64.2	5.7	5.6	50.8	22
30	69.0	6.6	6.5	50.8	22
31 NOV	68.3	5.7	5.6	47.6	21
32	48.3	4.1	4.1	31.5	21
33	66.4	4.7	4.7	47.0	21
34 DEC	34.4	2.8	2.7	15.8	20
35	27.3	2.8	2.8	16.2	20
36	33.5	2.7	2.6	23.0	20

Table 5.2.5: Temperature (°C)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.
Mean temp.	23.0	23.0	22.4	22.6	22.1	21.6
Mean max.temp.	30.0	30.4	30.0	28.7	27.9	27.4
Mean min.temp.	15.9	15.7	15.7	16.5	16.3	15.8
	JUL.	**AUG.**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**
Mean temp.	22.4	21.6	20.9	22.5	22.2	22.6
Mean max.temp.	27.2	27.7	27.0	29.1	28.4	29.3
Mean min.temp.	15.6	15.5	14.7	16.0	15.9	15.8

annual mean: 22.2 mean max.: 28.6 mean min.: 15.8

Table 5.2.6: Potential Evaporation (Eo) in mm per Decade:

	JAN.	FEB.	MAR.	APR.	MAY	JUN.
1st decade	57	57	55	48	44	43
2nd decade	57	57	55	48	44	43
3rd decade	63	46	60	48	49	43
Total:	177	160	170	144	137	129
	JUL.	**AUG.**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**
1st decade	41	45	47	53	49	54
2nd decade	41	45	47	53	49	54
3rd decade	45	50	47	58	49	59
Total:	127	140	141	164	147	167

average annual potential evaporation: 1803 mm.

For all the climatic data published in this Section, a data bank has been established by FURP on Personal Computers at the National Agricultural Laboratories in Nairobi.

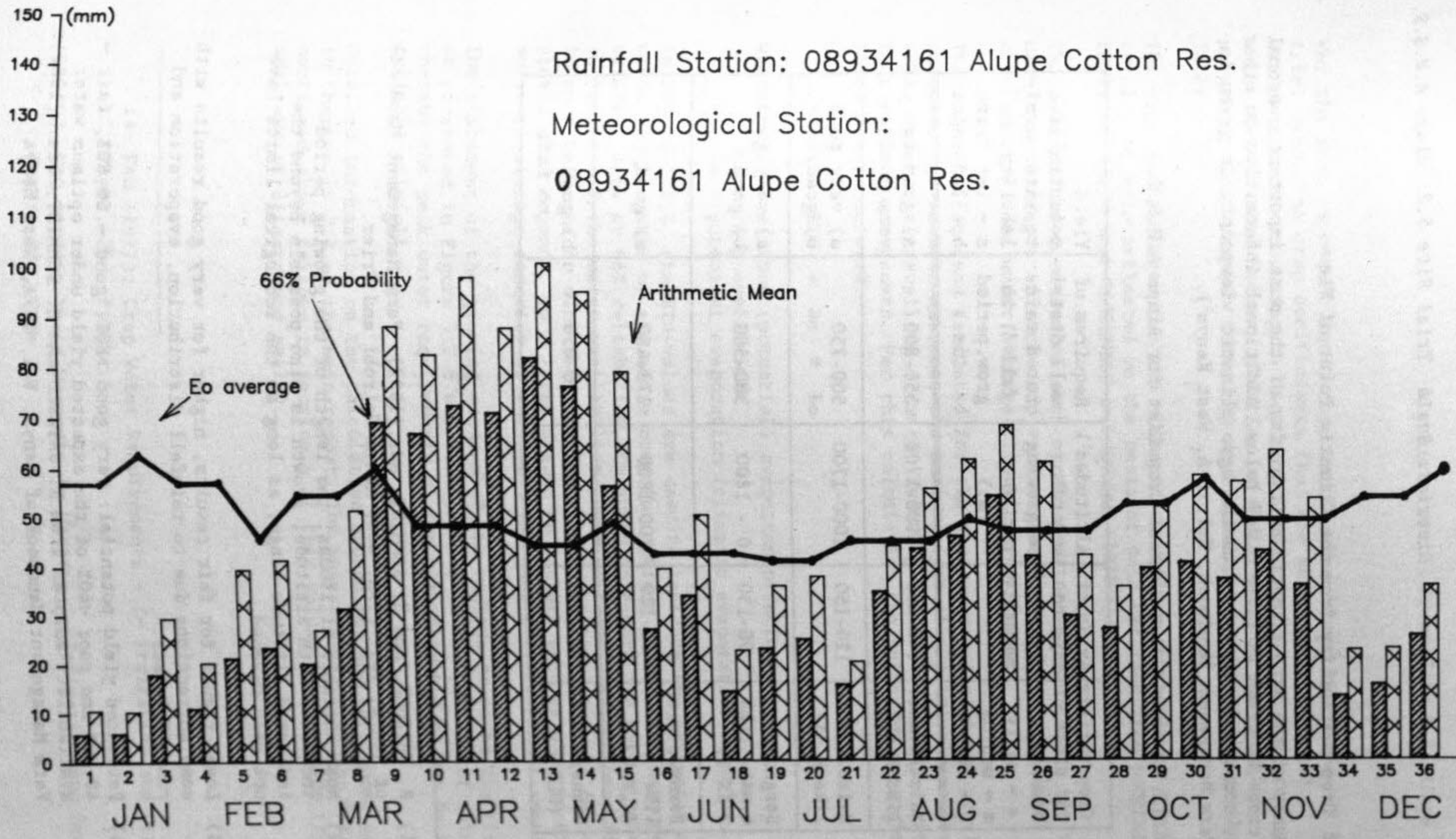


Figure 5.2.5: Rainfall and Potential Evaporation

2.1.3 Crop Suitability from the Climatic Point of View

A summary of the agro-climatic suitability of the most important seasonal food crops is given in Table 5.2.7 below. Additional information on other crops, considered suitable from the agro-climatic viewpoint, is given in the Farm Management Handbook, Vol.II A, West Kenya[1]).

Table 5.2.7: Agro-Climatological Crop List for Alupe A.R.S.S.

Crop/variety (or place of breeding) e = early m = medium l = late	Av.No.of days to physiol. maturity	Altitudes[2]) according to growing period (m.)	Requirem.of well distributed rainfall [3]) in grow.period (mm.)	Yield potential acc. to water availability [4]) a = 1st rains b = 2nd rains
Maize/l.mat. like H 622	140-180	1000-1700	550-800	a) good to very good
Maize/m.mat. like H 511	120-150	1000-1700	500-750	a) very good b) good/fair
Sorghum/ e.mat. like 2 KX 17	90-130	0 - 1800	300-550	a) very good b) good
Beans/e.mat. like (GLP 92)	90-120	700-1800	270-480	a) good
Beans/e.mat. (GLP 2)	80-110	700-1800	250-450	b) good to fair

1) R. JÄTZOLD, and H. SCHMIDT, eds.(1982): Farm Management Handbook of Kenya, Vol. II/A, West Kenya-Nairobi and Trier.

2) Most suitable altitudes; the length of the growing period increases with altitude; growth is also possible beyond the indicated altitude range, as long as the ecological limits have not been reached.

3) Lower figure for fair results, higher for very good results with some corrections due to rainfall distribution, evaporation and run-off losses.

4) Estimated yield potential: very good >80%, good = 60-80%, fair = 40-60% and poor <40% of the expected yield under optimum water availability adapted from R. JÄTZOLD and H. SCHMIDT, eds. (1982): Farm Management Handbook of Kenya, Vol. II/A, West Kenya .

For the most important food crops in the area around the Alupe A.R.S.S. trial site, the crop coefficients (kc) are shown in Table 5.2.8, differentiated according to decades (10 day periods) of the growing season which is the time between planting or sowing and the physiological maturity. Furthermore, four crop development stages are distinguished in Table 5.2.8.

The crop coefficients for the climatic conditions at the Alupe A.R.S.S. trial site were estimated on the basis of data obtained from DOORENBOS and PRUITT (1977)[1]) and DOORENBOS and KASSAM (1979)[2]).

The data on the duration of each of the growing seasons and on the various development stages of each crop were assessed on the basis of local observations made under average climatic conditions.

The crop coefficients estimated for the various decades of the growing seasons were used to estimate the maximum (potential) evapotranspiration (ETm) under the prevailing climate, assuming that water is not a limiting factor for plant growth. For this calculation the following approximative formula was employed:

$$ETm = kc * Eo$$

whereby: ETm= maximum (potential) evapotranspiration
kc = crop coefficient
Eo = potential evaporation (climatic evaporative demand)

In Figure 5.2.6, the ETm-values are used to indicate the estimated maximum water requirements of the maize crop for optimum growth. Furthermore, the rainfall data at 66% reliability are shown in Figure 5.2.6 to give an indication of the water availability. However, when reading these figures, it must be borne in mind that the actual availability of water for the plants also depends, to a large degree on factors such as the run-off, the moisture storage capacity of the soil, the deep percolation of water etc.

The placement of the growing seasons of the various crops on the time axis as presented in Figure 5.2.6 was mainly based on the pattern of rainfall, whereby the peak water requirements of the plants should be met by high, reliable rainfall.

Detailed information on the calculation procedures and references are given in Chapter IV.2.2 of the main report. The interpretation of the diagrams mentioned above follows in Section 4 of this volume (Conclusions from the analyses of climate and soils).

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1) FAO (1977): Crop Water Requirements - (= Irrigation and Drainage Paper, 24), Rome

2) FAO (1979): Yield Response to Water - (= Irrigation and Drainage Paper, 33), Rome

Table 5.2.8 Crop development stages 1) and crop coefficients (Kc) 2) for approx. maximum (potential) crop evapotranspiration of the most important seasonal crops grown at Alupe A.R.S.S. (site no. 5.2)

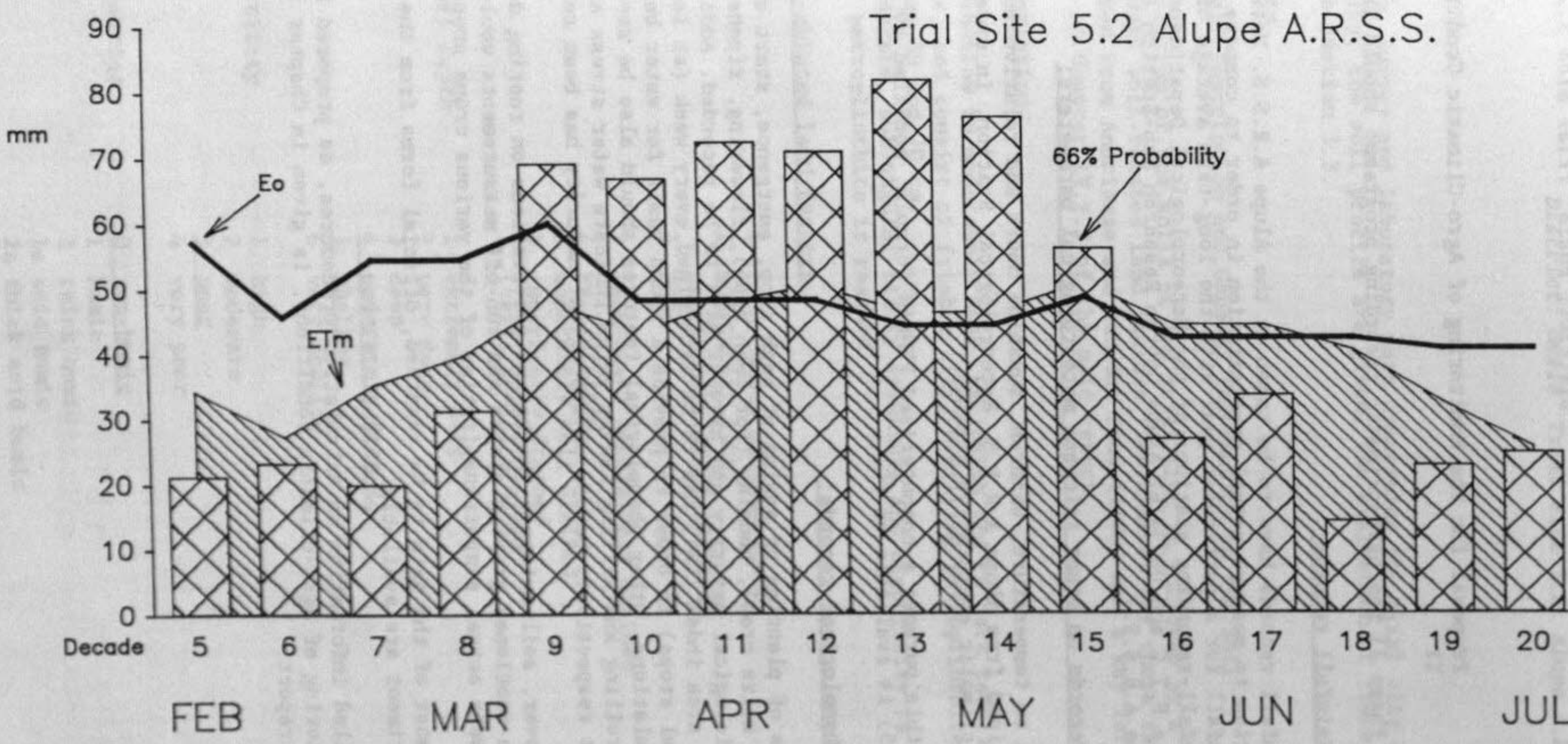
Crop/	Number of decades from seeding resp. planting to (physiological) maturity																							
Variety	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
MAIZE	0.6	0.6	0.65	0.7	0.8	0.9	1.0	1.05	1.05	1.05	1.05	1.05	1.05	0.96	0.8	0.63								
H622	I	I	I	II	II	II	II	III	III	III	III	III	III	IV	IV	IV								
MAIZE	0.6	0.6	0.65	0.73	0.86	0.99	1.05	1.05	1.05	1.05	1.05	0.96	0.8	0.63										
H511	I	I	I	II	II	II	III	III	III	III	III	IV	IV	IV										
SORGHUM	0.65	0.65	0.71	0.82	0.94	1.0	1.0	1.0	1.0	0.89	0.63													
2 KX 17	I	I	II	II	II	III	III	III	III	IV	IV													
BEANS	0.6	0.6	0.7	0.93	1.05	1.05	1.05	1.05	0.82	0.49														
GLP 92	I	I	II	II	III	III	III	III	IV	IV														
BEANS	0.6	0.6	0.7	0.93	1.05	1.05	1.05	0.82	0.49															
GLP 2	I	I	II	II	III	III	III	IV	IV															

1) Crop development stages as defined in chapter IV 2.2 (main report)
I = initial stage II = development stage III = mid season IV = late season

2) Kc = crop coefficient as defined in chapter IV 2.2 (main report)

Figure 5.2.6: Water requirements and availability for crop Maize H 622, first rains

Rainfall Station: 09034161
Alupe Cotton Res.



2.2 Proposal for the Monitoring of Agro-Climatic Conditions in Phase II

For Phase II the agro-climatic recording programme should include:

1) **Rainfall records:**

Rainfall records have to be taken at the Alupe A.R.S.S. Meteorological Station to measure actual precipitation in order to compare data on rainfall for a particular year with the long-term average of the nearest rainfall-recording stations of the Meteorological Department: 08934105 Busia F.T.C and 08934161 Alupe Cotton Research Sub-Station (now called Alupe A.R.S.S.).

2) **Records on other relevant meteorological parameters:**

Data on temperature, windrun, sunshine hours and relative humidity can be obtained from Alupe A.R.S.S. Meteorological Station, in order to calculate Eo (climatic evaporative demand).

For this purpose a computerized PENMAN formula, modified by MC CULLOCH (1965) is available on PC.

3) **Phenological records:**

Dates of planting or sowing of each crop, emergence, start of tasselling (for maize crop), budding (for bean crop), flowering, ripeness or physiological maturity and harvest have to be recorded. Additionally, the leaf area index (LAI) has to be determined every week (at least for the cereal crops) in order to provide a sound basis for water balance calculations. Other phenological features should also be recorded, above all rolling and wilting leaves which indicate water stress and wilting point respectively before physiological maturity has been reached.

Moreover, soil moisture checks and observations on rooting depth at the above-mentioned growing stages and run-off measurements would be needed to estimate actual evapotranspiration of the various crops properly.

For most of the data to be recorded, official forms from the Meteorological Department are available.

Detailed information on calculation procedures, as proposed for the monitoring of agro-climatic conditions, is given in Chapter IV.2.2 of the main report.

3. Soils

In this Section, survey and laboratory data concerning the trial site and, more specifically, the soil profile are given. The evaluation of these data is shown in Sub-Section 3.3.

3.1 Survey Data

3.1.1 Brief Soil Description and General Information on the Soil

The brief description of the soils of the trial plot is followed by a rating of relevant soil-related land factors. The classes for these factors have been adapted from Andriesse and van der Pouw (1985) and a key for them is to be found in Chapter IV.2.3 of the main report.

Brief soil description

The soils are shallow to moderately deep, yellowish red to dark reddish brown in colour, and consist of friable clay, overlying petroplinthite (murram) between 35 and 70 cm.
They have a moderate, sub-angular blocky structure and bioporosity is very high until the petroplinthite is reached.

Rating of soil-related land factors

- Parent rock
  - 1 rich: basic igneous rocks
  - 2 moderately rich: sandstones, grits, arkoses
  - 3 poor
- Drainage
  - 1 (somewhat) excessively drained
  - 2 well drained
  - 3 moderately well drained
  - 4 imperfectly drained
  - 5 (very) poorly drained
- Effective soil depth
  - 1 extremely deep
  - 2 very deep
  - 3 deep
  - 4 moderately deep to
  - 5 shallow
  - 6 very shallow
- Inherent fertility
  - 1 high
  - 2 moderate
  - 3 poor
  - 4 very poor
- Topsoil properties
  - 0 non-humic
  - 1 humic
  - 2 thick humic
  - 1a acid humic
  - 2a thick acid humic

- Salinity	<u>0 non-saline</u> 1 slightly saline 2 saline
- Sodicity	<u>0 non-sodic</u> 1 slightly sodic 2 sodic
- Stoniness	<u>0 non-stony</u> 1 slightly stony 2 stony 3 very stony
- Rockiness	<u>0 non-rocky</u> 1 slightly rocky 2 rocky 3 very rocky
- Consistency (moist)	1 half-ripe 2 loose 3 very friable <u>4 friable</u> 5 firm 6 very firm
- Moisture storage capacity	1 very high 2 high 3 moderate <u>4 low</u>
- Excess surface water	<u>0 none</u> 1 occasional 2 seasonal 3 permanent

3.1.2 Detailed Profile Description and Soil Classification

Detailed information on the various soil properties as they occur in the different horizons is given in Table 5.2.9.
The location of the profile near the trial plot is shown in Figure 5.2.7.

The soil profile is classified according to two systems, which are explained in Chapter II.2.2 of the main report.

1. Legend to the Soil Map of the World (FAO-Unesco, 1974), with adjustments according to the Kenya Concept (Siderius and van der Pouw, 1980): <u>ferralo-orthic Acrisol, petroferric phase</u>.

2. USDA Soil Taxonomy (Soil Survey Staff, 1975): <u>orthoxic petroferric Tropudult, fine-clayey family</u>.

Table 5.2.9: Detailed Profile Description of Trial Plot Alupe ARSS

Profile number: 5.2
Date of examination: 13-2-1986
Author: Gachene

Sample No.	Horizon: Genetic	Horizon: Depth	Horizon: Boundary	Colour (Moist)	Mottling	Texture	Cutans	Structure	Biopores	Consistence	Field pH	Concretions	Other Features
5.2.1	Ah	0 - 20	clear irregular	7.5 YR 3/2 dark brown	---	clay	---	weak medium subangular blocky	many v.f. many f. many m. few c.	firm; sl.sticky-sl.plastic	4.9	---	compacted due to tractor ploughing
5.2.2	Bt1	20 - 34	clear smooth	5 YR 3/4 dark redd. brown	---	clay	patchy thin clay	moderate medium angular blocky	many v.f. many f. many m. few c.	friable; sticky-plastic	4.4	---	---
5.2.3	Bt2	34 - 50	clear smooth	5 YR 4/4 reddish brown	---	clay	patchy thin clay	moderate medium subangular blocky	many v.f. many f. many m. few c.	friable; sticky-plastic	4.4	Fe, <10%, rounded, (<4 mm)	---
5.2.4	Btcs	50 - 80		5 YR 4/6 yellowish red	---	gravelly clay	patchy thin clay	moderate fine-medium subangular blocky	many v.f. many f. many m. few c.	friable; sticky-plastic	n.d.	Fe + Mn, +-25%, rounded, (<5 mm)	---
---	Cms (murram)	80+											

Remarks: Colour: redd. = reddish
Biopores: v.f. = very fine; f. = fine; m. = medium; c. = coarse
Consistence: sl. = slightly

3.1.3 Soil Sampling

Soil samples (profile, composite, pF rings) are listed in Sub-Section 3.2 Figure 5.2.7 shows the location of the composite sampling blocks (I to IV) as well as the location of the profile pit.

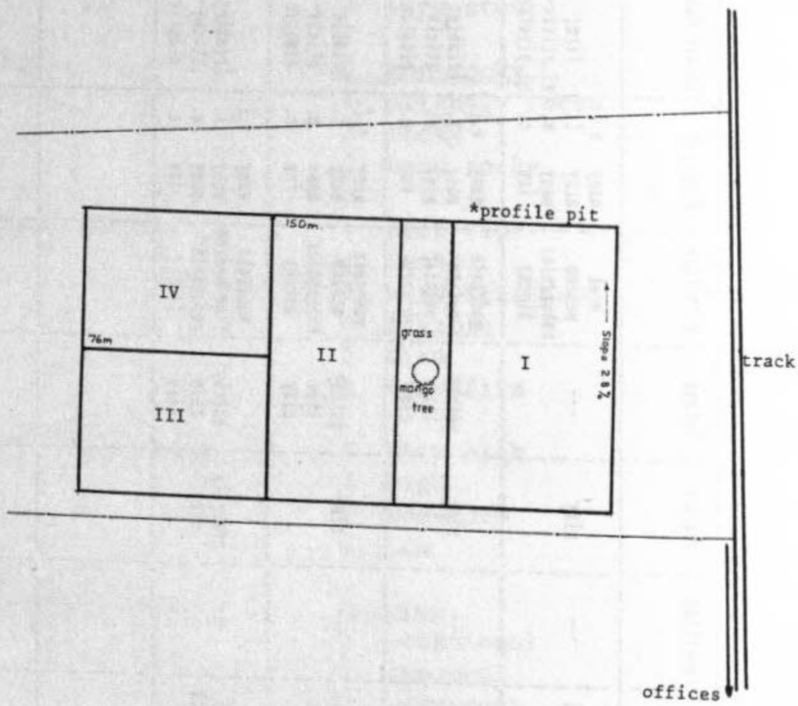


Figure 5.2.7: Location of Composite Sampling Blocks and Profile Pit at the Alupe A.R.S.S Trial Plot

3.2 Laboratory Data

The soil samples from the profile and the composite samples from the various blocks of the main trial site and from the farmers' fields were analyzed in the laboratory. The results are compiled in Tables 5.2.10 and 5.2.11. The methodology applied for obtaining these results is described in detail in Chapter IV.2 of the main report.

Table 5.2.10 : Analytical Results (physical and chemical analysis, results on air dry soil basis)
Profile Samples from Trial Site

	Horizon	Depth cm.	Field No.	Lab. No.	> 2 mm. %	Sand %	Silt %	Clay %	Texture Class	pH KCl	pH H2O	Diff. pH	Cond. H2O
1	Ah	0-20	5.2.1	11282/85	--	27	24	49	C	4.3	5.3	1.0	
2	Bt1	20-34	5.2.2	11283	--	25	18	57	C	4.2	5.0	0.8	
3	Bt2	34-50	5.2.3	11284	--	23	18	59	C	4.2	5.5	1.3	
4	Btcs	50-80	5.2.4	11285	--	21	18	61	C	4.2	5.6	1.4	
5													
6													
7													
8													

	Saturation Extract % water	pH	El.Cond.	Na (me./100gm. AgTU)	K	Mg	Ca	Mn	ECEC	Bases %	Al %	Al me./100gm.	H+Al KCl
1	NA	NA	NA	0.03	0.12	2.45	6.20	0.91	10.60	83.02	4.72	0.50	0.54
2	NA	NA	NA	0.03	0.12	1.95	5.40	0.66	9.30	80.65	15.05	1.40	1.72
3	NA	NA	NA									1.16	1.58
4	NA	NA	NA									0.88	1.40
5													
6													
7													
8													

	Na (me./100gm. Acetate)	K	Mg	Ca	CEC pH8.2	Bases %	Bases+Al me./100gm.	Al %	Org. C %	N %	C/N	P Olsen ppm.	105 deg.C in rel.to air dry
1	0.12	0.15	2.90	3.30	19.50	33.18	6.97	7.17	1.70	0.15	11.3		0.96
2	0.10	0.13	2.00	2.40	18.00	25.72	6.03	23.22	1.20	0.11	10.9		0.96
3	0.08	0.13	1.50	2.20	16.30	23.99	5.07	22.88	1.09	0.10	10.9		0.96
4	0.04	0.15	1.40	2.80	14.20	30.92	5.27	16.70	0.94	0.10	9.4		0.96
5													
6													
7													
8													

Moisture Retention Capacity

	Horizon	Depth cm.	Vol.% Moisture bar 0 / pF 0	1/10 / 2	1/3 / 2.5	5 / 3.7	15 / 4.2	Avail. Moisture Capacity mm./10cm.	Bulk Dens gm./cc. 105 deg.C
1	Bt1	30-35	42.9	34.8	33.5	26.8	21.4	13.4	1.34
2									
3									
4									

NA = not applicable
me./100gm. = milliequivalents per 100 gm. of soil
AgTU = Silver Thio Urea Extraction
Acetate = Bases by Ammonium Acetate of pH 7, CEC by Sodium Acetate pH 8.2
pH and conductivity in suspension 1:2.5 v/v

Table 5.2.11 : Analytical Results (chemical analysis, results on air dry soil basis)
Trial Site Composite Samples

No.		Depth cm.	I	II	III	IV	V	VI	VII	$\bar{x}$	s	Max. diff.
1	Lab. No. /85	20	11195	11197	11199	11201						
2		50	11196	11198	11200	11202						
3												
4	Fine earth %	20	100	100	100	100				100	0.00	0.00
5		50	100	100	100	100				100	0.00	0.00
6	Vol.weight gm./cc.	20	1.09	1.07	1.13	1.07				1.09	0.03	0.06
7		50	1.08	1.09	1.06	1.11				1.09	0.02	0.05
8	105 deg.C / air dry	20	0.96	0.96	0.96	0.96				0.96	0.00	0.00
9		50	0.96	0.96	0.96	0.96				0.96	0.00	0.00
10												
11	pH H2O 1/1	20	5.9	5.6	5.7	5.6				5.70	0.14	0.30
12		50	6.0	5.2	6.0	5.6				5.70	0.38	0.80
13	pH H2O 1/2.5	20	6.3	6.3	6.1	6.1				6.20	0.12	0.20
14		50	6.2	6.2	6.2	6.6				6.30	0.20	0.40
15	pH N KCl 1/2.5	20	4.7	4.7	4.6	4.6				4.65	0.06	0.10
16		50	4.5	4.5	4.6	5.0				4.65	0.24	0.50
17												
18	C org. %	20	1.92	1.80	1.48	1.92				1.78	0.21	0.44
20	N tot. %	20	0.27	0.19	0.17	0.16				0.20	0.05	0.11
22	C/N	20	7	9	9	12				9.32	2.04	4.89
24												
25	Mod.Olsen Abs. 260nm	20	113	136	120	106				118.75	12.84	30.00
26	(1/1000)	50	81	85	91	85				85.50	4.12	10.00
27												
25	SO4 soluble	20										
26		50										
27												
28	P Meh.1/5 ppm.	20	22	14	19	14				17.25	3.95	8.00
29		50	19	14	16	11				15.00	3.37	8.00
30	P Olsen ppm.	20	7.90	5.10	5.40	4.00				5.60	1.65	3.90
31		50	21.00									
32	P mod.Olsen ppm.	20	7.90	5.10	5.40	4.00				5.60	1.65	3.90
33		50	6.40	3.00	6.30	2.80				4.63	1.99	3.60
34	P Citric ac. ppm.	20	7									
35		50	7									
36												
37	ECEC AgTU me./100gm.	20	11.90	9.70						10.80	1.56	2.20
38	Bases %	20	94	89						91.57	3.24	4.59
39	Al%	20								0.00	0.00	0.00
40												
41	Hp BaCl2 me./100gm.	20										
42		50		0.50								
43	H & Al KCl me./100gm	20										
44		50		0.46								
45	Al 3- KCl me./100gm.	20										
46		50		0.20								
47	Al 3- AgTU me./100gm	20										
48												
49	Sat.Ext. % H2O	20	not applicable									
50		50	not applicable									
51	Sat.Ext. El.Cond.	20	not applicable									
52		50	not applicable									
53	Sat.Ext. pH	20	not applicable									
54		50	not applicable									
55												

Table 5.2.11 : Analytical Results (chemical analysis, results on air dry soil basis)
Trial Site Composite Samples

No.		Depth cm.	Block number I	II	III	IV	V	VI	VII	$\bar{x}$	s	Max. diff.
1	Lab. No. /85	20	11195	11197	11199	11201						
2		50	11196	11198	11200	11202						
3												
56	Na Meh.1/5 me./100gm	20	0.14	0.14	0.10	0.10				0.12	0.02	0.04
57		50	0.10	0.14	0.10	0.10				0.11	0.02	0.04
58	Na Ag-TU me./100gm.	20	0.07	0.06								
59												
60	K Meh.1/5 me./100gm.	20	0.90	0.64	0.38	0.36				0.57	0.25	0.54
61		50	0.72	0.14	0.30	0.18				0.34	0.27	0.58
62	K mod.Ol. me./100gm.	20	0.67	0.56	0.33	0.18				0.43	0.22	0.49
63		50	0.54	0.08	0.18	0.08				0.22	0.22	0.46
64	K Ag-TU me./100gm.	20	0.95	0.70								
65												
66	Mg Meh.1/5 me./100gm	20	2.00	2.10	1.80	2.20				2.03	0.17	0.40
67		50	2.00	1.10	2.30	1.50				1.73	0.53	1.20
68	Mg mod.Ol. me./100gm	20	2.50	3.10	2.50	2.30				2.60	0.35	0.80
69		50	2.50	1.70	2.20	1.90				2.08	0.35	0.80
70	Mg Ag-TU me./100gm.	20	2.95	2.30								
71												
72	Ca Meh.1/5 me./100gm	20	3.60	2.40	2.40	2.40				2.70	0.60	1.20
73		50	2.40	4.00	4.00	0.80				2.80	1.53	3.20
74	Ca mod.Ol. me./100gm	20	8.00	8.00	8.00	7.00				7.75	0.50	1.00
75		50	8.00	5.00	9.00	5.00				6.75	2.06	4.00
76	Ca Ag-TU me./100gm.	20	7.20	5.60								
77												
78	Mn Meh.1/5 me./100gm	20	0.54	1.18	1.36	0.78				0.97	0.37	0.82
79		50	0.40	0.78	1.56	0.84				0.90	0.48	1.16
80	Mn mod.Ol. me./100gm	20	0.11	0.22	0.14	0.18				0.16	0.05	0.11
81		50	0.10	0.15	0.10	0.20				0.14	0.05	0.11
82	Mn Ag-TU me./100gm.	20	1.60	0.67								
83												
84	Zn HCl ppm.	20	1.50									
85		50	1.50									
86	Zn mod. Ol. ppm.	20	1.50	1.40	3.60	2.40				2.23	1.02	2.20
87		50	2.90	1.40	2.90	1.90				2.28	0.75	1.50
88												
89	Cu HCl ppm.	20	1.30									
90		50	1.30									
91	Cu mod. Ol. ppm.	20	7.20	8.80	9.00	2.80				6.95	2.88	6.20
92		50	1.60	7.00	8.10	3.00				4.93	3.12	6.50
93												
94	Fe HCl ppm.	20	7.10									
95		50	7.60									
96	Fe mod. Ol. ppm.	20	45	73	51	62				57.75	12.37	28.00
97		50	33	87	73	52				61.25	23.70	54.00
98												
99	Fe Oxalate %	20	0.25									
100		50	0.30									
101	Al Oxalate %	20	1.30									
102		50	1.05									

NA = not applicable
me./100gm. = milliequivalents per 100 gm. of soil
Meh. = Mehlich Analysis
mod. Ol. = Modified Olsen Extraction
AgTU = Silver Thio Urea Extraction

3.3 Evaluation of Soil Data

3.3.1 Literature References and Soil Correlation

From 1972 onwards, the Kenya Soil Survey has carried out many soil surveys and site evaluations and, in addition, some surveys were conducted by other agencies.

A complete list of soil survey reports is given in Chapter II.2 of the main report. Those reports, which refer to the area in which the trial site is situated, are listed below.

Literature references:	
E1	W.G. Sombroek, H.M.H. Braun and B.J.A. van der Pouw (1982). Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980, scale 1:1,000,000.
LBDA	W. Andriesse, and B.J.A. van der Pouw (1985). Reconnaissance Soil Map of the Lake Basin Development Authority Area, Western Kenya, scale 1:250,000.
R8	D.O. Michieka and J.R. Rachilo (in prep.). Soils of the Busia Area (with map, scale 1:100,000).
P4	H.F. Gelens, and G. Ngari (1973). Report of a Site Evaluation of the Proposed Location of Alupe Substation.
M5 (5)	W. Siderius, and F.N. Muchena (1977). Soils and Environmental Conditions of Agricultural Research Stations in Kenya, No. 5: Alupe.

In order to correlate existing information with findings at the trial site, the map units and classification units in the above-mentioned reports have been grouped in Table 5.2.13. Moreover, the FURP soil map unit (Map 5.0.4) and the classification of the soil of the profile at the trial plot are given.

Table 5.2.13 Soil Correlation with Respect to the Alupe A.R.S.S Trial Site

Reference	Map unit	Soil Classification
E1	Ul 11	complex of orthic Ferralsols, partly petroferric phase and ironstone soils
LBDA	UlS 1	orthic Acrisols, with orthic Ferralsols, petroferric phases
R8	PSb2M	dystric and chromic Cambisols, petroferric phase
M5 (5)	-	plinthic Acrisol
FURP	UlS1	orthic Acrisols, with orthic Ferralsols, petroferric phase
Trial plot profile		ferralo-orthic ACRISOL, petroferric phase

Table 5.2.13 shows a wide range of soil classification units for soils which have different effective soil depths. This soil-depth is highly variable in the area, even within the research sub-station.
All sources agree on a "petroferric phase". The soils of the trial plot are ferralo-orthic Acrisols, petroferric phase, but the shallow spots key out as ferralic Cambisols, petroferric phase.

3.3.2 Representativeness

For two reasons, statements about the representativeness of the soils of the trial site should be made with care.
Firstly, soil classification units are mainly based on properties of a relatively permanent nature, i.e. those of the sub-surface horizons and not those of the topsoil.
Secondly, the generally high variability of topsoil properties within short distances is not reflected in relatively small-scale reconnaissance soil maps (1:100,000 to 1:1,000,000).

In this report, soils of a map unit considered to be within the "area of representativeness" must meet the following requirements:

(a) the soil-related land factors must have the same or similar ratings;

(b) soil classification must be the same or similar.

The extent to which all the FURP trial sites are representative of the soils of Busia District is shown in Map 5.0.5: "Groupings of Soil Mapping Units Represented by Trial Sites in Busia District". This map is discussed in Sub-Section 5.0.5.

Distinction is made between <u>high</u> representativeness - code A - and <u>moderate</u> representativeness - code B+ if soil conditions are slightly <u>more</u> favourable than at the trial site and code B- if soil conditions are slightly <u>less</u> favourable than at the trial site. Code C is applied for the remaining parts of the District, where <u>none</u> of the FURP trial sites are representative.

Within Busia District, the Alupe ARSS trial site has high to moderate representativeness (5.2.A/B+/C) in the sandstone-arkoses belt in the central part of the District.
The grouping is a complex one, since soil depth is quite erratic. It is constituted of soil map unit UlSl, in which the Alupe ARSS trial site is situated, and soil association UlSA (see Map 5.0.4).
The Soil Representativeness Code refers to shallow and moderately deep soils (5.2.A), but also to the more favourable deep soils (5.2.B+), and it excludes the hydromorphic soils (gleyic Acrisols) which are included in the association UlSA (C).

The Alupe ARSS trial site is also representative for small areas outside Busia District, in particular across the borders of Bungoma and Kakamega Districts.

3.3.3 Variability of Soil Properties within the Trial Site

For the Alupe ARSS trial plot the soil depth variability already mentioned is shown in Figure 5.2.8.

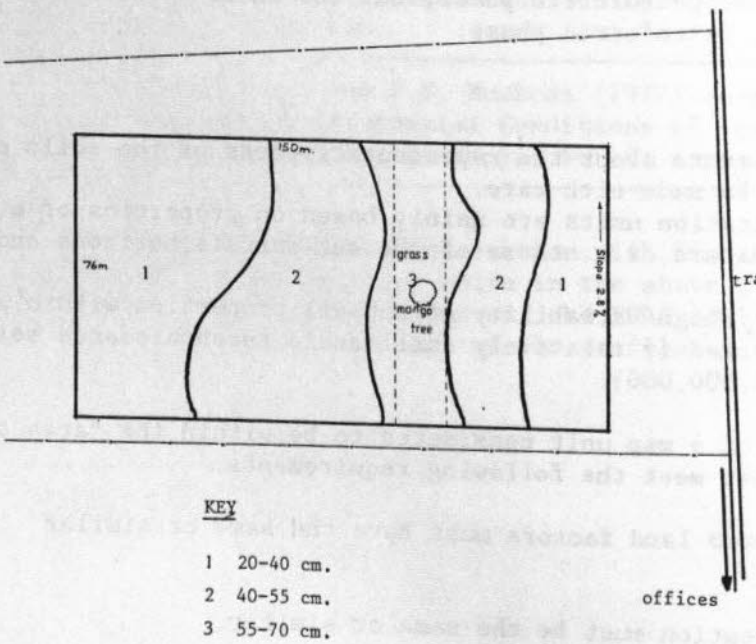


Figure 5.2.8: Variability of Soil Depth to Petroplinthite at the Alupe ARSS Trial Plot

The chemical properties, indicated in Tables 5.2.10 and 5.2.11, show a low variability within the trial plot, although a plant on shallow soil cannot take up the same amount of nutrients as a plant on moderately deep or deep soils.

The pH-KCl is within the range 4.5-4.7 (4.3 for the profile), and organic carbon content of the upper 20 cm ranges between 1.5% (Block III) and 1.9% (Blocks I and IV). For the profile, this value is 1.7%.

3.3.4 Fertility Status of the Soil

The criteria applied for the interpretation of the analytical data are outlined in Chapter IV.2 of the main report.

3.3.4.1 Soil Profile

The analytical data of the soil samples taken from the profile pit, situated at the side of Block I (see Figure 5.2.7), are presented in Table 5.2.10 and are interpreted in the following paragraphs.

The rooting depth of the soil is limited to about 80 cm. by the murram (Ccms horizon) in the subsoil. The capacity for plant available water may only be roughly estimated from the pF analysis of the Bt1 horizon and attains approximately 100 mm. in the upper 80 cm. The available moisture capacity may thus be rated as moderate.

The entire profile to a depth of 80 cm. has a moderate CEC (pH 8.2) of 15 to 20 me./100 gm.. The base saturation is moderate (24 to 33%), in accordance with a strongly to moderately acid soil reaction.

The exchangeable K is low (0.13 - 0.15 me./100 gm.) and much lower than the "available" K determined from the composite samples. This difference between profile and composite samples is corroborated by the AgTU extraction carried out on both types of samples. In the entire profile Mg (1.4 - 2.9 me./100 gm.) occupies a very high portion of the exchange complex while Ca (2.2 - 3.3 me./100 gm. by Ammonium Acetate) is in the low to very low range. However, exchangeable Ca by AgTU is higher by approximately the factor two. The Ca/Mg ratio is narrow.

The soil reaction of the entire profile is in the strongly acid range around pH KCl 4.2. This is below the optimum for the growth of sensitive plants, but, nonetheless, exchangeable Al shows low values (7% of exchangeable bases + Al) in the topsoil and moderate values in the Bt horizons. Soluble Al may, therefore, hardly affect even sensitive plants. The pH determined from the trial site composite samples is above 4.5 and only moderately acid.

The organic matter content of the topsoil is moderate to high (1.7% C). The underlying Bt horizons still contain moderate amounts of humus (0.94 - 1.2% C). In all horizons the total N content and the C/N ratio are both in the moderate range.

3.3.4.2 Soil Fertility Assessment of Composite Samples

The analytical results for the composite samples from the trial site (depths 0-20 cm. and 20-50 cm.) are presented in Table 5.2.11. Since there are no trials on farmers' fields around this site Table 5.2.12 is omitted.

The composite samples were analyzed to assess the chemical fertility status of the soil, with special emphasis on the availability of the important nutrient elements to the plants. The "available nutrients" were estimated by means of two complementary methods, the "Mehlich" diluted double-acid method (NAL routine) and a "modified Olsen" bicarbonate + EDTA extraction.

The interpretation of the analytical data presented is in so far tentative for both methods, as the validity of the applied ratings (ranges for Low, Medium, High) has not yet been verified by field trials in the various regions of Kenya.

The total N content of the moderately to very humic soils is medium to high (0.16 - 0.27 %). This and the moderate C/N ratios indicate that N availability is probably moderate; although the low pH of the topsoil and the quite low P status might adversely affect the availability of N to plants. The UV-absorption of the modified Olsen extract indicates only a low N supplying capacity of the soil.

The various methods used to determine "available" P produced somewhat inconsistent results. The Mehlich-P is mainly in the moderate range (>15 ppm.) while the citric acid extractable P is below an absolute deficiency level (<8 ppm.). The Olsen-P is moderate (the very high subsoil value may not be considered) but the modified Olsen-P is in the low range (<7 ppm) for all samples. Trials will have to show which method assesses P-availability best in this soil.

The "available" quantities of K and Mg are in the moderate to high range with considerable variation from place to place; the Ca levels are moderate. The "available" cations are better balanced in respect of plant nutrition than the NH_4-O-Ac exchangeable bases.

According to the Mehlich analysis, "available" Mn is in the range of adequate supply, whereas the modified Olsen method shows only low Mn values.

According to the modified Olsen method, Zn is available in very low amounts. Similarly, the HCl extractable Zn in Block I is far below the threshold. Cu appears available in sufficient amounts.

While the HCl extractable Fe is very low and below the critical level, the modified Olsen method extracted at least moderate amounts of Fe.

The oxalate extraction for amorphous oxides and hydroxides yielded only low amounts of Fe and low to moderate quantities of Al.

All composite samples investigated are in the moderately acid range (pH KCl 4.5 - 5). Consequently, exchangeable acidity and especially exchangeable Al appear too low to have any limiting effect on crop production.

The evaluation of the Mehlich Analysis data according to NAL standards is given in Table 5.2.14.

Table 5.2.14: Evaluation of the Mehlich Analysis Data According to NAL Standards

Parameter	Trial Site	Farmers' Fields
Soil reaction (pH)	Moderately acid	
Acidity (Hp)	Low	
Available nutrients		
Sodium	Adequate	
Potassium	Adequate	
Calcium	Adequate	
Magnesium	Adequate	
Manganese	Adequate	
Phosphorus	Low	
Total Nitrogen	Low	
Organic Carbon	Moderate	
C / N Ratio	Favourable	
Ca / Mg Ratio	Favourable	
Ca / K Ratio	Favourable	
K / Mg Ratio	Favourable	

Remarks on Trial Site:
Soil reaction is favourable. Positive yield responses to manure, N and P application are expected. Responses to K and lime application are unlikely.

3.4 Sampling Programme for Laboratory Analyses

3.4.1 Soil Samples

Soil samples will be collected once a year at the beginning of the long rains in February just after ploughing and before the fields are planted. The samples will be taken individually from two depths (0 - 20 cm and 20 - 50 cm) for each replication of the selected fertilizer treatments, and only from the plots in module 2 with maize/beans mixed cropping.

The treatments to be sampled are:

Trial I:	N0:P0	N75:P0	N0:P75	N75:P75
Trial II:	0	FYM	FYM+NP	NP+K
	lime	FYM+lime	FYM+NP+lime	NP+lime

3.4.2. Plant Samples

Harvest samples from the maize/beans mixed crop include the individual samples for grain and straw for maize and beans respectively. Samples will be collected separately from each replication of the following treatments:

Trial I:	N0:P0	N75:P0	N0:P75	N75:P75
Trial II:	0	FYM	FYM+NP	NP+K
	lime	FYM+lime	FYM+NP+lime	NP+lime

3.4.3 Other Samples

From every batch of applied FYM three representative samples will be taken.

4. Conclusions from the Analyses of Climate and Soils

4.1 Moisture Availability

The amount of rainfall, which is surpassed in 20 out of 30 years (i.e. 66% probability), constitutes the basis for estimating moisture availability during the growing periods. Other parameters of the water balance such as the moisture storage capacity, run-off, and deep percolation also have to be considered in order to obtain a comprehensive picture of the moisture availability.

For example, the water requirements and the water availability for Maize H 622, first rains, at the Alupe A.R.S.S.trial site, can be interpreted as follows:
Figure 5.2.6 shows that the maximum water requirements (ETm) of the maize crop are quite in line with the rainfall pattern at the 66% probability level. The ratio of reliable rainfall (i.e. 66% probability) to maximum evapotranspiration (ETm) for maize H 622 is >0.8 for the total length of the growing period of the first rains.

Run-off is moderate. Although the crop provides an adequate ground-cover at the time of maximum rainfall-intensity in April and May, the soil is to some extent susceptible to sealing and crusting and the storage capacity is low to moderate. Thus, the continuous water surplus (end of March - end of May) cannot be stored completely, causing appreciable amounts of run-off and deep percolation. The slope is 3-3.5%.

Lateral sub-surface flow and run-on could be estimated, but can be omitted, since they are generally very low.

For the Alupe A.R.S.S. trial site, the moisture storage capacity is low to moderate (80 - 100 mm.). Nevertheless, the surplus of water which is likely to occur in April and May offsets the deficits of June and July. This leads to almost continuous water availability from March to December.

Summarizing the evaluation of the climatic factors, the yield potential from the climatic point of view can, for the maize crop in the first rains, be rated good to very good on a "20 out of 30 year" basis.

4.2 Nutrient Availability in Relation to Possible Fertilizer Requirement

For all samples analyzed availability of N and P appeared low, even very low. However, data for available P are inconsistent. Although K should be adequately available in the topsoils, the subsoils of Blocks II to IV appear to be low in K. The soil reaction was, however, found favourable for plant production.

Fertilizer applications should first of all involve P in the form of TSP or finely ground soft rock phosphate (e.g. Hyperphos). Under the moderately acid soil conditions the rock phosphate should be almost as effective as TSP even in the first season. P from rock phosphate is less subject to fixation than P from TSP. Nonetheless, the risks of P fixation into non-available forms are considered to be quite low. The efficiency of P application may be enhanced by the addition of fresh FYM to stimulate soil biological activity.

Repeated mineral N applications are considered useful only in combination with adequate P supply, in which case reasonable responses to N application may be expected repeatedly. N losses due to leaching are probably rather low, as the distribution of bases in the profile indicates only a low or moderate leaching intensity.

The application of FYM will have only little sustained effect if not combined with P. Green manuring with leguminous plants will probably depend even more on P fertilization. Organic amendments to the soil will also be very important for the physical properties of the soil (erodibility, water infiltration etc.) and not only in respect to plant nutrition.

K fertilizer will most probably be needed to complement repeated N and P applications, although response to K alone may not be obtained. The analytical data give no estimate of the reserves of K beyond the exchangeable pool, but in this case only a very limited K reserve may be expected (see K in profile samples).

As K fertilizer K_2SO_4 should generally be preferred to KCl (both contain 50% K_2O) as the SO_4-ion enhances P availability. The form in which K is applied should also take into account crop requirements (e.g. KCl to cabbage, but not to Irish potatoes).

Under the present soil conditions liming is not needed, but the acidifying effects of the applied mineral fertilizers should be compensated, i.e. approximately 1.8 Kg. of $CaCO_3$ per Kg. of applied N; in the case of CAN, which contains Ca, only about 0.8 Kg. $CaCO_3$ per Kg. N or 0.2 Kg. lime per Kg. of CAN will be needed. TSP does not contribute substantially to the Ca budget of the soil; soft rock phosphate (30% P_2O_5) contains about 2.7 Kg. $CaCO_3$ equivalents per Kg. of P_2O_5.

If lime is applied in larger amounts, micro-element availability and plant uptake should be monitored, at least for Zn and Mn. Micro-nutrient fertilizer should only be applied when a deficiency has been verified in the field.

4.3 Other Relevant Land Qualities

In addition to an assessment of moisture and nutrient availability, the following land qualities are relevant in the context of fertilizer use:

a) Oxygen availability.
In wet years, excess rainfall can, notably on the shallow soils, lead to temporarily impeded soil aeration. This is a serious setback to plant metabolism, particularly during crop emergence. It is also a major cause of low nitrogen fertilizer recovery.

b) Rootability.
The shallow to moderately deep soils provide a poor environment for root development and tuber expansion, as shallow petroplinthite acts as a barrier for the tap root of most crops.

c) Resistance to erosion.
The area around Alupe has a moderate resistance to erosion. The combination erosive rainfall - moderate structure stability of the topsoil - undulating topography - inadequate vegetative cover (notably at the start of the growing season) imposes some danger as to the occurrence of sheet erosion at the trial site. Because of higher organic matter content and lower relief intensity, erosion hazard is not as high as in Ukwala (trial site 4.2, Siaya District), where shallow soils also prevail.

d) Ease of cultivation and scope for agricultural implements.
Although the soils impose no limitations to manual land preparation, the shallowness of the soils restrict the scope for use of heavy machinery.

5. Trial Design and Execution Plan, Alupe A.R.S.S.

(Full details of the methodology for carrying out the trials are shown in Section V of the main report.)

Selection of crops for each of the 3 modules.

Site 5.2 Alupe A.R.S.S	RAINY SEASONS	
	1st, Long, March	2nd, Short, Sept
S1 Standard Maize	Hybrid 622	Hybrid 511
S2 Maize & Beans	Hybrid 622 + GLP 2	Hybrid 511+GLP 2
S3 Sorghum, ratooned	Sorghum Serena	Ratoon Sorghum

The 1st sequence is thus continuous, pure maize, 2 times per year.
The 2nd is intercropped maize and beans, also 2 times per year.
The 3rd is sorghum planted in 1st rains, ratooned in the 2nd rains.

Each module contains 2 experiments, namely Experiment 1 and Experiment 2.
Experiment 1 is a 4N x 4P factorial, with 2 replications in each module.
Experiment 2 is a 2NP x 2K x 2L x 2 FYM factorial, also with 2 replications in each module.
Each module thus consists of 64 plots, and the total for the 3 modules is 192 plots.

FYM will be applied only to the crops during the first rains, whereas mineral fertilizers will be used in both seasons. Where maize and beans are intercropped, the fertilizer will be given to the maize. The beans will not receive any fertilizer directly, but will "scavenge" from the maize and from residual fertilizer left in the relevant plots after the first trial season.