

J. Makeni.

DEPARTMENT OF AGRICULTURE

THE SOILS IN THE COUNTRY AROUND SHIMBA HILLS SETTLEMENT,
KIKONENI AND JOMBO MOUNTAIN.

COAST PROVINCE

SOIL SURVEY UNIT

FEBRUARY : 1968

KENYA

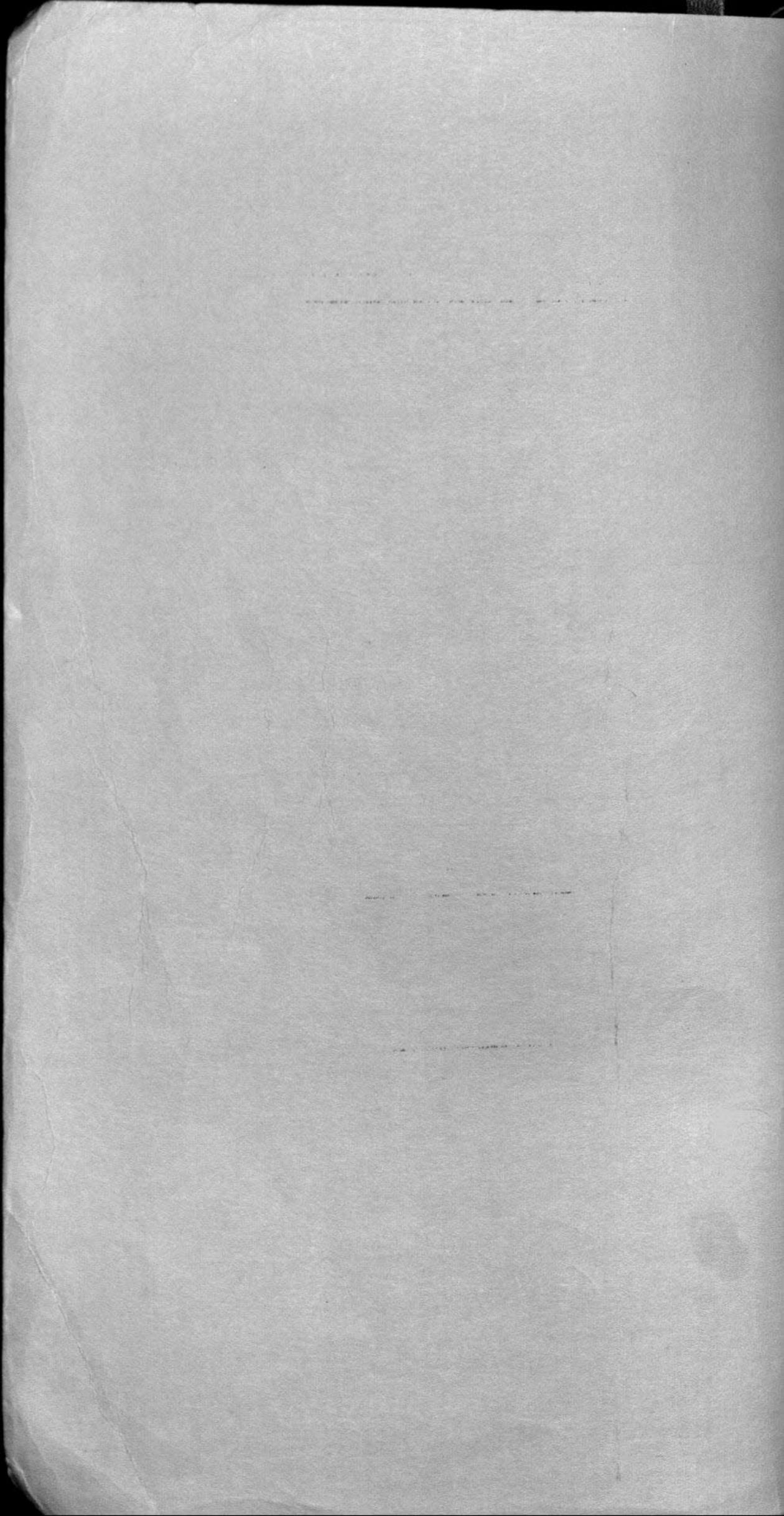


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Section 1

1911

ARTICLE IV. JUDICIAL DEPARTMENT

SECTION 1. JUDICIAL BRANCH

- (a) The judicial branch shall consist of the following:
 - (1) The Supreme Court of the State.
 - (2) The Courts of Appeals.
 - (3) The District Courts.
 - (4) The County Courts.
 - (5) The County Clerks.
 - (6) The Justices of the Peace.
 - (7) The Constables.
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 - (9) The Coroners.
 - (10) The Clerks of the District Courts.
 - (11) The Clerks of the County Courts.
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THE SOILS IN THE COUNTRY AROUND SHIMBA HILLS SETTLEMENT
KIKONENI AND JOMBO MOUNTAIN.

INTRODUCTION

Investigations to determine the suitability and distribution of soils for cash crop development (with special reference to tobacco and coconuts) were carried out at a "semi-detailed" level of surveying over an area of approximately 83,000 acres, embracing much of the Lower Mts. Valley; lands between Kikoneni and Jombo to the north; and the Shimba Hills Settlement to the North-East. Though not extending as far as the immediate coastal strip, the entire Project Area lies within the climatic zone of Coastal Influence. The precise boundaries can be determined from the six accompanying Soil Maps (at 1 : 12,500). It is to be noted that the project area borders on the Shimba Hills Forest, Buda Forest, Mrima Forest and Jombo Forest reserves; and is represented on the Survey of Kenya 1 : 50,000 sheets - 200/iv (Msambweni) and 200/iii (Zombo).

The Soil Survey Unit wishes to acknowledge the cooperation of the various Government officers who, though initially shy, became inextricably involved in the survey.

We also wish to record our appreciation for the support provided by the BRITISH-AMERICAN TOBACCO COMPANY which kept the mail flowing and also supplied all facilities for producing this Report; the staff of the National Agricultural Laboratories for analysing soil and water samples; the M.O.W. Workshops in Mombasa for repairing numerous landrovers; and the Survey of Kenya in Nairobi who prepared and turned out the final map sheets.

(a) Methodology

(i) Field Investigations

The soil survey was conducted along the following lines:-

1. Appreciation of the landscape and the effect of the prevailing climate in moulding it.

2. Judgement of the criteria (e.g. Soil Texture) to be employed in defining the soils. These were chosen having regard to the proposed scale of the investigation and its ultimate objective.

3. Definition of the soil types during preliminary reconnaissance, by reference to those features of soil morphology shown to be of high significance in soil characterisation.

4. Establishment of a modal concept for each defined soil. A representative soil profile, approximating to this concept and sited with regard to those factors active in local soil formation, was sampled to ascertain precise physicochemical data for each visually distinct layer. The samples were analysed according to the methods currently in vogue at the National Agricultural Laboratories (Reference - Senior Soil Chemist, N.A.L., Box 30028, Nairobi).

CONCLUSION

Investigations to determine the suitability and
of soils for cash crop development (with special
reference to tobacco and coconuts) were carried out at a
level of surveying over an area of
approximately 55,000 acres, embracing much of the lower
level lands between Kikomi and Jombo to the
the Shimba Hills Settlement to the North-East.
Project Area lies within the climatic zone of
extending as far as the immediate coastal strip.
The precise boundaries can be determined
by accompanying Soil Maps (at 1 : 12,500).
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Laboratories (Reference - Senior Soil Chemist,
N.A.L., Box 3025, Nairobi).

5. Between four soil auger boring the course of the The siting of the on the preliminary pairs; each auger plotted onto aeri

(ii) Map Production

This was based on inspection of air photographs KE 79 (Shimba Hills, 1960) supplemented where necessary by level photography from 0 (Shimba Hills, 1958 - 1960)

Some soil borings were made in the field; many were from their pre-determined land physiognomy.

The soil borings along streams and roads, were plotted on the Survey of Kenya.

The final soil maps were each independently oriented to overlap with its neighbors. They are titled as follows:-

1. JILORE - MAJ
2. KIDONGO - MK
3. LUKORE - KIC
4. MKUNDI - MAN
5. MAFISINI - K
6. MWANANYAMALA

(b) Abbreviations

It is regretted that space and tables within bounds, a list of abbreviations have had to be

C	Organic Carbon
Ca	Calcium
C.E.C.	Cation Exchange Capacity
Cl.	Chloride
CO ₃	Carbonate
E.C.	Electrical Conductivity
E.S.P.	Exchangeable Sodium
F.Y.M.	Farm Yard Manure.
HCO ₃	Bicarbonate
H _p	Concentration of Per
H _v	Concentration of Var
	Charge Hydrogen
K	Potassium; or Potas
m.e.%	Milli equivalents pe
m.e./l.	Milli equivalents pe
Mg.	Magnesium
m.mhos./cm.	Milli mhos per cer
Mn.	Manganese
Mod.	Moderate (-ly)
M.R.D.	Maximum Rooting Dens

and five thousand
were described during
general field survey.
The auger borings was based
inspection of stereo-
hole was subsequently
1 photographs.

ed upon the stereoscopic
raphs from Contract
5 - 1 : 12,500),
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contract KE 2/8/57
(: 25,000).

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MBONI

MBA - SETTLEMENT H.Q.

AKA SIMBA - MWALUVANGA

AWANI - KIKONENI

GOMBERO

- MRIMA - JOMBO.

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Between four and five thousand soil water borings were described during the course of the general field survey. The siting of these water borings was based on the preliminary location of areas; each water bore was subsequently plotted onto aerial photographs.

(ii) Map Production

This was done upon the stereoscopic inspection of air photographs from Contract KE 79 (Shamba Hills, 1955 - 1 : 12,500), supplemented where necessary by older high-level photography from Contract KE 2/8/57 (Shamba Hills, 1958 - 1 : 25,000).

Some soil boundaries were determined in the field; many were inferred a priori from their pre-determined relationship with land physiognomy.

The soil boundaries, together with streams and roads, were pieced together at the Survey of Kenya.

The final soil map comes in 6 Map Sheets, each independently oriented and having a variable overlap with its neighbours. The map sheets are titled as follows:-

1. JILOBE - MALIMONI
2. KIPKOJO - MACHAKA - SETTLEMENT H.O.
3. MOKORE - KICHAKA SIMBA - KWADUVAWANA
4. MUMUNI - MANGAWAKI - KIKKENI
5. MATHENI - KICHOMBO
6. MWANAHAMANA - MUMA - JOMBO.

(iii) Abbreviations

It is regretted that, in order to keep text tables within bounds, a large number of technical abbreviations have had to be used.

Organic Carbon	
Calcium	
Cation Exchange Capacity	E.C.
Chloride	
Carbonate	
Electrical Conductivity	
Exchangeable Sodium Percentage	E.S.P.
Field Capacity	Y.M.
Bicarbonate	0g
Concentration of Permanent Charge Hydrogen	
Concentration of Variable (Adsorbable) Charge Hydrogen	
Potassium, or Potash	
Milli equivalents per cent	m.e.c.
Milli equivalents per litre	m.e.l.
Milligrams	mg.
Milli mhos per centimetre	mhos/cm
Percentage	%
Hydrate (1/2)	
Normal Acidity	N.A.

N.	Nitrogen; or Nitrogenous
NO ₃	Nitrate
O.M.	Organic Matter
P	Phosphorous; or Phosphate
pH	The Negative Logarithm of the Hydrogen-ion activity in the soil solution.
p.p.m.	Parts per million
R.M.	Rust Mottling
R.S.C.	Residual Sodium Carbonate
S.	Sulphur
S.A.B.	Sub-angular Blocky Structure
S.A.R.	Sodium Adsorption Ratio
Sat. Ext.	Saturation Extract
SO ₄	Sulphate.

NOTES: 1. The wholly inaccurate usage of the terms N, P and K as applied to fertilizers which merely contain these elements amongst others is general amongst Agriculturists, and is employed in this loose sense in the Report; e.g. "N" may refer either to Nitrogen or to the generalised group of nitrogenous fertilizers, depending on the sense of the text. Sympathy is expressed towards proper soil scientists who may be forgiven for regarding such a perversion as pernicious nonsense.

2. The Shimba Hills Settlement Scheme is familiarly referred to throughout as "SHIMBA".

CONDITIONS IN THE PROJECT AREA

(a) Prevailing Climate

The project area lies within the belt of 'coastal influence'. Between December and April, the North-East trades prevail; from June to October the wind tends to be Southerly or even South-Westerly. During the rains under the influence of the Convergence Zone, the winds are lighter and more variable; during the day they are between East and South-East. All these winds, with the exception of the South-Westerly, are winds off the sea (the South-Westerly is also indirectly a sea wind; because of the circular motion of winds it is South-Easterly farther South). Land breezes blow weakly from the North-West for a few hours most nights of the year.

The equable climate is warm and humid. Figures for temperature, evaporation and sunshine are not available. Those quoted below are based on recordings at Mombasa. Due to the prevalence of sea breezes this data should apply in the project area with only minor modifications.

The hours of sunshine at Mombasa are not, however, comparable with those in the project area, due to orographic effects resulting from South-East - facing escarpments and hills. Thus Shimba and Kikoneni are significantly cloudier than the

Nitrogen; or Nitrogenous	
Nitrate	
Organic Matter	
Phosphorus; or Phosphate	
The Negative Potential of the Hydrogen-ion	
activity in the soil solution.	
Parts per million	
Rust Mottling	
Residual Sodium Carbonate	
Sulphur	
Sub-angular Blocky Structure	
Sodium Adsorption Ratio	
Sat. Ext. Saturation Extract	
Sulphate.	

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T A B L E 1

AIR AND SOIL TEMPERATURES (°F) UNDER LIGHT GRASS COVER

SHIMBA HILLS : SOIL 1 : NOV. 1952.
(AFTER HURSH AND PEREIRA)

TEMPERATURE	NOON	3 p.m.	7 p.m.	MIDNIGHT	6 a.m.	9 a.m.
3 Feet above ground	87	80	73	69.5	70	83.5
At ground level	99	82.5	74	69.5	71.5	85
Soil: At 1"	106	94	80	73	72.5	87
At 6"	83	88	89	83	80	82
At 12"	82	83.5	85.5	84	82	82
At 48"	80	80	81.5	81	79	79

DATE	TIME	TEMP	WIND	MOON	PHASE	MOON	TEMP	WIND	MOON	PHASE
80	81.2	80	81	80	81.2	80	81	80	81.2	80
83	82.2	83.2	84	83	82.2	83	84	83	82.2	85
83	83	88	83	83	83	83	83	80	83	85
80	80	84	83	80	80	84	83	80	80	81
80	85.2	84	83.2	80	84	85.2	83.2	80	84	83
81	83	80	83.2	81	83	80	83.2	80	81	83.2

(VALLEY HOUSE AND BEEHIVE)

CHIMNEY HEIGHT : SOIL T : MOA. 1923.

VIB AND SOIL TEMPERATURES (°F) DATES TIGHT PLAYS COLES

coastal strip. The cloudiest months are May to July; the sunniest are October, November and January through to March.

The mean maximum temperature will be about 87°F; mean minimum about 73°F. Hence the mean daily temperature range is around 14°F (about the minimum for tobacco); the mean annual temperature is 80°F. The coldest months are June to August; the warmest January to March. Soil surface temperatures of 120° to 140°F have been recorded at mid-day. Table 1 shows Air and Soil temperatures recorded by Hursh and Pereira at Shimba. (East African Agricultural Journal, 18, 1953, p.139). The rather high and uniform nature of the sub-soil temperatures may well lead to sub-soil moisture vapourization and subsequent condensation during the night in the topsoil. Supposing that this moisture is subsequently evaporated, this mechanism may well account for a significant daily moisture loss. Due to insulation, soil evaporation would, of course, be relatively insignificant under forest.

Mean aerial relative humidity exceeds 80% except during January to March, when it averages out at about 75%. Formal estimates of potential evaporation from open water surfaces (Penman - E_o) indicate figures of between 2000 and 2200 m.m. in the project area. Actual observations of cloud cover would suggest that a truer figure might be around 1900 m.m. Monthly Penman estimates for Mombasa are quoted below. To obtain an estimate for Shimba, these data should be multiplied by the factor 0.86.

Mombasa: Potential Evaporation (E_o).
Average 1946 - 1962.

F	M	A	M	Months				S	O	N	D	YEAR
				J	J	A	J					
204	221	180	152	148	144	162	181	198	200	204	2205	

The precipitation of night mist on cool bodies is clearly an important feature at Shimba, especially at the higher altitudes. This alone accounts for the presence of rain forest within a rainfall zone that could not normally be expected to support such vegetation. Hursh and Pereira (op cit) point out that the heaviest deposit will occur in the cool season when the Southerlies are flowing. This dew, combined with morning mist, is considerable in the forests where an enormous stem and leaf area is exposed: in grassland, however, much of what little condensation is deposited will be dissipated as the temperature rises. The presence of this moisture upon normally transpiring surfaces effects a reduction in effective transpiration and so helps maintain soil moisture.

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 May to July, the summer and October
 November and January through to March.

The mean maximum temperature will
 be about 87°F; mean minimum about 67°F.
 Hence the mean daily temperature range is
 around 20°F (about the same for Toronto).
 The mean annual temperature is 50°F. The
 coldest months are June to August. The
 warmest January to March. Soil surface
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 recorded at mid-day. Table 1 shows air and
 soil temperatures recorded by Bush and
 Lewis at Shikha. (East African
 Agricultural Journal, 18, 1957, p. 139). The
 rather high and uniform nature of the sub-
 soil temperatures may well lead to sub-soil
 moisture evaporation and subsequent
 condensation during the night in the
 regions, suggesting that this moisture
 is independently evaporated. This mechanism may
 well account for a significant latent moisture
 loss. Due to transpiration, soil evaporation
 would, of course, be relatively insignificant
 under forest.

Mean aerial relative humidity
 except for a slight dip during January to March
 when it averages out at about 75%. Journal
 of potential evaporation from
 open water surfaces (Penman - 3) indicates
 a range of between 1000 and 1500 g/m² in the
 present area. Actual evaporation of cloud
 cover would suggest that a 10% deficit
 might be around 1500 g/m². Monthly latent
 estimates for Mombasa are quoted below. To
 obtain an estimate for Shikha, these data
 should be multiplied by the factor 0.8.

Mombasa: Potential Evaporation (g/m²)
 Average 1945 - 1962

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
180	155	145	144	145	152	181	195	200	204	205	204	202	

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 It is also accounts for the presence of
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 This is combined with morning mist, is
 considerable in the forests there an enormous
 stem and leaf area is exposed. In contrast,
 however, most of what little condensation is
 deposited will be dissipated as the
 temperature rises. The presence of this
 moisture upon aerially transported particles
 will be a requisite to direct precipitation
 and an help maintain soil moisture.

RAINFALL MEANS (INCHES) TO 1965

STATION AND NO. OF YEARS RECORDED	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL YEAR
MWANGULU 11 years	0.87	0.93	2.95	4.49	5.61	1.76	1.73	2.12	1.66	3.13	4.66	3.54	33.46
KIKONENI 9 years	0.87	0.61	2.25	9.41	8.42	4.15	4.38	3.35	2.50	2.92	4.59	3.66	47.11
SHIMBA HILLS SETTLEMENT 12 years	1.98	0.50	2.44	9.02	9.87	3.78	4.16	3.11	2.59	5.03	4.12	3.10	49.73
MUHAKA 13 years	0.91	0.66	1.42	8.54	10.07	3.43	3.55	2.76	2.33	3.43	3.19	1.83	42.13

Table 2 presents the mean monthly rainfall recorded at 4 stations. Two of these (Kikoneni and Shimba Hills) lie within the project area: Mwangulu is 6 miles West North-West of Jombo Mountain, i.e. about as far west of Jombo as Kikoneni is east of Jombo. Kikoneni is, however, more representative of even the extreme West of the project area, since Mwangulu lies within a partial rain shadow caused by Jombo in the long rains and by the Usambara Mountains following the long rains: Muhaka is 2 miles outside the extreme North-Eastern corner of Shimba Hills Settlement and may be regarded as representing that side of the project area. (N.B. The Kikoneni rain gauge was partially shaded by a broad-leaved tree and so may have been reading on the low side - the gauge has been resited). Whilst the figures speak for themselves, certain points may be emphasised:

- (i) Potential evaporation significantly exceeds mean annual rainfall.
- (ii) The length and severity of the December - April dry season is a factor of the utmost agronomic significance. There is some suggestion that this dry season may be shorter in the Kikoneni/Mrima area where short rains tend to fall later in the year; and most severe in the North-East (Njele/Mwapala) where the short rains finish early and frequently fail altogether.
- (iii) By far the wettest months are April and May, though the long rains in an average year may be regarded as continuing into July. In these 4 months (April to July) both Shimba and Kikoneni receive about 27 inches (i.e. just over half the annual total).
- (iv) The data appear to provide a micro-demonstration of two significant features of Coast rainfall, viz.
 - (a) The immediate coastal strip has heavier long rains than areas inland.
 - (b) The hinterland has more reliable short rains. (The culmination of this tendency is illustrated further inland at stations as diverse as Tsavo, Voi and Galole where the main rains fall in November.
- (v) Muhaka is 5 miles from the sea, yet only receives 42 inches. It would seem that inland there is a dramatic decline in rainfall which is partially reversed by the orographic influence of the Shimba Hills.

/over ...

Table 1 presents the mean monthly rainfall recorded at 4 stations. Two of these (Kikomet and Shimba Hills) lie within the project area; Mwanjini is 2 miles west North-West of Jomo Mountain, i.e. about as far west of Jomo as Kikomet is east of Jomo. Kikomet is, however, more representative of even the extreme West of the project area. Since Mwanjini lies within a rainfall zone shadow caused by Jomo in the long rains and by the Usambara Mountains following the long rains; Mwanjini is 2 miles outside the extreme North-Eastern corner of Shimba Hills settlement and may be regarded as representing that side of the project area. (N.B. The Kikomet rain gauge was partially shaded by a broad-leaved tree and so may have been reading on the low side - the gauge has been raised). Whilst the figures speak for themselves, certain points may be emphasized:

- (i) Potential evaporation significantly exceeds mean annual rainfall.
- (ii) The length and severity of the December - April dry season is a factor of the utmost economic significance. There is some suggestion that this dry season may be shorter in the Kikomet/Mwanjini area where short rains tend to fall later in the year, and most severe in the North-East (Mwanjini) where the short rains finish early and frequently fall altogether.
- (iii) By far the wettest months are April and May, though the long rains in an average year may be regarded as continuing into July. In these 4 months (April to July) both Shimba and Kikomet receive about 27 inches (i.e. just over half the annual total).
- (iv) The data appear to provide a micro-demonstration of two significant features of Coast rainfall, viz.
 - (a) The immediate coastal strip has heavier long rains than areas inland.
 - (b) The hinterland has more reliable short rains. (The culmination of this tendency is illustrated further inland at stations as diverse as Tavvo, Voi and Gidiga where the main rains fall in November.
- (v) Mwanjini is 2 miles from the sea, yet only receives 42 inches. It would seem that inland there is a dramatic decline in rainfall which is partially reversed by the orographic influence of the Shimba Hills.

MONTHLY RAINFALL EXTREMES (In Inches). SHIMBA HILLS SETTLEMENT.

1951 - 1966

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR	TOTAL MONTHLY EXTREMES
LOWEST TOTAL RECORDED	0	0	0.06	3.28	3.25	0.56	0.82	0.61	0.45	1.20	0.21	0.41	34.2	10.8
HIGHEST TOTAL RECORDED	5.24	2.16	8.31	20.00	21.48	7.99	9.59	6.50	14.32	12.79	8.65	7.16	67.3	124.2

RECORDED HIGHER JOLLY	15.5	5.12	8.31	50.00	31.48	1.28	2.28	9.20	14.35	15.13	8.02	1.12	21.3	15.5
	0	0	0.00	2.58	3.82	0.20	0.85	0.21	0.42	7.50	0.51	0.41	34.5	10.8
RECORDED FOREIGN JOLLY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	EXEMPTED HIGHER JOLLY

MONTHLY RAINFALL EXTREMES (In Inches). SHIMBA HILLS SETTLEMENT.

1951 - 1966

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR	TOTAL MONTHLY EXTREMES
LOWEST TOTAL RECORDED	0	0	0.06	3.28	3.25	0.56	0.82	0.61	0.45	1.20	0.21	0.41	34.2	10.8
HIGHEST TOTAL RECORDED	5.21	2.16	8.31	20.00	21.48	7.99	9.59	6.50	14.22	12.70	8.65	7.16	67.2	104.0

RECORDED FISHERY LOGS	2'51	3'10	8'37	50'00	57'49	1'20	8'20	9'30	9'20	14'35	15'10	8'02	1'70	01'3	754'5
RECORDED FISHERY LOGS	0	0	0'00	3'30	2'52	0'20	0'85	0'42	0'57	0'42	750	0'57	0'47	34'5	70'8
	700'	600'	400'	200'	100'	50'	20'	10'	5'	2'	1'	0.5'	0.25'	0.125'	EXHIBIT NUMBER 10000

(vi) Lands between Mkundi and Jombo are somewhat drier than Kikoneni. Based on observations of local cloud development and the nature of the natural vegetation, one would be inclined to predict an annual rainfall in the extreme West at 40 to 45 inches.

Why should the short rains fall later at Kikoneni than at Shimba? The answer may lie in the difference between the two stations as regards Aspect. Shimba Hills face South-Eastwards towards the sea and so tend to receive more precipitation in the early stages of the short rains whilst Southerlies are still prevailing. Kikoneni, on the other hand, is sited on slopes facing North-Eastwards and is moreover immediately backed by Mrima Hill. Orographic rainstorms will, therefore, tend to develop over the Kikoneni sector whilst the North-East monsoon becomes established, i.e. at a later stage of the short rains.

The long rains are primarily frontal in character and so tend to be general, prolonged and more reliable. The short rains are primarily a result of convectional instability. The rain when it comes tends to be thundery in character, yet local and much dependent for development upon orographic influences and local low level convergence (as may occur around Jombo).

Monthly rainfall extremes recorded over 16 years at Shimba are compiled in Table 3. This well illustrates the unreliable nature of the rainfall, and demonstrates that mere consideration of monthly means can be quite misleading. Clearly, significant rainfall cannot be relied upon in any month other than April and May, and even the long rains may fail on occasion (as they did in 1961). The short rains can be expected to fail about one year in five; this implies that in some years little effective rainfall may be recorded between July and the following April. Indeed it must be anticipated that in a really exceptional year the total rainfall may not exceed 25 inches.

The prevailing climatic conditions when considered in relationship to the generally low moisture retaining capacity of the soils may help to explain the relative popularity of semi-drought resistant crops at Shimba - cashew, cassava, chillies and sesame.

(b) The Bedrock, Landscape and Drainage Systems

During the Survey, a strong correlation was established between the nature of the topography and the texture of the bedrock, the consequent drainage patterns serving admirably to illustrate the lithological variations of the Durama Sandstone succession (see Table A). This relationship was valuable in assessing soil parent material since the Geological Map ("Geology of the Mombasa - Kwale Area" by Caswell P.V. and Baker B.H.; 1953) was largely inaccurate when it came to considering the Project Area in detail: e.g. it greatly overestimates the extent of the Magarini Sands around Kidiani, and particularly between Kikoneni, Kiruku and Kigombero

(vi) Lands between Shamba and Jombo are somewhat drier than Likiep. Based on observations of local cloud development and the nature of the natural vegetation one would be inclined to predict an annual rainfall in the extreme west of 40 to 45 inches.

Why should the short rains fall later at Likiep at Shamba? The answer may lie in the difference between the two stations as regards aspect. Shamba Hills face south-eastwards towards the sea and so tend to receive precipitation in the early stages of the short rains at Shamba. At Likiep, on the other hand, it faces north-eastwards and so receives precipitation later. It is moreover immediately backed by the main island. The Kikomeal sector which the north-east monsoon has established, i.e. at a later stage of the short

The long rains are primarily frontal in character and tend to be general, prolonged and more reliable. Short rains are primarily a result of convectional activity. The rain when it comes is in a heavy character, but local and such dependent on development ofographic influences and local low level convergence occur around Jombo).

Monthly rainfall extremes recorded over 10 years at Shamba are compiled in Table 3. This well illustrates the variable nature of the rainfall, and demonstrates that considerable variation can be quite misleadingly, significant rainfall cannot be relied upon in any other than April and May, and even the long rains all on occasion (as they did in 1951). The short rains can be expected to fall about one year in five; this is that in some years little or no rainfall may be recorded between July and the following April. Indeed it is anticipated that in a really exceptional year total rainfall may not exceed 20 inches.

The prevailing climatic conditions were considered in relation to the generally low moisture content of the soils may help to explain the relative fertility of semi-arid resistant crops at Shamba - v. cassava, chilies and sesame.

(b) The bedrock, landscape and vegetation

During the survey a strong correlation was established between the nature of the topography and the texture of the bedrock. The topography and patterns serving directly to illustrate the lithological variations of the bedrock. This relationship was valuable in assessing soil parent material and the Geographical Map (Geology of the Marshes - Taira Area) by Caswell F.V. and Baker R.E. (1953) was largely inaccurate when it came to considering the project. Areas in detail are of great importance. The extent of the vegetation cover is also of particular importance between Likiep and Shamba.

T A B L E 4

% GRADE SIZES OF THE DURUMA SERIES.

PARTICLE DIAMETERS IN M.M.

< 0.10

0.25 - 0.10

0.5 - 0.25

1 - 0.5

2 - 1

MAZERAS

LOWER MAZERAS

MARIAKANI

MAJI-YA-CHUMVI

Grade Size	Mazeras	Lower Mazeras	Mariakani	Maji-Ya-Chumvi
< 0.10	1	7	9	74
0.25 - 0.10	22	32	40	25
0.5 - 0.25	29	46	2	1
1 - 0.5	48	15		
2 - 1				

PROPORTION OF AREA

5%
40%
20%
35%

All this country is underlain by massive, cross-bedded, coarse sandstone of the Mazeras (Upper Duruma) formation, which is relatively resistant to erosion. These sandstones are predominantly quartzitic, the included pebbles being generally weathered and often kaolinized. Micas and feldspars comprise the most common cementing materials and the rock is usually disintegrating. The mode of presentation of certain pieces of fossil wood has suggested the identification of a fossiliferous Upper Duruma layer. The weathering product is extremely poor in soil, and the soil fractions being of the clayey type. Mineralogically, the soil is of the kaolin type. As the soil is of the kaolin type, it is not suitable for agriculture. The soil is of the kaolin type, and the weathering product is extremely poor in soil, and the soil fractions being of the clayey type. Mineralogically, the soil is of the kaolin type. As the soil is of the kaolin type, it is not suitable for agriculture.

REPTILES - AMPHIBIANS

TRADITIONAL

FINISH PAPER

REPTILES

	J	82	34
	40	40	0
	35	J	
	55	J	

5	J	5	
48	48	50	

5 + J J - 0.2 0.2 - 0.52 0.52 - 0.10 < 0.10

EXPLICITE DIVISIONE EM M.W.

where, in fact, only a few patches remain in valleys and round the base of hillsides. In mitigation it should be remarked that it is often difficult to distinguish the weathering Triassic Duruma Sandstones from the dominantly quartzose Pliocene Magarini Sand, which was after all derived from the weathered and subsequently eroded Duruma Sandstone.

Seven distinctive landscape patterns are recognised in the Project Area:-

(1) The strongly upstanding conical hill features and steep ridges of Shimba, which constitute rather more than half the Project Area.

This landscape is very broken, consisting of winding watersheds with narrow ridges running down between steep-sided valleys. The heads of these valleys are often very steep and are in process of being cut back. Few of the ridges are more than 400 metres wide from the centre of one valley to the centre of the next and many valley slopes exceed 20° (34%). Of the area initially proposed for settlement between Kidongo and Kidiani (known as "Tanganyika"), it was estimated that the following slopes occurred:-

<u>SLOPES</u>	<u>PROPORTION OF AREA</u>
0 - 5%	5%
5 - 10%	40%
10 - 20%	20%
20%	35%

i.e. about half the land was assessed as being too steep for development, at least without elaborate bench terracing (slopes exceeding 8°, or 14%). This broken topography continues South of the Ramisi in Sadani location.

All this country is underlain by massive, cross-bedded, coarse sandstone of the Mazeras (Upper Duruma.) formation, which is relatively resistant to erosion. These sandstones are predominantly quartzose, the included feldspathic grains being generally weathered and often kaolinized. Micaceous and feldspars comprise the most common cementing materials and so the rock quite readily disintegrates. The mode of presentation of contained pieces of fossil wood has suggested that silicification was prevalent during Upper Duruma times. The weathering product is extremely poor in feldspars, the sand and silt fractions being almost entirely composed of quartz. Mineralogical analysis also indicated the frequent presence of a mineral having a spacing of 3.53 Å. As this is the only spacing detected, the mineral could not be identified. The lack of weatherable minerals, especially feldspars, explains the inherent infertility of soils derived from these coarse sandstones. The contained basic elements (and even clay minerals) are readily translocated ("podzolised") down through the coarse matrix, by washing, dispersion and solution. Thus the removal of the natural forest that promoted a closed nutrient cycle and the

where, in fact, only a few patches remain in valleys and round the base of hillsides. In mistletoe it should be remarked that it is often difficult to distinguish the weathering Triassic Durum Sandstones from the dominantly quartzose Pliocene Kauri Sand, which was after all derived from the weathered and subsequently eroded Durum Sandstone.

Seven distinctive landscape patterns are recognized in the Project Area:-

- (1) The strongly upstanding central hill features and steep ridges of Shimba, which constitute rather more than half the Project area.

This landscape is very broken, consisting of individual watersheds with narrow ridges running down between steep-sided valleys. The heads of these valleys are often very steep and are in process of being cut back. Few of the ridges are more than 100 metres wide from the centre of one valley to the edge of the next and many valley slopes exceed 30%. Of the area initially proposed for settlement between Kidongo and Kidiani (known as "Tanganika"), it was estimated that the following slopes occurred:-

PROPORTION OF AREA	SLOPES
5%	0 - 5%
40%	5 - 10%
20%	10 - 20%
35%	20%

... about half the land was assessed as being too steep for development, at least without elaborate bench terracing (slopes exceeding 5% or 10%). This broken topography continues south of the Kauri in Sabaki location.

All this country is underlain by massive, coarse-bedded, coarse sandstone of the Mbezi (Upper Kauri) formation, which is relatively resistant to erosion. These sandstones are predominantly quartzose, and include feldspathic grains being generally altered and often kaolinized. Micas and feldspars comprise the most common cementing materials and so the rock quite readily disintegrates. The beds of sandstone contained pieces of local wood has suggested that a significant was prevalent during the Durum times. The weathering product is a sandy soil in feldspars, the sand and silt particles being almost entirely composed of quartz. Petrological analysis also indicated the presence of a mineral having a spacing of 3.0 Å. This is the only spacing detected, the mineral could not be identified. The lack of weatherable minerals, especially feldspars, explains the inherent fertility of soils derived from these coarse sandstones. The contained basic elements (and even heavy minerals) are readily transported ("podsolized") via through the coarse matrix, by weathering, dispersion and solution. Thus the removal of the mineral forest at projected a closed nutrient cycle and the

subsequent losses due to cropping and intensified soil leaching impoverish the level of basic elements; these cannot be replenished from weathering minerals. The clay fraction ultimately derived from Mazeras sandstone is, however, found to include about 25% illite which provides a limited but continuing supply of potassium.

Certain hill summits and ridges at Shimba are covered with deep deposits of unconsolidated coarse sands (e.g. at Majimboni) and sandy loams (e.g. around Kichaka Simba). These can probably be explained as relic deposits of Magarini Sand. In general, however, the severity of the topography reflects the coarseness of the underlying sandstone. Thus, to take two extreme cases, coarse grits form a resistant capping to the summits of the Shimba Hills (above about 1,000 ft.); and Kidiani, a flat-topped but pre-eminent hill feature (543 ft.) is capped by a coarse breccia, probably formed from sandstone fragments cemented by iron compounds. On the other hand, the relatively gentle topography of the Bambakofini basin ("Tanganyika") derives from a finer textured sandstone and consequently gives rise to somewhat finer weathering products. The more upstanding hill features (e.g. especially those West of Lukore) are steeper-sided, more deeply incised and are underlain by coarser sandstones. The severely eroded escarpment leading up to the Shimba Hills Forest (at 400 feet rising to 700 feet or more) is mostly composed of exposed coarse sandstone outcrops. It was the variable conditions that prevailed during the original deposition of these sandstones that resulted in marked deviations in the distribution of the size grades and hence in the resulting relief.

The steep nature of the Shimba topography has caused considerable colluviation and erosion. Thus hilltops are covered with deep soil generally weathered in situ from Mazeras sandstone, but hill slopes are blanketed by very variable colluvial materials, ranging from coarse sand to coarse sandy clay depending on the local conditions prevailing during deposition. The finer colluvial fractions tend to be differentially eroded and are finally deposited on the lower apron slopes as loam and clay. Above these finer materials hill run-off tends to emerge as ill-defined, surface or sub-surface spring lines. Incursions of this acid drainage water have a profound effect on soil development downslope and are a cause of much hillside poor drainage. The valley bottom is normally V-shaped and very steep due to the active down-cutting of the stream into Mazeras bedrock; this represents a contemporary cycle of erosion, presumably resulting from recent uplift. Stream potholes are common. The sides of these 'mini-valleys' are normally flanked by sandstone outcrops. Alluvium is rare.

disseminated masses due to cropping and interstitial
of leaching impoverish the level of basic
elements; these cannot be explained from
weathering minerals. The clay fraction
entirely derived from massive sandstone is,
however, found to include about 2% illite which
provides a limited but continuing supply of
Aluminum.

Certain hill summits and ridges at Shinda
are covered with deep deposits of unconsolidated
coarse sands (e.g. at Majindori) and sandy loams
e.g. around Kichaka Shinda). These can probably
be explained as talic deposits of basaltic sand.
In general, however, the severity of the topography
affects the coarseness of the underlying sandstone.
As to take two extreme cases, coarse grained loam
resistant capping to the summits of the Shinda Hills
above about 1,000 ft.; and Kichaka, a Khat-
topped but pre-eroded hill feature (543 ft.) is capped
by a coarse sandstone, probably formed from sandstone
fragments cemented by iron compounds. On the other
hand, the relatively gentle topography of the
Mpakoloni basin ("Tanganyika") derives from a
finer textured sandstone and consequently gives
rise to somewhat finer weathering products. The
upstanding hill features (e.g. especially
those West of Lakore) are steeper-sided, more easily
eroded and are underlain by coarser sandstones. The
extremely eroded escarpment leading up to the Shinda
Hills forest (at 400 feet rising to 700 feet or more)
is mostly composed of exposed coarse sandstone outcrops,
was the variable conditions that prevailed during
the original deposition of these sandstones that
resulted in marked deviations in the distribution of
the size grades and hence in the resulting relief.

The steep nature of the Shinda topography has
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hills are covered with deep soil generally
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materials, ranging from coarse sand to coarse sandy
clay depending on the local conditions prevailing
during deposition. The finer colluvial fraction tends
to be differentially eroded and are finally deposited
on the lower apron slopes as loam and clay. Above
these finer materials hill profiles tend to emerge as
well-defined, surface or sub-surface sandstone lines.
Erosions of this sort drainage water have a profound
effect on soil development downwards and are a
cause of much hillside poor drainage. The valley
bottom is normally V-shaped and very steep due to the
active down-cutting of the stream into massive bedrock;
this represents a contemporary cycle of erosion,
mainly resulting from recent uplift. Stream
holes are common. The types of these "mini-valleys"
are normally flanked by sandstone outcrops. Aluminum

Many of the streams flowing off this landscape are seasonal, but the major systems are perennial, being constantly replenished from considerable reserves both above and within the coarse sandstone and grit formations.

The Jilore/Majimboni area (Soil Map 1) is drained by a system flowing Eastwards into the Mwachema. All these tributaries are seasonal. The Tanganyika/Mkomba basin (Soil Map 2) is drained Southerly by the much larger Mkurumuji which has cut a defile through the final Mazeras escarpment South-East of Settlement H.Q. A relatively high lying water-shed, which serves to carry the road (through Shimba Hills) to Kwale, separates the Mkurumuji basin to the East from the Lower Ramisi drainage system. This latter flows through narrow, steep-sided, parallel valleys (Soil Map 3), firstly in a South-Westerly direction and later Southerly before debouching into the Ramisi River (Soil Map 4). Three major systems are involved -

(i) The Lovu to the East, between Mwaluvanga and Kichaka Simba;

(ii) The Mkanda, between Kichaka Simba and Lukore;

(iii) The Choro Choro, between Lukore and Mkundi in the West. The perennial Mkanda through "river-piracy" has captured some of its neighbours' tributaries and is the largest and most active system. In Sadani (South of the Ramisi - Soil Map 5) the predominant direction of drainage is Eastwards.

(2) In contrast to the Shimba-topography, that prevailing between Kigombero and Jombo (Kikoneni - Soil Maps 5 and 6) is significantly more gentle, the country being underlain by a fine sandstone of the Lower Trias, the so-called 'Maji-ya-Chumvi' beds. These give rise to long and broad continuous ridges which may, nevertheless be steep-sided; or high mounds (a mile or so in diameter) like those surmounted by Kigombero and by Mwananyamala. It is rare for slopes to exceed 20° . Between these mounds and ridges are broad intervening valleys often U-shaped in cross-section, occasionally opening out into flat basins filled with colluvial/alluvial clays.

These Maji-ya-chumvi beds comprise generally dark often micaceous, fine sandstones (or coarse siltstone) which weather brownish or greenish and, which, being more easily eroded than the coarse sandstones of Shimba, allow the formation of broad valleys along their strike. Quartz and felspar are the dominant components, with quartz normally predominating. The rocks weather to illite and kaolin and the resulting soils contain higher levels of both silt and clay than those at Shimba. The reserves of weatherable minerals are considerable. There is nevertheless evidence for significant leaching.

Many of the streams flowed off this landscape are seasonal, but the major systems are perennial, being constantly replenished from considerable reserves both above and within coarse sandstone and grit formations.

The Jijora/Majumdar area (Soil Map 1) drained by a system flowing Eastwards into the Chama. All these tributaries are seasonal. The Jijora/Majumdar basin (Soil Map 2) is drained southerly by the much larger Mungwa which cuts a defile through the final Mungwa formation South-East not far from the actively high lying water-shed, which carries the road (through Shamba Hills) to the East across the Mungwa basin to the East from the Mungwa drainage system. This latter flows through narrow, steep-sided, gullied valleys (Soil Map 3), finally in a South-Westerly direction later southerly before debouching into the East River (Soil Map 4). Three major systems are involved -

(i) The flow to the East, between Mungwa and Kibaka Simba;

(ii) The Mungwa, between Kibaka Simba and Jijora;

(iii) The Choro Choro, between Jijora and Mungwa in the West. The perennial Mungwa through "river-grassy" wet captured some of its tributaries, tributaries and in the largest and most active system. In general (South of the East - Soil Map 5) the predominant direction of drainage is Eastwards.

In contrast to the Shamba-topography, that varies between Kibakoro and Jijora (Kibakoro - Maps 2 and 3) is significantly more complex, country being underlain by a fine sandstone of the Trias, the so-called 'Maji-ya-Chama' beds. These give rise to long and broad continuous ridges which may, nevertheless be steep-sided, or high and (a mile or so in diameter) take those sandstone Kibakoro and by Mungwa. It is rare for peaks to exceed 50'. Between these rounded and ridges broad intervening valleys often U-shaped in cross-section, occasionally opening out into flat basins filled with colluvial/alluvial clay.

These Maji-ya-Chama beds comprise generally K often micaceous, fine sandstone (or coarse sandstone) which weathers brownish or greenish and, being more easily eroded than the coarse sandstone of Shamba, allow the formation of broad levels along their strike. Levels and valleys are dominant components, with peaks generally dominating. The rocks weather to little and fine and the resulting soils contain higher levels of both silt and clay than those of Shamba. The series of weatherable shales are considerable, it is nevertheless evidence for significant folding.

The Maji-ya-Chumvi fine sandstones are typically current-bedded and well-jointed (3 sets of joints); aided by the laminar nature of the strata, the beds disintegrate into rectangular blocky fragments. Thus water falling on high ground tends to soak into the body of the rock and does not emerge as spring-lines at lower levels. Hence the soils on these hillsides are well drained. Local accumulations of colluvial sand occur on slopes, but are not as extensive as at Shimba. Lying above the decomposing sandstone there is normally an horizon of abundant but unconsolidated lateritic gravels (i.e. containing concretions of iron and manganese compounds). Within these gravels, there are often fragments or boulders of decomposing sandstone; sometimes well-rounded quartz pebbles are included. These latter may represent the remains of a former playa or part of some ancient river terrace. On slopes these gravels may accumulate to form sheets that outcrop locally.

Water draining off this landscape generally remains beneath the valley veneer of silty clay. Thus, except following the heaviest rains, there is not a great deal of stream flow; there are no perennial streams, with the possible exception of the Mamtambwi (between Kigombero and Kikoneni) in all but the driest years. Whilst the valley clays may be regarded as poorly drained, this is due to their inherently low permeability rather than the reception of drainage waters. The valleys tend to run North or North-Eastwards towards the Ramisi.

The relatively gentle Kikoneni landscape extends North of the Ramisi at Mwaluvanga, Kibuyuni and Mkundi. Between the Shimba - topography and the Kikoneni - topography there is some intermediate relief, where there tend to be broad flattish ridges yet with intervening steep slopes and partially incised streams. Here, as anticipated, the underlying rock is intermediate in texture being a medium sandstone; the soils proved difficult to classify, there being finer "Kikoneni" soils on the ridge tops and coarser "Shimba" soils on the steeper slopes. Areas with this intermediate relief include Vivwini, Nzilole, Mwazare, Godoma, Gandini, Mangawani and parts of Mauya (this latter may conceivably be underlain with Mariakani Sandstone).

Deviations from the normal Kikoneni - topography, yet occurring within the South-Western half of the Project Area, give rise to five distinctive landscape patterns of minor importance. These are:-

- (1) The superficial sandy deposits of Mkundi. (Soil Map 4)
- (2) The incised valley of the Ramisi. (Soil Maps 4 and 5)
- (3) The hot springs of the Ramisi valley. (Soil Map 4)
- (4) The river terraces at Mafisini. (Soil Map 5)
- (5) The alkaline intrusive of Jombo, and its associated satellite intrusions. (Soil Map 6)

The Malji-Churni line represents a typical current-bedded and well-sorted (sets of joints) : sided by the lateral accretion of the strata, the beds are irregular blocky fragments. The high ground tends to sink into the body of the rock and does not emerge as sharp ridges at lower levels. Hence the soils on these ridges are well lined. Local accumulations of siliceous sand occur on slopes, but are not as extensive as at Shimla. Above the decomposing zone there is usually an horizon of abundant but unconsolidated territic gravels (i.e. containing concretions of iron and manganese compounds). Within these gravels there are often fragments or borders of decomposing andstone; sometimes well rounded quartz pebbles are included. These layers may represent the remains of former plays or part of some ancient river terrace. slopes these gravels may accumulate to form sheets at outcrop locally.

Water draining off this landscape generally remains beneath the valley veneer of silty clay. us, except following the heaviest rains. There is a great deal of stream flow; there are no perennial streams, with the possible exception of the Mantahal (between Rigoberto and Kikoni) in but the driest years. Within the valley clay is regarded as poorly drained, this is due to its inherently low permeability rather than the seepage of drainage waters. The valleys tend to drain north or north-eastwards towards the Mantahal.

The relatively gentle Kikoni landscape extends north of the Mantahal at Mhambani, Kikoni and Mantahal. Between the Mantahal and the Kikoni - topography there is a zone of intermediate relief, where there tend to be broad flat-topped ridges with intervening steep slopes and partially incised streams. Here, as anticipated, the underlying rock is intermediate in texture being a medium andstone; this proved difficult to classify, these being "Kikoni" soils on the ridge tops and coarse "Mantahal" soils on the steep slopes. Areas with this intermediate relief include Mhambani, Kikoni, Rigoberto, Godama, Gandini, Kunguani and parts of Malji (this latter may conceivably be underlain with Kikoni sandstone).

Deviations from the normal Kikoni - topography, occurring within the same general half of the subject area, give rise to five distinctive landscape patterns of minor importance. These are:

- (1) The superficial sandy deposits of Mhambani. (Soil Map 4)
- (2) The lacustrine valley of the Mantahal. (Soil Maps 4 and 5)
- (3) The hot springs of the Mantahal valley. (Soil Map 4)
- (4) The river terrace of the Mantahal. (Soil Map 5)
- (5) The alpine terrace of the Mantahal and its associated features. (Soil Map 5)

(1) In Mkundi location, mostly North of the Ramisi but also to a limited extent to the South and undoubtedly underlain by Maji-ya-Chumvi beds, a gentle relief is masked by a considerable depth of superficial medium sands and sandy loams. These may have derived from the Shimba Hills during a previous erosion cycle in much the same way as the similar but (?) earlier Magarini Sands, or they may be related to the deep but intermittent sandy loams of the Lower Ramisi Valley. The deposits are not indicated on the Geology Map. On all but the summits, these sands are seasonally poorly drained due to the lateral reception of acid drainage. The broad shallow valleys only carry surface water after heavy rains.

(2) Much of the Lower Ramisi Valley comprises low mounds of (?) colluvial fine and medium sands, surrounded by low basins of poorly drained sand or rock pavement. The Ramisi is itself deeply incised within a relatively deep channel hemmed in by exposed sandstone. (Mazeras sandstone between Bambo and Mafisini; elsewhere Maji-ya-Chumvi). Steeper slopes near the Ramisi usually demonstrate sandstone outcrops as do certain of the neighbouring valley basins. In dry seasons the continuing flow of the Ramisi depends to some extent upon perennial hot springs.

(3) The alkaline hot springs relate to the presence of intrusive dykes composed mostly of lamprophyric monchiquite. These dykes, which are associated with the Jombo intrusive, rarely exceed 6 feet in width and are often much less. Since the hot water contains much dissolved salt, neighbouring soils are intensely saline and alkaline. Surrounding sand mounds may also become temporarily or permanently affected by alkali. The hot streams flow over jointed sandstone into the Ramisi.

(4) The flattish lands around Mafisini represent previous river terraces at somewhat different levels. These are covered by deep deposits of coarse and medium sands with occasional layers of coarse quartz gravels (an example of this latter is the outcrop in the Mamtambwi valley near Mwazare). These are the Magarini sands which also occur extensively around Mwaluvanga, and on the low ground that separates the Lovu and Mkanda confluences (with the Ramisi). The bulk of this Pliocene Magarini Sand is derived from Duruma Sandstones by water erosion and redeposition, though fractions may have an aeolian origin. It is predominantly coarse quartzose, and so highly weathered as to leave practically no weatherable minerals remaining. These highly infertile sands are poorly stratified, ill-sorted, generally unconsolidated and leached whitish or very pale brown. Associated streams tend to be acid and carry a fine peaty suspension (of a type that might make good whisky).

(5) The steep conical intrusives all have a somewhat dissimilar composition and are best described separately (based on 'Geology of the Mombasa - Kwale Area'; Caswell and Baker, 1953).

(1) In the lower part of the ...
 but also to a limited extent to the ...
 undoubtedly underlain by ...
 the relief is marked by a considerable ...
 horizontal ...
 have derived from the ...
 local erosion cycle in which the ...
 can be ...
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 The ...
 water after heavy ...

(2) Much of the lower ...
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(3) The ...
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(4) The ...
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(5) The ...
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(i) Jombo Mountain, which is the highest peak in the area (1,543 ft.), is sub-conical with a summit ridge running East-West. Its basal diameter is about $1\frac{1}{2}$ miles. This hill was probably first "discovered" by Hobley in 1895. It comprises alkaline rocks of great complexity. Since Jombo Forest Reserve is, in fact, outside the scope of the soil survey, these rocks need not concern us directly. However, the weathering of these rocks liberates quantities of basic elements (especially sodium) which are ultimately carried down the valleys emanating from Jombo. This partly explains the prevailing alkalinity of the valley subsoils in contrast with the marked acidity encountered in valleys on the Shimba side of the Ramisi.

(ii) Mrima Hill (982 ft.) is broad and dome-shaped, lying 5 miles South-East of Jombo. It is believed that this hill comprises sandstone capped by manganiferous laterite. Sections in the hillside reveal boulders of manganiferous laterite embedded in weathering sandstone and ferruginous earth. The gentler lower slopes (the only part actually within the Project Area) comprise deep, dark red clay presumably derived from weathered laterite. Sheet laterite and associated gravels lie close to the surface beneath shallow valleys leading off Mrima.

(iii) Kikonde Ridge, which extends from Mrima Hill in a North or North-Westerly direction, is long, sinuous and relatively low. It shows several exposures of altered and veined sandstone of the Maji-ya-Chumvi type. The contained syenitic veins rarely exceed 40 m.m. in width, but are numerous and invariably strike in the direction of Jombo. These rocks are said to be fenitized; this is a process that may be simply but incompletely explained as metamorphism by alkaline materials, whereby silica is abstracted from the country rock whilst sodium, potassium and sesquioxides, inter alia, are added. The sides of Kikonde are masked by lateritic gravels.

(iv) The conical Kiruku Hill (626 ft.) lies some 3 miles North-East of Mrima. In plan, it is roughly ovoid with a greatest dimension of 500 metres at the base. The outcrops on the summit and upper slopes consist of dark chert containing numerous brecciated fragments of partly silicified sandstone. This silicified agglomerate forms the infill of an explosion vent. As at Mrima a deep reddish clay covers the lower apron slopes.

(v) At Nguluku, there is another steeply conical (to just under 500 ft.) ex-explosion vent situated about 4 miles North-East of Jombo. The outcrops on the summit and upper slopes consist of sandstone and shale agglomerate set in a siliceous and calcareous matrix.

(c) Composition of the Drainage Waters

Table 5 illustrates the chemical composition of typical surface drainage waters. The general character of the drainage systems is described above (Section 2 (b)).

(i) Jombo Mountain, which is the
 east peak in the area (1, 2, 3, 4, 5) is sub-
 local with a summit ridge running east-west. The
 diameter is about 1000 ft. This ridge was
 probably first "discovered" by Hottel in 1905. It
 crosses alkaline rocks of great complexity. Since
 the Forest Reserve is, in fact, outside the scope
 of the soil survey, these rocks need not concern us
 here. However, the weathering of these rocks
 creates quantities of basic elements (especially
 iron) which are ultimately carried down the
 valley emanating from Jombo. This partly explains
 the prevailing alkalinity of the valley siltstone in
 contrast with the marked acidity encountered in
 the siltstone on the opposite side of the Range.

(ii) Mines Hill (925 ft.) is broad and
 fan-shaped, lying 2 miles south-east of Jombo. It
 is believed that this hill comprises sandstone capped
 by manganese laterite. Sections in the hillside
 show boulders of manganese laterite embedded in
 a matrix of sandstone and ferruginous earth. The
 lower slopes (the only part generally within
 the Project Area) comprise deep, dark red clay
 sandstone derived from weathered laterite. Under
 this and associated gravels lie close to the
 surface shallow valleys leading off Mines.

(iii) Kiondo Ridge, which extends from
 the Hill in a north or north-westward direction,
 is long, sinuous and relatively low. In places several
 hundred feet of altered and veined sandstone of the
 Lys-Chumvi type. The contained siltstone is
 only about 40 m.m. in width, but are numerous and
 usually strike in the direction of Jombo. These
 are said to be faulted; this is a possibility
 that may be simply but incompletely explained by
 amorphism by alkaline materials, which siltstone is
 fractured from the country rock which siltstone
 and sandstone, inter alia, are added.
 Siltstone and sandstone are marked by laterite gravels.

(iv) The conical Peak (925 ft.)
 is some 3 miles north-east of Jombo. In plan, it
 is roughly oval with a general direction of
 north-south. The base of the summit
 upper slopes consist of dark chert containing
 various precipitated fragments of highly silicified
 sandstone. This silicified sandstone forms the
 rim of an explosion vent. As it forms a deep reddish
 clay covers the lower slopes.

(v) At Kiondo, there is another steeply
 conical (to just under 100 ft.) explosion vent
 located about 4 miles north-east of Jombo. The
 crops on the summit and upper slopes consist of
 sandstone and siltstone alternating in a siliceous
 calcareous matrix.

Composition of the Hyaline Water

Table 2 illustrates the chemical composition
 of typical surface drainage waters. The general
 character of the drainage systems is described
 in Section 3 (v).

TABLE 5
ANALYSES OF DRAINAGE WATERS

	KITONI HOT SPRING	RAMISI RIVER	DRAINAGE OFF JOMBO	MAMTAMBWI RIVER	MKANDA RIVER	MKURUMUJI RIVER
pH	7.5	6.7	6.9	6.3	6.5	7.1
E.C. m.mhos	8500	650	187	108	125	128
Na m.e./l	73.9	2.7	0.7	0.7	0.6	0.6
K "	1.6	0.1	0.1	TRACE	0.1	0.1
Ca "	1.7	0.7	0.6	0.3	0.3	0.4
Mg "	1.3	1.0	0.6	0.1	0.3	0.3
CO ₃ "	NIL	NIL	NIL	NIL	NIL	NIL
HCO ₃ "	18.4	2.7	2.0	1.4	1.4	1.4
Cl "	78.3	6.2	1.0	1.0	1.1	1.1
SO ₄ "	NIL	NIL	NIL	NIL	TRACE	NIL

Cl	18.3	8.5	1.0	1.0	1.1	1.1
HCO ₃	18.4	5.1	5.0	1.4	1.4	1.4
CO ₃	NIL	NIL	NIL	NIL	NIL	NIL
MG	1.3	1.0	0.8	0.1	0.3	0.3
Ca	1.2	0.2	0.8	0.3	0.3	0.4
K	1.8	0.1	0.1	13.0	0.1	0.1
Na	23.2	5.2	0.3	0.1	0.8	0.8
S-C. in. area	8200	820	162	108	152	158
PH	7.3	8.2	8.8	8.3	8.2	7.1

ANALYSES OF DEBRIDGE WATERS
TABLE 2

The most extensive drainage basin in the Project Area, that of the Ramisi, is responsible for transporting the highest concentration of electrolyte. It should be noted that the Ramisi water was sampled during heavy rains and is, therefore, much diluted by surface run-off. The river water would be classed as being of Medium to High Salinity. During the dry season, however, when this water derives from ground-water reservoirs and from the numerous and highly saline hot springs, it can be predicted that its salt content will be markedly more concentrated. Despite seasonal dilution, even the sample reported in Table 4 demonstrates a fairly high content of chloride, so illustrating its partial dependence on supply from the hot springs which are characterised by exceptionally high chloride concentrations (c.f. Columns 1 and 2: Table 4). If Ramisi water were ever considered for irrigation, contained salinity is such that it could only be used on permeable and non-alkaline soils.

The saline Hot Springs probably derive from subterranean regions where aquifers transect hot volcanic dykes. These waters contain very high concentrations of sodium, chloride and bicarbonate; they also appear to be rich in iron. Since sulphate was not detected, it is suggested that the "sulphurous" aroma derives from an organic source (algae or bacteria).

A small temporary stream flowing North-Eastwards off Jombo was sampled after rains to illustrate the nature of seasonal surface waters in that area. Though apparently transporting a small amount of salt, the water would be satisfactory for rice if impounding by bunds proves feasible.

The Mkanda and the Mkurumuji are the major rivers flowing off this part of Shimba. The Mkanda was sampled within the Settlement Scheme; the Mkurumuji sampled near its estuary at Msambweri. Both demonstrate a low mineral content and a near-neutral reaction. These waters may be presumed to be representative of streams flowing off the Mazeras and Mariakani Sandstones of Shimba Hills and, from the point of view of quality, are admirably suited to irrigation. In contrast, streams flowing through the leached coarse Magarini Sands, as typified by the Mamtambwi near Mwazare, are somewhat acid; and, though low in electrolyte, contain a fine suspension of peaty humate.

(d) Vegetation Associations and Edaphic Types

The woody vegetation of the project area has been described by Dale (Imperial Forestry Institute Paper 18, 1939. "The Woody Vegetation of the Coast Province".) Intensive plant collections were made by Verdcourt on Mrima Hill. An introductory outline of the general ecology has been attempted by Moomaw ("Plant Ecology of the Coast Region". 1960. Government Printer, Nairobi.) A study of the vegetation is not included within the scope of this survey; and the following notes, far from being exhaustive, are merely set down to provide some

/over ...

The most extensive drainage basin in the project area, that of the Ramist, is responsible for transporting the highest concentration of electrolyte. It should be noted that the Ramist water was sampled during heavy rains and, therefore, much diluted by surface runoff. The water would be treated as being of medium to high salinity. During the dry season, however, when this water derives from ground-water reservoirs and from the numerous and highly saline hot springs, it can be predicted that its salt content will be markedly more concentrated. Despite seasonal fluctuations, even the sample reported in Table 4 demonstrates a fairly high content of chloride, as illustrating its partial dependence on supply from the hot springs which are characterized by exceptionally high chloride concentrations (see Columns 1 and 2, Table 4). If Ramist water were not considered for irrigation, contained salinity is such that it could only be used on perennials and non-alkaline soils.

The saline hot springs probably derive from subterranean regions where sulfates, nitrates and volcanic dykes. These waters contain very high concentrations of sodium, chloride and bicarbonate; they also appear to be rich in iron. Since sulfate was not detected, it is suggested that the "sulfurous" aroma derives from an organic source (sulfide or bacteria).

A small temporary stream flowing Northwards off Jumbo was sampled after rains to illustrate the nature of seasonal surface waters in that area. Though apparently transporting a small amount of salt, the water would be satisfactory for use in irrigating by double cropping.

The Manda and the Manda are the major rivers flowing off this part of the Manda. The Manda was sampled within the settlement scheme; the Manda was sampled near its estuary at Manda. Both demonstrate a low mineral content and a neutral reaction. These waters may be presumed to be representative of streams flowing off the Manda and Manda sandstones of Shimo Hills and, from the point of view of quality, are markedly suited to irrigation. In contrast, streams flowing through the leached coarse Manda beds, as typified by the Manda near Manda, are somewhat acid; and though low in electrolyte, contain a fine suspension of peaty humus.

(4) Vegetation Associations and Basic Types

The woody vegetation of the project area has been described by Dale (Imperial Forestry Institute Paper 18, 1939). "The woody vegetation of the Coast Province." Intensive plant collections were made by Veracourt on Mima Hill. An introductory outline of the general ecology has been attempted by Noyes ("Plant Ecology of the Coast Region", 1938). Government Printer Nairobi. A study of the vegetation is not included within the scope of this survey, and the following notes are from being extensive, are merely set down to provide some

indication of the prevailing ecological conditions. Associated soil types quoted below are described in Sections 3 and 4.

The general aspect of the natural vegetation is of open bush and grassland with varying proportions of savanna bush species. Occasional patches of remnant forest occur. The essential association has been well named by Edwards (Empire Journal of Experimental Agriculture 24. p.89. 1956) as "Coastal high grass - bush".

There can be little doubt that much of the vegetation cover is, in fact, a secondary sub-climax variously maintained by fire, shifting cultivation, elephant, etc. The presence of rather widespread remnant pockets of tall rain-forest (supported during the long dry season by mist deposition) suggests that this association was previously more widely disseminated on at least the better drained and seasonally poorly drained soils, with the exception of the really coarse whitish sands (Soils 14, 52). It would seem that much of this forest was at one time felled and the soils subsequently cultivated. (Some forest destruction has also recently been caused by logging). Then as a probable consequence of both the slave trade and smallpox, much of the land became abandoned. Old mango trees scattered amongst the bush and even in high woodland testify to the considerable extent to which the countryside was once occupied.

The invading moist savanna type was subject to periodic burning. It has been proposed by Dale that this history of human disturbance may well have influenced the migration of the Doum Palm (Hyphaene coriacea) which originated along the forest edges of swampy land, but now occurs on many soil types, on well drained as frequently as on poorly drained sites. Indeed the country around Lukore may be designated 'Doum Palm parkland savanna' such is the widespread nature of this palm (it is rapidly spread by animal vectors, especially baboon, elephant and man). The disturbed history of the Shimba Hills also accounts for the extensive distribution of the unpalatable and poorly nutritious grass (Andropogon which characterises burnt-over and infertile soils. This grass (together with Hyparrhenia and Digitaria) grows tall but, especially on the sandier topsoils, tends to form separate clumps with bare soil patches in between. The grass clump roots extend down to 2 feet below ground level and spread laterally so providing a continuous subsurface root mat that helps bind the soil.

There is considerable doubt as to whether primary forest regeneration is possible. Dale has suggested that loss of soil minerals following forest destruction is the factor limiting its potential for regeneration. Whilst this may be a plausible hypothesis in some parts of the tropics, it does not seem to apply in the project area. Moomaw failed to detect any difference between soils inside and those outside the forests; the results of this survey indicate that the forest litter, though rapidly decomposed, is, in fact,

Indication of the prevailing ecological conditions associated soil types noted below are described in sections 2 and 3 of the report.

The general aspect of the natural vegetation of the area and grassland with varying proportions of various soil types. Occasional patches of remnant forest occur. The essential association has been noted by Edwards (Empire Journal of Experimental Agriculture, 1955) as "Coastal high grass - bush".

There can be little doubt that much of the vegetation cover is, in fact, a secondary sub-forest variously maintained by fire, shifting cultivation, elephant, etc. The presence of rather widespread remnant pockets of tall forest (supported during the long dry season by a soil deposit) suggests that this association was previously more widely disseminated on at least the better drained and seasonally poorly drained soils, with the exception of the really coarse white sands (Soils 14, 23). It would seem that much of this forest was at one time killed and the soils subsequently cultivated. Some forest destruction has also recently been caused by logging. Then as a probable consequence of both the slave trade and malaria, much of the land became abandoned. Old mango trees scattered amongst the bush and even in high woodland testify to the considerable extent to which the countryside was once occupied.

The invading forest growth type was subject to periodic burning. It has been proposed by Dale that this history of human disturbance may well have influenced the migration of the palm rain (Nephrolepis) which originated along the forest edges of swampy land, but now occurs on very soil types, on well drained or frequently on poorly drained sites. Indeed the country around Lakeore may be designated 'palm rain parkland' savanna' such as the widespread nature of this palm (it is rapidly spread by animal vectors, especially baboon, elephant and man). The disturbed history of the Shamba Hills also accounts for the extensive distribution of the impatiens and poorly nutritious grass (Andropogon) which characterizes burnt-over and infertile soils. This grass (together with Hyparrhenia and Digitaria) grows tall but, especially on the sandy topsoils, tends to form separate clumps with bare soil patches in between. The grass clump roots extend down to 2 feet below ground level and spread laterally so providing a continuous substrate root mat that helps bind the soil.

There is considerable doubt as to whether primary forest regeneration is possible. Dale has suggested that loss of soil nutrients following forest destruction is the factor limiting its potential for regeneration. Whilst this may be a plausible hypothesis in some parts of the tropics, it does not seem to apply in the present area. Thomas failed to detect any difference between soils inside and those outside the forest; the results of this survey indicate that the forest litter, though rapidly decomposed, is, in fact,

very acid. Seedlings of "Mvule" (Chlorophora excelsa) near Kwa fail to become established when open plots. Some natural regeneration is evident along the margins of experimental plots. Observations would seem to support the idea that it is the level of soil moisture that determines the success of establishment, especially in the relatively low rainfall (found only in the humid microclimate of forest or tall coppice that seedlings

Throughout the project, it is clear that characteristic edaphic types develop in response to differences in soil moisture. Thus a distinct vegetation develops on deep and reasonably fertile loams and loamy sands. (Soils 53). This is dominated by Panicum coeruleum; and may include Brachiaria and Euphorbia nyikae in the extreme. The grass cover is dominated by Panicum and Digitaria mombasana. The cycad hildebrandtii may be seen in the woodlands. Most occurrences of this woodland are associated with the presence of water at depth. On even coarser sands, especially during severe droughting, very little grass and the grass is sparse and stunted. A common bush species is the dwarf Hyphaene parvula. A few of the more resistant species of the neighborhood invade along the fringes. Where coarse sand is underlain by subsoil (as is the case with Soil 52) the vegetation is dominated by the bracken fern Pteridium and Phoenix reclinata and Raffia in coarse sandy and acid riparian areas (Soil 80). The distinctive bushy vegetation and woodlands in the swamps between the Ramisi Sugar Estate were not described.

The poorly drained areas of the Ramisi are mostly of open grassland by Hyparrhenia/Themeda with scattered Coast Whistling Thorn (Acacia). Denser clumps of savanna bush occur in these situations on termitaria and small pockets of gravels. Open grassland in the Shimba Hills often represents a result of lateral seepage and hence seasonal flooding, though these areas may now be dominated by grass fires.

Dry rocky sites also may carry a few stunted specimens (baobab), Commiphora pteleifolia with Cassine shweinfurthiana, and Mariscus circumclusus. This is a colonizer of bare ground along seepage lines.

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Cissus rotundifolia
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very acid. Seedlings of "Wauke" (*Chlorophora excelsa*) near Kwaia (soil 1) fail to become established when planted out in open plots. Some natural regeneration is, however, evident along the margins of existing forest. These occurrences would seem to support the contention that it is the level of soil moisture that determines the success of establishment. One to the relatively low rainfall (for inland) it is only in the humid microclimate provided by existing forest on tall slopes that seedlings can thrive.

Throughout the project area it was found that characteristic edaphic types essentially develop in response to differing levels of available soil moisture. Thus a distinctive open woodland develops on deep and porous, well drained sandy loams and loamy sands. (Soils 4, 5 and occasionally 32). This is dominated by *Pterocarpium* *concolorum* and may include *Islandia* *sp.* and *Lophocarpus* *sp.* in the extreme west. Ground cover is dominated by *Islandia* *sp.* and *Lophocarpus* *sp.*. The *Cyrtosperma* *sp.* may be seen in the *Pterocarpium* *concolorum* woodlands of this woodland area, however, associated with the presence of ground water at depth. On even coarse sands (soil 14) subject to really severe droughting, very few species survive and the grass is sparse and stunted. The most common grass species is the dwarf *Themis* *sp.*. *Hypochaeris* *sp.*. A few of the more resistant species of the neighbourhood may invade along the fringes. Where, however, the coarse sand is underlain by subterranean water (as is the case with soil 52) the ground may be covered by the broken fern *Pteridium* *sp.*. The same *Themis* *sp.* and *Lophocarpus* *sp.* are encountered in coarse sands and silt regions on steep slopes and woodlands in the swamps between Mamuti and the Mamuti Paper Estate were not described.

The poorly drained clay soils south of the Mamuti are mostly of open grassland dominated by *Hypochaeris* *sp.* with some open patches of *Themis* *sp.* (Soil 53). These patches of savanna have only found in these situations on summits or where there are pockets of gravel. Open grass patches on the Shikha Hills often represent areas with considerable litter, sedge and ferns associated with them. Though these areas may now be primarily maintained by grass fires.

Dry rocky sites along the Mamuti valley have carry a few scattered specimens of *Themis* *sp.* (Soil 54), *Commersonia* *sp.* and *Lophocarpus* *sp.* with *Themis* *sp.* and *Lophocarpus* *sp.* and *Marrubium* *sp.* in the *Themis* *sp.* *concolorum* *sp.* is a colonizer of bare ground over on stony hills. Sedge lines.

Grass/bush savanna grows on most of the intermediate-textured and reasonably well drained soils (found on Soils 1, 2, 4, 5, 7, 10, 12, 50, 51, 53). The composition of the bush South of the Ramisi is somewhat different from that to the North though there is a considerable overlap of species. The bush in the Kikoneni sector tends to be taller and denser than that at Shimba and the associated grass cover may be quite different even on similar soils. The reason for this would seem to be partly historical and partly due to differing patterns of burning.

Since the Kikoneni sector is still largely uncleared it is best to describe this type of secondary bush as a basis for comparison. The following is a list of representative bush species:-

Acacia clavigera, A. mellifera, A. hockii,
A. nilotica, Adansonia digitata, Albizia glaberrima,
Annona chrysophylla, Boscia salicifolia,
Commiphora spp., Dalbergia melanoxylon, Diospyros sp.,
Fagara chalybea, F. holtziana, Fernandoa magnifica,
Haplocoelum sp., Lanea stuhlmannii, Maerua angolensis,
Manilkara mochisia, Ormocarpum kirkii, Rytigynia
oligacantha, Sclerocarya caffra, Stereospermum
kunthianum, Strychnos spp., Terminalia prunioides,
Tricalysia ovalifolia, Vitex doniana, Ziziphus
mauritiana: Accompanied by the major grasses;
Hyparrhenia spp., Panicum maximum and Themeda triandra.

The major bush species of the Shimba savanna are:-

Afzelia cuanzensis, Albizia glaberrima, Annona chrysophylla, Dichrostachys cinerea, Ehretia sp., Ficus bussei, Harrisonia abyssinica, Heeria mucronata, Lanea stuhlmannii, Markhamia zanzibarica, Piliostigma thoningii, Securidaca longepedunculata, Stadmannia sideroxylon, Stereospermum kunthianum, Tetracera boiviniana; and the grasses Andropogon and Hyparrhenia, with Digitaria mombasana and some Setaria sphacelata. Clipping studies have shown that the forage produced in one season is between 10 and 15 tons per acre on a dry-weight basis (Moomaw). Two 'sage' bushes are rapidly invading Shimba and threaten to choke some of the grassy glades in the hills. These are Lantana camara (the "Curse of India") and Vernonia zanzibarensis. Though both these bushes may on occasion be seen together, the Vernonia is more often found on coarser textured soils.

The heads of each tributary valley at Shimba are often covered by a clump of dense bush. It may be important to retain this bush so as to inhibit erosion. This may, however, obstruct the drive to reduce tsetse infestation.

Many of the species in the forested patches are those of the rainforest community, e.g. Afzelia cuanzensis, Albizia sp., Apodytes dimidiata, Erythrophleum guineense, Sorindeia obtusifoliolata, and Trichilia roka (Moomaw).

Apart from the Doum Palm savanna described above, parts of Central Shimba are characterised by remnant stands of Borassus Palm (Borassus aethiopum.), especially on the seasonally poorly drained soils around Kidiani.

Dale reported that the Shimba, Muhaka, Mrima and Buda forests are essentially of one type with minor variations, and are of a somewhat dry nature. The highest storey species include (after Dale and Verdcourt):-

Afzelia quanzensis, Albizia spp., Antiaris toxicaria, Bombax rhodognaphalon, Cassipourea eurypoidea, Chlorophora excelsa, Cola spp., Combretum schumanii, Erythrina webberi, Erythrophleum guineense, Fagara sp., Fernandoa magnifica, Lannea amaniensis, Lova swynnertonii, Manilkara sansibarensis, Melanodiscus oblongus, Memecylon verrucosum, Mimusops spp., Newtonia paucijuga, Pachystela sp. Parkia filicoidea, Sterculia appendiculata, Terminalia kilimandscharica, Trachylobium verrucosum, Uvariadendron sp., Vitex sp.

On poorly drained moderately alkaline sandy clay in the general vicinity of hot springs and their associated effluents, common herbaceous plants include:-

Buchneria hispida, Fimbristylis dichotoma, F. obtusifolia, F. triflora, Hibiscus cannabinus, Jatropha spicata, Lobelia anceps, Pluchea sordida, Pycneus hildebrandtii. On better drained, shallower or more highly alkaline sites, however, the plant cover is very sparse; where these conditions are combined with a topsoil concentration of salts the sandy surface is usually bare. Very poorly drained and alkaline organic bog soils are usually sparsely covered by stunted sedges and grasses - Cyperus difformis, C. laevigatus, Sporobolus sp. near marginatus; with a species of Blepharis, which normally dominates the raised alkaline bogs. In areas subject to frequent incursions of cold saline and alkaline waters, one finds individual tussocks of Cyperus laevigatus and Fimbristylis obtusifolia; sites flooded by hot spring water are invariably barren.

(e) History of Settlement

From considerations of the remaining natural vegetation, it may be surmised that:-

(a) Much of the Kikoneni/Mwananyamala/Gandini areas were extensively cultivated at some time in the past.

(b) Those East Shimba areas bearing open savannah had also been previously settled.

(c) The open glade/forest thicket areas of West Shimba were, however, a natural sub-Climax maintained by elephants and perennial fires.

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It may, therefore, be postulated that, with the exception of Nikunde, Kidongo, Lukore, Mkomba and Kichaka Simba, much of the project area used to be settled. Wadigs oral tradition, such as it is, tends to support this. The people probably moved into the South Coast and North Tanganyika in response to the Southward pressure from the Gallas and Somalis, possibly originating from the hinterland behind Malindi or Lamu. It was the slave trading and subsequent waves of smallpox of the last century rather than minor raiding from the Masai that initiated depopulation. The Digs way of life centres around the Village and so, as local populations were decimated, the survivors tended to consolidate in a few centres where the soil was most fertile and water relatively plentiful. These were Kibuyuni, Mangawani, Muhaka, Kidiani, Mwaluvanga, Mwananyamala and Nguluku (Kikoneni).

With the improvement in communications afforded by the new Coast road and the associated social amenities and trading facilities, a steady drift of population then occurred from the hinterland to the Sea Coast. This movement of population Eastwards may have been enhanced by the increasing difficulties of dealing with the advancing bush and consequent depredation by game, or it may have been fear of further smallpox outbreaks. Whatever the reason, whereas in 1925 the Kikoneni area had a rather greater population than Msambweni, by 1940 it had only half. Mrima, Nzole, and Mafisini likewise declined. The Shimba Hills feasibility survey of 1949 made estimates of the numbers of huts in the following localities:-

Mwapala	6:	Jilore	10:	Nzole	2
Mbambakofini	5:	Kichaka Simba	3:		
Nguluku (Kidiani)	30:	Mangawani and Kibuyuni	about	70.	

Incidentally the only livestock recorded on this same survey were 3 lonely goats at Nzole!

The first proposal for official settlement within the project area would appear to have been made in 1938 - 15 acre holdings to be developed between Mrima and Kikoneni to relieve "coastal congestion". It was at that time pointed out that settlement there would be dependent upon increased water supplies. Also in 1938, proposals were put forward for the return of Mafisini (then alienated) to the African Reserve on "approved lines of control" with 10 to 12 acre holdings.

With the outbreak of war the possibility for development vanished.

After hostilities had ceased, official interest switched from the Kikoneni area to the lands South and East of the Shimba Hills, despite insistence from Mombasa that Kikoneni was the more fertile. It seemed that the argument that told in favour of Shimba was its easier access through Muhaka. Areas South of the Ramisi River were at this time exceedingly remote, it is true. However, despite the closer proximity of Shimba Hills to Mombasa and the Coast road, because of broken

topography internal communications were exceedingly difficult, whilst Kikoneni on the other hand had been opened up by the new link road from Msambweni to Lungu Lungu.

With unaccustomed determination but customary pig-headedness, the Administration in 1949 called on the Coast Development Officer to present a report concerning the suitability of the Shimba area for African Settlement. At an early stage of this survey (March, 1949) the Officer hazarded the opinion that, having regard to the steep slopes at Shimba Hills and the discontinuous nature of the relief, the scheme area would be most profitably employed growing marketable timber; and an agricultural assistant, asked at this time after a visit to the Shimba Hills whether Giriama would like to settle there, is reported as answering "No, because the land is no good for maize".

In his final Report (July, 1949) the Development Officer presented rudimentary and wholly misleading views regarding the soils. Based solely upon consideration of the natural vegetation, he declared that "the area appears to be very fertile". He further failed to perceive those crucial differences in texture (and hence in consistency, organic content and general fertility) that serve to distinguish the reddish soils at Kikoneni from those at Shimba Hills.

The Shimba Hills Settlement Scheme was finally launched at a meeting of the Coast Provincial 'Team' in August 1950, when it was agreed to initiate a demonstration area of up to 240 acres.

The earliest settlers came from Taita Hills, but in 1954 the first party arrived from Machakos. The initial aim was to develop farms of 20 acres, based on a system of topographic layout; contour strips of tree crops separating arable fields, tied ridging, and the use of farm yard manure and phosphates (the latter at 1 cwt. superphosphate per acre). Experience soon demonstrated that crops could not be grown economically without fertilizer: diseases and soil infertility took a heavy toll in these early years.

The 12 acre arable area assigned to each farm (there was also 1 acre set aside for the homestead) was divided into 3 blocks, with 9 fields in all (each of $1\frac{1}{3}$ acres), subject to a 3 x 6 rotation, each section being cultivated for 3 years with maize, cowpeas, cassava, cotton and groundnuts. The balance of the acreage was reserved for grazing, with trees (cashew and kapok) planted along the farm boundaries. The original plan also envisaged communal grazing.

In practice the Scheme actually developed along more flexible lines, since the layout and utilization of each holding were modified according to the variability of the topography and the soils. Farmers were discouraged from cultivating slopes in excess of 14%. Sesame, grams, chillies and sweet

topography internal communications were exceedingly difficult, whilst Kikometi on the other hand had been opened up by the new link road from Masambani to Tanga Island.

With unobscured determination but customary pig-headedness, the Administrator in 1949 called on the Coast Development Officer to present a report concerning the suitability of the Shimoa area for African settlement. At an early stage of this survey (March, 1949) the Officer handed the opinion that, having regard to the steep slopes at Shimoa Hill and the discontinuous nature of the soil, the scheme area would be most profitably employed growing marketable timber; and an agricultural assistant, asked at this time after a visit to the Shimoa Hill weather station would like to settle there, is reported as answering "No, because the land is no good for maize".

In his final report (July, 1949) the Development Officer presented rudimentary and woefully misleading views regarding the soils. Based solely upon consideration of the natural vegetation, he declared that "the area appears to be very fertile". He further failed to perceive those crucial differences in texture (and hence in consistency, organic content and general fertility) that serve to distinguish the reddish soils at Kikometi from those at Shimoa Hill.

The Shimoa Hill settlement scheme was finally launched at a meeting of the Coast Provincial Team in August 1950, when it was agreed to initiate a demonstration area of 50 to 500 acres.

The earliest settlers came from Tanga Hill, but in 1954 the first party arrived from Masambani. The initial aim was to develop farms of 20 acres, based on a system of topographic layout, contour strips of tree crops separated by 15-20 ft. wide ridging, and the use of farm yard manure and phosphate (the latter at 1 cwt. superphosphate per acre). Experience soon demonstrated that crops could not be grown economically without fertilizers; diseases and soil infertility took a heavy toll in these early years.

The 12 acre arable area assigned to each farm (there was also 1 acre set aside for the homestead) was divided into 2 blocks, with 2 fields in all (each of 1/2 acre), subject to a 2 x 2 rotation, each section being cultivated for 2 years with maize, cowpeas, cassava, cotton and groundnuts. The balance of the acreage was reserved for grazing with trees (cassava and kapok) planted along the farm boundaries. The original plan also envisaged communal grazing.

In practice the scheme actually developed along more flexible lines, since the layout and utilization of each holding were modified according to the variability of the topography and the soils. Farms were distributed from existing blocks in excess of 1 1/2 acres, trees, timber and small

potatoes were soon added to the rotation, whilst cotton proved to be quite uneconomic. The proportion of tree crops was restricted owing to their detrimental effect in promoting the tsetse population, already a menace to stock. Great stress was laid on the role of livestock in producing farm yard manure; on each holding a maximum of 8 cattle and 15 sheep were permitted. Goats were, however, forbidden. Communal grazing was never, in fact, allocated, and the size of the individual holdings varied between 20 and 25 acres.

In the late 1950s it was proposed to realign the Scheme based on a sugar economy, as outgrowers supplying the Ramisi sugar mills. For some time much cane was grown on holdings; but all foundered on problems arising over cane cutting and transportation. In this regard, it should be noted that the nearest point on the scheme (Kidiani) is 9 miles direct from the factory; by road it is very much further. In 1958, there were signs of renewed international interest in Anatto, a red dye produced from the seeds of BIXA ORRELANA. Several acres were initially planted at Mtwapa and latterly heavy plantings of Bixa have taken place on the Shimba Hills.

Throughout the whole period of the Scheme's operation, Chillies have maintained their position as by far the most important cash crop.

Up until 1966, about £50 was invested in each new settler to cover - first rations, ploughing and land preparation, fertilizers, bush clearing and necessary transport. This aimed at making a farmer self-supporting within 6 months.

During 1966, the British-American Tobacco Company (B.A.T.) initiated trials to assess the feasibility of growing tobacco at Shimba. Curing barns were constructed at the Settlement H.Q.

(f) Existing Pattern of land use.

The 83,000 acre project area is made up as follows:-

	<u>Acres</u>
Shimba Hills Settlement Scheme (S.S.S.)	35,000
Lands North and East of Ramisi River (not scheduled in S.S.S.). Mafisini to Mkundi.	16,000
Proposed Kikoneni Scheme, including lands demarcated South and West of the Ramisi River. Mafisini to Jombo.	32,000

The pattern of land use in these three distinct localities is outlined below. Observations on the existing cash crops, together with proposals for their future development are discussed in Sections 6 (Tobacco) and 7 (Other Crops), in the light of the soil information.

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(f) Existing Pattern of Land Use.

The 25,000 acre project area is made up as follows:-

ACRES	
32,000	Shimba Hills Settlement Scheme (2,8.8.)
16,000	Lands North and East of Ramani River (not scheduled in 2.8.8.) Malindi to Mtwani.
32,000	Proposed Kikoni Scheme, including lands demarcated South and West of the Ramani River. Malindi to Jombo.

The pattern of land use in these three distinct localities is outlined below. Observations on the existing cash crops, together with proposals for their future development are discussed in sections 6 (Tobacco) and 7 (Other Crops), in the light of the soil information.

1. Shimba Hills Settlement

The development of this Scheme was outlined in the previous sub-section (2 (e)). Most of the demarcated lands are now officially settled. In 1966, it was estimated that there were about 1,270 farmers on the scheme. Of these, the majority are Kamba, with considerable numbers of Wadigo, Wanduruma and Wa-Taita. All the farms have been surveyed and many access roads constructed. The total population within the scheme boundary was estimated (1966) at between six and seven thousand.

The result of a recent economic survey has indicated that the best farmers receive shs 5,000/- per year. This estimate is disturbing when one considers the total official earnings of the Settlement in 1966, viz. shs 296,000/-, i.e. an overall average of only 240/- per settler. Two very significant factors should, however, be taken into account:

- (i) A considerable amount of produce was sold unofficially (i.e. not through the local co-operative) and was, therefore, not included in official estimates of earnings.
- (ii) Many of the tree crops had not come into full bearing.

It is really very difficult to assess the proportion of land actually under agricultural production, but it would appear to vary between 10 and 35% of the total acreage. This means that on an average farm (each farm is 20 to 25 acres) only between 2 and 9 acres are actually utilized, the remainder being covered in rough grassland, bush or swamp. Despite the relatively high proportion of lands subject to potential erosion, rock outcrops or poor drainage, it is clear that the acreage under production could be raised significantly. Food crops for subsistence hold the highest priority for farmers especially in the more recently settled areas, despite the relatively high level of capital that Government has sunk into the scheme.

The major food crop is Cassava. The condition of this plant varies with soil type, being better where there is a heavier subsoil, and doing poorly on deep sandy soils. On coarse textured and infertile sands, cassava is often the sole crop grown, yet on this sand, it may fail to form swollen roots. Cassava also does badly on all poorly drained soils. The incidence of virus mosaic is low.

1. Shimla Hills Settlement

The development of this scheme was outlined in the previous sub-section (2 (e)). Most of the demarcated lands are now officially settled. In 1966, it was estimated that there were about 1,250 farmers on the scheme. Of these, the majority are Jambas, with considerable numbers of Waddis, Wamburans and Wa-Taitas. All the farms have been surveyed and many access roads constructed. The total population within the scheme boundary was estimated (1966) at between six and seven thousand.

The result of a recent economic survey has indicated that the best farmers receive \$5,000/- per year. This estimate is disturbing when one considers the total official earnings of the settlement in 1966, viz. \$26,000/-, i.e. an overall average of only \$20/- per settler. Two very significant factors should, however, be taken into account:

(i) A considerable amount of produce was sold unofficially (i.e. not through the local co-operative) and was, therefore, not included in official estimates of earnings.

(ii) Many of the tree crops had not come into full bearing.

It is really very difficult to assess the proportion of land actually under agricultural production, but it would appear to vary between 10 and 35% of the total acreage. This means that on an average farm (each farm is 20 to 25 acres) only between 2 and 9 acres are actually utilized, the remainder being covered in rough grassland, bush or swamp. Despite the relatively high proportion of lands subject to potential erosion, rock outcrops or poor drainage, it is clear that the acreage under production could be raised significantly. Food crops for subsistence hold the highest priority for farmers especially in the more recently settled areas, despite the relatively high level of capital that Government has sunk into the scheme.

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Maize is the second most important food crop, yet generally does poorly and would be considerably outyielded by Sorghum. The implication behind this observation will be discussed in Section 8. The best maize is pure "P.P." maize grown on the heavier soils. Throughout, maize shows visible symptoms of both phosphate and nitrogen deficiency.

Other food crops of lesser importance include pigeon peas, sesame, beans, bananas, sweet potato (grown on high ridges), paw-paw, bambarra and ground nuts. A very little rice is grown on the bottomlands, and as 'Upland' Rice.

Cash Crops of major importance are Bixa, Cashew and Chillies. Those filling a minor role include citrus, coconut, cotton, maize, pineapple, sesame, sugar and tobacco.

The land is generally light and easy to cultivate. Where, due to erosion, the subsoil sandy clay or sandy clay loam is exposed, this becomes indurated on drying. The use of ox-ploughs is widespread. There are 9 tractors, of which 5 are owned by 2 full-time ploughing contractors. The standards of husbandry vary widely. On some farms all that is attempted is a little maize and cassava near the homestead; on others, up to half a dozen cash crops may be produced.

It was noted that several farms had been abandoned in the Majimboni, Jilore and Mwabila areas (Soil Map Sheet No.1). This was due to adverse soil conditions (poorly drained soils on the slopes and bottomland; with deep, coarsely-textured and infertile sands or even rock outcrops on the tops), prohibiting the successful establishment of even basic food crops. The conditions prevailing over much of the North-Eastern corner of the scheme are generally Unsuitable for Agriculture.

Weeding is of quite a high standard; weeds are a major headache for farmers. Many "ridge-up" their crops and ploughing is normally 'along the contour'. Little use is made of insecticides or fertilizers, and on steeper slopes it is rare to come across anti-erosion measures. No drainage has yet been attempted on lower slopes.

Much of the household refuse is placed in rubbish pits. It would be relatively simple for the A.Is. to instruct farmers in the scientific production of compost. The effectiveness of this refuse in raising fertility has been amply indicated by analyses showing a concentration of available phosphate in proximity to homesteads at ten to twenty times the normal level.

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Some farmers rear indifferent types of cattle on the scrub grazing; standards of husbandry are generally abysmal. The nearest dairy is at Mariakani; milk produced is consumed within the scheme (50 cents per pint). If animal production were ever to be taken seriously, there would need to be a marked grading-up of local stock. 1,800 Cattle were recorded on the scheme in 1966.

No improved grazing presently exists. Actually the Setaria is a good grass, but other species are of indifferent quality, the proportion of these inferior species tending to increase through sheer neglect. A light infestation of tsetse occurs throughout and is maintained not only in the widespread areas of low bush, but also amongst unpruned cashews and bixa and even beneath mangoes. Cattle deaths from trypanosomiasis are relatively frequent.

Hedging and fencing are mostly rudimentary or non-existent. Euphorbia cuneata makes a popular thorn hedge.

A few farmers keep improved poultry and sell eggs in Mombasa. Rabbits are bred on the National Youth Service farm near Lukore - this provides a useful outlet for sweet potato tops.

Ravages from wildlife are relatively slight and mainly affect farmers on the fringes of the scheme. Lions prefer to consume cows rather than people. Baboon and Pig cause the severest losses.

2. Lower Ramisi Valley

It is convenient here to consider lands along both banks of the Ramisi, i.e. including the Northern and Eastern fringes of the proposed Kikoneni Settlement. This area comprises in many respects the most variable soils in the Project Area (Soil Map Sheets 4 and 5). Saline and alkaline soils are locally associated with hot alkaline springs occurring on both sides of the Ramisi. Along the right bank, deep sandy soils are sporadic and there are only small pockets of cultivation in the bush mostly of maize, cassava, paw-paw, and sweet potato with a few chillies. Close to the Ramisi River, however, are a few scattered coconut plantations of indifferent quality. One such plantation at Bambo had been abandoned because the palms were dying. Lack of rain, excessive rain and poor soil were all advanced by the ex-farmer as likely causes of death. Since good plantations have been observed elsewhere on these deep sandy loams, some other explanation seems probable. Possibly the coconuts are suffering from Bronze Wilt or some other

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mysterious disease (the author is not competent to advance an opinion); but more likely the trees have suffered bark burning during grass fires which occur extensively throughout this sector during dry seasons.

A large proportion of the Ramisi valley is now uninhabited: It is occupied by a considerable density of baboon. In the West, herds of elephant move seasonally between Shimba Hills and Marenje Forest to the South of Jombo. There now appear to be no resident herds of elephant or buffalo, though an occasional solitary animal may be encountered. There is a sparse population of lion and leopard.

Three main population centres occur: since these are quite distinct they are best considered separately.

(i) Mbuguni Location. (Soil Map Sheet 4).

Recent Kamba incursions into Mkundi seem to stem directly from population pressure that reached a climax in Ukambani at the time of the 1960/61 climatic convulsions. Many of the "settlers" have, therefore, been on the land for about 4 to 6 years (1967) and quite significant areas of bush have been cleared locally along the extreme West of the Project Area, especially within the open Paramacrolobium woodlands on deep well drained and loose sandy soil. It is significant that the widespread sandy but poorly drained grassland areas are by and large neglected, despite the negligible bush clearing that these would require. The Kambas have mostly bought the land from Digos and regard it as theirs by purchase. The main effort is presently being put into plots of cassava; some also grow maize, cabbages, beans and sesame. Coconut and cotton are being tried locally.

(ii) Mangawani and Kibuyuni (Soil Map Sheet 4.)

These are traditional Digo settlements on relatively fertile soil of the type widely found around Kikoneni, and are based on dense and highly variable plantations of mature coconuts interplanted with citrus (excellent quality oranges and grapefruit). The plantations are badly overgrown with heavy incursions of Lantana bush. Round the periphery of the plantations the people grow cassava, maize and sweet potato. Cashew is only seen on the more recently occupied and less favoured lower slopes where the soils are by and large coarser textured and less well drained. This "system" appears able to support a surprisingly high population density.

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These are traditional Digo settlements on relatively fertile soil of the type widely found around Likoni, and are based on dense and highly variable plantations of mature coconuts interplanted with citrus (excellent quality oranges and grapefruit). The plantations are badly overgrown with heavy incursions of *bananus* bush. Round the periphery of the plantations the people grow cassava, maize and sweet potato. Cassava is only seen on the more recently occupied and less favoured lower slopes where the soils are by and large coarser textured and less well drained. This "system" appears able to support a surprisingly high population density.

(iii) Mafisini Location. (Soil Map Sheet 5).

Here widespread areas of coarse and infertile sands (both well drained and with high water table) are lightly but permanently settled by Digos. The economy is based on cashews and coconuts, with cassava and sweet potato. Whilst some of the coconut plantations are long-standing, much of the cashews are of more recent vintage. In places along the banks of the Ramisi where there are high lying levee-type deposits of fertile loam there are narrower stretches bearing excellent stands of sugar. Extensive coconut plantations with some cashew also occur around Mwaluvanga near the left bank of the Ramisi below the Lovu Confluence.

The acid white sand/swamp lands towards Ramisi (and in the Mantambwi Valley) are uninhabited with pockets of forest. These areas are frequented by python and cobra, as well as lion, leopard and civet.

3. The Kikoneni Sector

Permanent Digo settlement is focussed on several centres:- The Mwazare - Kikoneni - Kiruku - Mrima belt along the main Lunga Lunga road; Kigombero; Mwananyamala; Godoma; and at Nguluku. In all these places, the coconut occupies much of the cultivated acreage. Citrus, cashew, cassava, maize and sweet potato are widely grown, and a little rice in certain valley bottoms East of Kikoneni. Sugar is the mainstay of the economy around Kigombero and Kikoneni where it grows well: this sugar is milled at Ramisi factory. Numerous access tracks have been cut to get the sugar out. It was observed that citrus and bananas grow especially well. With fertilizer maize also flourishes. Cotton is rare and does poorly. Native tobacco is sometimes grown in small plots close to the homestead. This is of a "Ceylonese type" and was observed to be freer of leaf spot than the B.A.T. trial tobacco (Long Rains; 1967).

Since the farming in this sector continues along traditional lines almost undeviated by the efforts of the local Department of Agriculture, no estimates can be given on productivity, yields, etc. Generally though, with the probable exception of cotton, it can be stated that all 'arable' crops thrive better than on the Shimba Hills. This can be attributed to the better fertility status of the Kikoneni soils and their lack of excess acidity. It might also be mentioned that cassava does best in the gravelly soils where it appears to form larger swollen roots. Other than hens, livestock are rare. Outside these village settlements there are few farms and very large stretches of this sector are empty with certain exceptions described below:-

/over

(iii) Mainland Location. (Soil Map Sheet 2).

Here widespread areas of coarse and infertile sands (both well drained and with high water table) are rapidly but permanently settled by Dipterocarp. The economy is based on cashews and coconuts, with cassava and sweet potato. Whilst some of the coconut plantations are long-standing, much of the rubber are of more recent vintage. In places along the banks of the Ramisi where there are high lying favorable deposits of fertile loam there are narrower stretches bearing excellent stands of sugar. Extensive coconut plantations with some cashew also occur around Mawambwa near the left bank of the Ramisi below the lower Confluence.

The soil white sand/swamp lands towards Ramisi (and in the Mawambwa Valley) are unhabited with pockets of forest. These areas are frequented by python and cobra, as well as lion, leopard and civet.

3. The Kikometi Sector

Permanent Dipterocarp settlement is focussed on several centres:- The Mwasira - Kikometi - Kiruku - Mruka belt along the main drainage road; Kikometa; Mwanambwa; Gidamba; and at Mruku. In all these places, the coconut occupies much of the cultivated acreage. Citrus, cashew, cassava, maize and sweet potato are widely grown, and a little rice in certain valley bottoms East of Kikometi. Sugar is the mainstay of the economy around Kikometa and Kikometi where it grows well: this sugar is milled at Ramisi factory. Numerous access tracks have been cut to get the sugar out. It was observed that citrus and banana grow especially well. With fertiliser maize also flourishes. Cotton is rare and does poorly. Native tobacco is sometimes grown in small plots close to the homestead. This is of a "Ceylonese type" and was observed to be free of leaf spot than the B.A.T. trial tobacco (long Ramisi 1957).

Since the farming in this sector continues along traditional lines almost unaltered by the efforts of the local Department of Agriculture, no estimates can be given on productivity, yields, etc. Generally though, with the exception of cotton, it can be stated that all 'Arabia' crops thrive better than on the Salima Hills. This can be attributed to the better fertility status of the Kikometi soils and their lack of excess acidity. It might also be mentioned that cassava does best in the gravelly soils where it appears to form larger swollen roots. Other than beans, livestock are rare. Outside these village settlements there are few farms and very large stretches of this sector are empty with certain exceptions described below:-

(i) It is important patches of bush are now being (unauthorised) settlement Kambas, especially around Kikoneni. If it is decided in this sector a formal Settlement model, then the Ministry is faced with an insuperable settlement.

(ii) Scattered settlements carved out of the bush in the Project Area by parties of them originating post-1964 Mariakani. These occur in the base of Jombo mountain, East Mwanachini, Rira and Gandini.

A Mombasa saw mill is the one remaining extensive forest 2 miles due East of Jombo. The forest tracks, large areas in this sector would be permanently there are quite large tracts impenetrable. There is a tsetse infestation throughout the area. It is appropriate to mention the findings of the Department of Mines associated with the niobium complex within the alkaline complex.

With the exception of big game are absent from the Project area. Elephant and buffalo on Jombo the major valley North-East of Gandini and Nguluku) as a result of the Ramisi River and Shimba Hills encountered on the Ramisi River South-East of the Project.

SOIL CLASSIFICATION

The soils were divided, not according to the recognised International system but according to agronomic pragmatism. It is considered that the soil factors limiting crop growth are:-

- (i) Rock and gravel outcrops
- (ii) Poor Drainage
- (iii) Moisture Stress
- (iv) Erosion and severe soil loss
- (v) Salinity
- (vi) Soil reaction and nutrient availability
- (vii) Attack by soil nematodes

Of these factors, all but (ii) are readily assessed in the field. (iii) and (iv) have furthermore confirmed that soil texture distinctions (especially texture) are highly significant in determining inherent fertility, nutrient holding capacity and

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(i) It is important to appreciate that patches of bush are now being cleared for (unauthorised) settlement by incoming Japos and Kambar, especially around Mwananyama and Kikonani. If it is decided to declare this sector a formal Settlement Scheme on the Shimba Hills model, then the Ministry should move swiftly or be faced with an insuperable (superior) problem of re-settlement.

(ii) Scattered settlements are also being carved out of the bush in the extreme West of the Project Area by parties of Wandurwa, many of them originating post-1961 from Samburu and Marakani. These occur intermittently round the base of Jombo mountain, East of Jombo, and around Mwasichini, Rira and Gandini.

A Mombasa saw mill extracts timber from the one remaining extensive forest which is about 2 miles due East of Jombo. If it were not for the forest tracks, large areas of this Kikonani sector would be permanently inaccessible; as it is there are quite large tracts that are presently impenetrable. There is a light to moderate tsetse infestation throughout. It is perhaps appropriate to mention the continuing interest of the Department of Mines in extraction problems associated with the niobium - rare earth deposits within the alkaline complex of Mlima Hill.

With the exception of leopard, resident big game are absent from this sector. There are elephant and buffalo on Jombo and these animals use the major valley North-East of Jombo (between Gandini and Wamburi) as a passage through to the Rami River and Shimba Hills. Lion were encountered on the Rami Sugar Estate, immediately South-East of the Project Area.

SOIL CLASSIFICATION

The soils were divided, not according to any recognised International system, but on the basis of agronomic pragmatism. It is considered that the major soil factors limiting crop growth in the Project Area are:-

- (i) Rock and gravel outcrops
- (ii) Poor Drainage
- (iii) Moisture stress
- (iv) Erosion and severe slope
- (v) Salinity
- (vi) Soil reaction and infertility
- (vii) Attack by soil nematodes.

Of these factors, all but (vi) and (vii) are readily assessed in the field. Laboratory analyses have furthermore confirmed that field morphological distinctions (especially texture and consistency) are highly significant in determining differences in inherent fertility, nutrient holding capacity, etc.

Nematode composition tends, of course, to be a function more of Land Use than of Soil Type. Since every soil (except unweathered rock) can be ascribed to a drainage class, it was decided to make this criterion the basis for classification: 3 drainage classes are distinguished:-

1. Well Drained Soils

This class includes soils with mottled subsoil that might on the basis of their morphology be regarded as imperfectly drained. It is considered that the presence of subsoil mottling in these parent materials is due to the nature and distribution of the minerals within them. If, however, the mottles are, in fact, primarily due to less than perfect drainage this is unlikely to be of much agronomic significance.

2. Seasonally Poorly Drained Soils (S.P.D.)

Soil moisture in excess of field capacity remains in subsurface horizons throughout the rains and for a period following the rains due, either to the lateral reception of drainage waters from upslope, or to a continuing high seasonal water table. The subsoils are mottled and gleyed.

3. Very Poorly Drained Soils (V.P.D.)

Free water remains near the soil surface through most of the year - except during long dry seasons. These soils are often mottled to the surface and normally demonstrate strong gleisation in the subsurface. This class includes permanent swamp.

Each soil type is referred to by its Map Number as defined below and in Section 4. Well drained soils are numbered 1 to 14. (There are no Soils 9 and 11, since these were eliminated during soil mapping). S.P.D. soils are arbitrarily numbered 50 to 53; V.P.D. 80 to 84.

Two specific situations fall outside this scheme:-

1. Open Water is designated "90".
2. Saline and Alkaline soils are grouped together as Soil 70.

Soil Texture is regarded as being of fundamental importance in distinguishing individual soil types since this property determines to a greater or lesser extent the following soil features:-

1. Soil permeability and the intensity of soil leaching. Hence the fertility status, reaction and O.M. content.

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waters from up slope, or to a continuing high
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Each soil type is referred to by its Map Number
as defined below and in Section 4. Well drained soils
are numbered 1 to 14. (There are no soils 9 and 11,
since these were eliminated during soil mapping).
S.P.D. soils are arbitrarily numbered 50 to 59.
V.P.D. 80 to 84.

Two specific situations fall outside this
scheme:-

1. Open Water is designated "90".

2. Saline and Alkaline soils are grouped
together as Soil 70.

Soil texture is regarded as being of fundamental
importance in distinguishing individual soil types
since this property determines to a greater or
lesser extent the following soil features:-

1. Soil permeability and the intensity of
soil leaching. Hence the fertility
status, reaction and O.M. content.

2. Structure and consistency; tillage properties.
3. Level of available soil moisture, retention of moisture and hence the degree of moisture stress.
4. Erodability.

Both topsoil and subsoil textures have been taken into account.

It will be seen that a fundamental distinction is made in the Soil Key as to whether the sandy (sandy loam or loamy sand) surface topsoil is more or less than 90 cms. deep. It is, of course, appreciated that a soil with a relatively deep sandy top of, say, 85 cms. has somewhat different properties from one with only 5 cms. sand cover; yet a line had to be drawn somewhere. Having regard to the extreme variability in the depth of the sandy topsoils and the chosen map scale, it can be readily understood that there is only room for one line to be drawn!

It cannot, of course, be guaranteed that the divisions between soil types will all be significant for each and every crop. The latest tobacco trials at Shimba, for example, seem to suggest that small differences in the quantity of surface O.M. may be crucial for production. If this result is confirmed, then the soil survey will only be of limited value for the optimum siting of tobacco; since these minor differences, being a variable function of natural vegetation, crop or land management and so transient by nature, cannot conceivably be mapped.

S O I L K E Y

See Over

3. Structure and consistency: tillage properties.

2. Level of available soil moisture, retention of moisture and hence the degree of moisture stress.

4. Eradability.

Both topsoil and subsoil textures have been taken account.

It will be seen that a fundamental distinction in the soil key as to whether the sandy loam or loamy sand (surface topsoil) is more than 90 cms. deep. It is, of course, noted that a soil with a relatively deep sandy topsoil, say, 85 cms. has somewhat different properties one with only 5 cms. sand cover; yet a line has been drawn somewhere. Having regard to the extreme variability in the depth of the sandy topsoils and chosen map scale, it can be readily understood there is only room for one line to be drawn!

It cannot, of course, be guaranteed that the lines between soil types will all be significant each and every crop. The latest tobacco trials, for example, seem to suggest that small differences in the quantity of surface O.M. may be crucial to production. If this result is confirmed, then the survey will only be of limited value for the growing of tobacco; since these minor differences, being a variable function of natural erosion, crop or land management and so transient, cannot conceivably be mapped.

SOIL KEY

See Over

NOTL: This key is unable to cater for 2 Map Units:- (i) Saline/Alkaline Soils - SOIL 70 (p. 70)
 (ii) Open Water - 90

KEY NOS.

- | | | |
|-------|--|-------|
| (1) | <p><u>Rock outcropping</u>; or occurring frequently in the surface 90 cms.</p> | (2) |
| (2) | <p><u>Rock absent</u>; or rock present below 90 cms.</p> <p>Sedimentary sandstone or siltstone present</p> <p>Altered sandstone or agglomerate present, forming conical peaks or steep ridges.</p> | (3) |
| (3) | <p>(i) Well drained soils and gravels of hilltops, ridges, hillsides and elevated terraces; also imperfectly drained soils of <u>high lying</u> situations where mottling is permitted below 45 cms. if unaccompanied by <u>glei</u>. <u>Subsoils</u> normally uniform red, brown, yellow or whitish. Surface J.M. < 2½%.</p> <p>(ii) Seasonally poorly drained soils of hillsides, lower slopes and lower terraces; evidence for impeded drainage within the surface 90 cms. i.e. distinct mottling normally accompanied by glei below 45 cms. In sands, Loamy Sands and Coarse Sandy Loams, mottling alone is evidence of degree of drainage impudence.</p> <p>(iii) Very poorly drained soils of lower slopes, lower terraces, valley basins and swamps; evidence for periodic standing water; or glei within the surface 60 cms. Topsoils may or may not be mottled. Sub-surface horizons prominently mottled. Surface O.M. exceeds 2½%</p> | (4) |

/over

KEY NOS.

(4)

Sheet gravels present within the surface 60 cms. and persisting to depth; often overlying laterite.

SOIL 12 (P. 55)

1
08
1

(5)

Sheet gravels absent; or present below 60 cms; or present in thin intermittent layers

(5)

Slope exceeds 8° ($- 6^{\circ}$); (where hills are capped by SOIL 10, slopes exceed 10°).

SOIL 2 (P. 40)

(10)

Slope less than 6° ($- 10^{\circ}$)

(6)

(6)

(i) Surface texture of light clay

SOIL 6 (P. 45)

(ii) Surface texture of sand, loamy sand or sandy loam.

Texture at 90 cms. not heavier than sandy loam. Soil does not normally become significantly heavier with depth. Subsoil hues are 5 YR or yellower

(7)

(iii) Surface texture heavier than Coarse loamy sand and lighter than clay. Soil becoming significantly heavier with depth (i.e. at least one textural grade heavier). If the topsoil is loamy sand, the subsoil (at 90 cms.) should be heavier than sandy loam unless subsoil hues are dominantly Red (i.e. 10 R or 2.5 YR).

(8)

(7)

Coarse whitish sands and loamy sands. Natural vegetation obviously subject to drought.

SOIL 14 (P. 55)

Reddish yellow to light brown sandy loams (some horizons may be loamy sand). Natural vegetation not obviously subject to drought.

SOIL 4 (P. 43)

(8)

Topsoils of fine sandy loam, fine sandy clay loam; or more silty than this.

(9)

Topsoils coarser than fine sandy loam.

(11)

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(9)

Imperfectly drained with distinctly mottled subsoil. Strongly acid silty soils highly susceptible to erosion. Rare. Only in certain major valleys in Shimba Hills. Not cultivated.

SOIL 8 (p. 48)

Well drained with uniform or only faintly mottled subsoil. Mod. acid. Not particularly susceptible to erosion. Fine sandy loam or sandy clay loam overlies fine sandy clay or clay subsoil.

(10)

(10)

Soils of relatively high base status derived from fine sandstone which may be encountered below 90 cms. Gravel layers often present below 60 cms. Subsoil otherwise uniform red or brown without mottling. Mod. fertility.

SOIL 10 (p. 50)

Soils of relatively low base status derived from coarse sandstone. No gravel layers nor stones within the surface 150 cms. Subsoil normally red or brown with fine yellow mottles at depth. Low fertility. Confined to Shimba Hills.

SOIL 7 (p. 47)

(11)

Topsoil of medium or coarse sandy loam of colluvial origin. Subsoil sand fraction fine grained (fine sandy clay loam, fine sandy clay or light clay). Often overlying gravel at depth.

SOIL 10 (p. 50)

Topsoil of medium sandy loam to coarse loamy sand. Subsoil sand fraction coarse grained (Coarse sandy loam to coarse sandy clay). No subsoil gravel.

(12)

(12)

Topsoil of coarse loamy sand to coarse sandy loam. Subsoil dominantly red (10 R or 2.5 YR) coarse sandy loam to coarse sandy clay loam.

SOIL 5 (p. 44)

Topsoil of sandy loam. Subsoil red to yellowish brown (10 R to 5 YR) coarse sandy clay loam to coarse sandy clay.

SOIL 1 (p. 34)

S.P.D. 4 soils are grouped in this class.

Since, in the Shimba Hills, SOIL 50 comprises a complex of SOILS 50, 52, 53, it is obviously not possible to key them out in the usual way. There follow (below) generalised descriptions of these soils which should ensure their correct identification.

SOIL 50

Coarse sandy loam to sandy clay loam, or loam, topsoil overlies coarse sandy clay loam to clay loam. Highly acid subsoils are distinctly or prominently mottled with dominantly red colours against a gleied matrix background. This map unit embraces a wide range of colluvial apron deposits, especially on the lower slopes and valleys of the Shimba Hills where an intimate complex of Soils 50, 52, 53 is mapped as SOIL 50.

SOIL 51

Fine sandy clay loam, or loam, topsoil overlies fine sandy clay, clay loam or clay. Mod. acid subsoils are distinctly mottled against a giei matrix often with soft Mn concretions. On average contains 10% more clay than Soil 50 and has a higher base status. Confined to the area between Kikoneni and Jombo.

SOIL 52

Deep pale brown infertile coarse sandy loams and loamy sands affected by a seasonally high water table on lower-lying terraces around Mafisini and Mwaluvanga. Distinctly mottled subsoil.

SOIL 53

Coarse sandy loam topsoil overlies a loose distinctly mottled and somewhat gleied coarse sandy loam or coarse sandy clay loam subsoil. Subjected to the slow movement of lateral drainage on gentle slopes, these soils are wet to near the surface except during long dry seasons. Soils characterised by marked sub-surface acidity. Despite the low pH there is considerable subsoil sodium accumulation.

- (14) V.P.D. Open swampland, vlei and periodically flooded coarse textured and acid alluvium of steep valleys. SOIL 80 (P. 66)
- (15) V.P.D. Soil surface normally dry (15)
- (15) Acid profile dominated by the coarse sand fraction. Coarse sandy at surface, or in the subsoil or in layers throughout. SOIL 80 (P. 66)
- (16) Fine textured profiles. Loam or heavier throughout with significant quantities of silt. (16)
- (16) Acid to neutral gleied Subsoils of clay loam or clay with abundant prominent red or brownish yellow mottles. Gravels may or may not be present. (17)
- (17) Alkaline clay glei Subsoils with common distinct brownish yellow mottles, and distinguished by concretions of Ca and Mn or by "lime" spots; overlying some gravels below 90 cms. SOIL 82 (P. 69)
- (17) With sheet gravels within the surface 90 cms. SOIL 81 (P. 66)
- (18) Only a few pieces of gravel within the surface 90 cms.; or gravels absent. SOIL 83 (P. 69)
- (18) Topsoil of loam or clay loam. SOIL 84 (P. 71)
- (18) Topsoil of clay.

(21)

YRB YLLENTON SOWTINE LIOS .D.P.V

(22)

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(21)

(24)

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4. DETAILED DESCRIPTIONS AND ANALYSES OF THE SOILS

In this section each soil type will be considered in relation to its topographic position and probable origin. Some indication will be provided as to the general distribution of the soil type and its chief morphological features. The essential chemical and physical properties of each soil will be discussed.

These preliminaries are followed by a soil profile description, selected as being representative of the modal soil type. This soil profile was sampled in the field and subsequently analysed. The data are set out in accompanying tables. This data is not as complete as had been anticipated due to the prolonged break-down of the apparatus designed to provide information on clay mineralogy. In the absence of any Soil Physicist, all the samples taken for Soil Moisture determinations had perforce to be discarded.

Further information on the soils can be provided by the Soil Survey Unit at the National Agricultural Laboratory. For specific indications as to the whereabouts of each soil, resource should be had to the Soil Maps.

Notes on the Analytical Data

1. The well drained and acid soils, being apparently low in salts, calcium compounds and alkali, were not subjected to the full range of chemical analysis.

2. For those acid soils that possess a relatively high variable charge, the routine procedure of assessing the C.E.C. at pH 8.2 can hardly be justified. Where the tables lack data for C.E.C., it can be realistically deduced from the summation of $Hp + Na + K + Ca + Mg$ m.e.%.

3. The mechanical analysis (by Hydrometer) distinguishes 3 size fractions:-

- (a) Sand is 2 - 0.05 m.m. diameter
- (b) Silt is 0.05 - 0.002 m.m. diameter
- (c) Clay is less than 0.002 m.m. diameter.

4. Although the analyses may indicate relatively high levels of phosphate in the more alkaline soils, the availability of this element to the plant may be much less. This is because the routine laboratory procedure tends, at high pH levels, to extract considerable proportions of non-available phosphate.

(a) WELL DRAINED SOILS

SOIL 1

A very dark greyish brown topsoil of coarse quartzitic sandy loam (occasionally loamy sand) overlies a red to yellowish brown (Hues of 10 R to 5 YR) coarse sandy clay loam or sandy clay subsoil. This soil invariably

FIELD DESCRIPTIONS AND ANALYSES OF THE SOILS

In this section each soil type will be considered in relation to its geographic position and local origin. Some indication will be provided as to general distribution of the soil type and its morphological features. The essential chemical and physical properties of each soil will be discussed.

These preliminaries are followed by a soil profile description, selected as being representative of the soil type. This soil profile was obtained in the field and subsequently analyzed. The data are set out in accompanying tables. This data are not as complete as had been anticipated due to prolonged break-down of the apparatus designed to provide information on clay mineralogy. In the absence of any Soil Physicist, all the samples analyzed for Soil Moisture determinations and particle size distribution were discarded.

Further information on the soils can be obtained by the Soil Survey Unit at the National Agricultural Laboratory. For specific indications as to the whereabouts of each soil, reference should be had to the Soil Maps.

RESULTS ON THE ANALYTICAL DATA

1. The well drained and acid soils, being generally low in salts, calcium compounds and phosphorus, were not subjected to the full range of chemical analysis.

2. For those acid soils that possess a relatively high variable charge, the routine procedure of assessing the C.E.C. at pH 8.5 can only be justified. Where the tables lack data on C.E.C., it can be realistically deduced from summation of $h_p + Na + K + Ca + Mg + Mn + Fe$.

3. The mechanical analysis (by Hydrometer) distinguishes 3 size fractions:-

- (a) Sand is 0.075 m.m. diameter
- (b) Silt is 0.02 - 0.002 m.m. diameter
- (c) Clay is less than 0.002 m.m. diameter.

4. Although the analyses may indicate relatively high levels of phosphate in the more saline soils, the availability of this element to the plant may be much less. This is because the laboratory procedure tends, at high pH levels, to extract considerable proportions of non-available phosphate.

(a) WELL DRAINED SOIL

SOIL 1

A very dark greyish brown topsoil of coarse quartzitic sandy loam (occasionally loamy sand) overlies a red to yellowish brown (hues of 10 R to 5 YR) coarse sandy clay loam or sandy clay subsoil. This soil invariably

becomes heavier with depth. This is the characteristic high-lying soil at Shimba. At Kikoneni, however, SOIL 1 tends to occur on slopes, the summits of which are dominated by SOIL 10 (below). The coarse sandy loam topsoil may extend as far as 90 cms. in depth before the change occurs to a heavier texture. The depth of this coarse topsoil frequently fluctuates, and commonly varies between 15 and 90 cms. within quite short distances. Subsoils tend to be brownish on slopes, but red on ridge tops where the solum is "excessively" well drained and in a state of oxidation almost the year round. On flattish topped summits at Shimba, however, where, despite the elevation of the topography, there tends to be temporary and local accumulation of soil water during the Rains, there is normally some distinct mottling below 45 cms. though this should not be accompanied by glei.

These soils are normally very deep and may often extend below 200 cms. They overlie variable sandstones usually in the form of weathering rubble. Structures are normally sub-angular blocky and are highly stable, being strongly cemented by iron compounds. The subsoils become indurated on drying in which condition they are extremely hard. This induration, which may occur following topsoil erosion, is reversible; subsoils are normally friable or slightly firm. Permeability is very rapid at the surface under forest; it is significantly less under grass. Permeability tends to decline somewhat with depth; this decline is associated with the increase in subsoil clay content. Marked leaching is evident during long rains.

In the dry season, the sandy loam topsoil dries out quickly. This may cause the rapid death of the surface roots of tobacco. The sandy clay loam subsurface layers start to dry out about 10 days after effective rainfall. Lack of water retention is one of the major problems associated with this soil type. Also during a prolonged dry season, where there is bare soil, as on plant ridges, a surface crust forms: this may be sufficiently hard to prevent seedling emergence.

An important and invariable feature of this soil is the steady decrease in pH (i.e. increase in acidity) with depth. The topsoil pH averages out at 5.8; the subsoil (defined as the soil horizon at 90 cms. depth) averages 5.1. There is a concentration of soil bases in the topsoil, mostly derived from organic material which is drawn from a considerable depth by plant roots. The variable charge acidity (Hv) is rather high and accounts for a considerable proportion of the exchange capacity. The permanent charge acidity (Hp) is rather variable and averages 0.8 m.e.% in the subsoil (fluctuating between

becomes heavier with depth. This is the characteristic high-lying soil at Shimba. At Kikoni, however, SOIL 1 tends to occur on slopes, the summit of which are dominated by SOIL 10 (below). The coarse sandy loam topsoil may extend as far as 50 cms. in depth before the change occurs to a heavier texture. The depth of this coarse topsoil frequently fluctuates, and commonly varies between 15 and 30 cms. within quite short distances. Subsoils tend to be heavier on slopes, but red on ridge tops where the soil is excessively well drained and in a state of oxidation almost the year round. On the high topped summit at Shimba, however, where, despite the elevation of the topography, there tends to be temporary and local accumulation of soil water during the rains, there is normally some distinct mottling below 45 cms. In such cases this should not be accompanied by gley.

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0 and 3.4 m.e.). The high levels of Hv, coupled with the low overall C.E.C. and relatively low Hp, indicate that liming is unlikely to bring any improvement to these soils. On the contrary, the application of lime to these leached and predominantly kaolinitic soils is likely to induce hydrolysis leading to the production of unfavourable quantities of bicarbonate.

The low C.E.C. is itself a consequence of the combination of low levels of organic matter (average about 1% in the topsoil) with very high proportions of kaolinite (average about 75% of the clay complex).

Despite the acidity of the forest litter (average pH about 4.5), it is rapidly decomposed (presumably by saprophytic fungi) and is very light in colour. There appears to be an accumulation of dark surface "humus" under grass. Yet, in fact, there is little or no difference between the % carbon under forest and that under grass.

It would appear that SOIL 1 may develop in one of two ways:-

1. On relatively level areas in stable situations (e.g. under permanent savanna or forest), the soil results from very long-continued weathering of the coarse sandstone in situ. Under these conditions a profile develops demonstrating a gradual but continuous increase of clay with depth. This is probably largely due to the steady translocation of weathered clay minerals from the topsoil into the deeper soil layers. The decrease of pH with depth (noted above) is, however, partly caused by further processes of clay decomposition. This, coupled with a possibly more intense chemical decomposition of the subsoil feldspars, may also to some extent account for the increasing clay with depth.

This process of leaching out of the silica and bases, and the concentration, in their hydrated form, of iron and aluminium oxide, the latter compound being partially combined with silica to form kaolinite, is known as "laterization" (e.g. "Tropical Soils". E.C.J. Mohr and F.A. van Baren; 1959). SOIL 1, in this form, may, therefore, be regarded as an ancient lateritic soil, yet lacking any traces of laterite per se, iron concretions, etc. Another name for these soils would be "Reddish-Yellow Podzolic", though SOIL 1 fails to demonstrate translocation and subsequent deposition of organic compounds associated with sesquioxide. Either way, SOIL 1 may be included within the Order of Ultisols.

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2. Other than the most stable or level situations, long continuing colluviation (hill creep, hill wash, erosion, etc.) has led to the artificial concoction of soil having the same essential characteristics as that described above. The lateral movement of materials from the surface horizons is accompanied by a sorting out of the several size grades, such that the finer clayey fractions are washed away laterally down the slope to accumulate, ultimately, on the bottom lands, whilst the coarsest sand remains behind on the upper slopes and ridges. Indeed the coarsest sands are located on the steepest topography. Here, however, one must not confuse cause and effect since it is believed that the coarsest sandstones (and grits) give rise to the most pronounced hill features (see Section 2.b.). In the course of hill erosion or colluviation, the reddish sandy clay subsoil may or may not be truncated.

The combination of these various circumstances leads to the formation of a soil profile showing a most variable depth of coarse sandy loam deposited on top of the original sandy clay subsoil. The boundary between these two contrasting horizons is normally clear but may be abrupt if the subsoil had been subject to earlier truncation. This is, however, still 'Soil 1', but a SOIL 1 of partial colluvial origin and not, therefore, a result of pedogenesis in situ. Colluvial accumulations of coarse sandy surface wash are liable to be encountered on all slopes exceeding 2° (3%). Deep accumulations of sandy loam on hillsides merge into SOIL 4 (below) and, during mapping, these two soil types often proved difficult to separate. Where a hilltop is capped with a deep sandy deposit (SOIL 4), the slopes are usually covered with SOIL 1.

Since this investigation was only conducted at a semi-detailed level, quite a wide range of properties are permitted within the concept of SOIL 1. There is obviously some difference (in degree of leaching, organic content, water retention capacity, etc.) between soils, on the one hand, having almost 90 cms. of coarse sandy loam and those on the other with only some 15 cms. and sandy clay quite close to the surface. These latter soils are not subject to anything like the same intensity of leaching and so readily merge into the somewhat finer textured, more fertile and less acid SOIL 10. Over a wide area of South Shimba, Kigombero, Godoma and around Kikoneni (in fact much of the Central part of the Project Area), SOILS 1 and 10 could only be distinguished

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 Soil 10. Over a wide area of South Shikha,
 Rimbora, Gobara and around Rikimani (in fact
 much of the Central part of the project area),
 soils 1 and 10 could only be distinguished

by the coarseness of the sand fraction. Clearly soils with coarser sand grains are subject to a higher intensity of leaching; the analyses showed a strong correlation between this property and the base status. Particular difficulty was encountered over the mapping of the soils between Lukore and Mangawani where, over a wide area, the sand fraction is relatively coarse, but the proportion of clay is higher than is normal for SOIL 1 and the subsoil sandy clay is found close to the surface (on hills and ridge tops). The morphology indicated that these soils should be grouped with SOIL 1, but the data showed that the base status, general fertility and overall mechanical composition were closer to SOIL 10. A detailed consideration of these intermediate soils will be undertaken after SOIL 10 has been described. In all these 'intermediate' areas, typical forms of SOIL 1 are found on the hillsides where colluviation has been effective.

SOIL 1 is moderately acid and very deficient in phosphate. Almost all crops will respond to the application of 1 cwt. of superphosphate, though if more than this is used there may be little additional yield increase. There seems little doubt that these soils are subject to marked phosphate fixation due to the combination of free aluminium and iron with acid kaolinite. Relatively high phosphate levels (over 40 p.p.m.) were, however, found around homesteads. Calcium, Magnesium and Potash all tend to be low especially in the coarser textured variants: these bases rapidly decrease with depth. The organic content and hence that of nitrogen are very low, but there may be a poor response to nitrogen unless this is combined with phosphate. The nitrate/ammonium ratio is generally on the low side for tobacco. On the other hand, for tobacco SOIL 1 has favourably low levels of total nitrogen. Yet tobacco grown on this soil shows excessive nitrogen at maturity (See Section 6). SOIL 1 contains low chloride contents, in the range 0.2 to 1.0% (average topsoil chloride is about 0.3%).

It is the very low adsorption complex (C.E.C. + O.M.) that limits fertility improvement on SOIL 1. It is, therefore, most important to try to raise the level of organic matter. Due to its high rate of decomposition this will be difficult to achieve.

Because of the importance of this soil type, two examples are provided to illustrate the major morphological, physical and chemical properties. Kikoneni Pit 40 may be more representative of the colluvial forms of SOIL 1 in the Kikoneni sector, whilst it is possible that Ramisi Pit 45 (North of the Ramisi River) may have developed in situ. Both these soil profiles are typical of SOIL 1 in every respect, except for topsoil calcium which is somewhat higher than is usual (average topsoil calcium

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It is the very low adsorption complex (C.E.C. + 0.4) that limits fertility improvement on SOIL 1. It is, therefore, most important to try to raise the level of organic matter. Due to its high rate of decomposition this will be difficult to achieve.

Because of the importance of this soil type two examples are provided to illustrate the major morphological, physical and chemical properties. Kikoni Pit 40 may be more representative of the colluvial forms of SOIL 1 in the Kikoni sector, whilst it is possible that Ramisi Pit 45 (North of the Ramisi River) may have developed in situ. Both these soil profiles are typical of SOIL 1 in every respect, except for topsoil calcium which is somewhat higher than is usual (average topsoil calcium

for SOIL 1 = 1.9 m.e.%; subsoil calcium = 0.8 m.e.%).

Here follows Profile Descriptions for these 2 soils.

Analytical Data for Ramisi PIT 45 is presented in Table 6.

Analytical Data for Kikoneni PIT 40 is presented in Table 7.

PIT NO. 45 (RAMISI) Profile Description.

MAP REFERENCE: 309172 (200/iv)

LOCATION: Deep Latrine

ASPECT: South East SLOPE: 2° 40'

MICRO RELIEF: Plane.

PARENT MATERIAL: Mazeras Sandstone.

DRAINAGE: Good

ROOTING DEPTH: About 225 cms. M.R.D.: 0 - 17 cms.

PROFILE DEPTH: 222 cms.

LAND USE: Cultivated for 2 years to maize.

0 - 17 cms. Very dark greyish brown (10 YR 3/2) very friable sandy loam with weak very fine S.A.B. Common very fine to medium roots. Gradual LB.

17 - 49 cms. Very dark greyish brown to dark brown (10 YR 3/2 to 4/3) very friable, slightly blotched sandy loam with weak very fine SAB. Few fine and medium roots. Gradual LB.

49 - 150 cms. Red (2.5 YR 5/6) friable sandy clay with mod. fine blocky and SAB. Very few fine and very fine roots. Diffuse LB.

150 - 222 cms. This horizon is almost the same as preceding horizon. Red (2.5 YR 5/8) friable sandy clay with mod. fine blocky and SAB. Very few fine and very fine roots. LB clear and slightly undulating.

222 cms. + Not sampled. It is gravelly with very few fine roots.

/over

for soil = 1.2 m.e.k; amorphous calcium = 0.8 m.e.k.

Here follows Profile Description for these 2 soils.

Analytical Data for Ramisi PIT 45 is presented in Table 6. Analytical Data for Kikomet PIT 40 is presented in Table 7.

Profile Description	Reference
Deep latrine	20917 (200/14)
South East	20918
Plane	
Massive sandstone	
Good	
About 225 cms. M.R.D. 10 - 12 cms.	
225 cms.	
Cultivated for 2 years to maize	
Very dark greyish brown (10 YR 3/2) very friable sandy loam with very fine S.A.B. Common very fine to medium roots. Gradual lb.	
Very dark greyish brown to dark brown (10 YR 3/2 to 4/3) very friable, slightly dispersed sandy loam with weak very fine S.A.B. Few fine and medium roots. Gradual lb.	
Red (2.5 YR 5/6) friable sandy clay with fine blocky and S.A.B. Very few fine and very fine roots. Diffuse lb.	
This horizon is almost the same as preceding horizon. Red (2.5 YR 5/8) friable sandy clay with fine blocky and S.A.B. Very few fine and very fine roots. lb clear and slightly undulating.	
Not sampled. It is gravelly with very few roots.	

Notes

DEPTH IN CMS	%C	% SAND		% SILT		CLAY	pH	Hp	A V A I L A B L E N U T R I E N T S m.e.%					P p.p.m.		
		SAND		SILT					Hv	Na	K	Ca	Mg		Mn	
0-17	0.8	76		12		12	5.8	-	3.0	0.12	0.25	3.3	1.8		0.75	6
17-49		72		10		18	5.7	-	3.0	0.82	0.21	1.5	1.1		0.75	Trace
49-150		56		8		36	4.4	1.8	6.8	2.50	0.06	0.2	1.1		0.04	Trace
150-222		58		6		36	4.7	1.7	3.6	0.36	0.06	0.6	1.3		Trace	Trace

DEPTH CMS	C.E.C.	E X C H A N G E A B L E		B A S E S		E.S.P.
		Ca	Mg	Na	%	
0-17	7.0	2.4	0.12	0.75	0.0	0
17-49	4.6	1.2	0.0	0.75	0.06	1.3
49-150	6.2	0.6	0.0	0.60	0.25	4.0
150-222	7.6	1.0	0.6	0.65	0.06	0.7

DATE	TIME	WIND	TEMP	REL															
12-10-55	3.5	0.5	30.0	20.0	0.5	20.0	10.0	0.5	20.0	10.0	0.5	20.0	10.0	0.5	20.0	10.0	0.5	20.0	10.0
12-10-56	3.8	0.5	25.0	15.0	0.5	15.0	10.0	0.5	15.0	10.0	0.5	15.0	10.0	0.5	15.0	10.0	0.5	15.0	10.0
12-10-57	4.4	0.5	20.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0
12-10-58	5.1	0.5	15.0	5.0	0.5	5.0	10.0	0.5	5.0	10.0	0.5	5.0	10.0	0.5	5.0	10.0	0.5	5.0	10.0
12-10-59	5.7	0.5	10.0	0.0	0.5	0.0	10.0	0.5	0.0	10.0	0.5	0.0	10.0	0.5	0.0	10.0	0.5	0.0	10.0

DATE	TIME	WIND	TEMP	REL	WIND	TEMP	REL	WIND	TEMP	REL	WIND	TEMP	REL	WIND	TEMP	REL	WIND	TEMP	REL
12-10-55	6.1	0.5	20.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0	0.5	10.0	10.0
12-10-56	6.8	0.5	15.0	5.0	0.5	5.0	10.0	0.5	5.0	10.0	0.5	5.0	10.0	0.5	5.0	10.0	0.5	5.0	10.0
12-10-57	7.5	0.5	10.0	0.0	0.5	0.0	10.0	0.5	0.0	10.0	0.5	0.0	10.0	0.5	0.0	10.0	0.5	0.0	10.0
12-10-58	8.2	0.5	5.0	-5.0	0.5	-5.0	10.0	0.5	-5.0	10.0	0.5	-5.0	10.0	0.5	-5.0	10.0	0.5	-5.0	10.0
12-10-59	8.9	0.5	0.0	-10.0	0.5	-10.0	10.0	0.5	-10.0	10.0	0.5	-10.0	10.0	0.5	-10.0	10.0	0.5	-10.0	10.0

TABLE 7

Lab. Nos. 9367-69

IIT NO. 40 Kikoneni

DEPTH	% C	SAND	% SILT	CLAY	pH	AVAILABLE BASES m.e. %						P p.p.m.
						Hp	Na	K	Ca	Mg	Mn	
C-18	0.7	65	22	13	5.9	-	0.04	0.14	3.4	2.0	0.85	12
18-44		62	20	18	5.1	0.8	0.14	Trace	0.2	1.9	0.34	2
44-123		59	21	20	5.0	0.6	0.21	Trace	Trace	2.6	0.32	2

DEPTH	C.E.C.	EXCHANGEABLE BASES m.e. %			E.S.P.	pH 1:5 KCl	E.C. 1:5 H ₂ O
		Ca	Mg	Na			
0-18	8.3	3.6	2.2	0.2	7.9	0.23	
18-44	5.8	0.6	1.7	0.08	10.3	0.09	
44-123	6.0	0.6	2.5	0.10	10.8	0.15	

PIT NO. 40 (KIKONENI) Profile Description.
MAP REFERENCE: 255142 (200/iii)
LOCATION: Near a Summit; Gandini Ridge.
ASPECT: East. SLOPE: 2°
MICRO RELIEF: Undulating.
PARENT MATERIAL: Maji-ya-Chumvi Sandstone.
DRAINAGE: Very good.
ROOTING DEPTH: More than 130 cms. M.R.D.: 0 - 15 cms.
PROFILE DEPTH: 130 cms.
VEGETATION COVER: 90 - 100% 10% Bush
80% Chloris grassland.

0 - 18 cms. Dark brown (7.5 YR 3/2) very friable sandy loam with fine SAB and crumb. Common fine and medium roots. LB gradual.

18 - 44 cms. Reddish brown (5 YR 4/4) friable sandy loam with mod. fine SAB. Common fine and very fine roots. Diffuse LB.

44 - 123 cms. Yellowish red (5 YR 5/6) very friable sandy clay loam, with mod. fine SAB. Few gravel towards the horizon base. Few fine roots. LB abrupt and irregular.

123 cms. + Not sampled. Very abundant fine and medium rolled gravels of sandstone. Some rolled pieces of Quartzite and some medium Maji-ya-Chumvi stones, increasing below 130 cms. depth.

SOIL 2.

This is a slope category rather than a soil type per se. "SOIL 2" should be regarded as a Land Management Class. Arable agriculture performed on lands demarcated as "SOIL 2" should be accompanied by special erosion control measures (Section 5 a.). Recommended land use is for Grassland with tree crops; or forestry.

Over much of the Project Area, slopes exceeding 6 to 8° (10 to 15%) have been mapped as "SOIL 2".

Because of the extreme complexity of the colluvial slope soils, particularly in the Shimba Hills, the separate soil types within this complex could not be distinguished at the scale of mapping. These colluvial deposits range from deep sands to silty clays; may be poorly drained; and are of very variable depth often with included gravel lenses. The deposits generally become finer textured as one goes downslope. Lower slopes normally receive lateral drainage during the rains and may be subject to considerable incursions of acid seepage. This complex slope category may,

/over

Profile Description: (200 ft)
 Near a small, gravel ridge
 East, SLOPE: 2
 Underlying
 Mollis-Chernozem
 Very good
 More than 130 cms. M.R.D.: 0 - 15 cms.
 130 cms.
 90 - 100%
 10% Bush
 80% California grassland

Dark brown (1.5 YR 3/2) very friable sandy
 with fine S&B and crumb. Common fine and
 thin roots. LB gradual.
 Reddish brown (5 YR 4/4) friable sandy loam
 with fine S&B. Common fine and very fine
 roots. Diffuse LB.
 Yellowish red (5 YR 5/6) very friable sandy
 loam, with mod. fine S&B. Few gravel towards
 horizon base. Few fine roots. LB abrupt and
 gradual.
 Not sampled. Very abundant fine and medium
 sized gravels of sandstone. Some rolled pieces of
 shale and some medium Mollis-Chernozem
 pebbles below 130 cms. depth.

SOIL 2.

This is a slope category rather than a
 soil type per se. It should be regarded
 as a Land Management Class. Aerial photography
 performed on lands denoted as "SOIL 2" should
 be accompanied by special erosion control
 measures (Section 2.1). Recommended land use
 is for grassland with tree crop; or forestry.

Over much of the project area, slopes
 exceeding 6 to 8% (10 to 15%) have been mapped
 as "SOIL 2".

Because of the extreme complexity of the
 colluvial slope soils, particularly in the
 Shamba Hills, the separate soil types within
 this complex could not be distinguished at the
 scale of mapping. These colluvial deposits
 range from deep sands to silty clays; may be
 poorly drained; and are of very variable
 depth often with included gravel lenses. The
 deposits generally have a finer textured surface
 than downslope. Lower slopes normally receive
 lateral drainage during the rains and may be
 subject to considerable accumulations of acid
 seepage. This complex slope category may

therefore, effectively include several soil types, potentially subject to erosion: i.e. SOILS 1, 4, 5, 7, 12, 50, 52, 53; of which SOILS 1, 4, 50 are the most common variants.

Rock outcrops and shallow soils are, wherever possible, demarcated separately regardless of slope ("Soils" 3, 13.).

At Kikoneni, slopes are more uniform and less steep than those at Shimba; "SOIL 2" is consequently less common. Where, in the Kikoneni Sector, hillslopes are covered by the heavier textured SOILS 6 (topsoil light clay) and 10 (topsoil mostly fine sandy clay loam), slopes of up to 10° (18%) are permitted before lands are categorized as "SOIL 2". This is because SOILS 6 and 10 are less prone to erosion and hence able to support arable agriculture on rather steeper slopes without the introduction of soil conservation measures.

Because of the complexity of soil included within "SOIL 2", there is little merit in describing all possible combinations. There are 2 features that can be held to characterise SOIL 2, other than the slope criteria:-

(a) Some accumulation of topsoil organic matter: this is presumably due to the seasonal prevalence for surface (lateral) movement of drainage waters.

(b) Greater acidity as compared with similar soil types on more level areas. There is an accumulation of Hp in these slopes.

Pit 6 (Shimba) represents a form of SOIL 2 on a slope of about 35%. Analytical data for this profile is presented in Table 8.

/over

therefore, effectively include several soil types; potentially subject to erosion: i.e. soils 1, 4, 5, 12, 20, 22, 23 of which soils 1, 4, 50 are the most common variants.

Rock outcrops and shallow soils are wherever possible, demarcated separately regardless of slope ("soils" 3, 13).

At Kikondani, slopes are more uniform and less steep than those at Shimba; "SOIL 2" is consequently less common. Where, in the Kikondani sector, hillslopes are covered by the heavier textured soils 6 (topsoil light clay) and 10 (topsoil mostly fine sandy clay loam), slopes of up to 10° (12%) are permitted before lands are categorized as "SOIL 2". This is because soils 6 and 10 are less prone to erosion and hence able to support stable agriculture on rather steep slopes without the introduction of soil conservation measures.

Because of the complexity of soil included within "SOIL 2", there is little merit in describing all possible combinations. There are 2 features that can be held to characterize SOIL 2, other than the slope criteria:-

(a) Some accumulation of topsoil organic matter; this is presumably due to the seasonal prevalence for surface (lateral) movement of drainage waters.

(b) Greater acidity as compared with similar soil types on more level areas. There is an accumulation of H⁺ in these slopes.

pit 6 (Shimba) represents a form of SOIL 2 on a slope of about 32%. Analytical data for this profile is presented in Table 2.

over ...

FIT NO. 6 Shimba

LAB. NOS. 5607-09

TABLE 8

DEPTH CMS	% C	% SAND			% SILT		CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%						P p.p.m.
		SAND	SILT	CLAY	HP	HV			Na	K	Ca	Mg	Mn		
0-14	0.9	68	12	20	-	2.6	0.04	0.20	1.8	1.4	0.76	9			
14-44		52	8	40	-	4.8	0.06	0.24	0	1.8	0.64	7			
44 +		46	10	44	2.5	7.6	0.20	0.16	0	1.1	0.04	6			

10-11	48	70	40	27	512	800	0.50	0.10	0	111	0.104	Б
10-12	25	8	10	27	-	800	0.50	0.10	0	118	0.104	Б
0-14	88	15	50	0.0	-	500	0.04	0.50	1.9	1.1	0.50	Б
СМ ДЕЛ С 8	870	СІТ 8	СІТ 8	14	14	14	14	14	14	14	14	Б-Б-В*
												Б

БІЛ МОН О СІМПО

БІЛ МОН СЕОС-10

БІЛ МОН

PIT NO. 6 (SHIMBA HILLS) Profile Description.

MAP REFERENCE: 474 184 (200/iv)

ASPECT: South SLOPE: 20° 30' (35%)

MICRO RELIEF: Slightly undulating.

DRAINAGE: Good

PARENT MATERIAL: Mazeras Sandstone

ROOTING DEPTH: More than 128 cms.

PROFILE DEPTH: 128 cms. M.R.D: 7 - 20 cms.

VEGETATION COVER: 100%. 10% Bush - Piliostigma
Heeria
Annona
Hyphaene
coriacea

100% Grassland of Setaria
and Imperata.

0 - 14 cms. Dark brown (7.5 YR 3/2) friable sandy clay loam with very fine weak SAB. Containing a few pieces of charcoal. Abundant fine and medium roots. LB even and undulating.

14 - 44 cms. Yellowish red (5 YR 4/6 to 4/8) slightly firm sandy clay with Mod. fine to Med. SAB., containing few pieces of charcoal. Common very fine to medium roots. LB. gradual.

44 cms. + Red (2.5 YR 5/8) very firm sandy clay with Mod. fine to medium SAB. Below 117 cm. common distinct blotching (due to weathered sandy material) accompanied by abundant very fine quartz gravel. Below 140 cm. common pieces of sandstone. Very fine to fine few roots.

SOIL 3

Continuous sedimentary sandstone occurs within the surface 90 cms; often outcropping as boulders or rock sheets. The sandstone may be Mazeras, Mariakani or Maji-ya-Chumvi.

Areas especially prone to rock outcropping are valley heads in the Shimba Hills, the incised valley of the Ramisi, and the surrounds to Hot Springs.

No inference can be drawn as to the nature of any soil overlying the rock; it may be of any drainage class and have any texture.

The "soil" is unsuitable for development.

/over

SHIMBA HILLS

Profile Description

474 184 (100%)

South

Slightly undulating

Good

Massive sandstone

More than 100 cms

100 cms. M.R. 17-20 cms

100% 100% - 100%

100%

100%

100%

100%

100% Grassland of setaria and Imperata

Dark brown (2.5 YR 2/2) friable sandy clay with very fine weak S&B. Containing a few pieces of charcoal. Abundant fine and medium roots. Even and unstratified.

Yellowish red (2.5 YR 4/2 to 4/6) slightly sandy clay with mod. fine to med. S&B. Containing few pieces of charcoal. Common very fine to medium roots. Unstratified.

Red (2.5 YR 5/3) very fine sandy clay with fine to medium S&B. Below 100 cm. Common distinct blotching (due to weathered sandy material) composed by abundant very fine quartz gravel. Very fine to 100 cm. common pieces of sandstone. Very fine roots.

SOIL 3

Continuous sedimentary sandstone occurs within the surface 90 cms; often outcropping as boulders or rock sheets. The sandstone may be Hazers, Marikani or Maji-ya-Chauvi.

Areas especially prone to rock outcropping are valley heads in the Shimba Hills, the incised valley of the Ramisi, and the surrounds to Hot Springs.

No inference can be drawn as to the nature of any soil overlying the rock; it may be of any drainage class and have any texture.

The "soil" is wastable for development.

over....

SOIL 4

This is a deep, generally pale brown loose or very friable sandy loam or loamy sand with only weakly developed structures. There is a thin surface accumulation of organic matter (average about 0.5%). An important feature of this soil is that the texture does not become significantly heavier with depth. Indeed in the normal profile, the clay content actually decreases with depth. Surface textures are not so coarse as to permit frequent droughting of the natural vegetation. SOIL 4 is highly permeable and markedly leached, with a rather low capacity for retaining moisture. pH ranges between 5.0 to 6.0 throughout the profile with a moderate level of Hv. Hp is normally low.

SOIL 4 would appear to have several possible origins:-

- (a) Relic deposits on hill tops around the Shimba Hills. These remnants, which are far from being an invariable feature of hill summits, presumably represent all that remains of an earlier continuous erosion deposit (? Magarini Sand).
- (b) Extensive and very uniform low mounds of sandy loam deposited along the Ramisi Valley. These may well be alluvial in origin and may represent scattered ancient levees.
- (c) Sheets of superficial sandy loams blanketing the entire country around Mkundi. Whilst much of this landscape is poorly drained, some of the higher-lying ridges and summits are sufficiently well drained to be included as SOIL 4.
- (d) Relatively finer textured variants within the generally coarse Magarini Sands around Mafisini and Mwaluvanga.
- (e) Deep hillside sandy loams and loamy sands which are colluvial (hill wash) deposits derived from eroding SOILS 1, 2, 5, 7, 10, 12.

SOIL 4 has a very low adsorption complex (low O.M. + C.E.C.) throughout the profile. It is low or deficient in all the major plant nutrients (N, P, K, Ca, Mg). SOIL 4 is particularly suitable for tree crops (other than citrus); also for groundnuts.

Pit 10 (Shimba) represents SOIL 4 derived from a superficial relic hill deposit of sandy material, near Settlement H.Q.

Analytical data for Pit 10 is presented in Table 9.

This is a deep, generally pale brown loose or very friable sandy loam or sandy sand with only weakly developed structures. There is a thin surface accumulation of organic matter (average about 0.5%). An important feature of this soil is that the texture does not become significantly heavier with depth. Indeed in the normal profile, the clay content actually decreases with depth. Surface textures are not so coarse as to permit frequent dropping of the natural vegetation. SOIL 4 is highly permeable and markedly leached with a rather low capacity for retaining moisture. pH ranges between 5.0 to 6.0 throughout the profile with a moderate level of H_v. H_p is normally low.

SOIL 4 would appear to have several possible origins:-

- (a) Relic deposits on hill tops around the Salma Hills. These remnants, which are far from being an inevitable feature of hill summits, presumably represent all that remains of an earlier continuous erosion deposit (? Maternal sand).
- (b) Extensive and very uniform low mounds of sandy loam deposited along the Ramist Valley. These may well be alluvial in origin and may represent scattered ancient levees.
- (c) Sheets of superficial sandy loam blanketing the entire country around Munda. Whilst much of this landscape is poorly drained, some of the higher lying ridges and summits are satisfactorily well drained to be included as SOIL 4.
- (d) Relatively fine textured variants within the generally coarse Maternal Sands around Matinal and Matinanga.
- (e) Deep alluvial sandy loam and loamy sands which are colluvial (hill wash) deposits derived from eroding SOIL 4. 2. 7, 10, 12.

SOIL 4 has a very low absorption complex (low O.M. + C.E.C.) throughout the profile. It is low or deficient in all the major plant nutrients (N, P, K, Ca, Mg). SOIL 4 is particularly suitable for tree crops (other than citrus); also for groundnuts.

Pit 10 (Salma) represents SOIL 4 derived from a superficial relic hill deposit of sandy material, near Settlement H.O.

Analytical data for Pit 10 is presented in

TABLE 9

PIT NO. 10 Shimba	DEPTH CMS	%	SAND	SILT	CLAY	pH	LAB. NOS. 5620-22							
							AVAILABILITY	Na	K	Ca	Mg	Mn	P	
							Hp	Hv	Na	K	Ca	Mg	Mn	P
	0-20	0.2	62	12	26	5.0	1.2	4.6	0.08	0.02	0.8	0.9	0	6
	20-56		82	8	10	6.1	-	1.4	0.04	0.06	0.6	0.2	0.40	13
	56 +		82	10	8	6.1	-	1.0	0	0.05	0.2	0.1	0.02	10

<u>PIT NO. 10 (SHIMBA HILLS)</u>	Profile Description.
<u>MAP REFERENCE:</u>	449 168 (200/iv)
<u>LOCATION:</u>	Top of Hill.
<u>DRAINAGE:</u>	Very good.
<u>PARENT MATERIAL:</u>	Superficial sandy deposit.
<u>ROOTING DEPTH:</u>	More than 155 cms. <u>M.R.D.:</u> 0-10 cms.
<u>PROFILE DEPTH:</u>	155 cms.
<u>VEGETATION COVER:</u>	100%
<u>LAND USE:</u>	Mostly weeds; paw-paw; coconut, cashew, kapok, mango.

0 - 20 cms. Dark brown (7.5 YR 4/2, 4/3, 3/2) slightly firm sandy clay loam, with very weak fine SAB. Surface 4 cm. of washed very coarse sand with faint layering and blotching. Containing a few pieces of charcoal. Common fine and very fine roots. LB. gradual.

20 - 56 cms. Reddish yellow (7.5 YR 6/6) slightly firm to friable sandy loam, with fine and medium very weak SAB. Abundant very faint dark blotches and faint light speckles. Few very fine to medium roots. LB. diffuse.

56 cms. + Reddish yellow (5 YR 6/8 to 8/6) friable loamy sand, with extremely weak fine SAB and very faint rust blotching. Below 137 cm. very fine horizontal layers of somewhat ferruginous material. Very few very fine to medium roots.

SOIL 5.

This is best regarded as a variant of SOIL 1. It has a particularly coarse textured topsoil of coarse sandy loam or loamy sand (practically no silt) above a coarse sandy loam to sandy clay loam subsoil. Whilst the texture becomes heavier with depth, this is a very gradual process. The subsoil is normally red or reddish (Hues of 10 R or 2.5 YR), and red hues often occur close to the soil surface. For this reason, it is suggested that SOIL 5 may be a truncated version of SOIL 1. Such a hypothesis is perhaps supported by the usual topographic position of SOIL 5 - on summits and upper flanks of certain of the highest-lying hills at Shimba, frequently above very steep slopes and even minor "escarpments". The considerable acidity in the SOIL 5 topsoil (mean topsoil pH = 5.5; subsoil pH = 5.1; often accompanied by significant levels of Hp either in the topsoil or subsoil) may also be a pointer to prior truncation of the normal SOIL 1 topsoil.

/over

SOIL 5 (SHIMBA HILLS)

Profile Description

448 168 (200) (200) (200)

Top of Hill

Very good

Superficial sandy deposit

More than 155 cms. 155 cm. 0-10 cms.

155 cms.

100%

Mostly weeds; paw-paw; coconut, cashew, Xagol, mango.

Dark brown (7.5 YR 4/2, 4/3) slightly sandy clay loam, with very weak fine SAR. Face a cm. of washed very coarse sand with layering and blotching. Containing a few pieces of charcoal. Common fine and very fine roots.

Reddish yellow (7.5 YR 6/4) slightly fine to medium sandy loam, with fine and medium very weak layering and blotching. Abundant very fine dark blotches and faint streaks. Few very fine to medium roots.

Reddish yellow (5 YR 6/8 to 8/6) friable sand, with extremely weak fine SAR and very faint blotching. Below 155 cm. very fine to medium layers of somewhat fibrous material. Few very fine to medium roots.

SOIL 5

This is best regarded as a variant of SOIL 1. It has a particularly coarse textured topsoil of coarse sandy loam or loamy sand (practically no silt) above a coarse sandy loam to sandy clay loam subsoil. Whilst the texture becomes heavier with depth, this is a very gradual process. The subsoil is normally red or reddish (hues of 10 R or 2.5 YR), and red hues often occur close to the soil surface. For this reason, it is suggested that SOIL 5 may be a truncated version of SOIL 1. Such a hypothesis is perhaps supported by the usual topographic position of SOIL 5 - on summits and upper flanks of certain of the highest steep hills at Shimba, frequently above very steep slopes and even minor "escarpments". The considerable acidity in the soil's topsoil (mean topsoil pH = 5.2; subsoil pH = 5.1) is often accompanied by significant levels of iron either in the topsoil or subsoil, may also be a pointer to either truncation or the normal SOIL 1 topsoil.

TABLE 10

P1m 10. 18 Shimba

LAB. NOS. 5639-42

DEPTH CNS	% .C	% SAND			% SILT		CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%						P p.p.m.
									Hp	Hv	Na	K	Ca	Mg	
0-22	0.4	80	6	14	5.3	0.9	1.0	0.04	0	0.2	0.3	0.85	7		
22-49		82	4	14	5.4	0.2	0.4	0.02	0	0	0.3	0.20	8		
49-107		70	6	24	5.3	0.2	2.8	0.04	0	0	0.5	0.04	11		
107+		74	4	22	5.5	0.3	3.6	0	0	0	0.6	0	6		

With the exception of the points noted above, this soil type demonstrates the morphological features of SOIL 1. In comparison with SOIL 1, SOIL 5 has a rather lower capacity for retaining soil moisture, is more severely leached and has a greater tendency to fix phosphates.

This soil is of only moderate suitability for arable crops and is probably better suited for tree crops. SOIL 5 grows particularly poor quality tobacco.

SOIL 5 has a very scattered distribution at Shimba and covers only a very small proportion of the Project Area. Pit 18 (Shimba) is fully representative of SOIL 5.

Analytical data for this profile is presented in Table 10.

PIT NO. 18 (SHIMBA)

MAP REFERENCE:

Profile Description.

LOCATION:

437218 (200/iv)

MICRO RELIEF:

Top of high-lying ridge.

PARENT MATERIAL:

Plane.

DRAINAGE:

Mazeras Sandstone.

ROOT DEPTH:

Good. M.R.D.: 0 - 10 cms.

PROFILE DEPTH:

More than 145 cms.

VEGETATION COVER:

145 cms.

100% Grassland under a Cashew and Coconut plantation.

0 - 22 cms. Dark reddish brown (5 YR 3/3) friable coarse sandy loam, with very weak fine and medium SAB. Common very fine to medium roots. LB. abrupt and even.

2 - 49 cms. Dark red (2.5 YR 3/6) friable coarse sandy loam, with weak fine and medium SAB. Very abundant fine light speckles of quartz. Common very fine to medium roots. LB. gradual.

9 - 107 cms. Dark red (2.5 YR 3/8) slightly firm coarse sandy clay loam, with fine and medium weak SAB. Few fine and very fine roots. Diffuse LB.

07 cms. + Bright red (10 R 4/6) friable coarse sandy clay loam with weak medium SAB. Fine and very fine roots.

SOIL 6

This is a deep, rather uniform and well structured dark red light clay that tends to flank certain of the volcanic cones in the Kikoneni Sector (eg. Mrima and Kiruku Hills). Subsoil textures vary between light and medium clay. It should perhaps be emphasised that, despite the relative heaviness of texture,

With the exception of the points noted above, this soil type demonstrates the morphological features of SOIL 1. In comparison with SOIL 1, SOIL 2 has a rather lower capacity for retaining soil moisture, is more severely leached and has a greater tendency to fix phosphates.

This soil is of only moderate suitability for arable crops and is probably better suited for tree crops. SOIL 2 grows particularly poor quality tobacco.

SOIL 2 has a very scattered distribution at Shimba and covers only a very small proportion of the Project Area. Pit 18 (Shimba) is fully representative of SOIL 2.

Analytical data for this profile is presented in Table 10.

(SHIMBA)	
Profile Description.	
437218 (200/iv)	
Top of high-lying ridge.	
Plane.	
Massive sandstone.	
Good. M.S.P.: 0 - 10 cms.	
More than 145 cms.	
145 cms.	
100% Grassland under a Cashew and Coconut plantation.	

Dark reddish brown (5 YR 3/3) friable coarse loam, with very weak fine and medium SAs. Common very fine to medium roots. LB. abrupt and even.

Dark red (2.5 YR 3/6) friable coarse sandy loam, with weak fine and medium SAs. Very abundant light speckles of quartz. Common very fine to medium roots. LB. gradual.

Dark red (2.5 YR 3/8) slightly firm coarse clay loam, with fine and medium weak SAs. Fine and very fine roots. LB. diffuse.

Bright red (10 R 4/5) friable coarse sandy loam with weak medium SAs. Fine and very fine roots.

SOIL 3

This is a deep, rather uniform and well structured dark red light clay that tends to flank certain of the volcanic cones in the Shimba Sector (e.g. Muma and Kiriku Hills). Subsoil textures vary between light and medium clay. It should perhaps be emphasized that, despite the relative heaviness of texture,

this soil is friable, very well drained and has a considerable capacity for retaining moisture. The soil material may derive from weathering products of the metamorphic materials that constitute much of the volcanic cones. Weathering manganiferous laterite upslope of these clays may also contribute to their composition, as evidenced by their relatively high content of available manganese.

A high proportion of the exchange capacity is taken up by variable charge hydrogen (Hv), and the soil is moderately acid (pH 5 to 6). It may be anticipated that this soil will have a great tendency to fix phosphates. It is well endowed with Potassium, Calcium and Magnesium, but is deficient in phosphate and nitrogen. SOIL 6 has about 2½% O.M. in the topsoil.

SOIL 6 may be regarded as having possibly the highest potential for arable crops of any soil in the Project Area, though response to phosphatic fertilizer may be poor. It grows good coconuts, cashew and citrus. It is especially well suited to sugar. The area covered by SOIL 6, is, however, relatively small.

Kikoneni Pit 16 (Mrima village) is typical of SOIL 6.

Analytical data for this profile is presented in Table 11.

<u>PIT NO. 16 (KIKONENI)</u>	Profile Description.
<u>MAP REFERENCE:</u>	299 055 (200/iv).
<u>LOCATION:</u>	Part of a long slope North of Mrima.
<u>ASPECT:</u>	North-East. <u>SLOPE:</u> 4°.
<u>DRAINAGE:</u>	Very good.
<u>ROOTING DEPTH:</u>	More than 170 cms. <u>M.R.D.:</u> 0-6 cms.
<u>PROFILE DEPTH:</u>	170 cms.
<u>VEGETATION COVER:</u>	100%. Plantation of Coconut and Cashew, with Mango and Citrus.
0 - 18 cms.	Dark reddish brown (2.5 YR 2/4) very friable light clay with Mod. fine and medium SAB. Common fine and very fine roots. Diffuse LB.
18 - 51 cms.	Dark reddish brown to dark red (2.5 YR 3/5) friable to slightly firm clay, with Mod. fine and medium SAB. Few coarse to fine roots. LB. very diffuse.
51 cms. +	Dark red (2.5 YR 3/6) friable clay with Mod. medium SAB. Few medium to very fine roots.

/over

This soil is friable, very well drained and has a considerable capacity for retaining moisture. The soil material may derive from weathering products of the metamorphic materials that constitute much of the volcanic cones. Weathering manganese laterite deposits of these clays may also contribute to their composition, as evidenced by their relatively high content of available manganese.

A high proportion of the exchange capacity is taken up by variable charge hydrogen (Hv), and the soil is moderately acid (pH 5 to 6). It may be anticipated that this soil will have a great tendency to fix phosphates. It is well endowed with potassium, calcium and magnesium, but is deficient in phosphate and nitrogen. Soil 6 has about 2% O.M. in the topsoil.

SOIL 6 may be regarded as having possibly the highest potential for staple crops of any soil in the Project Area, though response to phosphatic fertilizer may be poor. It grows good coconuts, cashew and citrus. It is especially well suited to sugar. The area covered by SOIL 6 is, however, relatively small.

Kikomeni Pit 16 (Mama village) is typical of SOIL 6.

Analytical data for this profile is presented in Table II.

Profile Description	(KIKOMENI)
Part of a long slope North of Mama	
250 (1v)	
North-East	
Very good	
More than 170 cms. M.R.D.: 0-6 cms.	
170 cms.	
100% Plantation of Coconut and Cashew, with Mango and Citrus	
Dark reddish brown (2.5 YR 2/4) very friable clay with Mod. fine and medium S&B. Diffuse IR. and very fine roots.	
Dark reddish brown to dark red (2.5 YR 3/2) to slightly firm clay, with Mod. fine and S&B. Few coarse to fine roots. IR. very	
Dark red (2.5 YR 3/5) friable clay with Mod. S&B. Few medium to very fine roots.	

TABLE 11

PIT NO. 16 Kikoneni

LAB. NOS. 8882-4

DEPTH JMS	% C	SAND	% SILT	CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%							P p.p.m.
						Hp	Hv	Na	K	Ca	Mg	Mn	
0-18	1.4	30	16	54	5.7	-	12.8	0.18	0.98	4.8	3.8	1.35	8
18-51		24	10	66	5.1	0.5	10.8	0.08	0.20	2.0	2.2	1.94	7
51 +		26	10	64	5.5	0.0	8.0	0.10	Trace	1.4	2.3	1.60	6

SOIL 7

This is another variant of SOIL 1 at Shimba. SOIL 7 usually occurs immediately downslope of SOIL 1 on long gentle slopes where some accumulation of colluvial silt and clay becomes possible. A dark greyish brown fine sandy loam or sandy clay loam overlies a yellowish brown sandy clay, often with fine yet distinct yellowish mottles; rarely the subsoil may be reddish.

Morphologically this soil bears a close resemblance to SOIL 10 (below) and these two soils were extremely difficult to distinguish in the field (and in the Soil Key). But whereas SOIL 10 is a high-lying soil directly derived from a finer textured parent rock, SOIL 7 is merely a downslope colluvial derivative of a coarse textured one. SOIL 7, therefore, shares with SOIL 2 the high acidity and low base status typical of the hillslope soils at Shimba. This is in marked contrast to the relatively high base status of SOIL 10 at Kikoneni.

It can now be seen that SOIL 1 represents the median form of those high-lying soils at Shimba that are derived from the coarse Mazeras Sandstone. SOIL 7 is the fine textured variant of this form; SOIL 5 the coarse textured variant.

SOIL 7 has a rather acid subsoil with a significant proportion of Hp. (Average topsoil pH = 5.7; subsoil pH = 4.9). SOIL 7 is deficient in nitrogen and phosphate; other nutrients are in adequate supply.

SOIL 7 should prove suitable for a wide range of arable crops, though not as satisfactory as the higher base status and less acid SOIL 10. SOIL 7 occurs in small but widely scattered areas and occupies only a very minor proportion of the Project Area.

Pit 51, sited above the Lower Ramisi Valley at Mkundi, is typical of SOIL 7.

Analytical data for Pit 51 is presented in Table 12.

/over

SOIL 7

This is another variant of SOIL 1 at Shimba. SOIL 7 usually occurs immediately downslope of SOIL 1 on long gentle slopes where some accumulation of coluvial silt and clay becomes possible. A dark greyish brown fine sandy loam or sandy clay loam overlies a yellowish brown sandy clay, often with fine yet distinct yellowish mottles; rarely the subsoil may be reddish.

Morphologically this soil bears a close resemblance to SOIL 10 (below) and these two soils were extremely difficult to distinguish in the field (and in the soil key). But whereas SOIL 10 is a high-lying soil directly derived from a finer textured parent rock, SOIL 7 is merely a downslope coluvial derivative of a coarse textured one. SOIL 7, therefore, shares with SOIL 2 the high acidity and low base status typical of the hillside soils at Shimba. This is in marked contrast to the relatively high base status of SOIL 10 at Kikwani.

It can now be seen that SOIL 1 represents the median form of these high-lying soils at Shimba that are derived from the coarse Mweru Sandstone. SOIL 7 is the fine textured variant of this form; SOIL 2 the coarse textured variant.

SOIL 7 has a rather acid subsoil with a significant proportion of H₂O. (Average topsoil pH = 5.7; subsoil pH = 4.3). SOIL 7 is deficient in nitrogen and phosphate; other nutrients are in adequate supply.

SOIL 7 should prove suitable for a wide range of staple crops, though not as satisfactory as the higher base status and less acid SOIL 10. SOIL 7 occurs in small but widely scattered areas and occupies only a very minor proportion of the Project Area.

Plt. 51, cited above the lower Kamisi Valley at Kikwani, is typical of SOIL 7.

Analytical data for Plt. 51 is presented in Table 12.

over

TABLE 12

IIT NO. 51 (Ramisi)

LAB. NOS. 10615-17

DEPTH CMS	% C	SAND	% SILT	CLAY	pH	AVAILABLE NUTRIENTS m.e.%						P p.p.m.
						Hp	Na	K	Ca	Mg	Mn	
0-24	0.7	64	18	18	5.7	-	0.8	0.3	3.2	2.0	0.6	1
24-53		64	14	22	5.2	0.6	0.3	0.4	0.4	1.7	0.6	1
53+		50	12	38	4.7	1.5	0.7	0.1	0.2	2.0	0.1	Trace

PIT NO. 51 (RAMISI) Profile De
MAP REFERENCE: 2817 (200
ASPECT South-East
MICRO RELIEF: Plane.
DRAINAGE: Good.
LOCATION On the upper
ROOTING DEPTH: Ridge.
More than
PROFILE DEPTH: 134 cms.
VEGETATION COVER: 100%: 90%
20%

0 - 24 cms. Very dark greyish brown
brown (10 YR 3/3) friable fine
mod. fine and medium SAB. Co
Gradual LB.

24 - 53 cms. Reddish brown to yellow
and faintly blotched friable
mod. fine SAB. Few fine and

53 cms. + Yellowish red (5 YR 4/
with mod. fine to coarse SAB.
yellowish brown blotches. Fe
roots.

SOIL 8

This is a unique
Project Area in that it
to erosion, even on the
soil surface is often qu
covered in lichen, thoug
light woodland overhead
coeruleum. For the are
remarkably high silt con
profile. This, coupled w
situation - in broken to
basins - suggests that S
ancient alluvium. SOIL
by very high Hp (toxic l
especially in the subsoi
present, it tends to be

This is an extrem
since it is associated w
relief; textures can va
clay loam, though with m
(usually over 30%) in ev
variability, silt conten
situation, this soil has

ription.

v)

SLOPE: 3°

flanks of the Mkundi

4 cms. M.R.D.: 0-17 cms.

assland; mostly Panicum

ash: 10% Stereospermum
kunthianum

10% Lantana camara

(10 YR 3/2) to dark
sandy loam with
on fine roots.

sh red (5 YR 4/4, 4/6)
ndy clay loam with
dium roots. Diffuse LB.

friable sandy clay
Few distinct
very fine to medium

soil form within the
as a high susceptibility
lightest slopes. The
e bare or partially
there is usually a
over of Paramacrolobium
this soil has a
ent throughout the
h its rather low-lying
graphy within valley
L 8 is developed on
is also characterised
(levels of acidity)

If grass is
unted.

y variable soil type
h a steep micro-
from sandy loam to
e than 20% silt
y horizon. In its
and lowish lying
marked affinity

/over

Profile Description

2517 (200/4v)

Soils-East

Plane

Good

On the upper flanks of the ...
Ridge.
More than 134 cms. ...
134 cms.

100W: 90X Grassland; mostly ...
20X Bush: 10X ...
10X ...

Very dark greyish brown (10 YR 3/2) to dark ...
Reddish brown to yellowish red (5 YR 4/4, 4/2) ...
Yellowish red (5 YR 4/3) friable sandy clay ...

SOIL 8

This is a unique soil form within the ...
Project Area in that it has a high susceptibility ...
to erosion, even on the slightest slopes. The ...
soil surface is often quite bare or partially ...
covered in lichen, though there is usually a ...
light woodland overhead cover of *Panicum* ...
For the area, this soil has a ...
remarkably high silt content throughout the ...
profile. This coupled with its rather low-lying ...
situation - in broken topography within valley ...
basins - suggests that SOIL 8 is developed ...
ancient alluvium. SOIL 8 is also characterized ...
by very high pH (toxic levels of acidity) ...
especially in the subsoil. If grass is ...
present, it tends to be stunted.

This is an extremely variable soil type ...
since it is associated with a steep micro- ...
relief; textures can vary from sandy loam to ...
clay loam, though with more than 20% silt ...
(usually over 10%) in every horizon. In its ...
variability, silt content and lowish lying ...
situation, this soil has a marked affinity

with the (S.P.D.) SOIL 50, but differs from it in its excessive acidity and its liability to erode. The drainage of SOIL 8 is usually imperfect verging towards poorly drained and subsoils invariably show distinct mottling. The soil surface tends to become somewhat impermeable on desiccation. On the steepest slopes, there is a tendency for rocks and gravels to outcrop. (N.B. Despite small pockets of included SOILS 2, 3, 4, 12, 50, 53; the entire complex of rugged micro-relief dominated by SOIL 8 is mapped as SOIL 8, since it is not possible to separate out the individual pockets at the scale of mapping).

SOIL 8 has a surprisingly low level of O.M. for such an imperfectly drained soil type. It is strikingly deficient in every major nutrient. The pH is around 4.5.

SOIL 8 is found in certain major valley systems below the Shimba Hills. It is of negligible areal significance and is unsuitable for any form of development other than rough forestry. Shimba Pit 22 in the Mkurumuji valley is representative of SOIL 8.

Analytical data for Pit 22 is presented in Table 13.

PIT NO. 22 (SHIMBA)

MAP REFERENCE:

LOCATION:

ASPECT:

PARENT MATERIAL:

DRAINAGE:

ROOTING DEPTH:

PROFILE DEPTH:

VEGETATION COVER:

Profile Description.

464 214 (200/iv).

The Mkurumuji Valley.

North-West. SLOPE: 1°.

Mazeras Sandstone (? Alluvial).

Imperfect. M.R.D.: 0-14 cms.

108 cms.

140 cms.

100%. Woodland of Paramacrolobium coeruleum.

0 - 10 cms. Light brown (7.5 YR 6/4) very friable sandy (silty) loam, with weak fine and very fine SAB. Abundant fine and large roots. LB clear and even.

10 - 26 cms. Brown to strong brown (7.5 YR 5/4 to 5/5) friable, faintly blotched sandy clay loam, with Mod. fine and very fine SAB. Common fine roots. LB. gradual.

26 - 46 cms. Brown (7.5 YR 5/4) slightly firm loam, with Mod. fine and medium SAB. Common distinct red RM (2.5 YR 4/6). Distinct light yellowish brown blotching (10 YR 6/4). Common fine roots. LB gradual.

46 - 80 cms. Transitional layer with Mod. medium SAB. Few fine and very fine roots. LB diffuse. No sample.

/over

with the (S.P.D.) SOIL 50, but differs from it in its excessive acidity and its liability to erode. The drainage of SOIL 8 is usually imperfect varying towards poorly drained and subsoils having a slow distinct mottling. The soil surface tends to become somewhat impermeable on desiccation. On the steepest slopes, there is a tendency for rocks and gravels to outcrop. (N.B. Despite small pockets of included SOILS 2, 3, 4, 19, 50, 53; the entire complex of rugged micro-relief dominated by SOIL 8 is mapped as SOIL 8, since it is not possible to separate out the individual pockets at the scale of mapping).

SOIL 8 has a surprisingly low level of O.M. for such an imperfectly drained soil type. It is strikingly deficient in every major nutrient. The pH is around 4.5. SOIL 8 is found in certain major valley systems below the Shima Hills. It is of negligible areal significance and is unsuitable for any form of development other than rough forestry. Shima Pit 22 in the Murumaji valley is representative of SOIL 8.

Analytical data for Pit 22 is presented in Table 13.

Profile Description.	DEPTH:	ION COVER:
464 214 (200/v)		
The Murumaji Valley.		
North-West		
Mazera Sandstone (? Alluvial)		
Imperfect.		
M.R.D.: 0-14 cms.	108 cms.	
	140 cms.	
Woodland of <i>Pternocrochium</i>		
light brown (7.5 YR 6/4) very friable sandy clay loam, with weak fine and very fine SAR. Abundant fine and large roots. IS coarse and even.		
Brown to strong brown (7.5 YR 5/4 to 5/5) friable, faintly blotched sandy clay loam, with fine and very fine SAR. Common fine roots. IS gradual.		
Brown (7.5 YR 5/4) slightly firm loam, with fine and medium SAR. Common distinct red (2.5 YR 4/6). Distinct light yellowish brown blotching (10 YR 6/4). Common fine roots. IS gradual.		
Transitional layer with Mod. medium SAR. Few fine and very fine roots. IS diffuse. No sample.		

Over

DEPTH CMS	% C	% SILT			CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%						P p.p.m.
		SAND					Hp	Na	K	Ca	Mg	Mn	
0-10	0.5	56	28	16	4.5	1.6	0.11	0.25	Trace	0.6	0.05	1	
10-26		46	24	30	4.3	5.2	0.08	0.24	Trace	0.6	Trace	3	
26-46		40	34	26	4.5	6.7	0.22	0.10	Trace	1.0	Trace	Trace	
80+		40	20	40	4.9	6.6	0.69	0.11	Trace	2.1	Trace	3	

DEPTH CMS	C.E.C.	E X C H A N G E A B L E B A S E S m.e. %				E.S.P.	pH	E.C. 1:5 H ₂ O
		Ca	Mg	K	Ca			
0-10	5.2	1.0	0.3	1.35	3.5	1:5 KCl	0.05	
10-26	8.4	0	0	1.35	4.2	3.9	0.06	
26-46	9.4	0.5	1.3	1.20	1.3	3.9	0.06	
80 +	11.0	0.5	3.0	1.30	9.6	3.9	0.07	

80 cms. + Light grey (5 YR 7/1 and 10 YR 7/1) slightly firm clay loam glei, with Mod. fine and medium blocky and SAB. Abundant yellow streaks. Abundant reddish yellow and strong brown blotches (7.5 YR 6/6 and 5/8). Abundant red RM (2.5 YR 4/8). Few fine and very fine roots.

SOIL 10.

This is the characteristic high-lying soil developed from the finer textured Maji-ya-Chumvi sandstone. Compared with the equivalent soils developed from Mazeras sandstone (SOILS 1, 5), SOIL 10 has a higher proportion of silt and clay, whilst the sand fraction is appreciably finer. The topsoils average 24% clay (11% more than SOIL 1); subsoils average 40% clay (12% more than SOIL 1).

A dark brown medium or (usually) fine sandy loam to sandy clay loam overlies a yellowish red to yellowish brown friable sandy clay or light clay. Red colours tend only to occur on the highest lying situations and upper hill flanks: brown subsoil hues predominate elsewhere. Gravels of mixed iron and manganese concretions ("murrum"), with some medium, smooth, rounded quartz pebbles and slabs of Maji-ya-Chumvi sandstones and siltstones in varying stages of weathering, often occur at depth in the profile (by definition below 60 cms.; average depth of gravels = 90 to 150 cms.). This gravel sheet may be only about 50 cms. thick (on colluvial slope situations), in which case the normal SOIL 10 subsoil is resumed beneath the gravels. In more level situations, once the gravels are reached they continue to depth where they merge into the weathering parent rock. Mostly, therefore, SOIL 10 does not enjoy that great depth which is a characteristic and indeed desirable quality of SOILS 1, 4, 5, 6, 7.

Since, however, SOIL 10 possesses a greater inherent capacity for retaining moisture than any of these other soils, the profile depth is invariably more than adequate for normal plant growth. In any case, considerable root penetration of the gravel sheets was noted in all profiles. Marked acidity (pH down to below 5) was also observed in association with these subsoil gravels, combined with significant levels of Hp: no explanation can be offered for this phenomenon.

SOIL 10 is moderately permeable throughout the profile though, due to the higher content of silt and clay, leaching is less intense than in SOIL 1. Also the higher colloid content (O.M. + Clay) promotes a more effective adsorption capacity. Both these properties serve to explain the higher fertility status

(7.5 YR 5/6 and 5/8). Abundant red RM (2.5 YR 4/8).
 reddish yellow and strong brown blotches.
 blocky and SAB. Abundant yellow streaks. Abundant
 fine clay loam silt, with nod. fine and medium
 fragments (2.5 YR 4/8 and 10 YR 7/1) slightly

SOIL 10

This is the characteristic high-lying
 soil developed from the finer textured
 Maji-ya-Chumvi sandstone. Compared with the
 equivalent soils developed from Masera
 sandstone (SOIL 1, 2), SOIL 10 has a higher
 proportion of silt and clay, whilst the sand
 fraction is appreciably finer. The topsoil
 average 24% clay (1% more than SOIL 1).
 subsoil average 40% clay (12% more than
 SOIL 1).

A dark brown medium or (usually) fine
 sandy loam to sandy clay loam overlies a
 yellowish red to yellowish brown friable sandy
 clay or light clay. Red colours tend only to
 occur on the highest lying situations and upper
 hill flanks: brown subsoil more predominant
 elsewhere. Gravels of mixed iron and manganese
 concretions ("murrum"), with some medium
 smooth, rounded quartz pebbles and silt of
 Maji-ya-Chumvi sandstones and siltstones in
 varying stages of weathering, often occur at
 depth in the profile (by definition below
 50 cms.; average depth of gravels = 90 to 150 cms.).
 This gravel sheet may be only about 50 cms. thick
 (on coluvial slope situations), in which case
 the normal SOIL 10 subsoil is resumed beneath
 the gravels. In more level situations, once
 the gravels are reached they continue to depth
 where they merge into the weathering parent
 rock. Mostly, therefore, SOIL 10 does not enjoy
 that great depth which is characteristic and
 indeed desirable quality of SOILS 1, 4, 5, 6, 7, 8, 9.

Since, however, SOIL 10 possesses a
 greater inherent capacity for retaining moisture
 than any of these other soils, the profile depth
 is invariably more than adequate for normal plant
 growth. In any case, considerable root
 penetration of the gravel shears was noted in
 all profiles. Marked acidity (pH down to below 5)
 was also observed in association with these
 subsoil gravels, combined with abundant
 levels of Hg; no explanation can be offered
 for this phenomenon.

SOIL 10 is moderately permeable
 throughout the profile though, due to the higher
 content of silt and clay, leaching is less
 intense than in SOIL 1. Also the higher colloid
 content (O.M. + clay) promotes a more effective
 absorption capacity. Both these properties
 serve to explain the higher fertility status

of SOIL 10 compared with SOIL 1. Thus SOIL 10 is relatively deficient in magnesium; has adequate phosphorus except in the virgin series and nitrogen. The average calcium is 7.8 m.e.%, and the average figure of 1.9 m.e.% for phosphorus content of SOIL 10 average. Subsoils are moderately acid with pH = 6.2; subsoil pH = 5.5. Levels of H_v are present in the profile. H_p does not occur. Low levels are detected in the profile.

SOIL 10 is found on some of the highest-lying colluvial gentle upper slopes, a few miles West of Kikoneni. A few are also found on some of the lower slopes to the East of Kikoneni, where the Maji-ya-Chumvi beds are present. It also occurs on the hills immediately to the North of Kikoneni where there are broad hills. In the vicinity of Kibuyuni and Kikoneni it is important to realise that the soil (i.e. East of Kikoneni) is a sandy loam (i.e. the sand fraction is coarse) which is typical for SOIL 10. It is both morphologically and texturally intermediate between SOIL 1 (rather extensive) and SOIL 10. The procedure has been to map SOIL 10 on level ground, where there is no topsoil and on level ground, where there is no topsoil. On all slopes they are mapped as SOIL 10 there they are usually sandy loam characteristic of SOIL 10. Moreover subject, from the point of view of incursions of acid seepage, the SOIL "10" is really a soil of a status which was decided on the basis of the amounts of topsoil calcium and phosphorus coupled with relatively coarse and sandy clay textures. In terms of the coarseness of texture these soils are nearer to SOIL 10 than SOIL 1. They are mapped as SOIL "10" around Kikoneni, not doubtful since there is a high content in phosphate and low in phosphorus. They can only be regarded as SOIL 10 on the basis of the percentage of clay. The soils around Lukore, Kikoneni, etc. are in point of fact probably SOIL 10. The distinction between SOILS 1 and 10. The decision to map these levels on the basis of the rather broad distinction was observed. This distinction in crop yields is certainly the consequence of the retaining qualities of the

SOILS 1, 4 and 5. They are rich in calcium and potassium; but, the available phosphorus is low in phosphate level of topsoil compared with a mean SOIL 1. The O.M. ranges between 2 and 3%. The pH is acid (Mean topsoil 5.2). Quite high throughout the country occur in topsoils, but in most subsoils.

They occur extensively over much of the country and the more common and to the south. Pockets of SOIL 10 are found on the highest summits to be seen here, however, the soil is somewhat coarser than SOIL 1 in a very few areas along the banks of the Ramisi River and on the high tops, notably in the area of Mangawani. It is similar to SOIL 1 in these latter areas (south and North of the Ramisi), but is considerably coarser than SOIL 1 so that these soils are physicochemically similar to SOIL 1 and 10. In these intermediate situations the soil is like the soils on summits where there is little or no vegetation, as SOIL "10". On the other hand, as SOIL 1 because of the weathering covered in the coarse sand fraction of SOIL 1 and are similar to SOIL 10 from time to time, to lateral erosion which has the effect of exposing the sand. North of the Ramisi, the soil is rather coarse and its basis is of reasonable calcium and phosphate levels and high profile pH levels decrease to the soil surface. The soil is similar to SOIL 10 of the sand fraction, calcium and organic content similar to SOIL 1. The area around Lukore is particularly deficient in topsoil calcium. They are similar to SOIL 10 on the basis of the profile pH (6.2). The area around Wazare and Kigombero is very intermediate between SOIL 1 and 10. It was finally decided to classify these areas as SOIL "10" on the basis of the better crop growth that occurs on them with normal SOIL 1 land. The crop growth was almost equal to that of the superior moisture SOIL 1/10.

/over

of SOIL 10 compared with SOILS 1, 4 and 5. Thus SOIL 10 is relatively rich in calcium and magnesium; has adequate potassium; but, except in the virgin state, is low in phosphate and nitrogen. The average level of topsoil calcium is 7.8 m.e.% compared with a mean figure of 1.9 m.e.% for SOIL 1. The O.M. content of SOIL 10 averages between 2 and 3%. Subsoils are moderately acid (Mean topsoil pH = 6.5; subsoil pH = 5.2). Quite high levels of H_v are present throughout the profile. H_p does not occur in topsoils, but low levels are detected in most subsoils.

SOIL 10 is found extensively over much of the highest-lying country and the more gentle upper slopes around and to the west of Kikoneni. A few pockets of SOIL 10 are also found on some of the highest summits to the east of Kikoneni, where, however, the Matiya-Chumvi beds are somewhat common. It also occurs in a very few areas immediately to the north of the Ramisi River where there are broad hill tops, notably in the vicinity of Kibunda and Mpagwai. It is important to realize that in these latter areas (i.e. east of Kikoneni and north of the Ramisi) the sand fraction is considerably coarser than is typical for SOIL 10 so that these soils are both morphologically and physicochemically intermediate between SOILS 1 and 10. In these (rather extensive) intermediate situations the procedure has been to map the soils on summits and on level ground, where there is little or no topsoil, as SOIL "10". On all slopes they are mapped as SOIL 1 because there they are usually covered by the coarse sandy loam characteristic of SOIL 1 and are moreover subject, from time to time, to lateral incursions of acid seepage which has the effect of lowering the base status. North of the Ramisi the SOIL "10" is really rather coarse and its status was decided on the basis of reasonable amounts of topsoil calcium and phosphate coupled with relatively high profile pH levels. In terms of the coarseness of the sand fraction, general profile morphology and organic content these soils are nearer to SOIL 1. The area mapped as SOIL "10" around Lake is particularly doubtful since there the soils are deficient in phosphate and low in topsoil calcium. They can only be regarded as SOIL 10 on the basis of the percentage of clay and the profile pH (6.5). The soils around Lake, Mwaru and Kikoneni are in point of fact precisely intermediate between SOILS 1 and 10. It was finally decided to map these level areas as SOIL "10" on the basis of the rather better crop growth that was observed compared with normal SOIL 1 land. This distinction in crop growth was almost certainly the consequence of the superior moisture-retaining qualities of the intermediate SOIL "10".

Fertility management on these intermediate soils should, however, follow practices recommended for SOIL 1.

Pockets of SOIL 4 may occur on hillslopes dominated by SOIL 10. This is a colluvial sandy loam variant derived from SOIL 10 as a result of hill wash and soil creep. Minor pockets of SOIL 4 are mapped in as SOIL 10. In some cases, larger areas of SOIL 4 may also be included in an area demarcated as SOIL 10. Due to general inaccessibility and the scale of the survey it is inevitable that some pockets of deep sandy loam have been overlooked. Inevitably too a good many local gravel outcrops that should have been mapped as SOIL 12 (below) will also be included within areas of SOIL 10.

Since SOIL 10 is not as susceptible to erosion as some of the looser and coarser textured soils, slopes of up to 10° are permitted before it falls within the definition of the slope category "SOIL" 2. On slopes of 10° or over, it is more usual, in the Kikoneni Sector, to find forms of SOILS 1 or 4 rather than SOIL 10, owing to the prevalence of hill creep.

SOIL 10 was observed to grow relatively good crops of maize, bananas and sugar; also fine quality oranges and grapefruit. Even tobacco grows marginally better on this soil type. These observations (made on crops without the benefit of fertilizer) would seem to suggest that here we have a very promising soil and one that offers a more balanced nutrition than anything on the Mazeras sandstone. Since SOIL 10 is quite widespread on high ground in the Kikoneni Sector, this should auger well for any form of settlement proposed for that area.

Kikoneni Pit 55, South of Mwananyamala, may be regarded as typical of SOIL 10, but for its exceptionally high content of phosphate which is an unique characteristic of the Mwananyamala Ridge.

Analytical data for Pit 55 is presented in Table 14.

/over

Fertilizer management on these intermediate soils should, however, follow practices recommended for SOIL 1.

Pockets of SOIL 4 may occur on hillsides dominated by SOIL 10. This is a colluvial sandy loam variant derived from SOIL 10 as a result of hill wash and soil creep. Minor pockets of SOIL 4 may occur in some cases, larger areas of SOIL 4 may also be included in an area demarcated as SOIL 10. Due to general inaccessibility and the scale of the survey it is inevitable that some pockets of heavy sandy loam have been overlooked. Inevitably too a good many local gravel outcrops that should have been mapped as SOIL 12 (below) will also be included within areas of SOIL 10.

Since SOIL 10 is not as susceptible to erosion as some of the looser and coarser textured soils, slopes of up to 10° are permitted before it falls within the definition of the slope category "SOIL" 2. On slopes of 10° or over, it is more usual, in the Kikoni sector, to find forms of SOIL 1 or 4 rather than SOIL 10, owing to the prevalence of hill creep.

SOIL 10 was observed to grow relatively good crops of maize, bananas and sugar; also this quality oranges and grapefruit. Tobacco grows marginally better on this soil type. These observations (made on crops without the benefit of fertilizer) would seem to suggest that here we have a very promising soil and one that offers a more balanced nutrition than anything on the Mwananyama ridge. Since SOIL 10 is quite widespread on high ground in the Kikoni sector, this should appear well for any form of settlement proposed for that area.

Kikoni Pit 25, South of Mwananyama, may be regarded as typical of SOIL 10, but for its exceptionally high content of phosphate which is an unique characteristic of the Mwananyama Ridge.

Analytical data for Pit 25 is presented in Table 14.

PIT NO. 55 Kikoneni

DEPTH CMS	% C	SAND	% SILT		CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%							P p.p.m.
			SAND	SILT			Hp	Hv	Na	K	Ca	Mg	Mn	
0-10	1.7	56	18	26	6.4	-	7.2	0.14	0.87	10.8	5.2	1.28	225	
10-48	56	14	30	5.6	-	6.2	0.07	0.47	3.2	2.5	1.52	16		
48-133	48	12	40	5.2	0.1	4.2	0.12	0.12	2.8	1.2	0.58	6		

DEPTH CMS	C.E.C.	E X C H A N G E A B L E B A S E S m.e.%			E.S.P.	pH 1:5 KCl	E.C. 1:5 H ₂ O
		Ca	Mg	Na			
0-10	24.0	15.8	4.7	1.00	0.1	6.1	0.27
10-48	9.4	3.8	2.2	0.48	0.01	5.2	0.29
48-133	7.6	2.8	0.9	0.39	0.03	5.0	0.18

PIT NO. 55 (KIKONENI) Profile Description.

MAP REFERENCE: 280 082 (200/iv).

LOCATION: Near the top of a ridge.

ASPECT: West. SLOPE: 1°.

PARENT MATERIAL: Maji-ya-Chumvi Sandstone.

DRAINAGE: Good. M.R.D.: 0-6 cms.

ROOTING DEPTH: More than 145 cms.

PROFILE DEPTH: 145 cms.

VEGETATION COVER: 100%. 50% Savanna Bush.
100% Grass Cover:-
Mostly Panicum maximum.

- 0 - 10 cms. Very dark brown (7.5 YR 2/2), very friable sandy clay loam, with strong very fine SAB and crumb. Very few fine and medium gravel. Abundant fine and medium roots. LB. abrupt and even.
- 10 - 48 cms. Dark brown (7.5 YR 3/4) friable sandy clay loam, with Mod. fine SAB. Very faintly blotched. Very few medium gravel.. Common fine and medium roots. LB. gradual. This is a transitional layer.
- 48 - 133 cms. Yellowish red (5 YR 4/6 to 5/6) very friable sandy clay, with Mod. fine and medium SAB. Few faint yellow blotching. Very few medium gravel with occasional stones. Few fine and medium roots locally common. LB. abrupt and undulating.
- 133 cms. + Abundant fine and medium gravel concentration and some Maji-ya-Chumvi fine sandstone. Not sampled.

50% Forest Trees.
50% Forest Trees.
70% Forest.

Under high forest (e.g. Bombax rhodognaphalon and Chlorophora excelsa), the soil becomes very acid. It is leached of calcium, magnesium and potassium under the influence of a highly acid topsoil organic litter, which releases Hp at the soil surface. The mechanical composition, morphology, parent mineral material and topographic situation all point to a typical version of SOIL 10: Chemical data indicate a highly leached and acid soil. This is an invariable result: That under grassland, bases and nutrients accumulate in the topsoil associated with a visible concentration of O.M. Under forest, there is no visible surface organic layer and the bases are leached out. This general observation concerning the influence of the vegetation cover on soil character leads on to an important agricultural principle: That the chemical

Profile Description

280 082 (200/iv)

near the top of a ridge

West

Maji-ya-Chumvi Sandstone

Good. M.R.D. 0-6 cms.

More than 145 cms.

145 cms.

100X. 50X Savanna Bush

100X Grass

Mostly

Very dark brown (7.5 YR 2/2), very friable
clay loam, with many very fine sand and
stone. Very few fine and medium gravel. Abundant
fine and medium roots. LB. scarce and even.

Dark brown (7.5 YR 2/4), friable, sandy clay
loam, with Mod. fine sand, very friable, friable
fine and medium gravel. Common fine and medium
roots. LB. gradual. This is a transitional layer.

Yellowish red (5 YR 4/6 to 2/5), very friable
sandy clay, with Mod. fine and medium sand. Few
fine yellow blotching. Very few medium gravel.
Occasional stones. Few fine and medium roots.
LB. abrupt and well defined.

Abundant fine and medium gravel, common
Maji-ya-Chumvi fine sandstone. Not sampled.

Under high forest (e.g. Podocarpus
and Chlorophora), the
soil becomes very acid. It is leached of
calcium, magnesium and potassium under the
influence of a highly acid topsoil organic
litter, which releases H⁺ at the soil surface.
The mechanical composition, morphology, parent
mineral material and topographic situation all
point to a typical version of SOIL 10: Chemical
data indicate a highly leached and acid soil.
This is an inevitable result: That water
passing, bases and nutrients accumulate
in the topsoil associated with a visible
concentration of O.M. Under forest... there is
no visible surface organic layer and the bases
are leached out. This general observation
concerning the influence of the vegetation cover
on soil character leads on to an important
agricultural principle: That the chemical

composition of the well in the project Area is related to profile morphology as to the surface organic matter, i.e. Utilization determines the the Soil through its influence on the quantity of Organic Material

An example of SOIL is provided by Kikoneni Pit 2 miles East of Jombo Mount

Analytical data for presented in Table 15.

<u>NO. 94 (KIKONENI)</u>	Profile Description
<u>REFERENCE:</u>	2609 (200/ii)
<u>LOCATION:</u>	400 yards inside
<u>SUBJECT:</u>	South-West.
<u>TOPO-RELIEF:</u>	Slightly undulating
<u>ARENT MATERIAL:</u>	Maji-ya-Chumvi
<u>DRAINAGE:</u>	Good.
<u>ORGANIC MATTER:</u>	Forest litter,
<u>LAND USE:</u>	Forest. (Some
<u>DEPTH:</u>	More than 175
<u>PROFILE DEPTH:</u>	175 cms.
<u>VEGETATION COVER:</u>	80%
	50% Forest Trees
	70% Forbes.
	10% Grass.

0-59 cms. Reddish brown to yellowish reddish friable sandy clay loam, with Moderate fine SAB. Abundant fine to large roots and even.

59-100 cms. Dark reddish brown to yellowish reddish friable, slightly blotched sandy clay loam. Mod. fine and medium SAB. Few to medium roots. This is a transitional soil.

100-150 cms. + Red (2.5 YR 5/8) friable sandy clay loam. medium SAB. Very fine to medium roots.

ined soils in
not so much to
nature of the
The system of Land
ertility Status of
ce on the quality and

0 under rainforest
94, sited some
n.

pit 94 is

tion.

the Southern edge of
Forest.
LOPE: 1° 30'.

ting.

fine sandstone.

rapidly incorporated.

Marketable Timber).

ns. M.R.D.: 0-14 cms.

es.

(5 YR 4/5) very
fine and very
oots. LB. clear

h brown (5 YR 3/8)
ay loam with
ommon very fine
ional layer.

clay, with Mod.
ew to common

/over ...

composition of the well drained soils in the project area is related not so much to specific morphology as to the nature of the parent material, i.e. the system of land use. The influence of the quality and quantity of organic material.

An example of soil in under rainforest is provided by Kibonani Pit 94, sited some 1 mile east of Jomba Mountain.

Analysed data for Pit 94 is presented in Table 15.

Profile Description	Depth (cm)
400 yards inside southern edge of forest.	0-100
Slightly undulating, Najiya-Chumvi fine sandstone.	100-150
Good.	150-200
Forest litter, rapidly incorporated.	200-250
Forest. (Some Marketable Timber).	250-300
More than 175 cms. N.E.D. 1-6-16 cms.	300-350
175 cms.	350-400
80% Forest Trees.	400-450
20% Forbs.	450-500
10% Grass.	500-550

reddish brown to yellowish red (2 YR 4/5) very sandy clay loam, with mod. fine and very abundant fine to large roots. IS, clear.

reddish brown to yellowish brown (2 YR 3/5) slightly bleached sandy clay loam with mod. medium silt. Few to common very fine roots. This is a transitional layer.

(2.5 YR 5/8) friable sand clay, with mod. silt. Very fine to medium, few to common roots.

TABLE 15

LAB. NOS. 12784-86

PIT NO. 94 Kikoneni

DEPTH CMS	% C	SAND	% SILT	CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%					P p.p.m.	
						Hp	Na	K	Ca	Mg		Mn
0-17	0.6	62	12	26	4.6	0.9	0.08	0.04	1.6	0.3	0.61	15
17-59		58	10	32	4.8	0.5	0.08	0.15	0.9	1.0	0.40	7
59+		50	8	42	5.3	0.1	0.10	Trace	1.0	1.3	0.06	5

SOIL 12.

This is defined as Soil 10, with significant gravel sheets present within the surface 60 cms. and persisting to depth. It is assumed that these gravels exercise a detrimental effect on plant growth. These gravel sheets are sometimes found on steeper hill flanks in the Kikoneni Sector. In these situations they may be underlain by sheet laterite. Necessarily Soil 12 forms a complex with Soil 10 and it is often not possible to delimit the two soils. Furthermore, many of the occurrences of Soil 12 will inevitably have been overlooked since it was impossible to auger every inch of land. The composition of the gravels is identical to those described above (in Soil 10), though there is evidence for local in situ laterization (induration through ferruginisation plus the injection of compounds of manganese and aluminium). The gravel sheets often support the denser form of savanna bush. Soil 12 tends to be more acid than Soil 10.

Despite excellent rooting through crevices in the gravel sheets, Soil 12 has a generally low capacity for retaining moisture. For this reason, it is only moderately suitable for cultivation, though good quality cassava may be grown on this soil; the gravels promote the development of large roots.

SOIL 13.

These are steep-sided conical hills of altered alkaline sandstones or volcanic vents of silicified agglomerate; occurring rarely in the Kikoneni Sector. These conical hills (e.g. Kiruku and Nguluku Hills) were described towards the end of Section 2B. The steep upper slopes are composed of rock outcrops; lower slopes are affected by extensive gravels. "Soil" 13 is of course unsuitable for any form of development.

SOIL 14.

This is the deep and very coarse loose whitish Magarini sand and loamy sand. The associated natural vegetation is obviously subject to severe droughting.

Soil 14 occurs in 3 quite separate situations:

- (a) It has a discontinuous distribution on the flanks and summits of the lower ranges of the Shimba Hills. These may be relic deposits and are invariably associated with the finer textured Soil 4. On these higher lying sites there is no ground water table and the topsoil has less than 0.5% O.M.

/over

Soil 12.

This is defined as Soil 10, with significant
 gravel sheets present within the surface 60:cm, and
 relating to depth. It is assumed that these gravels
 exercise a detrimental effect on plant growth. These
 gravel sheets are sometimes found on steep hills flanks
 in the Kikand sector. In these situations they may
 be underlain by sheet laterite. Necessarily Soil 12 forms
 a complex with Soil 10 and it is often not possible to
 identify the two soils. Furthermore, many of the occurrences
 of Soil 12 will inevitably have been overlooked since it
 is impossible to sugar every inch of land. The composition
 of the gravels is identical to those described above (in
 Soil 10), though there is evidence for local in situ
 fertilization (induration through ferrugination and the
 presence of compounds of manganese and aluminum). The
 gravel sheets often support the denser form of savanna
 vegetation. Soil 12 tends to be more soil than Soil 10.

Despite excellent rooting through gravels in the
 gravel sheets, Soil 12 has a generally low capacity for
 retaining moisture. For this reason, it is only moderately
 suitable for cultivation, though good quality cassava may
 be grown on this soil; the gravels promote the development
 of large roots.

Soil 13.

These are steep-sided conical hills of altered
 Kikand sandstones or volcanic vents of altered
 composition; occurring rarely in the Kikand sector. These
 conical hills (e.g. Kiruku and Nguluku Hills) were
 described towards the end of Section 2B. The steep
 lower slopes are composed of rock outcrop; lower slopes
 are affected by extensive gravels. "Soil" 13 is of course
 suitable for any form of development.

Soil 14.

This is the deep and very coarse loose whitish
 granitic sand and loamy sand. The associated
 natural vegetation is obviously subject to severe
 logging.

Soil 14 occurs in 3 quite separate situations:

- (a) It has a discontinuous distribution on the
 flanks and summit of the lower ranges of the
 Shimsa Hills. These may be relic deposits and
 are invariably associated with the finer textured
 Soil 4. On these higher lying sites there is
 no ground water table and the topsoil has less
 than 0.5% D.M.

over ...

- (b) Local pockets at the base of steep V-shaped valleys in the deeply dissected Nikunde Forest country to the West of Lukore. These are merely deep colluvial deposits derived from previously eroded coarse-textured "Shimba Grits" (Mazeras Sandstone). Ground water is present at depth.

Soil 14 Type (a) is unsuitable for development due to its low moisture holding capacity. Type (b) is unsuitable because of its topographic position.

- (c) Extensive areas of Magarini Sand occur in relatively flat situations around Mwaluvanga, Mafisini and Vivwini. Here there is an intimate association of Soils 4 and 14 in higher-lying localities; Soil 52 (S.P.D; with seasonal water table affecting the profile,) in intermediate sites; and the V.P.D. Soil 80 (often as swamp) on low ground. Soil 14 in these more level areas has a water table at a considerable depth (below 125 cms. even during the rains). Topsoil has between 1 and 2% O.M. Soil 14 Type (c) may well, with fertilizer, have a limited suitability for coconuts, and possibly also cashews.

Soil 14 is excessively permeable and highly leached with very little capacity for retaining either moisture or nutrients. The pH is between 5 and 6. Soil 14 is severely deficient in all major nutrients.

Ramisi Pit 5 near Mwaluvanga is representative of Soil 14 (Type C). Analytical data for Pit 5 is presented in Table 16.

<u>PIT NO. 5 (RAMISI):</u>	Profile Description
<u>MAP REFERENCE:</u>	39212C (200/IV)
<u>ASPECT:</u>	South
<u>SLOPE:</u>	3°
<u>MICRO RELIEF:</u>	Plane
<u>DRAINAGE:</u>	Good
<u>PARENT MATERIAL:</u>	Magarini Sand
<u>ROOTING DEPTH:</u>	More than 125 cms
	<u>M.R.D.</u> 0 - 10 cms

/over.....

(b) Local pockets of low grade of steeply sloping hills in the heavily dissected Nkanga Forest country to the west of Lukosa. These are heavily deep (up to 100 ft) deposits derived from greyish sandstone (Nkanga Sandstone). Ground water is present at depth.

Soil 14 (a) is well suited for development due to its low moisture holding capacity. Type (b) is unsuitable because of its topographic position.

(c) Extensive areas of laterite sand occur in relatively flat situations around Kwana, Kibini and Vindini. Here there is an intimate association of Soils 4 and 14 in higher-lying localities; Soil 22 (S.P.D.) with seasonal water table affecting the profile, in intermediate areas; and the V.P.D. Soil 13 (often as swamp) on low ground. Soil 14 in these more level areas has a water table at a considerable depth (below 125 cm, even during the rains). (Soils 1 and 2, 1 and 2, D.M., Soil 14 Type (c) may well, with fertilizer, have a limited utility for coconuts, and possibly also cashews.

Soil 14 is excessively humic and highly leached with very little capacity for retaining either nutrients or nutrients. The pH is between 5 and 6; Soil 14 is severely deficient in all major nutrients.

Profile Pit 2 near Kwana is representative of Soil 14 (Type C). Analytical data for Pit 2 is presented in Table 10.

Profile Description

SOIL (20/IV)

Soil
3
Pine
Good
Laterite Sand
More than 100 cm
pH 5.5 - 6.0

(RAWITI)

TABLE

TABLE

TABLE

TABLE

Notes

PROFILE DEPTH:

125 cms

VEGETATION COVER:

80% 10% Hyphaene parvula

Less than 10% Cassia mimosoides

70% Grassland of Chloris and Hyparrhenia

0-30 cms

Dark brown (7.5YR 4/2) very friable loamy sand, with very weak fine SAB. Speckled white appearance owing to quartz. Common fine roots. Diffuse LB.

30 cms.

Very pale brown (10 YR 7/3) loose, structureless loamy sand, with few to common distinct coarse reddish yellow blotching (7.5 YR 6/6). Contains very coarse yellowish red quartz grains. Few to common fine roots.

/over.....

PROFILE DEPTH: 128 cm

VEGETATION COVER: 10% Hypochaeris glabra

Less than 10% Lespedeza microcarpa

20% Grewia of Chloris and Hypochaeris

Dark brown (7.5YR 6/2) very friable loamy sand, with very weak fine sand. Speckled white appearance owing to quartz. Common fine roots. Diffuse l.s.

30 cm. Very pale brown (10 YR 7/3) loam, structure less loamy sand, with few to common distinct coarse reddish yellow blotching (7.5 YR 5/3). Contains very coarse yellowish red quartz grains. Few to common fine roots.

lover.....

PIT NO. 5 Ramisi

TABLE 16

LAB. NOS. 10609-10

DEPTH CMS	% C	SAND	% SILT	CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%						P p.p.m.
						Hp	Na	K	Ca	Mg	Mn	
0-30	1.1	86	6	8	5.0	0.1	0.08	Trace	0.3	Trace	0.11	Trace
30+		82	12	6	5.1	0.2	0.08	Trace	Trace	Trace	Trace	Trace

(b) SEASONALLY POORLY DRAINED SOILS.

These demonstrate evidence for impeded drainage within the surface 90 cms. i.e. Distinct mottling normally accompanied by glei below 45 cms. These S.P.D. soils exhibit a greater range of properties within the soil type definition than is evident in the Well Drained soils. This is essentially due to the inherent variability of the S.P.D. lower slope colluvial deposits.

SOIL 50

This is a variable, deep soil which is particularly common on lower slopes receiving acid drainage in the Shimba Hills, though it also occurs locally throughout the Lower Ramisi Valley. A coarse sandy loam, sandy clay loam or loam topsoil overlies clay loam or sandy clay loam. There is normally some accumulation of surface O.M. due to the seasonally anaerobic conditions (1 to 3% O.M.) Subsoils are distinctly mottled with red colours against a pale glei matrix; they possess a higher silt content than soils further upslope. This map unit embraces a wide range of colluvial apron deposits, particularly on the lower slopes of the Shimba Hills, where an intimate complex of Soils 50, 52, 53, may be found on a single hillside; the entire complex being mapped as Soil 50.

Seasonal drainage waters tend to pass both downwards and laterally through this soil, so effectively acidifying the profile. Significant levels of Hp are often found in both topsoil and subsoil. Average topsoil pH=5.5; subsoil pH = 5.3; Soil 50 is rather low in calcium and potassium; deficient in phosphate and nitrogen. Subsoil calcium is extremely low.

Taking account of its topographic situation, acidity general infertility and poor drainage, Soil 50 has only limited suitability as arable and may well be best put under grass. Development for intensive arable or tree crops could require the cutting of interceptor drains (to 3 feet) to prevent seepage or even flooding during rains.

Such drains should be installed across the slope with an incline of 1%, immediately above the area subject to development.

Shimba Pit 25 is representative of some of the properties of Soil 50. Analytical data for Pit 25 is presented in Table 17.

/over

(b) SEASONALLY FLOODING SOILS

These diagnostic evidence for seasonally flooded soils within the surface 20 cm. i.e. distinct wetting normally accompanied by pH below 4.5 cm. These S.P. 0.1 soils exhibit a greater range of properties within the soil type definition than is evident in the well drained soils. This is essentially due to the inherent variability of the S.P. 0.1 lower slope colluvial deposits.

SOIL 30

This is a vertic, heavy soil which is particularly common on lower slopes receiving acid drainage in the lower hills, though it also occurs locally throughout the lower Hamlet Valley. A coarse sandy loam, sandy clay loam or loam topsoil overlies clay loam or sandy clay loam. There is normally some accumulation of surface S.P. due to the seasonally anaerobic conditions (1 to 3% DM). Pedoballs are distinctly mottled with red colour against a pale grey matrix; they possess a higher silt content than soils further up slope. This map will embrace a wide range of colluvial spon deposits, particularly on the lower slopes of the Green Hills, where an intimate complex of soils 30, 32, 33, may be found on a single hillside; the entire complex being mapped as Soil 30.

Seasonal drainage waters tend to pass both down-wards and laterally through this soil, so effectively neutralizing the profile. Significant levels of H₂O are often found in both topsoil and subsoil. Average topsoil pH = 5.5; subsoil pH = 5.3; Soil 30 is rather low in calcium and potassium; deficient in phosphate and nitrogen. Subsoil calcium is extremely low.

Taking account of its topographic situation, acidity, general infertility and poor drainage, Soil 30 has only limited suitability as a site and may well be best put under grass. Development for intensive crops or trees would reduce the output of interceptor drains (to 2 feet) to prevent seepage or even flooding during rains.

Such drains should be installed across the slope with an incline of 1%, immediately above the area subject to development.

Grade Pit 25 is representative of some of the properties of Soil 30. Analytical data for Pit 25 is presented in Table 17.

over

PIT NO 25 (SHIMBA):

Profile Description

MAP REFERENCE:

453184 (200/IV)

LOCATION:

On a low slope not far above river level; below Settlement H.Q.

ASPECT:

West

SLOPE:

6° 30'

PARENT MATERIAL:

Mazeras Sandstone

DRAINAGE:

Seasonally poorly drained (Receiving) Some lateral seepage in the subsurface horizon

VEGETATION:

10% Savanna Bush
100% Grassland

0-16 cms. Black to very dark brown (7.5 YR 2/1) very sandy (and silty) loam; with very weak SAB. Abundant fine and medium roots. LB clear and even.

16-52 cms. Dark brown (7.5 YR 5/4) friable. Sandy loam, with fine and medium weak SAB. Abundant very fine faint R.M. Common fine and very fine roots. LB Gradual.

52 cms. Yellowish red (5 YR 5/6) slightly firm sandy clay loam, with mod. fine and medium SAB. Common distinct yellow blotching. Common fine distinct dark blotches. Abundant distinct red (2.5 YR 4/6) R.M. Faint yellowish brown (10 YR 5/4) gleisation. Few fine and very fine roots.

PIT NO. 25 (SHIMBA):

Profile Description:

REF. REFERENCE:

433194 (200/IV)

LOCATION:

On a low slope not far above river level, below Settlement H.M.

ASPECT:

East

SLOPE:

5° SW

PARENT MATERIAL:

Massive sandstone

GRAINAGE:

Generally poorly bedded (bedding) some lateral escape in the surface horizon

VEGETATION:

10% Savanna Bush
100% Grassland

0-10 cms.

Black to very dark brown (2.5 YR 2/1) very sandy (and silty) loam; with very weak SAB. Abundant fine and medium roots. LB clear and even.

10-25 cms.

Dark brown 2.5 YR 2/4 (friable). Sandy loam, with fine and medium weak SAB. Abundant very fine faint R.M. Common fine and very fine roots. LB gradual.

25-50 cms.

Yellowish red (2.5 YR 2/6) slightly firm sandy clay loam, with nod. Fine and medium SAB. Common distinct yellow blotching. Common fine distinct dark blotches. Abundant distinct red (2.5 YR 4/3) R.M. Faint yellowish brown (2.5 YR 2/4) granulation. Few fine and very fine roots.

DEPTH CMS	% C	SAND	% SILT		CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%						P p.p.m.
							Hp	Na	K	Ca	Mg	Mn	
0-16	1.4	58	32	10	5.6	-	0.11	0.32	3.2	1.8	0.51	3	
16-52		56	28	16	5.3	1.2	0.08	0.06	0.4	1.1	0.02	3	
52+		48	18	34	5.1	3.3	0.11	0.06	0.2	1.5	Trace	3	

DEPTH CMS	C.E.C.	E X C H A N G E A B L E B A S E S m.e.%		E.S.P.	pH 1:5 KCl	E.C. 1:5 H ₂ O
		Ca	Mg			
0-16	10.4	3.0	2.2	1.7	4.9	0.08
16-52	5.4	1.5	1.5	5.0	4.3	0.03
52+	11.4	2.0	2.0	1.6	4.1	0.17

SOIL 51

This is the homologue for Soil 50 on lower slopes in the Kikoneni from Maji-ya Chumvi beds. Though (on average it contains 10% more iron) some lateral movement of drainage takes place, though this seepage has less than in the Shimba Hills. However common with Soil 50 a certain accumulation of Hp at least in the topsoil pH = 5.7; subsoil pH = 5.5. A fine sandy clay loam or loam is present at the surface these are fine sandy clay, clay loam or clay. is visible organic accumulation. The deep subsoil is distinctly often with soft manganese concretions centres of rust blotches. The colour is greyish to yellowish brown.

Soil 51 often occurs on lower slopes below a significant change of slope by the savanna bush above giving Hyparrhenia or Themeda grassland by termitaria, each hillock being a clump of thicket ("Grouped Bush"). sheet gravels are present in the topsoil presumably these alleviate the

Soil 51 has a relatively high iron content but is deficient in phosphate and nitrogen in seasons with really heavy rain. This soil should prove suitable for arable and tree crops, since the iron is largely in the subsoil whilst lateral incursions of surface seepage in seasons: seasons in which the rain is for Short Rains planting, Soil 51 is more favourable than Soil 10 because of its moisture status. Soil 51 appears well suited for sugar. It would be the best soil for intensive vegetable

Soil 51 is normally found on lower slopes Soil 10, and upslope of V.P.D.

Soil 50, occurring
sector developed
heavier than Soil 50
clay in the topsoil,
waters still takes
richer base content
, it shares in
amount of acidity and the
subsoil. Average
3.

Soil overlies
clay. If mottles are
only very faint; there
($1\frac{1}{2}$ to $2\frac{1}{2}$ % O.M.).
mottled or blotched,
mottles set in the
soil matrix is

er hill flanks
pe. It is signified
way to open
often accompanied
topped by a dense
"grassland"). Sometimes
subsoil;
drainage to some extent.

h base status,
nitrogen. Except
persistent rains,
r a wide range of
drainage impedence
it is not subject to
age. In drier
s cease early; and
may prove even
se of its higher
particularly well
probably prove the
e production.

downslope of
Soils 81 or 83.

over

Kikoneni Pit 1 is typical of Soil 51.
Analytical data for Pit 1 is presented in Table 16.

<u>PIT NO. 1 (KIKONENI):</u>	Profile Description
<u>MAP REFERENCE:</u>	332091 (220/IV)
<u>LOCATION:</u>	On lower side of B.A.T. Shamba 3 - Midway down the slope. The slope above is 5°.
<u>ASPECT:</u>	West
<u>SLOPE:</u>	3° 40'
<u>PARENT MATERIAL:</u>	Fine sandstone - Maji-ya-Chumvi
<u>DRAINAGE:</u>	Seasonally poorly drained Receiving downslope waters, essentially coming through the subsoil.
<u>M.R.D.</u>	0 - 16 cms.
<u>ROOTING DEPTH:</u>	More than 152 cms.
<u>PROFILE DEPTH:</u>	152 cms.
<u>VEGETATION COVER:</u>	100%
<u>0 - 23 cms.</u>	Very dark greyish brown (10 YR 3/2) very friable sandy clay loam, with Mod. fine and very fine SAB common fine and medium roots. LB gradual.
<u>23 - 65 cms.</u>	Dark brown (7.5 YR 4/2) friable, sandy clay loam, with Mod. medium SAB. Abundant distinct dark blotching. Common very fine and medium roots. Diffuse L.B. This horizon is transitional.
<u>65 - 107 cms.</u>	Brownish yellow (10 YR 6/6) slightly firm, sandy clay, with Mod. medium SAB. Common distinct red RM. (2.5 YR 5/6). Few fine dark blotches and some yellow blotches. Few fine and very fine roots. Diffuse LB.
<u>107 - 150 cms.</u>	Light yellowish brown (10 YR 6/4) slightly firm somewhat gleyed. light clay with weak medium SAB. Abundant medium prominent R.M. Few to common medium lateritic gravels. Very few fine and very fine roots. LB. abrupt and intermittent.
<u>150 cms.</u>	This horizon not samples; very abundant lateritic manganese gravels. Gravels have bluish - black centres surrounded by reddish weathering material.

Analysis data for pit 1 is presented in table 1.
 Pit 1 is typical of soil 21.

Profile Description	PIT NO. 1 (KRONEN)
Profile Description	MAP REFERENCE
On lower side of S.A.L. Shanda 3 - 4 ft down the slope. The slope above the S.	LOCAL DATA
vent	ASPECT:
3° SW	SLOPE:
Fine sandstone - white-gray	PARENT MATERIAL:
Seasonally poorly drained receiving down slope waters, essentially coming through the soil.	DRAINAGE:
0 - 10 cms.	M.F.D.
More than 150 cms.	ROOTING DEPTH:
150 cms.	SHOULDER DEPTH:
100%	VEGETATION COVER:
Very dark grayish brown (10 YR 2/2) very friable sandy clay loam, with fine and very fine S&B common fine and medium roots, LB gradual.	0 - 50 cms.
Dark brown (7.5 YR 4/2) friable, sandy clay loam, with med. medium S&B. Abundant distinct dark blotching. Common very fine and medium roots. Diffuse L.B. This horizon is transitional.	50 - 80 cms.
Brownish yellow (10 YR 8/6) slightly firm sandy clay, with med. medium S&B. Common distinct red FM (2.5 YR 5/8). Few fine dark blotches and some yellow blotches. Few fine and very fine roots. Diffuse LB.	80 - 100 cms.
Light yellowish brown (10 YR 6/4) slightly firm somewhat glistened. Light clay with weak medium S&B. Abundant medium prominent R.M. Few to common medium infertile gravel. Very few fine and very fine roots. LB. bluish and indurated.	100 - 150 cms.
This horizon not sampled; very abundant infertile angular gravel. Gravel have bluish - black centers surrounded by reddish weathering material.	150 cms.

TABLE 18

LAB. NOS. 8849-52

PIT NO. 1 Kikoneni

DEPTH CMS	% C	% SAND SILT CLAY			pH	A V A I L A B L E N U T R I E N T S m.e. %						P p.p.m.
		SAND	SILT	CLAY		Hp	Na	K	Ca	Mg	Mn	
0-23	0.9	58	22	20	6.2	-	0.13	0.95	7.4	3.1	1.22	10
23-65		58	16	26	6.0	-	0.13	0.42	1.9	2.5	1.60	1
65-107		50	12	38	5.4	0.6	0.21	0.06	1.7	3.2	0.23	3
107-150		44	14	42	5.4	0.2	0.39	0.03	1.6	3.1	0.08	5

SOIL 52

These are deep, pale brown, loose, coarse sandy loams and loamy sands with a high seasonal water table. Soil 52 is the S.P.D. version of Soil 14 and occurs on intermediate level terraces of the Magarini Sand. Subsoils are distinctly mottled (within the surface 125 cms), but are not usually gleied. Soil pH is around 5.0. Like Soil 14 it is deficient in all major nutrients.

Soil 52 occurs extensively in association with Soils 4 and 14 (upslope) and Soil 60 (downslope), in the general vicinity of Mafisini and Mwaluvanga, and also locally elsewhere along the Lower Ramisi Valley. Whilst, with regular fertilizing, this soil is nearly ideal for coconuts, it should also grow good cashew. Ramisi Pit 3 is typical of Soil 52. Analytical data for Pit 3 is presented in Table 19.

<u>PIT NO.3 (RAMISI):</u>	Profile Description
<u>MAP REFERENCE:</u>	384122 (200/IV)
<u>LOCATION:</u>	On junction of Shimba-Kikoneni Road and E.A.P.L. Line.
<u>MICRO-RELIEF:</u>	Plane.
<u>PARENT MATERIAL:</u>	Magarini Sand
<u>DRAINAGE:</u>	Slightly poorly drained.
<u>M.R.D.</u>	0 - 20 cms.
<u>ROOTING DEPTH:</u>	More than 160 cms.
<u>PROFILE DEPTH:</u>	160 cms.
<u>VEGETATION COVER:</u>	100%
Plantation of Cashew/Coconut with grassland:	10% <u>Hyparrhenia</u> 90% <u>Cenchrus ciliaris</u>

0 - 28 cms.

Dark greyish brown to very dark grey (10 YR 4/2: 3/21: 3/1) very friable coarse sandy loam, with very weak structure. Faint common rust blotching. Faint dark blotching. Common very fine and medium roots. Diffuse L.B.

/over.....

SOIL 32

These are deep, pale brown, loose, coarse sandy loams and loamy sands with a high seasonal water table. Soil 32 is the S.P.D. version of Soil 1A and occurs on intermediate level terraces of the region. Soil 32 is distinctively reddish (within the surface 150 cm), but are not usually plowed. Soil 32 is about 2.0. Like Soil 1A it is deficient in all major nutrients.

Soil 32 occurs extensively in association with Soil 4 and 1A (uplope) and Soil 10 (downslope), in the general vicinity of Wairangi and Mawanga, and also locally elsewhere along the Lower Hamlet Valley. Water, with regular fertilizing, this soil is nearly ideal for coconuts, it should also grow good cashew. Hamlet Pit 3 is typical of Soil 32. Analytical data for Pit 3 is presented in Table 1A.

Profile Description

30155 (300/VI)

On junction of Shimba-Kilimanjaro Road and E.A.P.L. Line.

Plains.

Washed sand

Slightly poorly drained.

0 - 20 cm.

More than 100 cm.

100 cm.

100%

Soil of Cashew/Coconut with grassland; 10% vegetation

Soil 32
30155

Dark grayish brown to very dark grey (10 YR 4/2; 3/2L; 0/1) very friable coarse sandy loam, with very weak structure. Faint common root blotching. Faint dark blotching. Common very fine and medium roots. Diffuse Lb.

Lower

PIT NO. 3 Ramisi

LAB. NOS. 10606-08

TABLE 15

DEPTH CMS	% C	SAND	% SILT		CLAY	pH	A V A I L A B L E N U T R I E N T S m.e. %						P p.p.m.
			SAND	SILT			Hp	Na	K	Ca	Mg	Mn	
0-28	0.3	78	12	10	5.1	0.2	0.62	0.05	0.6	0.4	0.49	Trace	





28 - 96 cms. This is a transitional layer. Very pale brown (10 Y.R. 7/3) very friable, coarse sandy loam with very weak structure. Few to common fine and medium distinct R.M. and streaks. Few fine and medium roots. Gradual LB.

96 cms. Very pale brown (10 YR 8/3) very friable coarse sandy loam, with very weak structure. Abundant coarse and medium prominent brownish yellow R.M. (10 YR 6/6).

SOIL 53..

A coarse sandy loam overlies a loose, distinctly mottled and somewhat gleyed, deep coarse sandy loam to sandy clay loam. Soil 53 only occurs extensively on gentle slopes at Mkundi in the far West of the Project Area; rarely elsewhere. It seems that this soil has developed within a deep superficial sandy loam deposit (? Magarini). It is difficult to explain why such a coarse textured material should be so poorly drained. During rains the subsoil and even the sub-surface become absolutely saturated. This can only be understood with reference to the chemical data. The deeper subsoil layers (below 75 cms), though acid in terms of pH, are seen to have an accumulation of sodium and hence a high E.S.P. (E.S.P. 20 to 40%). This subsoil sodium may well be causing clay dispersion and hence low subsoil permeability. This would have the effect of forcing much of the lateral (acid) seepage to travel through the sub-surface soil layers, which theory is borne out by data which show these layers to be particularly acid (mean pH = 5.3; Hp = 1.3 m.e.%). The movement of seepage close to the soil surface permits, in the dry season, the accumulation of low but significant levels of salts at the surface. Soil 53 therefore possesses certain rather unusual properties:-

1. Poor drainage, despite the coarse texture and a relatively high lying situation.
2. Some surface accumulation of sodium and magnesium salts.
3. Maximum acidity in the sub-surface layers:

28 - 88 cm. This is a transitional layer. Very pale brown (10 YR 6/3) very friable, coarse sandy loam with very weak structure. Few to common fine and medium distinct R.M. and streaks. Few fine and medium roots. Gradual LB.

29 cm. Very pale brown (10 YR 6/3) very friable coarse sandy loam, with very weak structure. Abundant coarse and medium prominent brownish yellow R.M. (10 YR 6/6).

SOIL 53.

A coarse sandy loam overlies a loess, distinctly mottled and somewhat gleyed, deep coarse sandy loam to sandy clay loam. Soil 53 only occurs extensively on gentle slopes at Merdun in the far west of the Project Area; rarely elsewhere. It seems that this soil has developed within a deep superficial sandy loam deposit (Wentworth). It is difficult to explain why such a coarse textured material should be so poorly drained. During rains the subsoil and even the surface become absolutely saturated. This can only be understood with reference to the chemical data. The deeper subsoil layers (below 75 cm), though acid in terms of pH, are seen to have an accumulation of sodium and hence a high E.S.P. (E.S.P. 20 to 40X). This subsoil sodium may well be causing clay dispersion and hence low subsoil permeability. This would have the effect of forcing much of the lateral (acid) seepage to travel through the sub-surface soil layers, which theory is borne out by data which show these layers to be particularly acid (mean pH = 5.2; H₂ = 1.3 m.e.%). The movement of seepage close to the soil surface permits, in the dry season, the accumulation of low but significant levels of salts at the surface. Soil 53 therefore possesses certain rather unusual properties:-

poor drainage, despite the coarse texture and a relatively high lying situation.

some surface accumulation of sodium and magnesium salts.

maximum acidity in the sub-surface layers.

Mean topsoil pH = 5.7; Hp = 0 m.e.%

Mean sub-surface

pH = 5.3; Hp = 1.3 "

Mean sub-soil pH = 5.9; Hp = 0.1 "

4. Relatively high levels of Hp, Na and MG in the subsoil e.g. Ramisi Pit 66, below 80 cms, had a pH of 5.5 and an E.S.P. of no less than 26%!

The accompanying grassland is usually rather short and is associated with scattered doum palms and termitaria. The topsoil has about 1% O.M. (i.e. little or no accumulation despite the poor drainage). On steeper slopes there may be very local gravel or sandstone outcrops. Upslope, Soil 53 gradually merges into Soil 4. Soil 53 is low in phosphate and nitrogen.

The general properties described above do not engender optimism regarding its potential and the local people do not cultivate Soil 53. This soil should be used for extensive grazing; otherwise it might be developed for forestry. The position of Soil 53 is such (at Mkundi) that it might be best left as open land to provide Game with access to the Shimba Hills from the South.

Ramisi Pit 52 is typical of Soil 53.

Analytical data for Pit 52 are presented in Table 20.

<u>PIT NO. 52 (RAMISI)</u>	Profile Description
<u>MAP REFERENCE:</u>	2816 (200/IV)
<u>LOCATION:</u>	Upper slopes of long low ridge (Mkundi)
<u>ASPECT:</u>	East
<u>SLOPE:</u>	5° 30'
<u>MICRO RELIEF:</u>	Undulating
<u>PARENT MATERIAL:</u>	Superficial Sandy Loam deposit
<u>DRAINAGE:</u>	Poor; receiving laterally
<u>ROOT DEPTH:</u>	More than 143 cms.
<u>M.R.D.</u>	0 - 20 cms.
<u>PROFILE DEPTH:</u>	143 cms
<u>VEGETATION COVER:</u>	100% Grassland Less than 10% Clumps of Thicket on raised Termitaria Scattered <u>Hyphaene coriacea</u>

0 - 28 cms. Very dark brown to very dark greyish brown (10 YR 2/2; 3/2) faintly blotched, very friable, coarse, sandy loam, with fine weak S.A.B. Common fine roots. LB gradual.

28 - 71 cms. Greyish brown (10 YR 5/2) faintly blotched very friable slightly gleied coarse sandy loam, with fine weak SAB. Common fine and medium roots, LB clear and even.

71 - 102 cms. Grey (10 YR 6/1) slightly firm coarse sandy clay loam glei with medium moderate S.A.B. Abundant prominent medium reddish yellow blotches (7.5 YR 6/6). Few soft Manganese concretions at the horizon base. Very few fine roots. LB clear and even.

102 cms. Pale brown to light yellowish brown (10 YR 6/3; 6/4) very hard, slightly gleied coarse sandy clay loam, with medium and coarse moderate S.A.B. Faint yellow blotching and distinct dark blotching. Some Manganese staining. Roots rare. Contains inclusions of coarse sand in pockets.

10-28 cm. ... brown to very dark greyish brown
[10-28 cm. ... faintly blotched, very faintly
bordered, with fine weak S.W. lines
for each segment.]

10-31 cm. ... brown (10-28-31) faintly blotched
very faintly, slightly bluish above sandy brown
very faintly, common fine and narrow legs
10-31 cm. ...

10-32 cm. ... (10-28-31) slightly fine brown
very faintly, very faint with narrow reddish S.W. lines
bordered, very faint reddish brown yellow blotched
(10-32 cm. ... in each segment contraction of
the body and legs very few, the color is clear
and clear.)

10-33 cm. ... brown to light yellowish brown (10-28-31)
very faint, slightly bluish above sandy
very faint, very faint and narrow reddish S.W. lines
with very faint, slightly and distinct very blotched
bordered, very faint, brown lines. Contains faint
very faint, very faint.

PIT NO. 52 Ramisi

LAB. NOS. 10618-21

TABLE 20

DEPTH CMS	% C	SAND	% SILT			CLAY	pH	A V A I L A B L E N U T R I E N T S m.e. %				P p.p.m.
			SAND	SILT	CLAY			Hp	Na	K	Ca	
0-28	0.7	62	24	24	14	5.6	-	1.64	0.22	2.2	0.28	Trace
28-71		60	24	24	16	5.2	0.8	0.64	0.10	0.2	Trace	Trace
71-102		62	16	22	22	6.3	-	2.50	0.18	0.4	Trace	Trace
102+		60	18	22	22	7.8	-	3.80	0.15	0.8	0.22	9

DEPTH

EXCHANGABLE BASES m.e.%

E.S.P.

pH

E.C.

0-28	18.6	1.8	3.5	0.30	1.70	9.1	5.2	0.55	4.0
28-71	10.2	0.2	3.9	0.15	0.45	4.4	4.4	0.35	0.5
71-102	10.0	0.6	2.6	0.30	2.80	28.0	5.0	0.45	2.5
102+	12.1	0.8	6.0	0.25	4.45	36.7	6.5	0.46	3.7

(c) VERY POORLY DRAINED SOILS

These are soils that are poorly drained for much of the year, only drying out during long dry seasons. During the rains these soils are waterlogged and may be subject to periodic standing water. Soil sub-surface horizons are normally prominently mottled and gleied. Gleis are present within the surface 45 cms. Surface organic matter exceeds $2\frac{1}{2}\%$.

V.P.D. soils occur only in lower-lying country - lower slopes, valley basins and permanent swamp.

SOIL 80

This is a widely variable deposit (colluvial or alluvial) normally occurring at the base of steep V-shaped valleys in the Shimba Hills and Lower Ramisi Valley. These deposits have two essential characteristics - the coarseness of the sand fraction, and considerable acidity (High Hp) especially in the topsoil. Textures range from coarse sand to loam and vary greatly from place to place according to the varying factors controlling local deposition. It is usually associated with swampy vegetation.

Soil 80 also occurs extensively in lower-lying basins of the Magarini Sands. These areas often form permanent swamp set in open scrub woodland. There (between Mwaluvanga, Mafisini and the Ramisi Sugar Estate near Kigombero), the mottled sands and coarse sandy loams usually overlie a considerable depth of prominently mottled, very pale grey-brown and very acid coarse sand. Sometimes heavier less permeable layers are present at depth.

Soil 80 is normally covered with raw humus (pH to 5). It is deficient in all major nutrients, particularly phosphate; there may be some accumulation of magnesium and sodium in the deeper layers.

All uninvestigated permanent swamps have been mapped in as Soil 80. Neither the acid swamps nor the "vlei" - type bottomlands are suitable for any form of development.

SOIL 81.

A loam, sandy clay loam, or clay loam topsoil with visible evidence for organic accumulation and normally more than 30% silt, overlies a grey clay loam or clay glei. The subsoil has abundant,

/over

(c) VERY POORLY DRAINED SOILS

These are soils that are poorly drained for much of the year, only drying out during long dry seasons. During the rains these soils are waterlogged and may be subject to periodic standing water. Soil surfaces are normally prominently mottled and gleyed. Gley is present within the surface 45 cm. Surface organic matter exceeds 5%.

V.P.D. soils occur only in lower-lying country - lower slopes, valley basins and permanent swamps.

SOIL B3

This is a widely variable deposit (colluvial or alluvial) normally occurring at the base of steep V-shaped valleys in the Girinda Hills and Lower Ramtal Valley. These deposits have two essential characteristics - the coarseness of the sand fraction, and considerable acidity (pH 4.0), especially in the topsoil. Texture ranges from coarse sand to loam and very greatly from place to place according to the varying factors controlling local deposition. It is usually associated with swampy vegetation.

Soil B3 also occurs extensively in lower-lying basins of the Western Ghats. These areas often form permanent swamps and in open scrub woodland. There (between Malavanga, Wairani and the Ramtal sugar Estate near Kigambiro), the mottled bands and coarse sandy loam usually overlie a considerable depth of relatively mottled, very pale grey-brown and very acid coarse sand. Sometimes heavier iron-bearing layers are present at depth.

Soil B3 is normally covered with raw humus (M). It is deficient in all major nutrients, particularly phosphate; there may be some accumulation of nitrogen and sodium in the deeper layers.

All uninvestigated permanent swamps have been mapped as Soil B3. Whether the acid swamps are "wet" or "dry" depends on the availability for any form of development.

SOIL B1

A loam, sandy clay loam, or clay loam topsoil with visible evidence for organic accumulation and normaly more than 30% silt, overlies a grey clay loam or clay gley. The subsoil is abundant,

Lower.....

PIT NO. 17 (SHIMBA):

Profile Description.

MAP REF
LOCATION
ASPECT
SLOPE
HEIGHT
PARENT
DRAINAGE
WATER TABLE
ROOT DEPTH
H.A.O.

medium and coarse, mottles - of a red hue if the subsoil pH is below 5.5; and of brownish yellow (10 YR 6/4 to 6/6) where the pH is above 5.5. Fine softish manganese concretions are commonly found in the subsoil. Calcium carbonate concretions are not present within the surface 125 cms. (by definition) i.e. subsoils may be of neutral reaction but are not alkaline, despite evidence of some sodium accumulation at depth. Soil 81 is therefore associated with stream valleys carrying acid drainage waters as in the Shimba Hills; and also lower colluvial slopes receiving acid seepage where, on relatively gentle relief, the finer sized soil particles are able to accumulate. Soil 81 also occurs in steep valleys in the Sadani location. It is present in isolated basins throughout the Kikoeni sector, and in valleys wherever the situation does not favour an accumulation of subsoil alkali. In parts of Mkundi a form of Soil 81 is found on lower slopes (above the Soil 80 of the valley basins) where subsoils are highly micaceous - these presumably derive from Mariakani sandstone.

PROFILE DEPTH

The characteristic light grey or grey (glei) subsoils derive from the mobility of the iron at low pH levels; the iron moves out of the matrix and is concentrated round nuclei of iron accumulation to form mottles, blotches and concretions.

Less than 17, Savanna Bush.

0 - 15

The average topsoil pH of Soil 80 = 5.5; subsoil pH may be between 4.5 and 7.0, depending on the depth of sodium accumulation. Both topsoil and subsoil may have significant levels of Hp. Soil 81 is low in calcium, potassium and nitrogen; severely deficient in phosphate. The soil has a good capacity for retaining moisture, and a slow permeability. At present much of Soil 81 is under grassland and, being below steep slopes at least at Shimba, has limited access. During the rains the soil becomes sticky and plastic. It is suggested that certain of the more favourable areas of Soil 81 might be producing modest yields of rice (on the long rains); cultivations and planting etc. to be performed as for "Upland Rice" (See Section 7). en. This is a transitional layer.

20 - 70 cms

Shimba Pit 17, situated near the reservoir in "Tanganyika", is representative of Soil 81. Analytical data for Pit 17 is presented in Table 21.

faint dark blotching. Abundant prominent medium red R.M. (2.5 YR 4/6). Few very fine roots. Diffuse LB.

70 cms +

Gray (5 Y 6/1) plastic and s/over loose glai, with mod. to strong fine and medium blocky structures. Common very prominent coarse and medium bright red (10 R 4/3) R.M. Very few fine roots.

/over.....

medium and coarse, mottles - of a red hue in the subsoil pH is below 5.5; and of brownish yellow (10 YR 2/4 to 5/5) where the pH is above 5.5. Fine soft manganese concretions are commonly found in the subsoil. Calcium carbonate concretions are not present within the surface 125 cm. (by definition) i.e. subsoils may be of neutral reaction but are not alkaline, despite evidence of some sodium accumulation at depth. Soil B1 is therefore associated with stream valleys carrying acid drainage waters as in the Shikha Hills; and also lower collied slopes receiving acid seepage where, on relatively gentle relief, the finer sized soil particles are able to accumulate. Soil B1 also occurs in steep valleys in the present location. It is present in isolated basins throughout the Kikani sector, and in valleys wherever the situation does not favour an accumulation of subsoil alkali. In parts of Kikani a form of Soil B1 is found on lower slopes (above the Soil B2 of the valley basins) where subsoils are highly micaceous - these presumably derive from marginal sandstones.

The characteristic light grey or grey (glist) subsoils derive from the mobility of iron at low pH levels; the iron moves out of the matrix and is concentrated round nuclei of iron accumulation in form mottles, blotches and concretions.

The average topsoil pH of Soil B2 - 6.2; subsoil pH may be between 4.5 and 7.0, depending on the depth of sodium accumulation. Both topsoil and subsoil may have significant levels of H₂O, Soil B1 is low in calcium, potassium and nitrogen; severely deficient in phosphate. The soil has a good capacity for retaining moisture, and a slow permeability. At present much of Soil B1 is under grassland and being below steep slopes at least at Shikha, has limited access. During the rains the soil becomes sticky and plastic. It is suggested that certain of the more favourable areas of Soil B1 might be producing modest yields of rice (on the long rains); cultivations and planting etc. to be performed as for "upland rice" (see Section 7).

Shikha Pit 17, situated near the reservoir in "Tanganyika", is representative of Soil B1. Analytical data for Pit 17 is presented in Table 21.

Lower 11111

PIT NO.17(SHIMBA): Profile Description.
MAP REFERENCE: 442217 (200/IV)
LOCATION: Near base of low lying col.
ASPECT: West
SLOPE: 1° 20'
MICRO-RELIEF: Plane
PARENT MATERIAL: Mazeras Sandstone
DRAINAGE: Very poor
WATER TABLE: About 25 cms.
ROOT DEPTH: More than 120 cms.
M.R.D.: 0 - 12 cms.
PROFILE DEPTH: 120 cms.
LAND USE: Light grazing.
VEGETATION COVER: 100% Setaria Grassland
Less than 10% Savanna Bush.

0 - 15 cms. Very dark brown (10 YR. 2/2) friable fine sandy (silty) loam, with weak to Mod. fine S.A.B. Abundant faint R.M. Fine dark blotching. Black organic accumulation in the top few centimetres (10 YR. 2/1). Common fine roots. LB gradual.

15 - 30 cms. Dark greyish brown (10 YR. 4/2) friable, slightly gleied, loam, with weak to mod. fine and medium S.A.B. Distinct dark blotching. Medium to very fine faint and distinct yellowish red R.M. (5 YR. 4/6) Fine and very fine common roots. LB clear and even. This is a transitional layer.

30 - 70 cms. Dark greyish brown (10 YR 4/2) slightly firm, slightly gleied, clay loam, with Mod.fine and medium Blocky structure. Common faint dark blotching. Abundant prominent medium red R.M. (2.5 YR 4/6). Few very fine roots. Diffuse LB.

70 cms + Grey (5 Y 6/1) plastic and sticky clay loam glei, with Mod. to strong fine and medium Blocky structure. Common very prominent coarse and medium bright red (10 R 4/6) R.M. Very few fine roots.

/over.....

Profile Description

ASSIS (BOLIVIA)

Near base of low lying cone

West

1' 20"

Plans

Mazama Sandstone

Very poor

About 25 cm.

More than 15L cm.

0 - 15 cm.

150 cm.

Light grayish

100% Grayish Greenish

Less than 10% Grayish Green

Very dark brown (10 YR 2/2) friable fine sandy (silty) loam, with weak to med. fine S.A.S. Abundant faint R.M. Fine dark blotching. Dark organic accumulation in the top few centimeters (10 YR 2/1). Common fine roots. LD gradual.

Dark grayish brown (10 YR 4/2) friable, slightly glist, loam, with weak to med. fine and medium S.A.S. Distinct dark blotching. Medium to very fine faint and distinct yellowish red R.M. (5 YR 4/2) Fine and very fine common roots. LB clear and even. This is a transitional layer.

Dark grayish brown (10 YR 4/2) slightly firm, slightly glist, clay loam, with med. fine and medium blocky structure. Common faint dark blotching. Abundant prominent medium red R.M. (2.5 YR 4/2). Few very fine roots. Diffuse LD.

Grey (2.5 Y 6/1) plastic and sticky clay loam glist, with med. to strong fine and medium blocky structure. Common very prominent coarse and medium bright red (10 R 4/6) R.M. Very few fine roots.

Lower.....

TABLE 21

LAB. NOS. 5637-38
6814-15

PIT NO. 17 Shimba

DEPTH CMS	% C	SAND	% SILT			CLAY	pH	A V A I L A B L E N U T R I E N T S m.e.%					P p.p.m.
								Hp	Na	K	Ca	Mg	
0-15	1.1	54	30	16	5.4	1.8	0.10	1.6	2.0	1.17	6		
15-30	0.7	44	30	26	5.2	0.7	0.12	0.8	2.9	0.57	6		
30-70		40	20	40	5.1	3.1	0.10	0.2	2.6	0.03	5		
115+		40	22	38	5.3	0.3	0.06	1.2	2.7	0.10	6		
DEPTH CMS	C.E.C.	E X C H A N G E A B L E B A S E S m.e.%						E.S.P.	pH 1:5KCl	E.C. 1:5 H ₂ O			
		Ca	Mg	K	Na								
15-30	11.6	2.0	3.2	1.25	0.53	4.6	4.2	0.05					
30-70	11.6	2.0	3.9	1.20	1.06	9.1	4.2	0.05					

SOIL 82.

This is a variant of Soil 81, having significant gravel sheets within the surface 90 cms. Otherwise the soil properties are as for Soil 81. It was only possible to map Soil 82 in places where the sub-surface gravels were detected; i.e. Many incidences of Soil 82 have presumably been overlooked. However, the only extensive areas of these V.P.D. gravels seem to occur below long steep slopes along the Eastern fringes of Shimba where the upstanding Mazeras Sandstone hills begin to give way to the Coastal Plain.

SOIL 83.

A dark grey to very dark greyish brown loam or clay loam, overlies a light grey to olive alkaline clay glei subsoil with common distinct brownish yellow blotching. The mechanical composition of this soil is very similar to that of Soil 81, but coarse gravels are commonly present in the deeper subsoils of Soil 83.

Soil 83 is distinguished by the presence of concretions of calcium and manganese within the surface 125 cms, sometimes amongst pockets of gravel. It is low solubility in alkaline solution that causes the precipitation of Ca and Mn round nuclei to form these concretions; and also explains the lack of distinct centres of iron concentration - due to the resulting immobility of that element. Free calcium carbonate may or may not be present in the deeper layers; "lime spots" sometimes occur. The subsoil normally shows evidence of slickensides and clay skins. Soil 83 usually demonstrates distinct fine rust mottles and/or iron concretions in the sub-surface layers.

It is at least conceivable that some of the increase in clay with depth is a result of (solonetzic) translocation of fine colloid through alkaline dispersion. The presence of subsurface clay skins and/or organic cutans in the more alkaline profiles of the lowest-lying areas provides some support for this hypothesis. Since however the topsoils are by and large moderately acid, it seems more likely that their coarser nature derives from depositional causes. Average topsoil pH = 5.7; subsoil pH = 8.3. Subsoils are rich in calcium (Average Ca = 17.1 m.e.%) Soil 83 has a very slow permeability because of the alkaline clay subsoil.

/over

SOIL 52.

This is a variant of Soil 51, having significant gravel sheets within the surface 30 cm. Otherwise the soil properties are as for Soil 51. It was only possible to map Soil 52 in places where the sub-surface gravels were detected; i.e. heavy incidence of Soil 52 have presumably been overlooked. However, the only extensive areas of these V.P.G. gravels seem to occur below long steep slopes along the Eastern fringes of Shinda where the quarrying meters Sandstone hills begin to give way to the Coastal Plain.

SOIL 53.

A dark grey to very dark greyish brown loam or clay loam, overlies a light grey to olive alkaline clay silt subsoil with common distinct brownish yellow blotching. The mechanical composition of this soil is very similar to that of Soil 51, but coarse gravels are commonly present in the deeper subsoils of Soil 53.

Soil 53 is distinguished by the presence of concentrations of calcium and manganese within the surface 150 cm, sometimes amongst packets of gravel. It is low solubility in alkaline solution that causes the precipitation of Ca and Mn to occur in the form of concretions; and also explains the lack of distinct concretions of iron concentration - due to the resulting immobility of that element. Free calcium carbonate may or may not be present in the deeper layers; "lime spots" sometimes occur. The subsoil normally shows evidence of slickensides and clay skins. Soil 53 usually demonstrates distinct fine root nodules and/or iron concretions in the sub-surface layers.

It is at least conceivable that some of the increase in clay with depth is a result of (a) lateral translocation of fine colloid through alkaline dispersion. The presence of sub-surface clay skins and/or organic coatings in the more alkaline profiles of the lowest lying areas provides some support for this hypothesis. It seems more likely that their present nature derives from depositional causes. Average cation exchange capacity (CEC) = 17.1 m.e./100g Soil 53 has a very slow permeability because of the alkaline clay subsoil.

It would appear to be an excellent soil for rice. In valleys with an adequate water supply, local bunding would provide padis. Elsewhere "Upland Rice" could be grown on the long rains.

Soil 83 develops from alluvial/colluvial fine deposits at the base of certain valleys receiving significant levels of sodium and calcium in the drainage. These are primarily the long valleys between Kikoneni and Jombo. This soil has therefore only a limited distribution. Kikoneni Pit 34 is representative of Soil 83. Analytical data for Pit 34 are presented in Table 22.

<u>PIT NO. 34 (KIKONENI):</u>	Profile Description
<u>MAP REFERENCE:</u>	288109 (200/IV)
<u>LOCATION:</u>	Base of broad "U" shaped valley
<u>ASPECT:</u>	North
<u>SLOPE:</u>	30'
<u>PARENT MATERIAL:</u>	Maji-ya-Chumvi (Derived Alluvium)
<u>DRAINAGE:</u>	Very poor
<u>M.R.D.</u>	0-10 cms.
<u>ROOTING DEPTH:</u>	91 cms.
<u>PROFILE DEPTH:</u>	140cms.
<u>VEGETATION COVER:</u>	100% : <u>Hyparrhenia</u> Grassland Less than 10% <u>Hyphaene coriacea</u>

0-12 cms. Dark grey (10 YR 4/1) friable, slightly gleied, clay loam, with Mod. fine and medium S.A.B. Common faint R.M. Abundant fine and very fine roots. LB clear and slightly undulating.

12 - 49 cms. Greyish brown (10 YR 5/2) firm somewhat gleied clay, with strong fine and medium Blocky. Distinct brown rust blotching (7.5 YR. 4/6). Distinct yellow blotching (10 YR 6/6). Very few gravel. Common fine and very fine roots. LB gradual.

/over ,.....

It would appear to be an excellent soil for rice. In valleys with an adequate water supply, local banding would provide pads. Elsewhere "upland rice" could be grown on the long rains.

Soil 63 develops from alluvial/coluvial fine deposits at the base of certain valleys receiving significant levels of sodium and calcium in the drainage. These are primarily the long valleys between Kikomet and Jomo. This soil has therefore only a limited distribution. Kikomet Pit 34 is representative of Soil 63. Analytical data for Pit 34 are presented in Table 22.

Profile Description

NO. 34 (KIKOMET):

Soils (Soil 63)

REFERENCE:

Base of broad "U" shaped valley

LOCATION:

North

GRID:

30'

Highly-Organic (Derived Alluvium)

SOIL MATERIAL:

Very poor

MOISTURE:

0-10 cms.

01 cms.

SOIL DEPTH:

140 cms.

TOE DEPTH:

100% : Hyperthene Ground

SOIL COVER:

Less than 10% Hyperthene cover

Dark grey (10 YR 4/1) friable, slightly gleyed, clay loam, with med. fine and medium S.A.S. Common faint R.M. Abundant fine and very fine roots. LB clear and slightly undulating.

Greyish brown (10 YR 5/2) firm somewhat gleyed clay, with strong fine and medium blocky. Distinct brown rust blotching (7.5 YR 4/5). Distinct yellow blotching (10 YR 5/5). Very few gravel. Common fine and very fine roots. LB gradual.

Notes:

TABLE 22

FIT NO. 34 Kikoneni

LAB. NOS. 8903-05

DEPTH CMS	% C	SAND	% SILT	CLAY	pH	A V A I L A B L E				N U T R I E N T S			P.p.p.m.
						Hp	Na	K	Ca	Mg	Mn	m.e. %	
0-12	1.0	42	28	30	5.6	-	0.40	0.07	2.5	4.0	0.72	10	
12-49		28	16	56	5.4	0.6	1.34	Trace	2.5	6.6	0.13	5	
83+		30	18	52	8.3	-	10.8	0.02	19.5	8.9	0.31	18	
DEPTH CMS	C.E.C.	E X C H A N G E A B L E			K	B A S E S m.e.%		E.S.P.	pH 1:5 KCl	E.C. 1:5 H ₂ O			
		Ca	Mg	Na									
0-12	13.6	2.5	4.2	0.19	0.16	0.16	1.2	4.4	0.14				
12-49	22.0	3.2	8.6	0.16	0.80	3.6	4.4	0.10					
83+	27.4	13.2	8.0	0.12	4.3	15.7	7.8	1.65					

49 - 83 cms. Light grey (10 YR 7/1) very sticky and plastic strongly gleyed clay, with Mod. to strong medium S.A.B. Some very thin clay faces and slickensides. Abundant prominent yellow blotching (10 YR 6/6). Occasional calcium concretions. Occasionally locally few Manganese concretions. Few very fine roots. LB very diffuse and undulating. No sample.

83 cms + Light grey (10 YR 7/1) firm, strongly gleyed, light clay, with Mod. to strong medium S.A.B. Some very thin clay faces and slickensides. Abundant prominent yellow blotching (10 YR 6/6). Few fine to medium calcium concretions. Few to common fine Manganese concretions. Locally slight reaction with 10% HCL. Very few very fine roots.

SOIL 84

A dark grey light clay overlies a light grey to olive alkaline medium clay gley. This is a variant of Soil 83 with a heavier textured topsoil (Soil 83 has an average of 23% clay in the topsoil; Soil 84 averages 48% topsoil clay). Soil 84 is invariably affected by coarse gravels at depth, accompanied by calcium and manganese concretions. This soil has similar properties to Soil 83 and would prove ideal for rice. Soil 84 only occurs in a single valley, North East of Jombo. It derives from alluvium. Kikoneni Pit 50 may be regarded as representative of Soil 84, though the texture of the subsoil is lighter than is typical; in the case of Pit 50 this is because it is located at the base of the alluvial slope below Gandini and away from the valley bottom. As a result, this profile has a considerable proportion of the coarser sized fractions. Analytical data for Pit 50 is presented in Table 23.

<u>PIT NO. 50 (KIKONENI).</u>	Profile Description
<u>MAP REFERENCE.</u>	2512 (200/III)
<u>LOCATION:</u>	Lower apron slopes below Gandini Ridge
<u>ASPECT:</u>	East
<u>SLOPE:</u>	1° 30'

/over

Light grey (10 YR 7/1) very sticky and plastic strongly gashed clay, with nodules in strong medium S.A.B. Some very thin clay faces and slickensides. Abundant prominent yellow blotching (10 YR 8/5). Occasional calcium concretions. Occasionally locally few manganese concretions. Few very fine roots. In very soft and unsetting. No sample.

Light grey (10 YR 7/1) fine, strongly gashed, light clay, with nodules in strong medium S.A.B. Some very thin clay faces and slickensides. Abundant prominent yellow blotching (10 YR 8/5). Few fine to medium calcium concretions. Few to common fine manganese concretions. Locally slight reaction with 10% HCl. Very few very fine roots.

A dark grey light clay overlies a light grey to olive siliceous medium clay giel. This is a variant of soil 53 with a heavier textured topsoil (Soil 53 has an average of 23% clay in the topsoil; Soil 54 averages 43% clay). Soil 54 is invariably affected by coarse roots at depth, accompanied by calcium and manganese concretions. This soil has similar properties to Soil 53 and would prove ideal for rice. Soil 54 only occurs in single valley, North East of Jambou. It derives from Llanum, Kikonani Pit 50 may be regarded as representative of Soil 54, though the texture of the subsoil is lighter than is typical; in the case of Pit 50 this is because it is located at the base of the alluvial slope and away from the valley bottom. As a result, this profile has a considerable proportion of the coarser sized fractions. Analytical data for Pit 50 is presented in Table 23.

Profile Description

TABLE 23 (KIKONANI)

Soils (Soil 53)
 Lower slope below bench
 Ridge
 East
 10 30'

Lower

MICRO RELIEF: Slightly undulating

PARENT MATERIAL: Colluvial Clay (ex Maji-ya-Chumvi sandstone)

DRAINAGE: Very Poor

M.R.D. 0 - 7 cms

ROOT DEPTH:: More than 125 cms.

PROFILE DEPTH: 125 cms

VEGETATION COVER: 100% Grassland
90% Grass Species
10% Forbes.

Less than 10% bush, including:-

- Acacia mellifera, A. zanzibarica
- Hyphaene coriacea, Euphorbia candelabrum

0 - 14 cms. Very dark grey (10 YR 3/1) friable, light clay, with fine strong S.A.B. and weak surface crust. Common fine and very fine roots. LB gradual

14 - 58 cms. Very dark brown (10 YR 2/2) firm, somewhat gleyed, light clay, with strong medium Blocky structure. Common and prominent yellowish red R.M. (5YR 4/6) Few to common very fine iron concretions. Common fine gravel. Few fine roots LB gradual.

58 - 98 cms. Dark grey (2.5 YR 4/1) firm, faintly blotched light clay glei, with fine and medium strong Blocky and S.A.B. Microstructure very blocky. Some slickensides and clay faces. Few fine Manganese concretions. Few fine gravel. Very few very fine roots LB gradual

98 cms + Grey to greyish brown (2.5 Y 5/1) extremely firm sandy clay loam glei, with very weak compact structure. Prominent rusting in some root channels. Common fine and medium Calcium concretions. Common fine Manganese concretions. Few medium gravel. Very few very fine roots.

/over

Slightly undulating
Colloidal clay (ex. water-
sensitive)

Very fine

0 - 7 cm

More than 100 cm

100 cm

100% Gravel
50% Sand
10% Pebbles

Less than 100 mesh, including

Acanthaceae, A. ...

Hydnangium, Euphorbia ...

Very dark grey (10 YR 5/1) friable, light
clay, with fine strong S.A.B. and weak surface
crust. Common fine and very fine roots. LB gradual.

Very dark brown (10 YR 5/2) firm, some-
what glazed, light clay, with strong medium
blocky structure. Common and prominent yellowish
red R.M. (8YR 4/5) few to common very fine
iron concretions. Common fine gravel. Few fine roots
LB gradual.

Dark grey (2.5 YR 4/1) firm, faintly
dotted light clay glaz, with fine and medium
strong blocky and S.A.B. blocky structure very
blocky. Some slickensides and clay faces. Few
fine manganese concretions. Few fine gravel.
Very few very fine roots LB gradual.

Grey to greyish brown (2.5 Y 5/1) extremely
fine sandy clay foam glaz, with very weak compact
structure. Prominent rusting in some root channels.
Common fine and medium calcium concretions. Common
fine manganese concretions. Few medium gravel.
Very few very fine roots.

Lower ...

TABLE 23

LAB. NOS. 9378 - 81

FIT NO. 50 Kikoneni

DEPTH CMS	% C	SAND	% SILT	CLAY	pH	A V A I L A B L E N U T R I E N T S m.e. %					P p.p.m.	
						Hp	Na	K	Ca	Mg		Mn
C-14	1.4	18	35	47	5.7	-	0.38	0.30	7.2	5.2	0.24	6
14-58		23	30	47	6.5	-	1.48	0.02	7.8	7.2	0.34	5
58-98		21	28	51	7.9	-	3.40	0.05	9.7	8.6	0.16	10
98+		58	18	24	8.1	-	5.70	0.02	18.8	9.6	0.20	18
DEPTH CMS	C.E.C.	E X C H A N G E A B L E B A S E S m.e.%					E.S.P.	pH 1:5 KCl	E.C. 1:5 H ₂ O			
		Ca	Mg	K	Ca	Ca						
0-14	19.3	7.2	5.4	0.50	0.90	4.7	5.1	0.09				
14-58	20.0	7.4	7.7	0.25	1.35	6.7	5.5	0.12				
58-98	33.1	8.9	10.2	0.27	2.10	6.4	6.5	0.48				
98+	36.9	10.0	11.4	0.26	2.65	7.4	7.5	0.90				

Year	Month	Day	Time	Temp	Wind	Dir	Humid	Bar	Cloud	Wind	Dir	Temp	Wind	Dir	Temp	Wind	Dir	Temp	Wind	Dir	
1910	Jan	1	10:00	32	10	SE	85	30.0	100	10	SE	32	10	SE	32	10	SE	32	10	SE	32
1910	Jan	2	10:00	30	15	SE	80	29.8	100	15	SE	30	15	SE	30	15	SE	30	15	SE	30
1910	Jan	3	10:00	28	20	SE	75	29.6	100	20	SE	28	20	SE	28	20	SE	28	20	SE	28
1910	Jan	4	10:00	26	25	SE	70	29.4	100	25	SE	26	25	SE	26	25	SE	26	25	SE	26
1910	Jan	5	10:00	24	30	SE	65	29.2	100	30	SE	24	30	SE	24	30	SE	24	30	SE	24
1910	Jan	6	10:00	22	35	SE	60	29.0	100	35	SE	22	35	SE	22	35	SE	22	35	SE	22
1910	Jan	7	10:00	20	40	SE	55	28.8	100	40	SE	20	40	SE	20	40	SE	20	40	SE	20
1910	Jan	8	10:00	18	45	SE	50	28.6	100	45	SE	18	45	SE	18	45	SE	18	45	SE	18
1910	Jan	9	10:00	16	50	SE	45	28.4	100	50	SE	16	50	SE	16	50	SE	16	50	SE	16
1910	Jan	10	10:00	14	55	SE	40	28.2	100	55	SE	14	55	SE	14	55	SE	14	55	SE	14
1910	Jan	11	10:00	12	60	SE	35	28.0	100	60	SE	12	60	SE	12	60	SE	12	60	SE	12
1910	Jan	12	10:00	10	65	SE	30	27.8	100	65	SE	10	65	SE	10	65	SE	10	65	SE	10
1910	Jan	13	10:00	8	70	SE	25	27.6	100	70	SE	8	70	SE	8	70	SE	8	70	SE	8
1910	Jan	14	10:00	6	75	SE	20	27.4	100	75	SE	6	75	SE	6	75	SE	6	75	SE	6
1910	Jan	15	10:00	4	80	SE	15	27.2	100	80	SE	4	80	SE	4	80	SE	4	80	SE	4
1910	Jan	16	10:00	2	85	SE	10	27.0	100	85	SE	2	85	SE	2	85	SE	2	85	SE	2
1910	Jan	17	10:00	0	90	SE	5	26.8	100	90	SE	0	90	SE	0	90	SE	0	90	SE	0
1910	Jan	18	10:00	0	95	SE	0	26.6	100	95	SE	0	95	SE	0	95	SE	0	95	SE	0
1910	Jan	19	10:00	0	100	SE	0	26.4	100	100	SE	0	100	SE	0	100	SE	0	100	SE	0
1910	Jan	20	10:00	0	105	SE	0	26.2	100	105	SE	0	105	SE	0	105	SE	0	105	SE	0
1910	Jan	21	10:00	0	110	SE	0	26.0	100	110	SE	0	110	SE	0	110	SE	0	110	SE	0
1910	Jan	22	10:00	0	115	SE	0	25.8	100	115	SE	0	115	SE	0	115	SE	0	115	SE	0
1910	Jan	23	10:00	0	120	SE	0	25.6	100	120	SE	0	120	SE	0	120	SE	0	120	SE	0
1910	Jan	24	10:00	0	125	SE	0	25.4	100	125	SE	0	125	SE	0	125	SE	0	125	SE	0
1910	Jan	25	10:00	0	130	SE	0	25.2	100	130	SE	0	130	SE	0	130	SE	0	130	SE	0
1910	Jan	26	10:00	0	135	SE	0	25.0	100	135	SE	0	135	SE	0	135	SE	0	135	SE	0
1910	Jan	27	10:00	0	140	SE	0	24.8	100	140	SE	0	140	SE	0	140	SE	0	140	SE	0
1910	Jan	28	10:00	0	145	SE	0	24.6	100	145	SE	0	145	SE	0	145	SE	0	145	SE	0
1910	Jan	29	10:00	0	150	SE	0	24.4	100	150	SE	0	150	SE	0	150	SE	0	150	SE	0
1910	Jan	30	10:00	0	155	SE	0	24.2	100	155	SE	0	155	SE	0	155	SE	0	155	SE	0
1910	Jan	31	10:00	0	160	SE	0	24.0	100	160	SE	0	160	SE	0	160	SE	0	160	SE	0

(d) SALINE AND ALKALINE SOILS

These are soils that are influenced by intense levels of salt and/or alkali throughout the profile. Because of the effect of the relatively high rainfall in leaching soils, such accumulations are only possible in the vicinity of hot springs where the composition of the ground water is such (See Section 2.c) that high levels of soil salt can be maintained. As a consequence of the spring water these soils accumulate sodium bicarbonate and chloride. Saline and alkaline soils are only found in intimate association with springs in the lower Ramisi Valley, particularly to the South of that river.

Although there are a wide variety of soils that fall within the definition above, because they only occupy very minor areas which are unmapable at 1:12,500, all of the saline-alkaline soils are grouped together into the composite mapping Unit 70. Even so, "Soil" 70 occupies only a very small proportion of the project area.

Some of these soils are shallow with sheets or flags of weathering Maji-ya-Chumvi fine sandstone within the surface 90 cms. In other cases only random pieces of sandstone are present and the profile extends to a considerable depth.

Most of these soils have textures between sandy loam and sandy clay; loam and sandy clay loam being most common. The pH of these soils ranges between 8.0 and 10.5. It is possible to make a division of the saline-alkaline soils on the basis of their organic content:-

(a) Soils that are very low in O.M. (about 1%). These may grow a grass/sedge vegetation (See Section 2.d) or, where there is a concentration of surface salt, may be quite bare. The bare areas are usually covered by white salt efflorescence, though patches of intense alkali, near vegetation, cause the formation of a characteristic black alkali crust. The surface few centimetres often comprise a porous reddish yellow coarse sandy wash encrusted with salt.

/over.....

(b) SALINE AND ALKALINE SOILS

These are soils that are influenced by intense levels of salt and/or alkali throughout the profile. Because of the effect of the relatively high rainfall in leaching soils, such accumulations are only possible in the vicinity of hot springs where the composition of the ground water is such (see Section 2.c) that high levels of salt can be maintained. As a consequence of the spring water these soils accumulate sodium bicarbonate and chloride. Saline and alkaline soils are only found in intimate association with springs in the lower Fennel valley, particularly to the south of that river.

Although there are a wide variety of soils that fall within the definition above, because they only occupy very minor areas which are unrepresented at this time, all of the saline-alkaline soils are grouped together into the composite mapping Unit X. Even so, "Soil" X occupies only a very small proportion of the project area.

Some of these soils are shallow with sands or flags of weathering Wajiy-Chuvai fine sandstone within the surface 30 cm. In other cases only random pieces of sandstone are present and the profile extends to a considerable depth.

Most of these soils have textures between sandy loam and sandy clay; loam and sandy clay loam being most common. The pH of these soils ranges between 6.0 and 10.5. It is possible to make a division of the saline-alkaline soils on the basis of their organic content:-

- (a) Soils that are very low in O.M. (about 1%). These may grow a grass/sedge vegetation (see Section 2.d) or, where there is a concentration of surface salt, may be quite bare. The bare areas are usually covered by white salt efflorescences, though patches of intense alkali, near vegetation, cause the formation of a characteristic black alkali crust. The surface for continuous areas comprises a porous reddish yellow coarse sandy wash encrusted with salt.

...../over

Up to 80 m.e. % Na have been recorded near a dried up "spring". Below the surface sandy wash, there is a saline and alkaline brownish grey sandy clay loam; this usually overlies a somewhat stony alkaline (but non-saline) and blotched greenish grey sandy loam. There are a few concretions of calcium carbonate at depth.

(b) Organic alkaline bog soils with over 10% O.M. The dark reddish brown peats may have a pH as low as 7.5. They nevertheless have a high sodium content and are somewhat saline. The spongy greenish lichen bogs of the alkaline cold springs are rather more saline and alkaline, though these are also particularly well endowed with calcium. Indeed all the soils near the cold spring bogs have a relatively high Ca : Na ratio, compared with high Na : Ca ratios near the hot springs. The peats may overlie grey alkaline sandy clay loam gleis which in turn merge into a stony alkaline (non-saline) bluish-green calcareous glei; with common though extremely fine concretions of calcium carbonate and a few coarse lime spots. In many cases the accumulation of peat over the years has led to the formation of structural "raised bogs".

Kikoneni Pit 69 is representative of the non-organic saline-alkaline soils. (Soil 70 (a)) It lies above the well-known Kitoni hot springs in an area bereft of vegetation. Analytical data for Pit 69 are presented in Table 24.

It goes without saying that Soil 70 is unsuitable for agriculture!

PIT No. 69 (KIKONENI)

Profile Description

MAP REFERENCE:

322135 (200/IV)

LOCATION:

Close to base of Kitoni hot springs

ASPECT:

South

SLOPE:

20'

MICRO RELIEF:

Plane

COLLUVIATION:

Surface Sand wash.

DRAINAGE:

Poor

WATER TABLE:

120 cms.

/over.....

up to 30-40%. We have been recording near a dried up "spring". Below the surface sandy layer there is a saline and alkaline brownish grey sandy clay loam; this usually overlies a somewhat greyish alkaline (but non-saline) and stained massive grey sandy loam. There are a few concretions of calcium carbonate at depth.

(5) Organic alkaline bog soils with over 1% O.M. The dark reddish brown peats may have a pH as low as 5.5. They nevertheless have a high sodium content and are somewhat saline. The stony ground in the cold bogs of the alkaline cold springs are rather more saline and alkaline, though these are also particularly well endowed with calcium. Indeed all the soils near the cold spring bogs have a relatively high Ca : Mg ratio, compared with high Ca : Mg ratios near the hot springs. The peats may overlie grey alkaline sandy clay loam soils which in turn merge into a stony alkaline (non-saline) bluish-green calcareous clay; with common though extremely fine concretions of calcium carbonate and a few coarse lime spots. In many cases the accumulation of peat over the years has led to the formation of structural "raised bogs".

Kilnont Pit 89 is representative of the non-organic saline-alkaline soils. (Soil No. 89) It lies above the well-known Kilnont hot springs in an area devoid of vegetation. Analytical data for Pit 89 are presented in Table 24.

It goes without saying that Soil 89 is unsuitable for agricultural

Profile Description

89213 (SOD/IV)

Close to base of Kilnont hot springs

Bough

50'

Plane

Surface sand wash

Foot

150 cm.

lover.....

89 (KILNONT)

REFERENCE:

TABLE 24

TABLE 24

TABLE 24

TABLE 24

PIT NO. 69 Kikoneni

LAB. NOS. 9395-97

DEPTH CMS	% C	SAND	% SILT		CLAY	pH	A V A I L A B L E N U T R I E N T S m.e. %					P p.p.m.
							Hp	Na	K	Ca	Mg	
3-16	0.3	61	24	15	10.0	-	18.0	0.76	7.4	1.7	0.33	23
16-105		71	16	13	9.8	-	19.1	0.46	8.0	0.4	0.08	14
105+		63	12	25	9.0	-	18.7	0.95	2.3	0.5	0.04	14
DEPTH CMS	C.E.C.	E X C H A N G E A B L E B A S E S m.e.%					E.S.P.	pH 1:5 KCl	E.C. 1:5 H ₂ O			
		Ca	Mg	K	Na							
3-16	9.4	2.0	0.6	0.75	3.20	34.0	9.4	5.2				
16-105	5.4	2.6	0.5	0.37	1.70	31.5	9.3	1.6				
105+	11.4	1.6	1.1	1.22	5.00	43.9	8.2	0.9				

PARENT MATERIAL: Maji-ya-Chumvi sandstone

ORGANIC MATTER: Surface accumulation possibly derived from a previous period when there was vegetation.

ROOT DEPTH: 15 cms.

M.R.D. 0 - 6 cms

PROFILE DEPTH 130 cms

VEGETATION COVER: 0

0-3 cms. Reddish yellow (7.5 YR 7/6) loose, speckled, structureless coarse, sand with coarse pores. No roots. Surface sand wash. LB very abrupt and slightly undulating. No sample.

3- 16 cms. Very dark greyish brown (10 YR 3/2) slightly firm, faintly blotched sandy clay loam, with weak medium S.A.B. Tastes slightly salty. Very slight reaction with 10% HCL. Occasional very fine roots. LB clear and even.

16 - 105 cms. Pale yellow and light grey (5Y 7/3; 2.5 Y 7/2) slight firm to loose; speckled, sandy loam, with weak SAB. Faint blotching and rusting. Few extremely fine Calcium concretions. Few fine to coarse sandstones. Very slight or nil reaction with 10% HCL No roots LB gradual.

105 cms + Grey (10 GY 6/1) firm, sandy clay loam, with Mod. medium SAB. Abundant distinct light yellowish brown (10 YR 6/4) blotches. Few very fine Calcium concretions. Tastes slightly alkali. No reaction with HCL.

5. MAJOR SOIL FEATURES LIMITING DEVELOPMENT

(a) Topography, Rock Outcrops and Erosion.

These features self-evidently restrict agricultural development.

The broken topography of the Shimba Hills, in particular, clearly reduces the acreage potential and often prevents access by transport and farm machinery.

Soil depth is obviously important to crops. Areas with rock within 90 cms. of the soil surface are liable to be droughted even if the rock does not outcrop. Furthermore a near-absence of stone in the plough layer is important for mechanised cultivation. Thus Soils 3 and 13 are considered unsuitable for development. The presence of gravel sheets within the surface 60 cms. (Soil 12) was also regarded as a detrimental feature despite root penetration into the sheets. Gravelly soils contain less available soil moisture and have a reduced capacity for retaining nutrients as compared with a non-gravelly solum.

Consideration of Erosion and Erosion Potential is however more complex. The sandy topsoils of Shimba are clearly susceptible to erosion; the great depth of the downslope colluvial deposits is evidence for insidious sheet erosion and soil creep continuing over a long period of time. Two features at Shimba help render the soil more resistant to erosion:-

Majhi-va-Gumud sandstone

Surface accumulation possibly derived from a previous period when there was vegetation.

15 cms.

0 - 5 cms

100 cms

0

Reddish yellow (2.5 YR 7/8) loess, speckled, structureless coarse, sand with coarse pores. No roots. Surface sand wash. LB very abrupt and slightly undulating.

Very dark grayish brown (10 YR 3/2) slightly firm, faintly blotched sandy clay loam, with weak medium S.A.B. Tastes slightly salty, very slight reaction with HCl. Occasional very fine roots. LB clean and even.

Pale yellow and light gray (5Y 7/3; 2.5 Y 7/2) slight firm to loess; speckled, sandy loam, with weak S.A.B. Faint blotching and rusting. Few extremely fine calcium concretions. Few fine to coarse sandstones. Very slight or all reaction with HCl. No roots LB gradual.

Gray (10 Y 6/1) firm, sandy clay loam, with medium S.A.B. Abundant distinct light yellowish brown (10 YR 6/4) blotches. Few very fine calcium concretions. Tastes slightly alkali. No reaction with HCl.

MAJOR SOIL FEATURES LIMITING DEVELOPMENT

(a) Topography, Rock Outcrop and Erosion.

These features self-evidently restrict agricultural development.

The broken topography of the Shinde hills, in particular, clearly reduces the sorage potential and often prevents access by transport and farm machinery.

Soil depth is obviously important to crops. Areas with rock within 30 cms. of the soil surface are liable to be droughted even if the rock does not outcrop. Furthermore a near-absence of stone in the plough layer is important for mechanised cultivation. Thus soils 3 and 12 are considered unsuitable for development. The presence of gravel sheets within the surface 30 cms. (Soil 12) was also regarded as a detrimental feature despite root penetration into the sheets. Gravelly soils contain less available soil moisture and have a reduced capacity for retaining nutrients as compared with a non-gravelly soil.

Understand of Erosion and Erosion Potential is however more complex. The sandy topsoils of Shinde are clearly susceptible to erosion the great depth of the downwash colluvial deposits is evidence for incision sheet erosion and soil creep continuing over a long period of time. Two features of Shinde help render the soil more resistant to erosion:-

(a) The ferruginous nature helps to bind particles structure.

(b) The very low levels from Mazeras sandstone.

Nevertheless a certain amount Shimba, with extensive gully edge of the forest reserve. and the general lack of coll aggregates. The tendency to on Soil 1) also enhances the

After consultation with the decided to make a distinction exceeding 6° to 8° (10 to 14%) The more steeply sloping soil unsuitable for normal arable introduction of sophisticated terracing. Incidentally this limitation is due to the physical demarcating slopes off aerial

Soils on slopes in excess of or for tree crops, combined non-erosion inducing cover

Owing to their higher content relative resistance to erosion up to 10° (18%) of slope before

The following anti-erosion measures slopes exceeding 5° (8%).

(a) Strip Cropping. Crops the hillside. The area left under grass with trees vary between 15 and 40 years

(b) Contour Ploughing. Plough along the contour "on the also be performed along the should be kept to a minimum

(c) Maintenance of soil F.Y.M. or other forms of

It should be noted in this context tobacco permit above-average should be planted in the inter-crops. Coconuts and citrus need even when mature and so these steepest slopes. The newly introduced (Mtwapa) - Vetiveria zizanioides protective cover against erosion

Should it be decided to develop Soil conservation at Matuga

(b) Drainage Status, Moisture Balance

1. Drainage Status.

The detrimental effects

of the subsoils (Soils 1,2,5,7) together and strengthens subsoil

silt prevailing in soils developed

of Rill erosion is evident at on the steeper slopes along the low content of organic matter and lowers the strength of the soil form a weak surface crust (especially possibility of erosion.

Soil Conservation Service it was between Soils with slopes and those with lesser slopes.

(Soil 2) are regarded as agriculture without the (and presumably uneconomic) range of 2° in slope local impossibility of precisely photographs by eye.

to 8° may be used for grazing; ch permanent pasture or a o like groundnuts.

of colloid and hence their Soils 6 and 10 are permitted being designated "Soil 2".

ures are recommended on all

are planted in strips across between the strips should be crops. The arable strips may s depending on the slope.

crops should be planted "ridge". Cultivations should e contour. Cultivations

ucture by addition of M.

ext that cotton, maize and osion. Cover crops or grass rows between young tree r do form a complete canopy hould not be planted on the roduced Vetiver Grass (at - can provide an adequate n.

Soil 2 employing terracing, ould be consulted.

Soil Stress and Field Moisture

of poor drainage are well known;

(a) The ferruginous nature of the subsoils (Soils 1, 2, 3, 4) helps to bind particles together and strengthens subsoil structure.

(c) The very low levels of silt prevailing in soils developed from basaltic sandstone.

Nevertheless a certain amount of silt erosion is evident at places, with extensive gullying on the steeper slopes along the edge of the forest reserve. The low content of organic matter and the general lack of soil structure and strength of the soil are probably to form a weak surface crust (especially on Soil 1) also enhances the possibility of erosion.

After consultation with the Soil Conservation Service it was decided to make a distinction between soils with slopes exceeding 5 to 10% (Soils 1, 2, 3) and those with lesser slopes. The more steeply sloping soils (Soils 1, 2) are regarded as unsuitable for normal arable agriculture without the introduction of sophisticated (and presumably unobtainable) terracing. Incidentally this range of 5% in slope limitation is due to the physical impossibility of precisely determining slopes off aerial photographs by eye.

Soils on slopes in excess of 5 to 10% may be used for grazing or for tree crops, combined with permanent pasture or a non-erosion inducing cover crop like groundnuts.

Due to their higher content of calcium and hence their relative resistance to erosion, Soils 5 and 10 are permitted up to 10% (15%) of slope before being designated "Soil 2".

The following anti-erosion measures are recommended on all slopes exceeding 5% (5%).

(a) Strip Cropping. Crops are planted in strips across the hillsides. The area between the strips should be left under grass with tree crops. The strips may vary between 15 and 40 yards depending on the slope.

(b) Contour Ploughing. Row crops should be planted along the contour "on the ridge". Cultivations should also be performed along the contour. Cultivations should be kept to a minimum.

(c) Maintenance of soil structure by addition of P.Y.M. or other forms of D.M.

It should be noted in this context that cotton, maize and tobacco permit above-average erosion. Cover crops or grass should be planted in the inter-row between your trees. Lucerne and clover never do form a complete canopy even when mature and so these should not be planted on the steepest slopes. The newly introduced Velvet Grass (a Velvet Grass - *Vetiveria zizanioides*) can provide an adequate protective cover against erosion.

Should it be decided to develop Soil 5 employing terracing, soil conservation at Mtwapa should be consulted.

(d) Drainage Scales, Mtwapa Stream and Field Waterways

1. Drainage Scales

The detrimental effects of poor drainage are well known.

there can be no doubt that the very poorly drained soils are unsuitable for most arable crops. The only point that needs to be made here is that, in an area where soil moisture is a limiting factor of the utmost importance, the well drained soils may not have the optimum drainage status for an average aerobic crop. Leaving aside the special case of coconuts which prefer to have a water table 'within striking distance', a soil that receives a considerable amount of additional water from a lateral source may, provided it possesses a high inherent level of available moisture (i.e. a low wilting point relative to field capacity), be better able to support crops through the entire growing season than a well-drained soil. This is because although, during prolonged and heavy rains, the average crop on the seasonally poorly drained soil (S.P.D.) may receive an initial set-back, once the rains decrease and the dry season sets in, the S.P.D. soil possesses a more considerable reserve of soil moisture than the permeable well-drained soil. Unfortunately none of the soil samples taken were reported on by the National Agriculture Laboratory. It is however suggested that, at least in the case of the S.P.D. Soil 51, the disadvantages accruing from impeded drainage during the rains may well be counter-balanced by the advantage of a superior moisture status afterwards.

2. Moisture Stress and Moisture Balance.

Quite apart from the excessively drained and extremely coarse Soil 14 which suffers continuous and obvious moisture stress as soon as the rains cease, there are several other soils (especially Soils 1, 4, 5, 52) within which soil moisture must be a critical limiting factor, particularly when considering the length of the dry seasons and the irregularity of the rains. This should be taken into account in dry years when fertilizer and planting trials may be rendered inconclusive. Soil moisture may be conserved to some extent by reducing cultivations to a minimum. Organic material has a high water-holding capacity; likewise it has a high wilting point. Nevertheless in these coarse sandy soils O.M. will on balance raise the soil moisture status, besides its beneficial effect on surface soil structure and hence on infiltration.

Hursh and Pereira (1953) found that, at a tension of 20 cms. a soil with the approximate composition of Shimba Soil 1 was able to hold about 20.5 inches of water in the top 5 feet. They also found, in a forest near Kwale, that there was a daily increase of about 1/10 inch of water to the topsoil as a result of dew and subsequent leaf drip. Due to the insulation in the forest, surface evaporation will be negligible. Less water reaches the ground in the forest however due to canopy interception. It was observed that the soil was particularly dry beneath broad-leaved trees like mangoes. Whilst some of this intercepted rain will, on evaporation from the leaves act as "negative transpiration", necessarily some of the moisture will be utterly wasted. Furthermore a rainforest will, overall, transpire more moisture than open grassland.

It seems probable, therefore, that, from the point of view of moisture balance, rather more water would be released under grassland compared with forest. The

There can be no doubt that the very poorly drained soils are unsuitable for most arable crops. The only point that needs to be made here is that, in an area where soil moisture is a limiting factor of the utmost importance, the well drained soils may not have the optimum drainage status for an average arable crop. Leaving aside the special case of crops which prefer to have a water table within striking distance, a soil that receives a considerable amount of additional water from a lateral source may, provided it possesses a high inherent level of available water, i.e. a low wilting point relative to field capacity, be better able to support crops through the entire growing season than a well-drained soil. This is because although, during prolonged and heavy rains, the average crop on the seasonally poorly drained soil (S.P.D.) may receive an initial set-back, once the rains decrease and the dry season sets in, the S.P.D. soil possesses a more considerable reserve of soil moisture than the permeable well-drained soil. Unfortunately none of the soil samples taken were mentioned on by the National Agricultural Laboratory. It is however suggested that, at least in the case of the S.P.D. soil, the disadvantages accruing from impeded drainage during the rains may well be counter-balanced by the advantage of a superior moisture status afterwards.

5. Moisture Stress and Moisture Balance.

Quite apart from the excessively drained and extremely coarse soil 14 which suffers continuous and obvious moisture stress as soon as the rains cease, there are several other soils (especially soils 1, 4, 5, 22) within which soil moisture may be a critical limiting factor, particularly when considering the length of the dry seasons and the irregularity of the rains. This should be taken into account in dry years when fertilizer and planting trials may be concerned. Soil moisture may be conserved to some extent by reducing cultivation to a minimum. Organic material has a high water-holding capacity; likewise it has a high wilting point. Nevertheless in these coarse sandy soils O.M. will on balance raise the soil moisture status, besides its beneficial effect on surface soil structure and hence on infiltration.

Murph and Perline (1953) found that, at a tension of 30 cms. a soil with the approximate composition of Shikha soil 1 was able to hold about 30.8 inches of water in the top 3 feet. They also found, in a forest near Kuala, that there was a daily increase of about 1/10 inch of water to the topsoil as a result of dew and subsequent leaf drip. Due to the insulation in the forest, surface evaporation will be negligible. Less water reaches the ground in the forest however due to canopy interception. It was observed that the soil was particularly dry beneath broad-leaved trees like mangoes. Whilst some of this intercepted rain will, on evaporation from the leaves, act as "negative transpiration", necessarily some of the moisture will be utterly wasted. Furthermore a rainforest will, overall, transpire more moisture than open grassland.

It seems probable, therefore, that from the point of view of moisture balance, rather more water would be released under grassland compared with forest. The

removal of the forest might however multiply the flood peaks. The ground water supply should be greatly increased by the substitution of annual crops for grassland. Planting tree crops at a relatively low density will of course raise the level of soil moisture transpired though probably not to a very great extent. The solution of the comparative field moisture balance as between annual crops, tree crops, grassland and forestry could be readily worked out over a 2 year period by the judicious siting of gypsum blocks in each of these sites.

Trees and shrubs should be cleared from stream margins as a matter of routine catchment management, and any forest developments would be better confined to the steeper slopes and upper ridge flanks.

(c) Soil Acidity

In contrast with temperate acid soils for which liming may be confidently recommended, these tropical kaolinitic soils with a very low exchange capacity have a larger pH-dependent charge than permanent charge. Orthodox pH levels are therefore a poor indication of the lime requirement of such a soil, and it is only considered necessary to neutralise the permanent negative charge (Hp). Excessive applications of lime tend to induce hydrolysis to form bicarbonate and aluminous trihydroxide. The bicarbonate may inhibit the uptake of crucial plant nutrients. Moreover the lime so swamps the exchange complex that the whole balance of available nutrients is upset and many trace elements may be rendered completely unavailable. Worse still, aluminium toxicity may result from the release of aluminium hydroxide. Furthermore much of the acidity to be neutralised occurs in the deep subsoil. On the soils of the Project Area it is considered unlikely that any economic benefit will be gained from liming since the level of surface Hp is generally low compared with Ca + Mg, and the C.E.C. is particularly low. Lime has no effect on tobacco on Soil 1.

On most acid soils in Kenya the benefits from liming even where they occur, can readily be obtained by giving a normal dressing of basic phosphatic fertilizer instead.

(d) Nutrient Supply and Organic Matter.

Those well drained and seasonally poorly drained soils that are recommended for arable and/or tree crop production are generally low in organic material, nitrogen, and phosphate. Some of the soils, notably Soil 1, also appear to be low in calcium, magnesium and potassium. Phosphate in particular may be severely deficient, and even tobacco responds to applications of water-soluble phosphates.

Fertilizer use comprises:-

- (a) Soil amelioration through the elimination of major nutrient deficiencies.

and

- (b) Fertilization for crop maintenance, optimum yields and quality production. This latter should provide for balanced nutrition in relation to crop requirements and soil differences. Anticipated fertilizer responses will not be obtained unless all the nutrients are in adequate supply; response may also be limited by lack of soil moisture e.g. During the

removal of the forest might however subject the
ground water supply should be greatly
increased by the substitution of annual crops for grass
land. Planting tree crops of a relatively low density
will of course raise the level of soil moisture
drained through probably not to a very great extent. The
rotation of the comparative field moisture balance as
between annual crops, tree crops, grassland and forestry
could be readily worked out over a 2 year period by
the judicious sifting of various books in each of these
fields.

These and other points should be discussed from stream head
as a matter of routine catchment management, and any
forestry development would be better confined to the
steeper slopes and upper flanks.

(c) Soil Acidity

In contrast with temperate acid soils for which liming may
be considered, recommended, these tropical latitudes soils
with a very low exchange capacity have a larger pH-equivalent
charge than permanent charge. Liming of these soils is therefore
a poor indication of the lime requirement of such a soil, and
it is only considered necessary to neutralise the permanent
negative charge (pH). Excessive application of lime leads to
silicate hydrates to form diatomaceous and siliceous hydroxides.
The diatomaceous may inhibit the uptake of essential plant nutrients.
Moreover the lime so applied the exchange complex that the whole
balance of available nutrients is upset and many trace elements
may be rendered completely unavailable. Iron, zinc, manganese,
boron, molybdenum, and cobalt are particularly affected.
Liming may result from the release of aluminium hydroxide.
Furthermore much of the acidity to be neutralised occurs in
the deep subsoil. On the soils of the Project area it is
considered unlikely that any economic benefit will be gained
from liming since the level of surface is generally low
compared with Ca + Mg, and the S.O.D. is particularly low.
Lime has no effect on cobalt on soil 1.

On soil acid soils in Kenya the benefits from liming even
where they occur, can readily be obtained by giving a normal
dressing of basic phosphate fertilizer instead.

(d) Nutrient Supply and Organic Matter

These well drained and essentially poorly textured soils
that are recommended for arable and/or crop production
are generally low in organic material, nitrogen, and phosphate.
Loss of the soils, naturally soil, also appear to be low in
calcium, magnesium and potassium. Research in particular may
be severely deficient, and even coarse response to application
of water-soluble phosphates.

Fertilizer use (comparative)

(a) Soil amelioration through the dilution of water
nutrient deficiencies.

(b) Fertilization for crop maintenance, optimum yields
and quality production. This latter strictly provides
for balanced nutrition in relation to crop require-
ments and soil differences. Ameliorated fertilizer
responses will not be obtained unless all the
nutrients are in adequate supply; responses may also
be limited by lack of soil moisture e.g. During the

and

short rains when drought is
fertilizer should not be applied
development and delays ripening
will tend to hasten maturity

Nitrogen: Response to nitrogen
depend upon raising the phosphorus
Nitrogen will be the most important
Annual crops that should receive
sorghum, sugar, grasses and
(A.S.) is the commonest form
yet the use of this fertilizer
of K, Ca, and Mg. It is proper
sulphate nitrate (A.S.N.) be
Elsewhere the neutral Calcium
should be employed, especially
that have a high calcium requirement
rather expensive, it is suggested
to apply C.A.N. and A.S. (or
maize and sorghum, part should
part slightly before flowering

Phosphate: For annual crops
limiting nutrient. For tree
system and are therefore more
phosphate may only be imported

The phenomenon known as "phosphorus
a problem in the Project Area
5,6, 7, 50. These soils are
quioxide (Iron and aluminium
indicate the presence of significant
trihydronium ion (exchangeable
of the applied water-soluble
rendered water-insoluble. At
roots and so reduce their potential
Furthermore acid kaolinites
up phosphate from acid solutions
localised positive charges which
precipitated films of hydrated
also be locked up in rust minerals
this might affect Soils 10 and
agriculturally valuable phosphorus
the organic matter which is

In view of the importance of
posed by fixation, it is suggested
to assess the merits of several
soil types before any attempt
rates of application. Single
 P_2O_5 is more expensive to transport
supers yet since it also contains
may prove the more effective
be anticipated from the use of
phosphates like hyperphosphates
these will become slowly available
acid soil. Since the uptake
encouraged if it is intimately
it would be interesting to test
(usually referred to as the
results may also be obtained
contain both readily available
available mineral phosphate.

Frequent light applications
kaolinitic soils, especially
occur. Wherever possible phosphorus
placed near the seed, since
reduces fixation. Otherwise

likely to occur, nitrogenous
ed since it encourages vegetative
g; phosphate on the other hand

en on most of these soils may
ate level at the same time.
rtant element for tree crops.
nd well to nitrogen are maize,
neapple. Ammonium sulphate
n which nitrogen is applied,
lowers the pH and the levels
ed that A.S. or Ammonium
sed on Soils 10, and 51.
ammonium nitrate (C.A.N.)
on those crops like citrus
ement. Since C.A.N. is
ted that farmers be advised
S.N.) alternatively. For
be applied at planting and

is is the most important
ops, which develop a large root
efficient in extracting nutrients,
t in the early stages of growth.

hate fixation" is undoubtedly
particularly on Soils 1, 2,
relatively rich in mobile ses-
Hp values in excess of 0.5 m.e.%
ficant quantities of the alumin-
aluminium). In this event some
hosphate may be expected to be
minium may also accumulate in
r of translocating phosphates.
ve a marked tendency to take
n and hold it closely to
ch themselves derive from pre-
squioxide. Some phosphate may
les and in iron concretions -
51. In all soils the
ate will be concentrated in
tself in short supply.

hosphate and the complex problems
sted that there should be trials
l likely fertilizers on different
is made to determine optimum
uperphosphate with only 18%
sport than double or triple
ins calcium (and sulphur) it
Better residual effects may
low water-soluble basic
or dicalcium phosphate since
ble as they react with the
f phosphate appears to be
associated with ammonium,
y monoammonium phosphate
mpound 13:52:0). Good
rom employing compounds that
superphosphate and a slowly

re more appropriate on these
here fixation is likely to
hatic fertilizer should be
his facilitates absorption and
e phosphate should be worked

well into the soil.

Potassium. This element is low or deficient in Soils 1,2, 4,5,14,50. Potash fertilizers do not however find much use in Kenya farming at present and often fail to give a worthwhile return. It would seem likely that only certain crops with a high K requirement will respond at the current intensity of production - these are crops like sugar which requires potash for maximum sucrose contents, or coconuts with a high uptake of potassium. With time, it may be that response to applications of K will become more general, and A.O.s should be on the look-out for this. Tobacco has not yet shown any response.

Calcium and Magnesium. These elements are low or deficient in most Soils 1,2,4,51,50. Since liming may have undesirable effects in these soils and since plant requirements for these elements are usually small, it is not recommended that anything should be done about these deficiencies at this stage, except for certain plants that require an all-round nutrition. Citrus, and also possibly cashews, may in the long-term respond to Ca and Mg. The two may be combined in Dolomitic Limestone; alternately, supplementary dressings of Magnesium sulphate.

Compound Fertilizers. The use of compound NP or NPK fertilizers has certain advantages for farmers in the more remote areas, besides being simpler to use. They incur lower costs per unit of nutrient for bagging, handling and transport. With the exception of certain crops of high potash requirement, it is proposed that the attention of farmers should at present be drawn towards compounds with a high phosphate: nitrogen ration. These should be worked well into the soil.

For Annual Crops, reasonable compounds for Soils 1,2,4,5,6, 7,12,50 would be 6: 32: 0, 8:40: 0, or 13:52: 0. For Soils 10, 51, there is 12: 30: 0, or 18: 46: 0. For Tobacco; 3: 27: 9 may be about the best (plus additional nitrogen in the nursery):

For Mature Tree Crops, 22: 22: 0 and 24: 12: 0 should be tried. For coconuts, 16: 8: 16 would seem more appropriate. Citrus also requires Ca and Mg (See above).

Organic Materials. It cannot be over-emphasised that the use of heavy dressings of organic manures will be highly beneficial on all soil types and especially on Soils 1,2,4,5,50.

Applications of F.Y.M. or compost should have the following effects:

1. Provision of nutrients to the crop in a highly available form.
2. Reduction in phosphate fixation.
3. Improvement in Soil Structure.
4. Increase the soil moisture holding capacity.
5. Provision of trace elements.
6. Raise, if only temporarily, the C.E.C. and so ensure a steady supply of balanced available nutrients. For this reason it is probable that an optimum treatment would consist of a high phosphate "compound" applied with organic matter.

Experiments at Matuga, performed on a soil resembling Soil 4, suggest that applications of F.Y.M. of the order of 3 tons per acre per years are required just to maintain yields and fertility at a modest level under continuous cultivation. There was no significant difference between the yields of plots (of maize, sorghum, cassava and sweet potatoes) receiving 3 tons of F.Y.M. and those which annually received an equivalent amount of N.P. and K as inorganic fertilizer.

In a long term trial at Matuga, there was no significant difference between three tons per acre per year and 9 tons per acre every third year. Consideration of the role of leys and rotations, and of the very real problem of obtaining large quantities of manure, is left to Section 7.

F.Y.M. should be applied shortly before planting; it should be ploughed or dug well in.

The use of locally available organic manures involves an operation within a closed cycle of nutrients. It is difficult to see how fertility will be maintained without a greatly increased use of inorganic fertilizers.

The soil test data is not designed to provide precise recommendations as to the amounts of each fertilizer to be applied, but merely to give a broad indication of those nutrients that are likely to be limiting production. Only a properly conducted crop trial sited on the relevant soil type can provide more sophisticated information. Some guidelines for the more important cash crops are laid down in Section 7 and certain suggestions are advanced for crop experimentation (Section 7.d.).

(e) Composition of Nematodes.

Soil nematodes can cause grave losses to susceptible crops in the tropics, especially to sugar and tobacco. For this reason tobacco plots are normally fumigated so as to control numbers. Soil nematodes can however cause insidious debilitation in a wide range of crops; in some areas nematode populations may prevent any response to fertilizers. The effects of root destruction by nematodes have often been overlooked or discounted in the past. Nematode infestations are especially prone to develop under susceptible crops growing on well drained, acid and sandy soils. Thus Soils 1,2,4,5,7,12,14 are especially at risk in this respect.

During 1967 a nematological survey of the Project Area was carried out by the Nematology Division of E.A.A.F.R.O. Their findings are summarised below.

An investigation of fumigated plots growing tobacco at Shimba (Soil 1) - in June - showed that, despite fumigation, extremely high nematode concentrations had developed. In an N.P.K. experiment under tobacco, several plants were severely stunted and showed moderate to heavy attacks by Meloidogyne (Root-knot nematodes). Results per 100 ml. soil:-

N.B. Nematode Abbreviations are as follows:-

HCT	=	Helicotylenchus;				
OTH	=	Other parasitic Nematodes				
RLU	=	Rotylenchulus				
TLR	=	Tylenchorhynchus				
MLG	=	Meloidogyne Larvae				
PTL	=	Pratylenchus				
SAP	=	Non-parasitic nematodes				
			MLG	PTL	HCT	SAP
Soil near healthy plant			500	-	60	570
Soil near stunted plant			6915	45	15	295

It is at least possible that in the sandy Shimba soils, fumigation will only be effective if the fumigated plots are sealed off from the air by polythene sheets. As the Head of the Nematology Division remarks, this will make it even more imperative for the economic aspects of tobacco-growing at Shimba to be carefully considered.

In a long term trial at Madaga, there was no significant difference between three tons per acre per year and 9 tons per acre every third year. Consideration of the role of lava and rotations, and of the very real problem of obtaining large quantities of manure, is left to Section 7.

F.Y.M. could be applied shortly before planting; it should be ploughed or dug well in.

The use of locally available organic manures involves an operation within a closed cycle of nutrients. It is difficult to see how fertility will be maintained without a greatly increased use of inorganic fertilizers.

The soil test data is not designed to provide precise recommendations as to the amount of each fertilizer to be applied, but merely to give a broad indication of those nutrients that are likely to be limiting production. Only a properly conducted crop trial on the relevant soil type can provide more sophisticated information. Some guidelines for the more important cash crops are laid down in Section 7 and certain suggestions are advanced for crop experimentation (Section 7.d.).

(e) Composition of Nematodes.

Soil nematodes can cause grave losses to susceptible crops in the tropics, especially to sugar and tobacco. For this reason tobacco plants are normally fumigated so as to control numbers. Soil nematodes can however cause damage to a wide range of crops in some areas. The population may prevent any response to fertilizers. The effect of root destruction by nematodes have often been overlooked or discounted in the past. Nematode infestations are especially prone to develop under susceptible crops growing on well drained, acid and sandy soils. These soils, 1, 2, 3, 4, 5, 12, 14 are especially at risk in this respect.

During 1957 a nematological survey of the Project Area was carried out by the Nematology Division of I.A.S.F.R.O. Their findings are summarized below.

An investigation of fumigated plots growing tobacco at Ghinea (Soil I) - in June - showed that, despite fumigation, extremely high nematode concentrations had developed. In an N.P.K. experiment under tobacco, several plants were severely stunted and showed evidence to heavy attacks by Meloidogyne (Root-knot nematodes). Results per 100 ml. soil:-

N.B. Nematode Aberrations are as follows:-

Soil near healthy plant	300	0	0	0
Soil near stunted plant	6218	45	18	255
	M.B.	P.T.	H.C.T.	S.A.P.
Non-parasitic nematodes				
Pratylenchus				
Meloidogyne larvae				
Tylenchorhynchus				
Pratylenchus				
Other parasitic nematodes				
Helicotylenchus				

It is at least possible that in the sandy Ghinea soils, fumigation will only be effective if the fumigated plots are sealed off from the air by polythene sheets. As the head of the Nematology Division remarks, this will make it even more imperative for the economic aspects of tobacco-growing at Ghinea to be carefully considered.

A comparative survey of nematode concentrations on the better drained soil types was undertaken in the October. The results are compiled in Table 25 below (after R.L.P. Wolff Schoemaker).

TABLE 25

Sample	Map Ref.	Soil Type	Numbers per 100 ml. soil						
			MLG	PTL	RLU	HCT	TLR	OTH	SAP
1	354109	1	-	295	445	590	-	10	835
2	356111	1	-	-	45	170	-	-	845
3	304132	1	-	-	115	150	-	5	1445
4	437166	1	240	25	-	70	-	5	450
5	462181	1	20	5	-	180	-	-	660
6	459183	1	-	-	-	-	-	-	650
7	446165	4	-	15	85	35	-	15	570
8	456172	4	15	20	10	190	-	-	280
9	338132.	4 - 14	-	-	-	65	20	40	915
10	298054	6	-	5	1290	185	-	5	875
11	328096	10	-	50	20	110	45	10	2915
12	328096	10	-	-	15	180	-	-	700
13	351108	10	-	-	805	25	-	15	2070
14	290102	10	-	40	1940	95	5	-	1015
15	282063	12	-	-	355	125	-	5	760
16	484094	14	-	-	25	20	-	-	90
17	436171	50	5	30	-	85	-	5	1060
18	304058	51	-	-	5	235	-	40	2075
19	338103	51	-	0	865	150	-	10	770

Of these sampling sites; 2, 3, and 6, were planted to tobacco: Site 6 is a thoroughly fumigated seedbed in the tobacco nursery at Shimba. The sites 4, 5 and 11 were previously planted to tobacco: at the time of sampling Site 4 was under maize; Site 5 had reverted to bush and grass; Site 11 was growing interplanted maize and sugar. Site 8 was cropped with maize and sesame. Site 15 was being maintained under cassava. Whilst Site 10 was sampled under a dominant weed cover, the farmer might have regarded it as a plantation of cashew and coconut with some citrus. All other sites had a cover of natural vegetation.

Samples 1,2,3,9,10,11,12,13,14,15,18,19, were taken from the Kikoneni Sector; the remainder derive from areas close to Settlement H.Q. at Shimba, excepting Sample 16 which was taken from a road cutting in the Magarini Sand near Mafisini.

An important conclusion from the data in Table 25 is that there is little relationship between nematode content and soil type, the concentration of nematodes being primarily determined by the previous history of land use. There are few nematodes on Soil 14, presumably because of its infertility and chronic deficiency in organic material.

A comparative survey of nematode concentrations on the better drained soil types was undertaken in the October. The results are compiled in Table 25 below (after R.L.P. Giff, Bonnacker).

TABLE 25

Numbers per 100 ml. soil

Soil Type	M.C.	PTL	FLU	HOT	T.P.	OTM	GAP
35010	0	665	180	-	-	10	720
35015	-	-	8	238	-	40	5075
35021	5	00	-	15	-	8	1080
35024	-	-	57	30	-	-	60
35025	-	-	358	158	-	8	780
35028	-	-	40	1040	8	-	1015
35030	-	-	608	28	-	18	2070
35035	-	-	18	140	-	-	700
35039	-	80	20	110	48	10	2475
35051	8	-	1250	180	-	8	825
35052	4-12	-	-	100	20	40	210
45015	18	20	10	140	-	-	880
45018	-	12	08	38	-	18	870
45019	-	-	-	-	-	-	680
45021	20	8	-	130	-	-	380
45022	240	25	-	70	-	8	480
50015	-	-	118	150	-	8	1440
50018	-	-	48	170	-	-	648
50019	-	288	448	820	-	10	808

Of these sampling sites; 5, 3, and 6, were planted to tobacco; Site 6 is a thoroughly fumigated site in the tobacco nursery at Shimla. The sites 4, 8 and 11 were previously planted to tobacco; at the time of sampling Site 4 was under maize; Site 8 was reverted to bush and grass; Site 11 was growing interplanted maize and sugar. Site 3 was cropped with maize and beans. Site 10 was being maintained under cassava. While Site 10 was being maintained under cassava, the farmer might have sown a dominant weed cover, the farmer might have regarded it as a plantation of cashew and coconut with some other. All other sites had a cover of natural vegetation.

Samples 1, 2, 3, 9, 10, 11, 12, 13, 14, 15, 16, 17, were taken from the Kikoni factory; the remainder derive from areas close to Settlement H.2. at Shimla, excepting Sample 15 which was taken from a road cutting in the Marginal Band near Shimla.

Of important conclusion from the data in Table 25 is that there is little relationship between nematode content and soil type, the concentration of nematodes being primarily determined by the previous history of land use. There are few nematodes on Soil 14, presumably because of its infertility and chronic deficiency in organic material.

Whilst the Kikoneni Sector is generally more heavily infested with *Rotylenchulus* and *Helicotylenchus* (both these genera contain species that are known tobacco parasites), it appears that root-knot nematodes are less likely to cause problems there than at Shimba. It should however be noted that many of the sites at Kikoneni are either uncropped or have only recently been brought into cultivation after a long period of fallow. It must be anticipated that a build-up of nematodes may occur as settlement gets under way at Kikoneni. In this regard it is surely important that only fumigated seedling material be moved from Shimba to Kikoneni.

A marked decrease in root-knot nematodes between June and October (at Shimba) may have been due to seasonal fluctuations, but is much more likely to have been the result of replacing the June tobacco with less favourable host crops.

One can but conclude that there is a serious nematode problem at Shimba, and that this might spread to Kikoneni if tobacco were to be introduced there on any scale. Fumigation is intermittently successful in controlling the nematodes, but investigations will be required to determine more effective ways of fumigating. Crop rotations may well have a place in any scheme to keep the nematodes down. A more effective approach, if tobacco experiments are to be continued, would be to try out several tobacco varieties with a view, amongst other things, to assessing their resistance to nematodes.

It was observed in the factorials that the high phosphate treatments appeared to be more susceptible to *Sclerotinia Leaf Spot*.

3. The compound fertilizer trials were based on combinations of 3 : 27 : 16 fertilizer. Application of this compound (400 lbs/acre) at planting, produced as much 'factory' a result as 3 : 27 : 16 at planting with the 4 and 5 repeated after 4 weeks. Where the entire compound (including nitrogen) was employed in one application (in an attempt to overcome nutrient fixation) reduced showed deleterious evidence of excessive nitrogen. Despite continuing heavy rains, top dressings are therefore to be regarded as unnecessary, even though there is independent evidence for phosphate fixation on soil that is high. It should be noted that every effort was made to incorporate top dressed phosphate thoroughly within the plants' rooting zone.

3. Trials with Individual Nutrients.

Major Conclusions:-

(a) There was no response on any soil to applications of potassium, calcium or magnesium. Even in the controlled lining trial, the initial top dressings were mostly killed by the line. However, lining had no significant effect on the yield.

(b) There is a response to nitrogen on all soils. Rates of growth. About 12 lbs of N/acre produced a desirable rate of application. 24 lbs N proved satisfactory. It is concluded that 24 lbs N is a reasonable

While the Kikoni sector is generally more heavily infested with *Polyblastus* and *Helicoverpa* (both these genera contain species that are known tobacco pests), it appears that ground-nesting nematodes are less likely to cause problems there than at Shinda. It should however be noted that many of the sites at Kikoni are either uncultivated or have only recently been brought into cultivation after a long period of fallow. It must be anticipated that a build-up of nematodes may occur as settlement gets under way at Kikoni. In this regard it is surely important that only fumigated seedling material be moved from Shinda to Kikoni.

A marked increase in root-lesion nematodes between June and October (at Shinda) may have been due to seasonal fluctuations, but is much more likely to have been the result of replacing the June tobacco with less favourable host crops.

One can not conclude that there is a serious nematode problem at Shinda, and that this might spread to Kikoni if tobacco were to be introduced there on any scale. Fumigation is intermittently successful in controlling the nematodes, but investigations will be required to determine more effective ways of fumigating. One may well have a place in any scheme to keep the nematode down. A more effective approach, if tobacco experiments are to be continued, would be to try out several tobacco varieties with a view, amongst other things, to assessing their resistance to nematodes.

6. REVIEW OF THE TOBACCO TRIALS

At the request of the Ministry of Agriculture, B.A.T. began investigations, in January 1966, into the possibility of producing flue-cured tobacco in the Shimba Hills. In 1967 the scope of the investigations was extended to include the Kikoneni area (also Ngerenyi).

Trials laid down covered time of planting, varieties, fertilizers, liming, cultural techniques, and leaf curing. These trials were conducted through the long rain seasons of 1966 and 1967, and the 1967 short rains.

Many problems were encountered. Indeed tobacco proved itself to be a highly perverse crop under Coastal growing conditions. This is probably due to the prevailing high night temperatures and the overall high humidity. These conditions lead to low rates of transpiration combined with excessively high levels of night time respiration. Such physiological disorders may well have a significant influence on the overall plant metabolism so that soil nutrients cannot be fully utilized. The consequent nutrient imbalance so weakens the plant as to render it particularly susceptible to disease.

Fertilizer Trials:

1. The N, P, K, factorial trials were all inconclusive due to irregular growth within the plots. Here it should be pointed out that some of the trials were laid out down the slopes so that the plot included more than one Soil Type. Ideally Soil Mapping should be undertaken before trial plots have to be selected rather than the other way round!

It was observed in the factorials that the high phosphate treatments appeared to be more susceptible to Cercospora Leaf Spot.

2. The compound fertilizer trials were based on Combinations of 3 : 27 : 18 fertilizer. Application of this compound (400 lbs/acre) at planting, produced as 'satisfactory' a result as 3 : 27 : 18 at planting plus the P and K repeated after 4 weeks. Where the entire compound (i.e. including nitrogen) was employed in the top dressing treatment (in an attempt to overcome nutrient fixation) tobacco showed deleterious evidence of excessive nitrogen, despite continuing heavy rains. Top dressings may therefore be regarded as unnecessary, even though there is independent evidence for phosphate fixation on most Soil Types. It should be noted that every effort was made to incorporate top dressed phosphate thoroughly within the feeder rooting zone.

3. Trials with Individual Nutrients.

Major Conclusions:-

(a) There was no response on any Soil Type to applications of Potassium, Calcium or Magnesium. Indeed on the controlled liming trial, the initial tobacco seedlings were mostly killed by the lime. Once established however, liming had no apparent effect on the tobacco.

(b) There is a response to Nitrogen in the early stages of growth. About 12 lbs of N is however, the maximum desirable rate of application even during heavy rains; and 24 lbs N proved excessive. It should be remarked that 24 lbs N is a relatively low application.

RESULTS OF THE TOBACCO TRIALS

At the request of the Ministry of Agriculture, S.A.I. made investigations, in January 1955, into the possibility of producing fire-cured tobacco in the Shire Highlands. In 1957 the scope of the investigation was extended to include the Kibondo area (also Nyanza).

Trials were conducted during the long rainy season of 1955 and 1957, and the 1957 trial was repeated in 1958 and 1959. These trials were conducted through the long rainy season of 1955 and 1957, and the 1957 trial was repeated in 1958 and 1959.

Many problems were encountered. Indeed tobacco proved itself to be a highly sensitive crop under local growing conditions. This is mainly due to the prevailing high night temperatures and the overall high humidity. These conditions lead to low rates of transpiration compared with the expected high levels of night transpiration. Such a physiological situation may well have a significant influence on the overall plant metabolism as the soil nutrients cannot be fully utilized. The consequent nutrient deficiency so weakens the plant as to render it particularly susceptible to disease.

Fertilizer Trials

1. The P, K, factorial trials were all inconclusive due to irregular growth within the plots. Here it should be pointed out that some of the trials were laid out on the slopes so that the plot treated with the best soil type locally soil weeping should be undertaken before any trial has to be selected rather than the other way round.

It was observed in the factorial trials that the high phosphate treatments appeared to be more susceptible to Phytophthora leaf spot.

2. The compound fertilizer trials were based on combinations of 5 : 27 : 10 fertilizer. Application of this compound (400 lbs/acre) at planting, produced a 'fertilizer' effect as a result of 5 : 27 : 10 at planting due to the fact that K repeated after 4 weeks. Where the entire compound (i.e. including nitrogen) was employed in the top dressing treatment (in an attempt to overcome nutrient fixation) although showed definite evidence of excessive nitrogen, despite continuing heavy rains. Top dressings may therefore be regarded as unnecessary, even though there is independent evidence for phosphate fixation on most soil types. It should be noted that every effort was made to incorporate top dressed phosphate thoroughly within the tobacco rooting zone.

3. Trials with Individual Nutrients

Major Conclusions:-

- (a) There was no response on any soil type to applications of Potassium, Calcium or Magnesium. Indeed on the controlled timing trial, the initial tobacco seedlings were mostly killed by the lime. This established, however, lime had no apparent effect on the tobacco.
- (b) There is a response to Nitrogen in the early stages of growth. About 12 lbs of N is however, the maximum desirable rate of application even during heavy rainfall and 24 lbs N proved excessive. It should be pointed out that 24 lbs N is a relatively low application.

This result supports the contention that even quite moderate additions to the soil tend to unbalance the release of nutrients from the soil complex because of its very low adsorption capacity.

It made no difference whether N was applied in the ammonium form or as nitrate.

(c) There is a definite response on all Soils to Phosphate in the water-soluble form. No differences were detected between triple superphosphate and double supers. Marked symptoms of phosphate deficiency were evident on 2 plots to which Dicalcium phosphate had been added.

SOIL TYPES:

Trials were performed on Soils 1, 5, 10, 12, 51 and 83. Certain conclusions emerged with regard to the suitability of the soils, though it must be emphasised that the results, in terms of Yield of curable tobacco, were extremely poor on all soil types investigated, both at Shimba and at Kikoneni:-

(a) Shallow soils and gravels are inimical to tobacco growth.

(b) During rains, tobacco suffers a set-back on the seasonally poorly drained soils. This may be partially due to the excessive weed growth that occurs under these conditions. Except where surface flooding has taken place, growth generally recovers later in the season. It is not recommended to grow tobacco on the Very Poorly Drained Soils (nor on Soil 70).

(c) The coarser, sandier soil types are more prone to drying out thus causing moisture stress in the later stages of growth. These Soils also have a particularly low adsorption complex. Soils 3,4,8, 12, 13, 14, 50,52, 53 cannot be recommended for tobacco.

(d) Particularly striking symptoms of excessive nitrogen were demonstrated on the coarse and acid Soil 5.

(e) Soils 10 and 51 at Kikoneni proved (marginally) to be the best soil types for tobacco. Variety NC 95, which is incidentally supposed to be resistant to soil nematodes, does somewhat better than White Gold.

(f) No trials have yet been conducted on Soil 6 at Kikoneni. The acreage of this soil type is inadequate to form the basis for tobacco production. If however it is decided to continue tobacco trials, it is proposed that one experiment be sited on Soil 6 where the well drained lightclays may prove to be better buffered than any other soil type.

Major Agronomic Problems:

In order of importance, the 3 main hazards to tobacco are discussed below:

1. Nutritional Imbalance

Regardless of variety, time of planting, soil type or fertilizer treatment, at maturity the leaf contained excess nitrogen. All attempts to bring nitrogen into balance with other nutrients were unsuccessful. This type of leaf cannot be flue-cured satisfactorily nor can tobacco of acceptable manufacturing quality be produced from it.

This result supports the contention that even with moderate additions to the soil tend to maintain the release of nutrients from the soil complex because of its very low absorption capacity.

It made no difference whether N was applied in the ammonium form or as nitrate.

(a) There is a definite response on all soils to nitrogen in the water-soluble form. No differences were observed between trials superphosphate and double superphosphate. Symptoms of nitrogen deficiency were evident on 2 plots to which fertilizer phosphate had been added.

SOIL TYPES:

Trials were performed on soils 1, 2, 10, 12, 13 and 22. Certain conclusions emerged with regard to the suitability of the soils, though it must be emphasized that the results, in terms of yield of certain crops, were extremely poor on all soil types investigated, both at Kilmory and at Kilmory.

(a) Shallow soils and gravels are inimical to tobacco growth.

(b) During rains, tobacco suffers a setback on the generally poorly drained soils. This may be partially due to the excessive weed growth that occurs under these conditions. Except where surface flooding has taken place, growth generally recovers later in the season. It is not recommended to grow tobacco on the very poorly drained soils (nor on Soil 20).

(c) The coarse, sandier soil types are more prone to drying out than causing moisture stress in the later stages of growth. These soils also have a particularly low absorption capacity. Soils 3, 4, 8, 12, 14, 20, 22, 23 cannot be recommended for tobacco.

(d) Particularly striking symptoms of excessive nitrogen were demonstrated on the coarse and soil 2.

(e) Soils 10 and 21 at Kilmory proved (especially) to be the best soil types for tobacco, Variety No. 22, which is incidentally supposed to be resistant to soil diseases, does somewhat better than White Soil.

(f) No trials have yet been conducted on Soil 5 at Kilmory. The acreage of this soil type is inadequate to form the basis for tobacco production. However, it is decided to conduct tobacco trials, it is proposed that one experiment be sited on Soil 5 where the well drained lightloam may prove to be better suited than any other soil type.

Other Agronomic Problems:

In order of importance, the 3 main ailments to tobacco are discussed below:

1. Nutritional Imbalance

Regardless of variety, time of planting, soil type or fertilizer treatment, at maturity the leaf contained excess nitrogen. All attempts to bring nitrogen into balance with other nutrients were unsuccessful. This type of leaf cannot be processed satisfactorily nor one tobacco of acceptable manufacturing quality be produced from it.

The excess nitrogen shows itself as the tobacco is approaching maturity i.e. towards the end of the Rains. Flushes of nitrogen (released from the microbial decomposition of organic material) normally occur at the onset of the rains so that, particularly in the sandier soils, by the end of the rains much of the released nitrate has been leached out of the solum. It is concluded therefore that the imbalance is probably not the result of a direct nitrogen flush. It could be due to a high ratio of N: P + K, developing as a consequence of continuing fixation of the P and K. The lack of any response to top dressings of these elements does not however support this theory.

Root Studies at Shimba (Soil 1) show that there are two quite separate types of roots:-

- (a) In the region 15 to 20 cms. below the start of the taproot (i.e. beneath ground level) there are several major laterals branching horizontally together with an enormous number of fine and delicate rootlets that ramify throughout the ridge, and between the ridges.
- (b) 25 to 30 cms. beneath ground level a large number of stouter, stronger roots branch off from the tap root and pass down to the top of the heavier sandy clay subsoil where they tend to travel horizontally, though with fine root branches penetrating well into the sandy clay. It is suggested that these latter roots are mostly involved in water uptake, and possibly also in the absorption of leached nitrate.

With the onset of the dry season the surface feeder roots will tend to die off so that much of the transpiration stream will derive from the subsoil which is where there might well be an accumulation of leached nitrate.

2. Cercospora Leaf Spot:

Coastal climatic conditions, especially during and following the Long Rains, favour the rapid development of Leaf Spot, which can be totally destructive. Fungicides are not very effective against it, and under conditions favourable to the disease their use is uneconomic. This disease is associated with nutrient imbalance since it is the unbalanced plants that are much more susceptible.

3. Wilt:

This very destructive but as yet unidentified wilt-producing organism is present throughout the Project Area. Becoming apparent as plants approach maturity, this wilt caused the death of up to 90% of the tobacco in certain plots at Shimba (Short Rains; 1967), and has been found in all the Kikoneni trial plots most of which had been out of cultivation for many years. This disease is not described in any of the major publications and, though the visible symptoms show close affinity with those of "blackshank", the National Agriculture Laboratory has so far been unable to isolate the pathogen. The possibility of severe Nematode infestation should not be overlooked, despite the pre-planting soil fumigation.

The excess nitrogen shows itself as the foliage is
 approaching maturity, i.e. towards the end of the rainy
 period of nitrogen (released from the microbial
 decomposition of organic material) normally occur at
 the end of the rains so that particularly in the earlier
 part of the rainy season the released nitrate
 has been washed out of the soil. It is concluded there-
 fore that the imbalance is probably not the result of a
 direct nitrogen loss. It would be due to a high ratio
 of N to K, developing as a consequence of continuing
 fixation of the P and K. The lack of any response to
 top dressings of these elements does not however support
 this theory.

Plot studies at Entebbe (Soil I) show that there are two
 quite separate types of roots:

(a) In the region 15 to 20 cm. below the surface
 of the soil (i.e. below ground level) there
 are several major lateral roots extending horizontally
 together with an average number of fine and delicate
 roots that run throughout the ridge, and
 between the ridges.

(b) 25 to 30 cm. beneath ground level a large number
 of shorter, stouter roots branch off from the main
 root and pass down to the top of the heavier sandy
 clay subsoil where they tend to grow horizontally,
 though with fine root branches penetrating well into
 the sandy clay. It is suggested that these latter
 roots are mostly involved in water uptake and
 possibly also in the absorption of leached nitrate.

With the onset of the dry season the surface
 feeder roots will tend to die off so that much of
 the transpiration stream will derive from the subsoil
 which is where there will be an accumulation of
 leached nitrate.

2. Temperature Leaf Spot

General climatic conditions, especially during the
 following the long rains, favour the rapid development of
 leaf spot, which can be totally destructive. Fungus
 are not very effective against it, and under conditions
 favourable to the disease their use is uneconomic. This
 disease is associated with nutrient imbalance since it is the
 advanced plants that are most susceptible.

3. Milt

This very destructive but as yet unidentified mild-producing
 organism is present throughout the Project Area. Occurring
 apparent as plants approach maturity, this will cause the
 death of up to 50% of the foliage in certain plots at
 Entebbe (Short 1957), and has been found in all
 the Kibindi trial plots most of which had been out of
 cultivation for many years. This disease is not described
 in any of the major publications and though the visible
 symptoms show close affinity with those of "Milt",
 the National Agriculture Laboratory has so far seen no
 aids to isolate the pathogen. The possibility of severe
 permanent infestation should not be overlooked, despite
 the pre-planting soil fumigation.

Conclusions:

1. Average yields (over all soil types) of about 50 lbs. cured tobacco per acre are not such as to engender optimism when one considers that a minimum economic yield is around 1,000 lbs/acre. Furthermore this 50 lbs. is largely bottom grade tobacco - "acceptable but hardly respectable". It is inconceivable, even assuming that the nutrient balance problem can be overcome, that improved techniques/fertilizers etc. could raise the yields (and quality) to a reasonable level.
2. The 3 major problems discussed above combine with others to make the production of good quality flue-cured tobacco on a commercial scale a distinct economic improbability.
3. If, despite all the evidence, a decision is taken to continue the trials, it is proposed that the entire effort be concentrated at Kikoneni on Soils 6,10,51 only.

7. AGRICULTURAL DEVELOPMENT

(a) Agriculture and Wildlife

Since it is understood that an ecological survey of the Shimba Hills Reserve will shortly be undertaken, it is hardly appropriate for an amateur to put in his oar on this heated topic. A few general points may however be in order.

The Shimba Reserve is relatively small; consequently it is vital that adequate living-space be maintained for the game so that the habitat does not deteriorate. Areas bordering the Reserve that are not particularly suited to agriculture might perhaps be set aside to form a buffer zone between Game and Settlement. These border areas might be partially developed for forestry. The Jilore/Majimboni salient in the North East of Shimba Settlement is by and large unsuitable for agriculture (See Map Sheet 1). Here several thousand acres along the Northern fringe (Mwabila to Majimboni), which are virtually unfarmed, might be taken out of settlement. As farms become abandoned elsewhere in this salient, it is hardly worthwhile recruiting replacements: so it should be possible to extend a buffer zone between the Reserve and the main area of settlement to the South of the Mkurumuji River.

There must be considerable doubt as to whether big game can survive after much of the surrounding area (and here one must also consider Shimba South and Shimba West) has been developed for agriculture. It may therefore be necessary for access to be maintained by means of a game corridor from the South: this would link up with Jombo Mountain and then extend Southwards towards Marenje and Chuna Forests and the Lower Mwena Valley - at present an elephant migration route of some importance. So far as the Project Area is concerned, such a corridor could pass through the poor sandy areas of Mkundi (i.e. West of the line of the Choro Choro), across the Ramisi and then through the bush to the West of Gandini, leading up to the West of Jombo. What is crucial throughout this area is firm control of squatters, before the habitat for wildlife is forever irretrievably destroyed. The in-

creasing National importance of maintaining a Game Reserve in close proximity to the Beach Resorts should outweigh all considerations for what would in any case amount to third rate Settlement.

It is to be remarked that there is at present no forest development anywhere in the Project Area even though the land is rather well suited to forestry. If a tobacco industry were ever to be established at Shimba it would require fuel for curing. It is considered that soils 1,2, 4,5,7, 10, 12, 50,51, 53 are good for forest development, especially on steeper slopes and valley heads. Exotics do reasonably well at Kwale - especially Pinus caribaea. Casuarina equisetifolia would be worth trying for its quick growth, straight poles and resistance to fire. Conifers and Eucalyptus are the most promising species.

(b) Farm Size and Layout:

The layout of the Shimba Settlement is now more or less fixed beyond redemption but there is no reason why these errors should be repeated at Kikoneni.

It is proposed that greater attention than hitherto should be paid to the pattern of soil types and topography. The practice at Shimba of demarcating each farm to a standard size (whether of 20 or 25 acres) can be seen in the light of the soil information to be ridiculously arbitrary: it is moreover grossly unfair and highly inefficient. The reader should by now have grasped the idea that 25 acres of Soil 80 do not have the same merit as 25 acres of Soil 10! Farm Size should be related to the calibre of the prevailing soils. Thus on the best soils, it would probably be unnecessary for farms to exceed 10 acres: where sandy soil, poor drainage, gravels or steep topography prevail, farms might go up to 50 acres to enable more extensive farm systems to succeed. There should moreover be some consideration as to whether farms should be laid out as far as possible on a single soil type so as to simplify management; or whether farms should include "a little bit of everything". Certain localities may be best left unallocated; these might be scheduled for forestry. Problems are posed by long-settled areas like Kikoneni Village. Here it may be prudent to leave 'islands' of unregimented land within the formal settlement.

Cash Crops - Introduction.

Generally speaking, Shimba is better suited to tree crops combined with grassland, especially on the slopes. Areas of Mafisini and the Ramisi Valley are suitable only for coconuts and cashew (possibly accompanied by groundnuts). Much of the Kikoneni Sector can be used either for trees or for intensive arable.

Throughout the Project Area, a considerable acreage is presently grossly underemployed, growing reserve food crops like cassava, maize and sweet potato. Whilst there is a case for leaving lands fallow or putting fields down to grass to conserve fertility and soil structure (this case will be considered in Section 7.d.),

providing National importance of maintaining a Game Reserve in close proximity to the Beach Reserves should outweigh all considerations for what would in any case amount to minor rate reductions.

It is to be remarked that there is at present no forest development anywhere in the Project Area even though the land is rather well suited to forestry. If a tobacco industry were ever to be established at Shinda it would require fuel for smoking. It is considered that soils 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 are good for forest development, especially on steeper slopes and valley heads. Soils on reasonably well at Shinda - especially fine sandstone. Cautioning and suitable would be worth trying for the quick growth, straight poles and resistance to fire, Goulers and Eucalyptus are the most promising species.

(d) Farm Size and Layout

The layout of the Shinda Settlement is now more or less fixed beyond redemption and there is no reason why these errors should be repeated at Kikandi.

It is proposed that greater attention than hitherto should be paid to the pattern of soil types and topography. The practice of Shinda of demarcating each farm to a standard size (whether of 20 or 25 acres) can be seen in the light of the soil information to be reasonably explicitly. It is moreover generally unfair and highly inefficient. The matter should be now have passed the idea that 25 acres of Soil 00 do not have the same merit as 25 acres of Soil 101. Farm size should be related to the nature of the prevailing soils. Thus on the best soils it would probably be unnecessary for farms to exceed 10 acres; where sandy soil, poor drainage, gullies or steep topography prevail, farms might go up to 25 acres to enable more extensive farm systems to succeed. There should moreover be some consideration as to whether farms should be laid out as far as possible on a single soil type so as to simplify management, or whether farms should include "a little bit of everything". Certain localities may be best left unallocated; these might be scheduled for forestry. Problems are posed by long-settled areas like Kikandi Village. Here it may be prudent to leave 'islands' of ungranted land within the former settlement.

Cash Crops - Introduction.

Generally speaking, Shinda is better suited to tree crops combined with grassland, especially on the slopes. Areas of Malindi and the Pental Valley are suitable only for coconuts and cashew (possibly accompanied by groundnuts). Much of the Kikandi sector can be used either for trees or for intensive arable.

Throughout the Project Area, a considerable acreage is presently grossly underemployed, growing reserve food crops like cassava, maize and sweet potato. Whilst there is a case for leaving lands fallow or putting fields down to grass to conserve fertility and soil structure (this case will be considered in Section 7.4.),

many of the below yielding so-called food crops in fact draw relatively heavily on the soil resources and therefore deserve a better, more specialised treatment. Regardless of soil type, progress in this area will in some measure depend on the active propaganda of the concept of Food Crops as Cash Crops; so that it comes to be accepted that it is unnecessary for each and every farmer to grow personal food crops regardless of the Quality of his land and other economic factors of production. In this way a more rational system of Land Utilization would develop; some degree of enterprise specialisation becomes possible on individual farms. Thus part of the income gained from tree crops in one area would go to buying in food from surplus production elsewhere. This radical change in fundamental attitudes would bring all the farmers into the cash economy and would moreover significantly raise the economic activity of the District. The absence of economic specialisation is clearly a major factor retarding development. (A statutory or co-operative organisation might be required for distributing food, operating in conjunction with a local price stabilisation fund). Marketing Facilities for Cash Crops are of course a conditio sine qua non.

Certain cash crops are considered in Sections (c) and (d) below. It is considered unnecessary to provide a detailed review of those well established crops concerning which there is already a wealth of local experience (e.g. Chillies, sesame.).

(c) Major Cash Crops with Limited Increased Potential.

Maize does not do well at Shimba. This is due to a combination of adverse climate, soil moisture stress and the prevailing infertility. Average yields of maize recorded experimentally at Shimba (1952-57; no fertilizer) were 615 lbs. (3 bags) per acre. It is suggested that maize production be gradually shifted into the Kikoneni Sector where, on Soils 10 and 51, P.P. maize is really promising. Soil 6 should also support good Maize. Quite dramatic responses can be anticipated from the use of P and N or heavy dressings of F.Y.M.

Sesame is an important post-rains and Short Rains oil crop at Shimba. At Shs. 94/40 a bag (180 lbs), it yields up to 500 lbs. an acre. This is a worthwhile crop in the Shimba rotation, on Soils 1, 5, and 7. It is doubtful if sesame can compete economically with other crops to be recommended for Kikoneni. Little is known of its fertility requirements; probably this low-yielding crop should be grown on the residual effects of previously applied fertilizer.

Average yield of Chillies at Shimba (1952 - 57; no fertilizer) was 1175 lbs. At 65 cents lb. this is an attractive crop, especially on Soils 1,5,6,7,10, 12,50,51. Little is known of fertility requirements; applications of P and F.Y.M. could hardly come amiss. There is indeed considerable scope for expanding the acreage under chillies; this might be encouraged on those areas of Kikoneni with Shimba-type soil (particularly Soil 1). It would be healthy if chillies were to lose the pre-eminent

position they presently occupy at Shimba especially since, in a wet year, the crop can be devastated by Vermicularia capsici.

There is room for a controlled expansion of Bananas on selected areas of Soils 1,2,6,7,10,51. This is a valuable food crop and the leaves can be used as a mulch or fed to stock. Since its roots are highly tenacious it may be grown on slopes. Bananas should be planted in a hole 2 to 3 feet deep, liberally supplied with F.Y.M. and $\frac{1}{4}$ lb. of phosphate. It is preferable to supply small annual dressings of N (say, 2 oz. per hole). On these acid soils there may be a risk from Panama Disease. No explanation can be advanced for the observation that on sandy soils at Shimba bananas are 'oversweet'.

As legumes, Pigeon Peas, Grams and Cowpeas make a welcome addition to the rotation in the Short Rains. Unfortunately, at prevailing price levels these crops can hardly be regarded as attractive to the farmer.

Bixa orellana, on the other hand, at Shs. 252/20 per 100 lb. bag and yielding up to a ton an acre, is vastly attractive. This is a crop that is well suited to the infertile soils of Shimba though it grows equally well at Kikoneni (Soil 6, 10.) World demand for Bixa, though increasing, is clearly limited. Recently there have been heavy Bixa plantings at Shimba; since Kenya is already a significant trader in world markets, there seems a very real danger that the price may soon begin to fall sharply. If future plantings have to be controlled it might be preferable to restrict Bixa to the poorer Soils 1, 2, 5, 7, at Shimba, leaving the more fortunate farmers at Kikoneni to specialise in crops that, from the fertility point of view, are more demanding. No fertilizer appears to be necessary but it has been observed that Bixa does better when provided with F.Y.M. Closely planted, Bixa can be grown on relatively steep slopes without risk of erosion.

Fortunately one of the areas best suited to Sugar is close to the factory. Kigombero, Kikoneni, Kiruku, Mrima and Mwananyamala are within 12 miles of Ramisi Factory; these are the localities where cane should be encouraged, on Soils 6, 10, 51. At Kikoneni cane responds dramatically to fertilizers and heavy dressings should be applied on all 3 soils. It has been found that 36 tons of cane can remove up to 76 lbs. N, 54 lbs. P_2O_5 , and 170 lbs. K_2O . Up to 4 cwts. of C.A.N.

(in all) should be applied in the first year; with 2 cwts. superphosphate just before planting. 1 cwt. phosphate may prove adequate for the ratoons (with additional N, of course). Experiments are needed to assess the K requirement (a provisional suggestion would be 1 cwt. muriate of potash for the plant crop). Some nematode damage is to be anticipated. Due to problems of transport and inferior soils, the growing of cane at Shimba should be discouraged, except as a local food crop. Sugar is locally irrigated from the Ramisi River, in the vicinity of Mafisini. On irrigated Soil 51, unfertilized, average yields of 33 tons/acre/year have been obtained.

location they presently occupy at Shikha especially since in a wet year, the crop can be devastated by Verticillium wilt.

There is room for a controlled expansion of banana on selected areas of Soil 1, 2, 3, 4, 10, 11. This is a valuable food crop and the leaves can be used as a mulch or fed to stock. Since its roots are highly rot-resistant it may be grown on sloping, banana should be planted in a hole 2 to 3 feet deep, liberally supplied with F.Y.M. and 1 lb. of phosphate. It is preferable to supply small annual dressings of 1 lb. (5 oz. per hole). On these soils there may be a risk from Panama Disease. No explanation can be advanced for the observation that on some soils at Shikha bananas are 'overwatered'.

At Idemasa, Pigeon Pass, Gwama and Gwama make a welcome addition to the rotation in the Gwama Range. Unfortunately, at prevailing price levels these crops can hardly be regarded as attractive to the farmer.

On the other hand, at Gwa. 25/30 per acre, but not yielding up to a ton an acre, is a very attractive crop that is well suited to the infertile soils of Shikha though it grows equally well on Kikome (Soil 6, 10). World demand for bixa, though increasing, is largely limited. Recently there have been heavy bixa plantings at Shikha; other farmers already a significant number in world markets, there seems a very real danger that the price may soon begin to fall sharply. If future plantings have to be controlled it might be preferable to restrict bixa to the poorer soils 1, 2, 3, 4, at Shikha, leaving the more fortunate farmers at Kikome to specialize in crops that, from the fertility point of view, are more demanding. No fertilizer appears to be necessary but it has been observed that bixa does better when provided with F.Y.M. liberally planted, bixa can be grown on relatively steep slopes without risk of erosion.

Fortunately one of the areas last called in 1957 is close to the factory, Kikome, Kikome, Kikome, Kikome and Mwananyama are within 15 miles of the factory; these are the localities where bixa should be encouraged, on Soil 6, 10, 11. At Kikome some response dramatically to fertilizer and heavy dressings should be applied on all 3 soils. It has been found that 10 tons of cane can remove up to 20 lbs. of P₂O₅, 100 lbs. of K₂O, 10 to 40 lbs. of N. (in all) should be applied in the first year; with 5 tons, superphosphate just before planting, 1 cwt. phosphate may prove adequate for the seasons (with additional N, of course). Experiments are needed to assess the K requirement (a provisional suggestion would be 1 cwt. sulfate of potash for the plant crop). Some methods damage is to be anticipated, due to problems of transport and infertile soils, the growing of cane at Shikha should be discouraged, except as a local food crop. Sugar is locally irrigated from the Shikha River in the vicinity of Idemasa. On Idemasa Soil 11, fertilized, average yields of 35 tons/acre/year have been obtained.

Cotton does not thrive on any soil type. As a cash crop, it was shown to be uneconomic at Shimba (Soil 1) 10 years ago. It is therefore difficult to understand why farmers are still being encouraged to grow the stuff (especially since the ginnery is at Malindi). The Shimba Settlement Officer optimistically estimated his yields (1967) at an average of 300 lbs. an acre. There is a tendency for rains at harvest; consequently a proportion of the crop is Grade B. Even allowing 300 lbs., Grade A at 48 cents per pound, this represents a poor return. Farmers recognise this by harvesting other crops before their cotton and loss occurs through boll shedding. A significant acreage under Kenaf, suggested below, would raise the density of cotton pests so making this an even less attractive crop. It is proposed that cotton growing should not be encouraged.

(d) Review of other Cash Crops and Possible Introductions.

1. The Coconut Palm.

Coconuts require a deep, sandy, free draining soil permitting good aeration and unrestricted root development. They are adversely affected by the fixation of P and K, and do not do so well on ferruginous soils or on gravels. The optimum pH range for the palms is 6.5 to 8.0; they prefer calcareous soils. The soils of the Project Area are therefore not ideal for coconuts.

The critical factor for growth however is not so much the Soil Type per se as the depth of the water table, which should be neither too deep nor too shallow. Studies between Mafisini and Mwazare indicate that, although feeder roots concentrate in the surface horizon (where there is O.M.), there are also extensive root systems diving down towards the water table (no taproot). In coarse sandy soil the surface feeder roots may spread outwards 75 feet from the trunk and are thus able to draw nutrients from a considerable area. On reaching the high water level of the seasonal water table, rooting density sharply decreases. However, even on soils seasonally affected by ground water (e.g. Soil 52) where the major rooting may be restricted to the top metre or so, the palm still seems able to make good growth. The roots appear able to survive limited periods of flooding so long as a portion of the system remains well aerated. The palm is even able to withstand partial surface water-logging, provided (a) it is inundated only on one side, and (b) the water is not stagnant; i.e. it is able to grow on steep stream banks. Indeed the slow movement of soil water within a hillside provides ideal growing conditions. Before the rooting becomes extensive, young palms are highly susceptible to inundation as well as to drought, and it is in the establishment period that the level of the water table is so important. It is moreover vital that the water table should not be at too great a depth, especially in coarse sandy soils with low moisture holding capacity, e.g. Soil 14. Unless fertilized artificially, the palm draws much of its nutrient requirements from the ground water. Furthermore since it is unable to store much moisture and has no taproot, it will not survive a dry season if this involves a marked fall in the water table.

Consequently the soil maps should be used cautiously with regard to the soils. Soils 4 and 52 are particularly suitable. Soil 14 may also be used, provided it is not too shallow i.e. As a general rule, areas of the Hills are unsuitable. Indeed Soil 14 near Majimboni. Certain areas around Mafisini, Mwazare and Mafisi are suitable for palms. Coconuts (which will require additional fertilization yearly): there may also be a deposit of Dolomitic Limestone.

Coconuts also grow reasonably well on soils 7, 10. They would no doubt also grow on the worst drained versions of Soil 14. A considerable acreage is therefore suitable for coconuts but priority should be given to soils 4 and 52, especially in the range of really suitable soils for coconuts and cashew.

So as to increase soil moisture, the soil should be lined with coconut husks and a catch crop can be grown beneath the palms in the early years; a legume is beneficial. Other crops like sugar or cassava should be grown with coconuts. After a few years the soil should be put down to grazing (very young palms should be protected from cattle).

The major nutrients in order of importance are:- K, N, P, Mg, Ca.

Nutrients Removed by Bearing Palms

K_2O	35 - 150
N	25 - 130
P_2O_5	6 - 45

(No specific figures available for these conditions).

Potassium is particularly important to regulate the water economy, phosphorus has an indirect role in chlorophyll and root development and hence in photosynthesis. Applications of K also advance the maturity of bearing palms. Bearing palms require annual applications of potash and Mtswapa recommends 2 lbs. per palm. To this should be added a small amount of phosphorus on the surface of the soil near the palms in the early stages but over a wider area. It may be that on these generally shallow soils there would also be a response to phosphorus but this is doubtful due to the presence of Dolomitic Limestone.

N.B. A response to fertilizer applications is not evident until 3 years to become evident. Some palms do not respond as much to fertilizer and there may therefore be a case for a regular application.

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Soil 14 on the Shimba
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Consequently the soil maps should be interpreted cautiously with regard to the silt of plantations. Soils 4 and 5 are particularly recommended. Soil 4 may also be used, provided it is relatively low lying. As a general rule, areas of Soil 4 on the plains are unsuitable. Indeed coconuts are dying on Soil 4 near Malindang. Certain areas of Soil 4 around Malindang, Malabon and Malabon are fairly suitable for palms. Coconuts grown on Soil 4 may well require additional fertilizer (applied twice yearly). There may also be a response to applications of Dolomite Limestone.

Coconuts also grow reasonably well on Soils 1, 2, 3, 6, 7, 10. They would no doubt also survive on all but the best drained versions of Soils 8, 9, 11, 12. A considerable acreage is therefore available for coconuts but priority should be given to new plantings on Soils 4 and 5, especially around Malindang where the range of really suitable crops is restricted to coconuts and cashew.

In order to increase soil moisture, planting holes should be lined with coconut husks and F.Y.M. should be used. A palm crop can be grown beneath the palms in the early years; a legume is beneficial. High N-demanding crops like sugar or cassava should not be grown with coconuts. After a few years plantations can be put down to grazing (very young palms are poisonous to cattle).

The major nutrients in order of importance for coconuts are - K, N, P, Mg, Ca.

Deficiencies Removed by Various Palm - 12/5/52

K ₂ O	55 - 150
P ₂ O ₅	55 - 150
N	5 - 45

(No specific figures available for these conditions).

Potassium is particularly important since it helps regulate the water economy, provides disease resistance and an indirect role in chlorophyll formation, also that development and hence increases drought resistance. Applications of K also advance the time of bearing. Bearing palms require annual dressings of fertilizer and always recommends 2 lbs. of nitrogenous fertilizer per palm. This should be added at least 1 lb. of potash. This fertilizer should be applied to the surface of the soil near the palm in the early growth stages but over a wider area as the palm matures. It may be that on these generally phosphate deficient soils there would also be a response to P, though this is doubtful due to the prevalence of fixation. N.B. A response to fertilizer may take up to 2 or 3 years to become evident. Initially high yielding palms do not respond as much as low yielding; there may therefore be a case for selective fertilizer application.

2. Cashew Nut

This tree is well suited to the deep well drained sandy soils of the Project Area. It does less well on S.P.D. soil. Once they have developed an extensive root system, cashews survive inundation for up to 2 months, but young trees are killed out by a high water table. Even mature cashew suffers downslope from a spring-line. For this reason cashew should not be planted on those areas of Soil 52 that lie immediately below steep hills from which seasonal springs emerge (e.g. to the East of Kibuguni and Vivwini).

Soil 4 is ideally suited to cashews; Soil 52 is less suitable. Soil 14 should only be used where it is in close association with Soils 4 and 52 (as around Mafisini). The cashew also thrives on Soils 1,2,5,6, 7,10,12. Priority should be given to plantings in Mafisini, Mwaluvanga and the Ramisi Valley, where intensive cashew/coconut economies should be established.

Whilst cashews may be intercropped during establishment, it may be preferable to develop pasture beneath the trees. Farms with steep slopes at Shimba are well suited to a Coconut/cashew/pasture regime (not on Soil 14). Analyses indicate that annual applications of N and P should be beneficial. On Soils 14 and 52, observation trials using dolomitic limestone would be valuable.

The attention of Settlement Officers should be drawn to the probability that consistent high yields of cashews depend on the maintenance of a significant local population of bees to ensure fertilization.

Cashew wood might be used as fuel for tobacco curing.

3. Citrus.

The best citrus grows on well drained calcareous soils. Acid soil is therefore far from ideal and on all soil types citrus leaves provide evidence of nutritional disorders. Nitrogen and magnesium deficiency appear widespread. There is however a marked difference between poor citrus grown on Soils 1,2,4,5, and 7; and good quality citrus (no irrigation) from similar varieties grown on Soils 6 and 10. This underlines the preference that citrus has for fertile and less acid conditions; a balanced nutrition is most important. Recommendations in Table 26 apply to Soils 6 and 10 and are based on suggestions from Mtwapa.

/over.....

This tree is well suited to the deep well drained sandy soils of the Project Area. It does less well on S.P.D. soil. Once they have developed an extensive root system, cashews survive inundation for up to 2 months, but young trees are killed out by a high water table. Even mature cashew suffers downfalls from a spring-tide. For this reason cashew should not be planted on those areas of Soil 25 that lie immediately below steep hills from which seasonal springs emerge (e.g. to the East of Kibungu and Vavuni).

Soil 6 is ideally suited to cashew; Soil 25 is less suitable. Soil 14 should only be used where it is in close association with Soils 4 and 25 (as known in the past). The cashew also grows on Soils 1, 2, 3, 4, 10, 12. Priority should be given to planting in Vavuni, Kibungu and the Pambai Valley, where intensive cashew/cocoa/custard should be established.

Other cashews may be introduced during establishment, it may be preferable to develop nurseries near the trees. Farms with steep slopes or ridges are well suited to a Cocoa/cashew/pasture regime (not on Soil 14). Analyses indicate that annual applications of N and P should be beneficial. On Soils 14 and 25, observation trials using domestic lime-stone would be valuable.

The attention of Settlement Officers should be drawn to the possibility that constant high yields of cashew depend on the maintenance of a significant local population of bees to ensure fertilization.

Cashew wood might be used as fuel for cooking during.

3. Citrus

The best citrus grows on well drained calcareous soils. Acid soil is therefore far from ideal and on all soil types citrus leaves provide evidence of nutritional disorders. Nitrogen and potassium deficiency appear widespread. There is however a marked difference between acid citrus grown on Soils 4, 5, 6, 7, and 8; and good quality citrus (no frost) from similar varieties grown on Soils 9 and 10. This suggests the preference that citrus has for fertile and less acid conditions; a balanced nutrition is most important. Recommendations in Table 25 apply to Soils 5 and 10 and are based on suggestions from Kibungu.

(over.....)

Table 26

FERTILIZER PER TREE - MEXI

<u>Year of Growth</u>	
0	Apply F.Y.M. <u>Single Superphosphate</u>
1	0
2	0
3	5 lbs. in 2 applications.
from the Fourth year onwards	5 lbs. in 2 applications.

It is certainly conceivable that citrus might also be grown on Soils 1, 2, 3, 4, 5 with regular manuring. On these soils it is suggested that an occasional sulphate would be beneficial. The holes should be prepared well before the rains; the young trees should be watered until established. It is suggested that 46 trees at 21' x 21', without irrigation, should be planted in 1957.

It is understood that the pipeline to establish Mexican citrus in the Mikurumuji Valley as a nucleus for juice production. This valley requires supplementary irrigation. The area downstream from the Project Area has been investigated. Certain points should be carefully considered before making a decision.

- 1) The low-flow of the Mikurumuji is as 2 cusecs.
- 2) The steep slopes will require terracing.
- 3) The topography is unsuitable for management.
- 4) It may be predicted that the soil will be acid, sandy and have a low capacity for retaining water. Soils 1,2,3,4,5. These soils require irrigation requirements when the flow of the Mikurumuji is low.

The argument against citrus in the Kikoneni Sector is based on the lack of water for irrigation. Points in favour of irrigation are:

- 1) Better soil moisture retention and 10; hence there is a need for irrigation.
- 2) Citrus is a proven crop in the area.
- 3) The ideal of a balanced diet is easily obtainable.

Of all the citrus species, the best suited to withstand the conditions at Shimba is the sweet orange.

It would be of interest to know the yield of citrus at Shimba.

IN LIMES

the Planting Hole.

C.A.N.

8 oz. per plant in
3 applications.

1 lb.

1 lb.

3 lbs. in 2
applications plus
100 lbs. F.Y.M.

that good citrus
and 7, given heavy and
infertile soils it
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is a proposal in the
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ing a lime plantation
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ention on Soils 6
less need for

at Kikoneni, without
nutrition is more

es, limes are probably
rather adverse conditions

to try a long-term

Table 23

FERTILIZER FOR TREE - MEXICAN LIMES

Apply F.Y.M. in the Planting Hole.

<u>F.Y.M.</u>	<u>Sludge Superphosphate</u>
5 oz. per plant in 3 applications.	0
1 lb.	0
1 lb.	2 lbs. in 2 applications.
3 lbs. in 2 applications plus 100 lbs. F.Y.M.	3 lbs. in 2 applications.

It is certainly conceivable that good citrus might also be grown on Soils 1 and 2, which have a heavy and heavy sanding. On these more fertile soils it is suggested that an occasional dressing of superphosphate would be beneficial. On all soils, planting holes should be prepared well in advance of the long rains; the young trees should be staked and regularly watered until established. Inter cropping is undesirable.

It is understood that there is a proposal in the pipeline to establish a citrus line plantation along the Marum Valley as a nucleus estate for lime juice production. This valley was chosen with a view to supplementary irrigation. The size seems likely to be determined from the project area; the soils have not been investigated. Certain problems should be carefully considered before making a final decision.

- 1) The low-flow of the Marum may be as little as 2 inches.
- 2) The steep slopes will necessitate such pumping.
- 3) The topography is unsuitable for uniform estate management.
- 4) It may be predicted that the well drained soils will be acid, sandy and infertile, with a low capacity for retaining moisture - probably Soils 1, 2, 3, 4, 5. Trees will have a high irrigation requirement in just those months when the flow of the Marum is minimal.

The argument against silt is a line plantation in the Kiboni Sector is based on the lack of water for irrigation. Points in its favour include -

- 1) Better soil moisture retention on Soils 2 and 10; hence there is less need for irrigation.
- 2) Citrus is a proven crop in Kiboni, without irrigation.
- 3) The ideal of a balanced nutrition is more easily obtainable.

Of all the citrus species, limes are probably best suited to withstand the rather adverse conditions at Sinda.

It would be of interest to try a long-term

liming trial with citrus on Soil 1.

4. Acietuno (Simarouba glauca)

This is an oil nut introduced from Central America in 1957. The oil is suitable for cooking and baking without artificial hardening. The remaining cake is poisonous but may be used as manure. Seedlings planted in Central Province and at Mtwapa in 1958 have by and large thrived, though with rather variable results. The tree grows on well drained and infertile soils and reputedly does well on slopes. It would therefore be of value for diversifying cropping on Soils 1,2,4,5,12. The matchwood is light and brittle and might be used as fuel (? for tobacco curing).

The means of processing still require investigation, though the nut could presumably be handled by local oil mills. It is also necessary to assess the long-term market prospects (these should be good since Kenya is a net importer of edible oils). A sample sent to T.P.I. in 1963 analysed out at 11% water and 17% oil, expressed as percentage total weight of undecorticated seed. The oil content of the kernals was 60%.

Details of the Mtwapa trial are as follows:-

The Observation Trial (12/E/5/1) comprises 46 trees at 21' x 21', without fertilizer, planted in 1958. No pests or diseases have yet been observed. Of these 46 trees only 24 were female (Acietuno comes in 3 sexes; male, female and hermaphrodite - for good yields the bulk of the trees should be female; one male per acre is adequate).

Yields - lbs/Acre Dry Seed

1963	152
1964	422
1965	209
1966	687

Since only 24 trees produced nuts, the potential yields are almost double the above figures. At the recommended spacing, an acre could be planted to 90 trees, of which 97 would be female. In 1966 the actual total yield from 24 trees was 322.5 lbs. Assuming an extraction rate of 17% and taking a price of £85 per ton (Crude edible palm oil; c.i.f. London - pre-devaluation), the gross return per acre is Shs. 160/-. This comparatively modest return (N.B. The Mtwapa mathematics are quite incomprehensible on this important point) is based on an average yield of only 13.43 lbs. per tree, whereas the highest yielder in 1966 gave 61.31 lbs. The Research Officer considers that yields might be doubled by establishing trees from high-yielding parents. Applications of P and N might also raise yields. Since this could be a modestly attractive crop, it is proposed that observation plots of selected stock be set up at Shimba on Soils 1, 2 and 4.

Living trial with strains on Soil I.

4. Analysis (Statistical)

This is an oil not introduced from Central Africa in 1957. The oil is suitable for cooking and used without artificial flavouring. The remaining cake is poisonous but may be used as manure. Seedlings planted in Central Province and of 1957 in 1958 have to and large shrives, though with rather variable results. The tree grows on well drained and infertile soils and reportedly does well on slopes. It would therefore be of value for diversifying cropping on soils 1, 2, 4, 5, 12. The woodwork is light and brittle and might be used as fuel (for tobacco curing).

The means of processing still require investigation, though this could presumably be handled by local oil mills. It is also necessary to assess the long-term market prospects (these should be good since Kenya is a net importer of edible oils). A sample sent to I.P.I. in 1953 analysed out at 11% water and 1% oil, expressed as percentage total weight of unwatered seeds. The oil content of the kernels was 60%.

Details of the 1954 trial are as follows:-

The Observation Trial (1954/55) comprises 10 trees at 21' x 21', without fertilizer, planted in 1954. No pests or diseases have yet been observed. Of these 10 trees only 24 were female (others were in 2 sexes; male, female and hermaphrodite - for good yields the bulk of the trees should be female; one male per acre is adequate).

Yields + 1954/55 Dry Weight

1953	1954
1954	1955
1955	1956
1956	1957

Since only 24 trees produced nuts, the potential yields are almost double the above figures. At the recommended spacing, an acre could be planted to 30 trees, of which 22 would be female. In 1958 the actual total yield from 24 trees was 325.5 lbs. Assuming an extraction rate of 1% and taking a price of 250 per ton (Crude oil price 0.17, London - pre-devaluation), the gross return per acre is £15.15/-, this comparatively modest return (N.I.C. the 1954/55 statistics are quite incongruous on this important point) is based on an average yield of only 13.43 lbs. per tree, whereas the highest yielder in 1954 gave 61.31 lbs. The Research Officer considers that yields might be doubled by establishing trees from high-yielding material. Applications of P and K might also raise yields. Since this could be a moderately attractive crop, it is proposed that observation plots of selected stock be set up at Shiraz on soils 1, 2 and 4.

5. Groundnuts.

Within the Project Area there is at present only a small and scattered acreage of groundnuts, which are mostly fried for domestic consumption. On trial at Shimba (1952 - 57; no fertilizer) groundnuts averaged 700 lbs/acre. Even at this low yield, the return from the comestible market of Shs. 95/25 per 160 lb. bag is useful (e.g. more attractive than sesame). Groundnuts can be grown well on Soils 1,4,5,6,7,10; and might be planted beneath tree crops to provide income whilst the trees are maturing. With a preliminary dressing of 2 cwts. of phosphate (less on Soil 10), yields from this long rains crop could be considerably increased - with variety Homa Bay. The seed should be dressed with Fernasan D to control soil pests and diseases. Weeding is important to conserve soil moisture. Groundnuts should be grown on the flat, and earthed up somewhat on final weeding. Whilst the crop requires considerable moisture (over 4 months) to produce reasonable yields, it is a moot point as to whether planting should be in April or later in May, since it is preferable to have dry weather at harvest (and September is normally dry). A date-of-planting trial would be useful.

Bambarra Groundnuts are also grown locally. These are harder than groundnuts and are not eaten raw. As they contain only 6% oil, they are of no value for its extraction; but the high protein and carbohydrate content makes them of value for domestic consumption (on the above soils).

6. Kenaf

Apart from a few recent observation trials at Shimba, this is virtually a new crop. Kenaf was observed in the Mkanda Valley on Soil 1, where it had failed to achieve the necessary 12 feet.

Kenaf is a complicated crop:-

- 1) It requires a supply of fresh water for retting.
- 2) It is close-spaced so that weeding is near-impossible.
- 3) Spacing is critical for yield and fibre quality; a full stand must be obtained.
- 4) Heavy dressings of fertilizer are required; and top dressings of N.
- 5) The crop should be cut about 120 days from planting (or when the 10th flower opens). If cut too early, a low yield results; if too late, quality suffers.
- 6) Retting is rather involved, requiring precise timing and organisation.
- 7) Even small farmers will need labour for cutting/retting. If a large acreage of kenaf is to be grown, a very uneven seasonal labour requirement will develop.

3. Groundnuts

Within the Project Area there is at present only a small and scattered acreage of groundnuts, which are mostly tried for domestic consumption. Of trial at Sialkot (1952 - 53; no fertilizer) groundnuts averaged 300 lbs/acre. Even at this low yield, the return from the domestic market of 300/22 per 100 lb. bag is about 2.5% more attractive than sesame. Groundnuts can be grown well on soils 1, 4, 5, 6, 7, 10; and might be planted beneath trees crops to provide income while the trees are maturing. With a preliminary dressing of 2 cwt. of phosphate (less on soil 10), yields from this long term crop could be considerably increased - with varying results. The seed should be dressed with Karmanol to control soil pests and diseases. Weeding is important to conserve soil moisture. Groundnuts should be grown on the flat, and earthed up somewhat on final weeding. While the crop requires considerable moisture (over 4000 lbs) to produce reasonable yields, it is a root crop as to whether planting should be in April or later in May since it is preferable to have dry weather at harvest (and September is normally dry). A cover-cleaning trial would be useful.

Barbara Groundnuts are also grown locally. These are poorer than groundnuts and are not eaten raw. As they contain only 6% oil, they are of no value for its extraction, but the high protein and calcium content makes them of value for domestic consumption (on the above soils).

4. Kenaf

Apart from a few recent observations trials at Sialkot, this is virtually a new crop. Kenaf was observed in the Mandla Valley on Soil 1, where it was failed to achieve the necessary 12 feet.

Kenaf is a complicated crop:-

- 1) It requires a supply of fresh water for retting.
- 2) It is close-spaced so that weeding is near-impossible.
- 3) Spacing is critical for yield and fibre quality; a full stand must be obtained.
- 4) Heavy dressings of fertilizer are required; and top dressings of N.
- 5) The crop should be cut about 120 days from planting (or when the 10th flower opens). If cut too early, a low yield results; if too late, quality suffers.
- 6) Retting is rather involved, requiring precise timing and organization.
- 7) Even small farmers will need labor for cutting, retting. If a large acreage of kenaf is to be grown, a very uneven seasonal labor requirement will develop.

It can be appreciated that this is a crop for the progressive farmer! The need to be near an effective stream restricts the crop to Shimba, where it can be recommended for the Mkurumuji basin, Mkomba, the Mkanda valley, the Lukore area, Kibuyuni and Mangawani, on Soils 1,7,10. It is suggested that 2 cwts. of single super-phosphate and 1 cwt. N be applied to the seed bed. If the rains are favourable, a top dressing of 1 cwt. of N should be provided when the crop is 1' to 2' high. This top dressed fertilizer should either be placed alongside the row; or broadcast, when care should be exercised since N causes leaf burn.

This is a sufficiently valuable crop (£80/ton Grade A) to merit properly conducted field trials. It will also be necessary to establish a Demonstration Plot and Retting Tank to initiate groups of farmers into the mysteries of kenaf. A considerable expansion of kenaf is envisaged to meet the high internal demand for soft fibre.

7. Rice.

Sufficient rice should be grown within the Project Area to provide for local demand. Soils 83 and 84 are particularly suited to rice. These types with impermeable alkaline clay subsoils occur in valleys between Kikoneni and Jombo; where there is however a general lack of surface water. The fact that moisture conditions will be far from ideal should not be taken to imply that direct-sown-rice should not be attempted. The cunning construction of cross bunds in suitable valleys (especially that running North East from Jombo) would act to retain some of the excess water in the Long Rains (Kikoneni Rainfall averages 18" in April/May) and so provide a measure of moisture control. This development should be preceded by a small Pilot Project. If the idea proves feasible, response may be obtained from applications of ammonium sulphate and P. or from F.Y.M. (Response will certainly prove uneconomic in dry years). The development will be somewhat hazardous in that the crop will fail in the driest years; this should be taken into account when devising an organisation for food distribution. Furthermore, farmers allocated land for "upland rice" should also have some acres of well drained soil for other enterprises.

Moderate yields of 'upland Rice' can also be expected on Soils 51 and 81, where fertilizer is not to be recommended. Soils 50, 52, 53, 80 are really too acid and/or infertile for rice.

8. Sorghum.

In purely agronomic terms, this is the most suitable cereal on most soils. It is not grown because of (a). Low prices, and (b), Local consumer resistance. This latter is born out of habit (other peoples in Africa, e.g. The Bakiga of Uganda, use sorghum as a staple and abhor maize). So far as consumption is concerned the relatively low price is a point in its favour.

During the 1952-57 trials at Shimba, sorghum averaged 10½ cwts. per acre. Modern varieties (e.g. Serena sorghum) given dressings of 1 cwt. of N and 2 cwts. of P should yield from 10 to 20 bags per acre.

Provided the rains are favourable it is advisable to top dress with 1 cwt. of N just prior to heading. At the current price of shs 22/50 per 180 lb. bag, returns of up to shs 450/- per acre should be possible. Furthermore sorghum would prove a more reliable crop (than maize) in adverse seasons. With fertilizer, sorghum should do reasonably well on Soils 1, 5, 6, 7, 10, 12, 51. Major problems are likely to arise from bird damage and stalk borer.

Apart from domestic consumption, sorghum can also be used for:-

- 1) Beer Production
- 2) Feed for cattle, pigs and poultry (There is scope for a considerable increase in poultry production).
- 3) As a fodder crop. In this role sorghum should be sown at several times the normal seed rate, when it may yield up to 9 tons per acre green matter. Cut green, sorghum can be made into valuable silage.

9. Other Possible Introductions

A number of different vegetables have succeeded at Shimba and Lukore (e.g. Beetroot, bringals, cabbage, melons, carrots, tomatoes and radishes). In view of the proximity of Mombasa, several hotels and the Dock trade, it is proposed that vegetable production be formally expanded with a proper system of transport and marketing (if necessary under the aegis of Government). A wider range of vegetables should be tried out in observation plots on Soil 51 in particular (also on Soil 10). e.g. Beans, cauliflower, leeks and various herbs. The major problems seem likely to stem from lack of soil moisture, and from pests and diseases.

Domestic demand for Pineapple is likely to increase now that much up-country fruit is being diverted to canning. Smooth Cayenne should do tolerably well on Soils 1, 6, 7, 10. Pineapple will require a preliminary dressing of P and heavy subsequent applications of N (about 15 lbs. of ammonium sulphate per 100 plants, applied in 4 dressings during rains, starting 2 months after planting).

There are special low-altitude varieties of soybean (e.g. Hennon Local is being used under irrigation at Galole) that might merit an observation trial - on, say, Soils 1 and 10. Another valuable crop would be Sunflower to be tried on the same soils. It would be interesting to see how Macadamia Nuts would do at the Coast.

(e) Fertility Conservation - Rotations and Leys.

Many of the observations that follow have been lifted from "Agriculture in the Tropics" (Webster C.C. and Wilson P.N. 1966.).

Provided the price and fertilizer is available in
top dress with 1 cent of N just prior to heading. At the
current price of 22/100 per 100 lb. bag, return of up
to 20% per acre should be possible. Fertilizer
return would give a more reliable crop (from maize)
in drier seasons. With fertilizer, sorghum should do
reasonably well on soils 1, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

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grown at several times the normal seed rate, and
it may yield up to 5 tons per acre green matter.
But green sorghum can be made into valuable silage.

8. Other Possible Investigations

A number of different vegetable crops are
at present and future (e.g. beetroot, rutabaga, cabbages,
celery, carrots, tomatoes and radishes). In view of the
proximity of Kordofan, several potato and the Jack potato.
It is proposed that vegetable production be finally
expanded with a proper system of transport and marketing
(if necessary under the aegis of government). A wider
range of vegetables should be tried out in observation
plots on soils 1, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

Domestic demand for pineapple is likely to increase
now that such up-country fruit is being obtained in
quantity. Smooth Cayenne should be seriously well on
soils 1, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

There are several low-alkaline varieties of
sorghum (e.g. Heron local) being used under
irrigation at Gafala) that might merit an observation
trial - on, say, soils 1 and 10. Another valuable crop
would be butterfly to be tried on the same soils. It
would be interesting to see how Mochaba fits would do
at the Coast.

(e) Fertility Conservation - Rotations and Lays

Many of the observations that follow have been
gathered from "Agri Culture in the Tropics" (Webster,
1952) and Wilson (1952).

Traditional forms of s not capable of arresting the will inevitably arise as more cultivation are introduced. performed to try to devise to conserve fertility. Per subject for such trials. Th is that the effect on soil be said by following crop y under legumes is similar to of natural regeneration or may however be valuable since for 2 of the 3 years 'fallow nutrients from the deep subs 58;. Soil 1, 4 or 5) compare sorghum with rotations in w 3 years under grazed star g cassava. The highest yields pigeon pea, but the effect almost as good - and slight grazed star grass. The ben and pigeon pea 'fallows' pe that of g: the grazed star g

Fertility cannot be m alone. The several advanta are well known however; a in fertility to a very mark pure stands and mixed crop that mixed cropping may (fo a slight advantage in terms practice of mixed cropping be condemned by agricultura

Numerous experiments the effects of pure grass l fertility are no better tha Hence it is unlikely that i money and labour on plantin return can be obtained from than from natural regenerat (High C:N ratio) in the gra deficiency of available nit the ley break. Furthermore yields may be obtained afte do not compensate for the l this may be serious for the hand cultivate a very small will only be satisfactory i arable break together with can more than compensate th

There is considerable ment of leys at Mtwapa. A animal production is beyond as is the possible introduc enterprises based on the st Suffice to note that this quantities of F.Y.M. could ment. The establishment of will undoubtedly require P single superphosphate, fol N and P.

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Traditional forms of shifting cultivation are not capable of arresting the decline in fertility that will inevitably arise as soil intensive forms of cultivation are introduced. Many experiments have been performed to try to devise efficient rotations so as to conserve fertility. Perennial legumes are a popular subject for such trials. The general experience however is that the effect on soil fertility (measured in any one year) is slight or nil. It is stated that in a period of natural regeneration or of planted grass, Pigeon Pea may however be valuable since it not only provides food for 2 of the 3 years 'fallow', but also brings up nutrients from the deep subsoil. Trials at Massey (1952) on 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000, 1010, 1020, 1030, 1040, 1050, 1060, 1070, 1080, 1090, 1100, 1110, 1120, 1130, 1140, 1150, 1160, 1170, 1180, 1190, 1200, 1210, 1220, 1230, 1240, 1250, 1260, 1270, 1280, 1290, 1300, 1310, 1320, 1330, 1340, 1350, 1360, 1370, 1380, 1390, 1400, 1410, 1420, 1430, 1440, 1450, 1460, 1470, 1480, 1490, 1500, 1510, 1520, 1530, 1540, 1550, 1560, 1570, 1580, 1590, 1600, 1610, 1620, 1630, 1640, 1650, 1660, 1670, 1680, 1690, 1700, 1710, 1720, 1730, 1740, 1750, 1760, 1770, 1780, 1790, 1800, 1810, 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Fertility cannot be maintained by crop rotations alone. The several advantages of using a good rotation are well known however; a rotation can retard the decline in fertility to a very marked extent. Experiments between pure stands and mixed cropping in the tropics suggest that mixed cropping may (for certain combinations) have a slight advantage in terms of overall production. The practice of mixed cropping should therefore not necessarily be condemned by agricultural officers.

Numerous experiments in the tropics have shown that the effects of pure grass (grazed or ungrazed) on fertility are no better than those of natural regeneration. Hence it is unlikely that it will be worthwhile expanding heavy and labour on planting grass unless a better return can be obtained from animal production on the ley than from natural regeneration. The low nitrogen levels (high D:N ratio) in the grass ley may even create a deficiency of available nitrogen in the first crop after the ley break. Furthermore, although overall increases in yields may be obtained after ley, such increases usually do not compensate for the loss of cropping during the ley; this may be serious for the farmer who is only able to hand cultivate a very small acreage. Although husbandry will only be satisfactory if crop yields during the ley break break together with animal production from the ley can more than compensate this loss of cropping.

There is considerable information on the establishment of leys at Massey. A consideration of leys and animal production beyond the scope of this report, as is the possible introduction of intensive livestock enterprises based on the stall feeding of fodder crops. Suffice to note that this would be one way by which quantities of P.V.M. could be provided for soil improvement. The establishment of leys to grass fodder crops will undoubtedly require P of the order of 3 cwt. of single superphosphate, followed by potash at 1 and P.

(f) Demonstration Farms.

Two representative 20-acre units be set aside (one at Shimba; one at) demonstrate to farmers how recommended farming systems can be made on own farms. (This is particularly important for crop production, livestock production and rotational farming.) An A.I. should be appointed Farm Manager. Complete farm records and accounts should be maintained to illustrate the various inputs that are used and the levels of output. Government should assist the farmers from an extension point of view to ultimately demonstrate how each activity should be integrated. This is surely more effective than selecting random plots, dumping fertilizer and finally labelling them "Departmental Demonstration". A farmer needs to be convinced that the return justifies the expense. He, the farmer, can be convinced that he can see the results back home on his own shamba by observing many aspects of local farming practice. The way I can see of achieving a rapid change in farming practice is by physically demonstrating farming systems in operation under conditions similar to those suffered by the average farmer.

JOHN

17th February 1968

Soil Survey Unit.

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