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Agriculture and Soils in Kenya  
—A Case Study of Farming Systems in the Embu District  
and Characterization of Volcanogenous Soils—

Edited by  
Shohei HIROSE

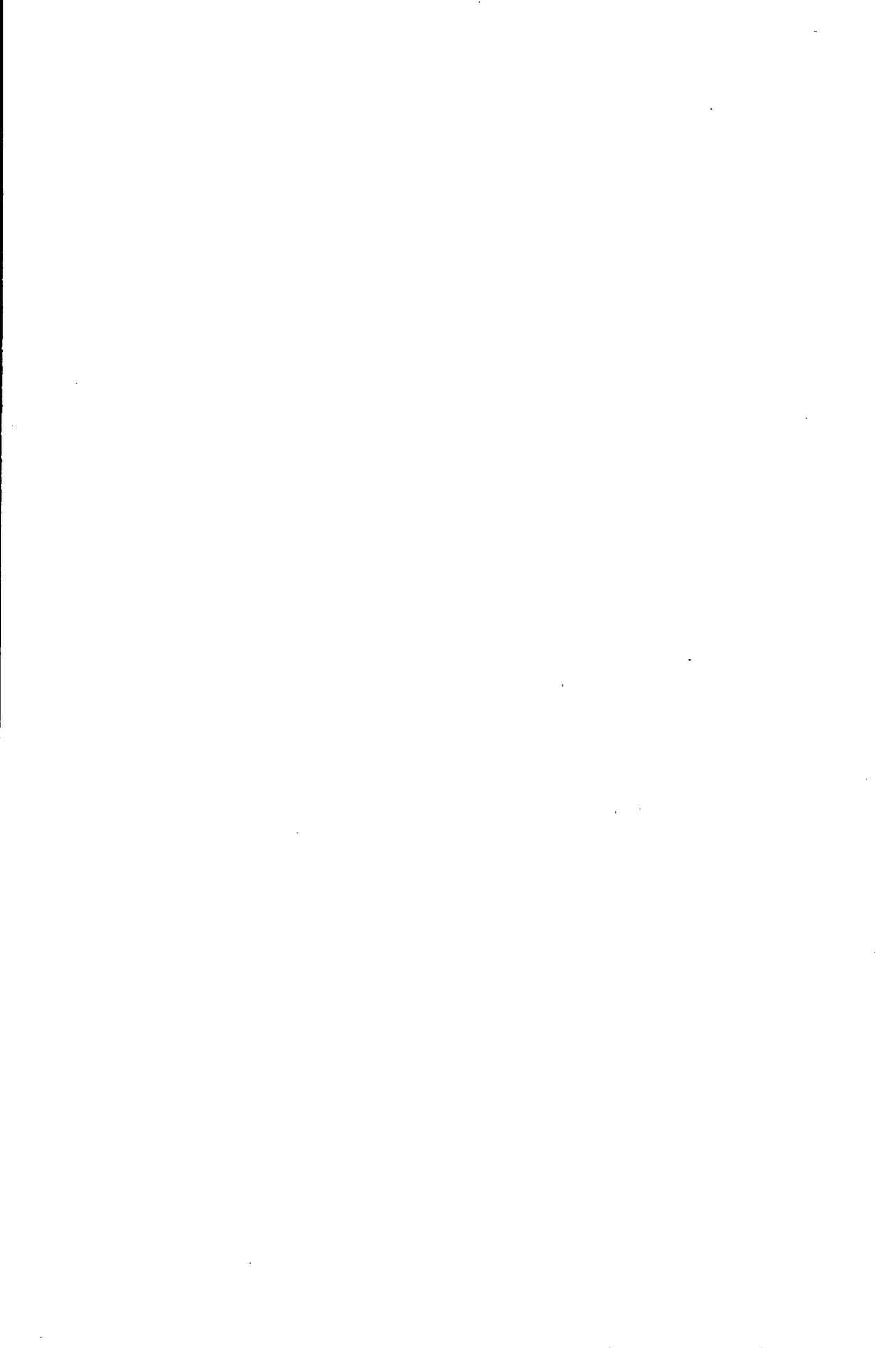
College of Agriculture and Veterinary Medicine  
Nihon University  
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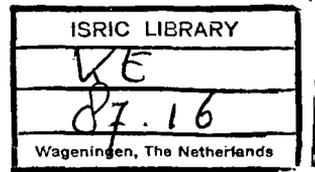
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11329

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## Preface

The food crisis in Africa in recent years has aroused world-wide concern about agriculture in arid and semiarid regions. It is unanimously recognized that along with emergency rescue activities there is an urgent need for restructuring of the food production system, both in its efficiency and stability.

In Japan there has been research done about Africa in the fields of geography, anthropology, and primatology, but almost none in technical aspects of agriculture. This study aims, first of all, at filling this gap and also contributing to the better understanding of agriculture in the semiarid regions of Africa.

Traditional agriculture is that that has been adapted to a given set of social and natural conditions over many generations. As such, it is an accumulation of the knowledge of the people, which they have acquired in a long process of adaptation. It is imperative to understand the traditional ways of adaptation before any effective suggestions can be made about how to improve current practices in agriculture. That is the basic thesis of this study and, thus, the prime objective of the study is to understand the present state of traditional agriculture in relation to its agro-ecological factors, particularly those involving climate and soil.

Another objective of the present study is to clarify the characteristics of volcanogenous soils in Kenya in comparison with those in Japan and elsewhere. Kenya is situated in the great African rift zone, and there are many extinct and active volcanos there. The soils derived from recent ashes and cinders, i.e., Ando soils, are of particular interest from the viewpoint of their classification. A recent study by Wielemaker and Wakatsuki (1984) pointed out unusual chemical and mineralogical characteristics of these soils. The alkali-rich nature of the parent material and the dry climate under which the material undergoes weathering may account for the peculiarities. Besides the Ando or Ando-like soils, there are Nitosols derived from older volcanogenous materials. As these volcanogenous soils are among the most productive soils in Kenya, where only about 17% of the land that has annual precipitation of more than 700 mm is cultivated, their study should also contribute to the agricultural production of the country.

The team consisted of the following six members:

- Dr. Shohei Hirose, Leader. Prof. of Agronomy, Nihon University;
- Dr. Kazutake Kyuma, Prof. of Soils, Kyoto University;
- Dr. Susumu Yazawa, Assoc. Prof. of Agronomy, Kyoto Prefectural University;
- Dr. Toshiyuki Wakatsuki, Assoc. Prof. of Soils, Shimane University;
- Dr. Chitoshi Mizota, Instructor of Soils, Kyusyu University; and
- Mr. Kazuo Hanzawa, Lecturer of Agricultural Economics, Nihon University.

All members of the team worked together in the village studied in the Embu District, where the agronomists and the agricultural economist stayed for most of the survey period; the three soil scientists covered a wider area for the study of volcanogenous soils. We stayed in Kenya from mid-June till the end of August, 1985. )  $\frac{1}{2}$  month

In this volume, the results of both field surveys and laboratory studies conducted by the team members are presented. The agronomic aspects studied in the Embu District and the pedological aspects studied in the areas of volcanic ejecta are treated separately for the convenience of the reader, but both in the field and in the later stage of this work, the two groups cooperated closely and exchanged views and information freely.

The team members wish to express their most sincere gratitude to the following offices, which made the study in Kenya possible, and individuals, who extended assistance

and support to them during the study period:

The Office of the President,  
Ministry of Agriculture and Livestock Development,  
Government of the Eastern Province.  
The late Mr. James J.O.C. Adalla, Senior Research Officer,  
Mr. Frederick N. Muchena, Head, Kenya soil Survey,  
Mrs. E. Mucai, Director of Agriculture, Embu District.

It is not possible to mention all of the individuals who helped us, but the assistance extended by the staff members of the Kenya Soil Survey and Divisional Agricultural Offices of Runyenjes and Gachoka Divisions of the Embu District is gratefully acknowledged. The team is indebted also to the members of the Training Program in Pedology of the State Agricultural University of the Netherlands, then working in the Embu District.

The Ministry of Education, Science and Culture of the Japanese Government gave the team three grants-in-aid (Nos. 59042012, 60041073, and 61043068) that enabled the team to conduct a preliminary survey in Kenya and Zaire in 1984 and the field survey in Kenya in 1985 and also to prepare this report in 1986. The team members greatly appreciate the understanding and support of the Ministry. The Embassy of Japan and the JICA Office in Kenya extended help to the team in various ways during the field work, for which the members are most thankful.

Last, the team members thank the then representatives of the Japan Institute of African Studies, Dr. Takahashi and Mr. and Mrs. M. Ohsaki, who made them feel at home whenever they came to visit the Institute during the field survey.

March, 1987

Shohei Hirose  
Kazutake Kyuma

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# A. AGRICULTURAL PRODUCTION AND ECONOMIC STRUCTURE IN THE EMBU DISTRICT, KENYA

## A 1. FOOD PRODUCTION AND TRADITIONAL FARMING TECHNOLOGY

Shohei HIROSE

*College of Agriculture and Veterinary Medicine, Nihon University*

### I. Introduction

The food crisis in Africa in recent years has drawn world-wide attention to agriculture in arid and semiarid regions. Along with the need for emergency rescue activity, there is an urgent need to reconstruct the food production system so that it becomes efficient and reliable. I recently had the opportunity to investigate agro-ecological condition in a semiarid area in Kenya, a country in East Africa more than half of which is arid or semiarid areas. Farming is possible in only about 17% of the land, where the annual precipitation is 700 mm or more ; the rest is not suitable for farming. Agricultural production in Kenya, therefore, depends mainly on precipitation.

The main purpose of the study was to understand the actual agricultural conditions and to know how farming is done by small farmers in the semiarid areas, with relation to agro-ecological factors such as climate and soil. People in such areas follow traditional methods in agriculture and have a farming system adapted to their social and natural environment. It is important to understand the traditional way of adaptation and the wisdom of the local farmers before making suggestions about how to improve current farming practices.

### II. Outline of the study areas

The study areas were selected so as to include various climate and soil condition within a relatively short distance. Five areas (I-V) in the Embu District of the Eastern Province, some 150 km northeast of Nairobi and on the southeastern foot of Mt. Kenya, were selected. The general agro-ecological zones of the area are shown in Fig. 1 (Jaetzold and Schmidt 1983).

The altitude and agro-ecological characteristics of the five areas are as follows :

Area	Sublocation	Location/Division	Altitude, (meters)	Agro-ecological zone
Upper	I Kiriari, Gitare	Ngandori/Runyenjes Kagaari/Runyenjes	1,600—1,850	Tea and coffee or coffee zone(UM 1,2)
	II Kangaru	Mbeti/Gachoka	1,400—1,500	Marginal coffee zone (UM3)
Lower	III Gachoka	Mbeti/Gachoka	1,200—1,250	Cotton zone (LM3)
	IV Kithunthiri, Mbita	Mavuria/Gachoka	1,100—1,200	Marginal cotton zone (LM4)
	V Mavuria	Mavuria/Gachoka	1,100—1,200	Livestock and millet zone (LM5)

The Embu District consists of three divisions, Runyenjes, Gachoka, and Siakago, located in the northwestern, southwestern, and southeastern portion, respectively, on the upper and lower slops of Mt. Kenya. The Embu and Mbere people who live in this district are generally believed to belong to the Bantu tribe, but their origin, route of migration, and period of settlement in this area are still unknown. Mwaniki (1973)

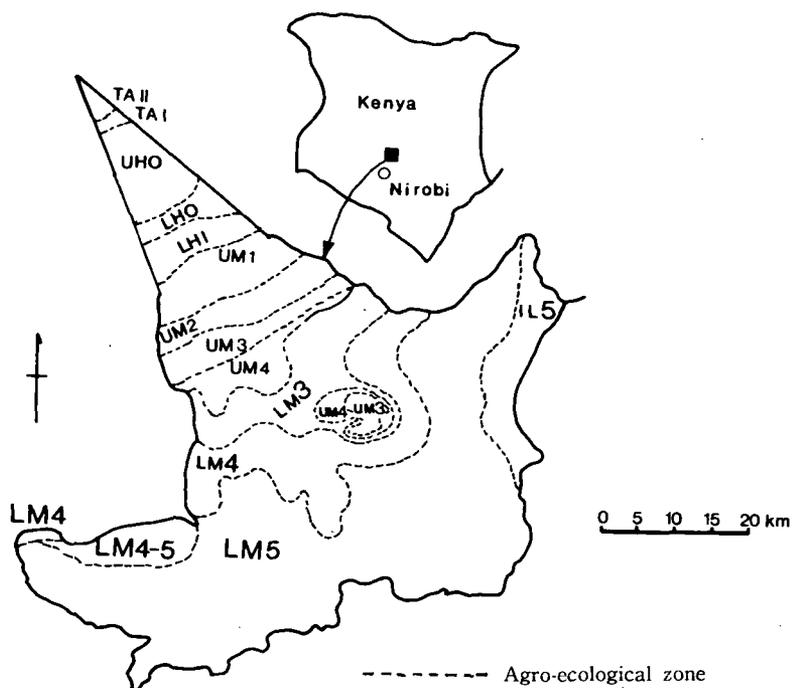


Fig. 1. Agro-ecological zones of the study areas in the Embu District (Jaetzold and Schmidt 1983)

Note) TA I, II, trop. alpine moor-and heathlands; UHO, forest zone; LH 1, tea-dairy zone; UM 1, coffee-tea zone; UM 2, main coffee zone; UM 3, marginal coffee zone; UM 4, sunflower-maize zone; LM 3, cotton zone; LM 4, marginal cotton zone; LM 5, lower midland livestock-millet zone; LM 5, lowland livestock-millet zone.

suggested that these peoples settled in the area via the several routes. According to this writer, the earliest Embu people, who settled in the upper area of the Embu District, were not cultivators but hunter-gatherers who hunted animals in the forest for meat and who supplemented their food supplies with roots, berries, fruits, and vegetables. The Mbere people, who live mainly in the lower area of the Embu District, were not primitive cultivators. According to the oral tradition of the farmers, both peoples were engaged in shifting cultivation up to about the 1960's, when land reform began in these areas. The present permanent farming system was established in the early 1970's after the end of land reform (Brokensha and Riley 1980).

Agronomic surveys were done by interviewing of the farmers to fill out questionnaires and by observation of their fields. In each area, six to 12 farms were chosen at random so as to study various ways of farming. Meteorological data were collected from the Meteorological Station of Nairobi and from the station nearest to the survey area. Soil in these areas was also studied and taken for analysis.

This field survey was done for the two and a half months from June 15 to August 31 in 1985.

### III. Natural environment

#### (1) Topography and climate

The Embu District is located on the southeastern slopes of Mt. Kenya, which reaches

5, 199 m. Brokensha and Riley (1980) write that the Embu District is in the shape of a pie that starts from the upper slopes of the northwestern section and fans out to the middle section of the river valley.

Embu town is at the elevation of 1, 470 m and farming land extends higher up to an area about 2, 000 m above sea level. On the slopes of Mt. Kenya, many small rivers flow down into the Tana river valley, carving away the surface of the slopes as they descend. Very few of the rivers are perennial ; most dry up in the dry season.

Gachoka Division, which is located on the lower slopes, ranges from about 600 to 1, 500 m. This division slopes gradually down the Tana river valley, so that the lay of the division is gentle. There are three hills, Kiambere, Kiangombe, and Kianjiru, that form peaks of about 1, 500 to 1, 700 m (Brokensha and Rilay 1977).

A portion of the Gachoka Division lies to the left bank of the tana river between 600 and 900 m ; the rest is between 900 and 1, 400 m. This investigation of the agriculture in the semiarid area in this division was mainly concentrated on the latter area.

The distribution of annual rainfall is shown in Fig. 2. The annual rainfall ranged from 1, 547 mm at the Runyenjes station to 667 mm at Machanga station near Mavuria ; all five areas had a bimodal pattern of precipitation. The annual amount of rainfall varied to a great extent, as can be seen by the coefficient of variation (CV) in Table 1. It was estimated from the rainfall data that most farmers would suffer from drought arising from shortage of rainfall at least two or three times during every decade. The wide variation in the time of onset of the rainy season added further difficulties to subsistence farming.

## (2) Soil

Soils in the upper areas are well drained, deep dark reddishbrown clayey soils classified as a Nitosol in the FAO/Unesco system. They are derived from basic volcanic rocks or eject or both and are high in natural fertility, water-holding capacity, and erosion resistance. The soils in the lower areas are usually coarser in texture, lighter in color, and poorer in both nutrient and water-holding capacities. They are classified as Ferralsols, Acrisols, or Luvisols, some of which are underlain by murram, a product of long-term severe weathering.

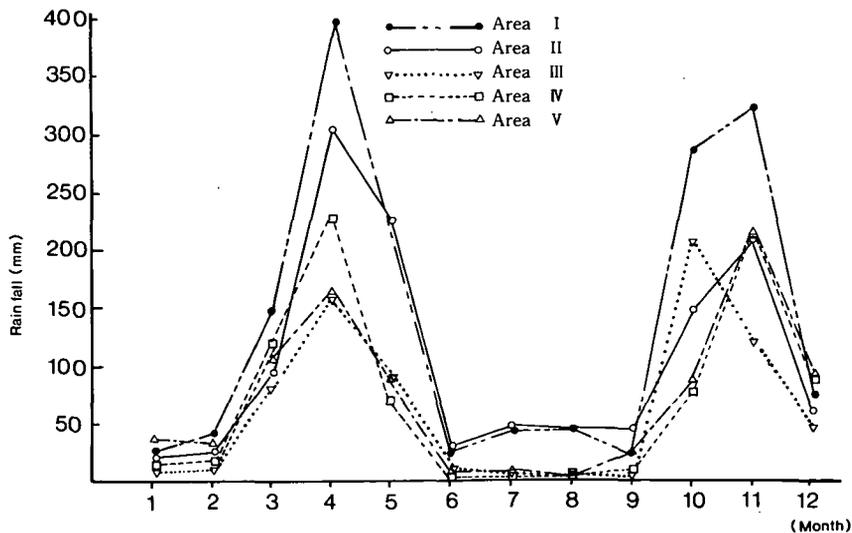


Fig. 2. Annual rainfall pattern in the study areas.

Table 1. Mean annual rainfall and its coefficient of variation in the study areas.

Area	Name of station	Annual rainfall, mm	Years	CV, %
I	Runyenjes	1242.3 (1547.0)*	6 (18)	26.8
II	Embu Met. Sta.	1208.0	6	20.0
III	Gachoka school	667.0	6	65.7
IV	Kiritiri chief camp	779.6	6	49.2
V	Machanga	787.8	7	36.2

\* Mean of 1547 mm over 18 years (Jaetzold and Schmidt 1983).

### (3) Agro-ecological zones

According to the Farm Management Handbook of Kenya (Jaetzold and Schmidt 1983), the Embe District is divided into several agro-ecological zones by agro-climatic factors and soil patterns. The study areas are described by the length of the cropping season and the agro-ecological zone type in the table below from Jaetzold and Schmidt (1983).

Areas	Sublocation	Zone	Length of cropping season* <sup>1</sup>
I	Kiriari, Gitare	Coffee-tea (UM1) Main coffee zone (UM 3)	m/1+ m/s/m+s/m
II	Kangaru	Marginal coffee zone (UM 3)	m/s+s
III	Gachoka	Cotton zone (LM3)	s+s
IV	Kithunthiri, Mbita	Marginal cotton zone (LM4)	s/vs+ vs/s
V	Mavuria	Livestock-millet zone (LM5)	vs/s+ vs

- \*) +, Distinct arid (dry) period between growing periods  
 m, Medium (135-154 days)  
 l, Long (195-214 days)  
 m/s, Medium to short (115-134 days)  
 s/m, Short to medium (105-114 days)  
 s, Short (85-104 days)  
 vs/s, Very short to short (55-74 days)  
 s/vs, Short to very short (75-84 days)  
 vs, Very short (40-54 days)

In the study areas, the higher the altitude, the longer the cropping season, resulting in higher potential yields. The potential yields of the crops decreased and the dependence on livestock increased with a decrease in the altitude. This second pattern was widespread in the Mavuria area, which was classified as a livestock-millet zone.

#### IV. Agriculture and land-use patterns

##### (1) Land use

Six to 12 farms were chosen for a field survey in each area, and the farmers in question were interviewed. The mean size of the farm and the area of the cropped land, fallow land, and grazing land are listed in Table 2. There were few sample farms in each area, so it is not possible to draw definite conclusions from the finding. The following results were obtained.

(i) Of the five areas investigated, the mean land holding was the largest in Area IV, at 12.04 ha. The mean was around 9.5 ha in Areas III and V. The mean size of the land decreased as the altitude of the land rose. (ii) The amount of cropped land was the largest in Area III, at 3.52 ha. In other areas, the amount was about 2 to 3 ha, with little difference found among these areas. (iii) The fallow (uncropped) land amounted to 27.5% of the cropped land in the Area IV, 10.2% in Area V and 8.0% in Area III. The percentage of fallow land was 5.3% in mean of the upper areas (Area I and II). (iv) The land was larger in the lower areas because of bushland for livestock grazing. The bushland was 450% the size of the cropped land in Area IV, 320% in Area V, and 160% in Area III. (v) In the upper areas, grassland, which was sown artificially, amounted to about 4% of the cropped land in Area II and 9% in Area I. (vi) Livestock was more abundant in lower than upper areas, as shown in Table 2. However, the numbers of livestock in the lower areas were not always in proportion to the size of the grazing land, probably because most of the livestock in the lower areas died during the serious drought of 1984.

The pattern of land use and the amount of livestock in relation to environmental condition like rainfall, temperature, and altitude are shown in Fig. 3.

##### (2) Crops grown in the study areas

Table 3 shows the kind of staple food crops and cash crops grown in the study areas. In the humid upper areas, mize, beans, and white potatoes, which originated in the American continent, were cultivated as the main staple foods. According to an elderly informant, sorghum, bulrush millet, finger millet, and yams were more popular up to the 1950-60's and maize was then planted only around the homestead in the Embu and Mbera (the present Gachoka Division) area. In Area II, there were more species used as staple foods than in Area I, because the climate in this area was more suitable than elsewhere for cultivation of cassava, sweet potatoes, and banana. In the lower areas (III ~ V), drought-resistant crops such as sorghum, bulrush millet, finger millet, cowpeas, and pigeon peas were prevalent instead of bananas, white potatoes, cassava, and beans. Of these, cowpeas, which originated in Africa, gave fair yields in the semiarid areas

Table 2. Size of operational land holdings, pattern of land use, and numbers of livestock per household in the study areas.

Area	Sublocation	No. of farmers	Total land, ha	Home-stead, ha	Cropped land, ha	Grazing and bush-land, ha	Fallow land, ha	Livestock	
								Cattle	Goats & sheep
I	Gitare, Kiriari	6	2.28	0.08	1.84	0.20*	0.16	2.5	1.8
II	Kangaru	8	3.56	0.09	3.20	0.12	0.11	2.0	2.9
III	Gachoka	12	9.68	0.17	3.52	5.72	0.28	8.4	5.8
IV	Kithunthiri, Mbita	10	12.04	0.28	2.04	9.16	0.56	4.7	11.6
V	Mavuria	10	9.40	0.14	2.16	6.88	0.22	6.8	15.0

\* Pasture.

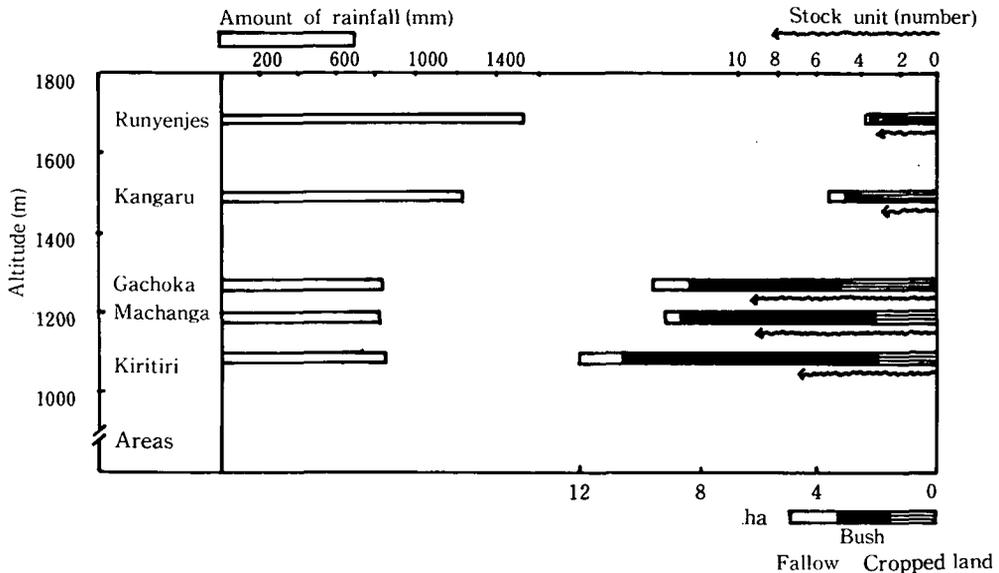


Fig. 3. Environmental and farming conditions in the study areas.

Note) Stock unit, one cattle = six goats, sheep.

because it is adapted to drought and infertile soils. However, maize was an important staple food crop throughout all study areas.

The humid upper areas had tea and coffee as cash crops and maize, beans, and white potatoes as the main staple crops. Yam, sweet potatoes, and bananas were also cultivated as supplemental crops in these areas. The semiarid lower areas had cotton as the cash crop and maize, sorghum, bulrush millet, finger millet, cowpeas, and pigeon peas as food crops. The crops were selected to cope with the degree of dryness or wetness and the temperature.

### (3) Cropping seasons and cropping patterns

The cropping season was basically divided into two seasons, the long and short rains, because of the bimodal pattern in precipitation mentioned before. Mixed cropping or intercropping was common in all study areas, and sole crop farming was rare. Table 4 shows the number of crops combined in each area during the long and short rains, as was either observed or learned through interviews with farmers. A combination of two to five crops was observed in the long rains; there seemed to be a combination of two to four crops in the short rains.

In the long rains, the most wide spread pattern was a mixing of two crops: maize and beans in the upper areas and maize and cowpeas in the lower areas. The combination of three crops was also observed in both areas. They were combinations of maize, beans, and white potatoes in the upper areas and of maize, cowpeas, and pigeon peas in the lower areas. In the short rains, the combination of maize and beans or maize and white potatoes was more common in the upper areas. That of maize and cowpeas or of bulrush millet and cowpeas seemed to be more common in the lower areas.

The kinds of crop combinations in each area and season are shown in Table 5. There were many more kinds of combinations in the lower area than in the upper ones. There being many kinds of crop combinations indicates that the farmers had to plant various crops in various combination to cope with the severe environmental conditions of the area.

Figure 4 shows the typical cropping season and pattern in each area. In the upper areas, which have about 1,500 mm of rainfall annually, the dry season between the two

Table 3. Staple food crops\* and cash crops in the study areas.

No.	English name	Scientific name	Local name	Area (Sublocation)				
				I Gitare Kiriari	II Kangaru	III Gachoka	IV Kithunthiri, Mbita	V Mavuria
1	Maize	<i>Zea mays</i> L.	mbenbe	##	##	##	##	##
2	Bulrush millet	<i>Pennisetum americanum</i> (L.) Leeke	mwere		+	+	+	+
3	Sorghum	<i>Sorghum vulgare</i> Moench	muvia		+	+	+	+
4	Finger millet	<i>Eleusine coracana</i> Gaertn.	mugimbi			+	+	+
5	Pigeon peas	<i>Cajanus cajan</i> (L.) Millsp.	njugu		+	+	##	##
6	Cowpeas	<i>Vigna sinensis</i> Endl.	nthoroko		+	##	##	##
7	Kidney beans	<i>Phaseolus vulgaris</i> L.	mboco	##	##	+	+	
8	Green gram	<i>Phaseolus radiata</i> L.	ngina		+	+	+	+
9	Hyacinth beans	<i>Dolichos lablab</i> L.	njave		+	+	+	+
10	Taro	<i>Colocasia esculenta</i> Schott	nduma	+	+	+	+	
11	Yautia	<i>Xanthosoma sagittifolium</i> Thunb.	thuna	+	+			
12	Yam	<i>Dioscorea cayenensis</i> Lamk.	gikwa	##	+			
13	White potatoes	<i>Solanum tuberosum</i> L.		##	##			
14	Sweet potatoes	<i>Ipomoea batatas</i> Lam.	ngwasi		+	+	##	+
15	Cassava	<i>Manihot esculenta</i> Crantz	mwanga		##	+	+	+
16	Banana	<i>Musa</i> spp.	marigu	+	##	+	+	
17	Cotton	<i>Gossypium hirsutum</i> L.	mbamba			##	##	+
18	Coffee	<i>Coffea arabica</i> L.	kahowa	##	##			
19	Tea	<i>Thea sinensis</i> L.	majani	##				

\*excluding vegetables, fruits.

Note) ##, very common; #, common; +, less common.

Table 4. Number of crops combined and number of common crop combinations in each area and season.

No. of crops combined	Area (Sublocation) and season									
	I Gitare, Kiriari		II Kangaru		III Gachoka		IV Kithunthiri, Mbita		V Mavuria	
	L	S	L	S	L	S	L	S	L	S
2	5	3	7	3	7	16	11	11	6	13
3	1	1	4	4	4	5	6	3	5	3
4	0	0	2	0	0	1	1	0	2	0
5	1	0	1	0	0	0	1	0	0	0
Total no. in each season	7	4	14	7	11	22	19	14	13	16
Total no. in each area	11		21		33		33		29	

Note) L, long rains; S, short rains

rainy seasons is not severe, so crop cultivation is possible through the year. Thus, relay cropping in which the second crop of maize is planted just before the harvest of the first maize and soon after the harvest of the first beans is common.

In Kangaru (Area II) with about 1,200 mm of rainfall annually, sorghum and cassava, which are resistant to drought and require two seasons to mature, are usually cultivated, but maize and beans are also cultivated by the relay cropping system when the

dry season is not severe. In the lower areas (III, IV. and V), the only crops cultivated in dry seasons without any rain are pigeon peas and some drought-resistant crops like cotton.

Figures 5, 6, and 7 show examples of how the crops are arranged in mixed cropping and also the relative illuminance in the community of these plants in Kiriari (Area I), Kangaru (Area II), and Gachoka (Area III). In the most common cropping combination of maize and beans in Kiriari, maize is planted in rows with 2 to 3-meter intervals, and beans are planted scattered between the maize at the same time. Just after the harvest of the beans, the second maize, which is to grow in the short rains, is planted between the rows of the first maize, which is awaiting harvest. The relative illuminance of the plant community in intercropping in Kiriari is fairly high even in the

Table 5. Kinds of common crop combination in the study areas.

No. of crops combined	No. and crop combination	I Gitare, Kiriari		II Kangaru		III Gachoka		IV Kithunthiri, Mbita		V Mavuria		
		LR*	SR**	LR	SR	LR	SR	LR	SR	LR	SR	
2	1 Ma/KB	⊙	⊙	⊙	⊙	⊙	⊙	○	○	○		
	2 Ma/Co			○		⊙	○	⊙	⊙	⊙	⊙	
	3 Ma/GG					○	○	○		○	○	
	4 Ma/So			○		○	○	○				
	5 Ma/PP					○	○	○		○		
	6 Ma/FM									○		
	7 Ma/HB							○				
	8 Ma/Ba	○		○			○					
	9 Ma/WP	⊙	○	○	○							
	10 Ma/Ca			○								
	11 Ma/Ka	○										
	12 Ma/Te	○										
	13 So/GG								○		○	
	14 So/SP				○							
	15 FM/Co										○	○
	16 Co/PP						○	○	○			
	17 Co/Ca								○			
	18 PP/Ct						○	○	○	○		
	19 Ca/Ba								○	○		
	20 Ma/BM				○			○	○		⊙	
	21 Ma/Ct							⊙	○		○	
	22 Ma/Sf								○		○	
	23 Ma/SP		○									
	24 BM/So								○		○	
	25 BM/Co								○		⊙	
	26 BM/GG										○	
	27 BM/PP							○			○	
	28 BM/Ct							⊙			○	
	29 So/Ct							○				
	30 So/Co								○		○	
	31 Ct/KB							○				
	32 Ct/Co							○				
	33 Ct/PP							○	⊙			

Table 5. (Continued)

No. of crops combined	No. and crop combination	I Gitare Kiriari		II Kangaru		III Gachoka		IV Kithunthiri, Mbita		V Mavuria	
		LR*	SR**	LR	SR	LR	SR	LR	SR	LR	SR
3	1 Ma/KB/PP					○		○			
	2 Ma/KB/Ca			○	○		○				
	3 Ma/Co/PP					○	○	◎	○	○	○
	4 Ma/Co/SP							○			
	5 Ma/Co/GG									○	
	6 Ma/Co/BG									○	
	7 Ma/Co/Ca					○		○			
	8 Ma/PP/WM						○			○	
	9 Ma/GG/PP							○		○	
	10 Ma/Ca/Cf			○	○						
	11 Ma/KB/WP	○	○	○	○						
	12 Ma/WP/Ba			○							
	13 So/Co/Ca								○		
	14 Ma/BM/Ct						○				
	15 Ma/So/Ct						○				
	16 Ma/BM/So								○		○
	17 Ma/PP/Ct						○		○		
	18 Ma/KB/SP				○						
	19 BM/So/PP										○
4	1 Ma/KB/SP/Ca			○							
	2 Ma/Co/PP/BG									○	
	3 Ma/KB/Co/GG									○	
	4 Ma/Co/PP/SP							○			
	5 Ma/KB/Ca/Ba			○							
	6 Ma/Co/PP/WM						○				
5	1 Ma/KB/Ba/Ya/SC	○									
	2 Ma/Co/KB/Ca/Ba			○							
	3 Ma/Co/PP/Ca/SP							○			

\* LR, long rains; SR, short rains; ◎, very common; ○, common.

Note) Ma, maize; Co, cowpeas; GG, green gram; So, sorghum; PP, pigeon peas; FM, finger millet; HB, hyacinth beans; Ba, banana; WP, white potatoes; Ca, cassava; Ka, kale; Te, tea; SP, sweet potatoes; Ct, cotton; BG, bottle gourd; WM, water melon; Cf, coffee; Ya, yautia; SC, sugar cane; Sf, sunflower; KB, kidney beans; BM, bulrush millet.

lower layer between the maize rows (Fig. 5).

A typical spatial arrangement of four crops is shown in Fig. 6, an example of cropping in Kangaru. The plant community is roughly divided into two layers, the upper layer of maize and cassava and the lower layer of beans and sweet potatoes. The relative illuminance of the latter was 30 to 45% of that at the top of the maize. The space was occupied effectively by tall and short crops.

In the example from Gachoka shown in Fig. 7, the crop combination was of maize, cowpeas, and pigeon peas. The pigeon peas were planted at the short rains as a two-season crop, and they were intercropped with maize or bulrush millet and cowpeas in both

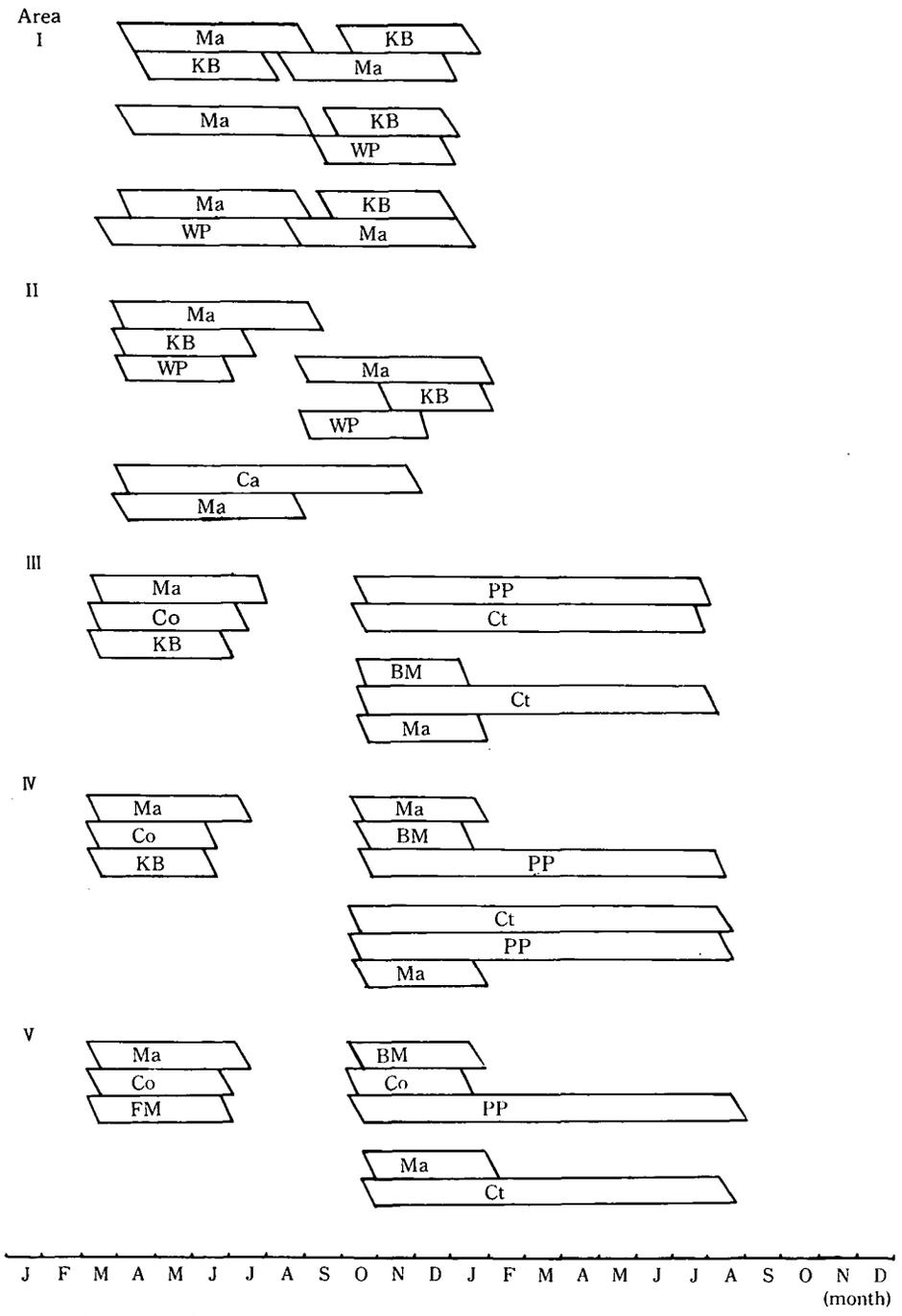


Fig. 4. Typical cropping seasons and patterns in the study areas.  
 Note) Ma, maize; KB, kidney beans; WP, white potatoes; Ca, cassava; PP, pigeon peas; Co, cowpeas; Ct, cotton; BM, bulrush millet; FM, finger millet.

rainy seasons. Pigeon peas were grown in rows planted from 2.5 to 6 meters apart and maize or bulrush millet was grown in rows from 0.8 to 1.4 meters apart between the rows of pigeon peas. Cowpeas were planted scattered between them. In the lower areas,

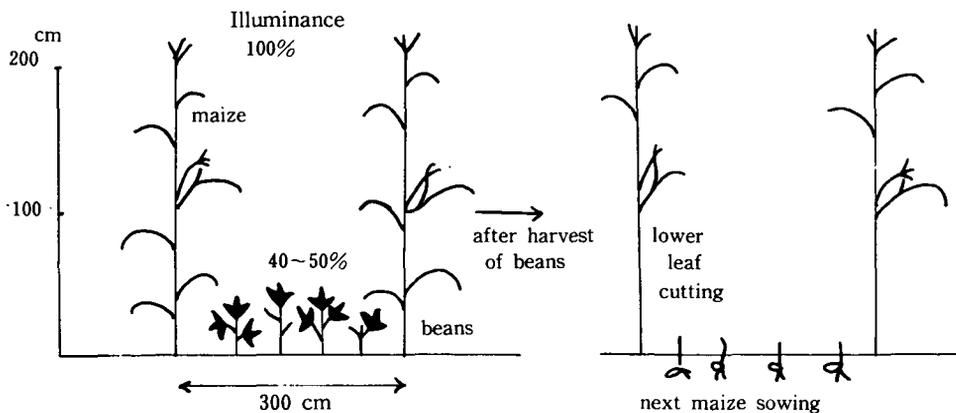


Fig. 5. Crop arrangement and relative illuminance in crop community in Area I.

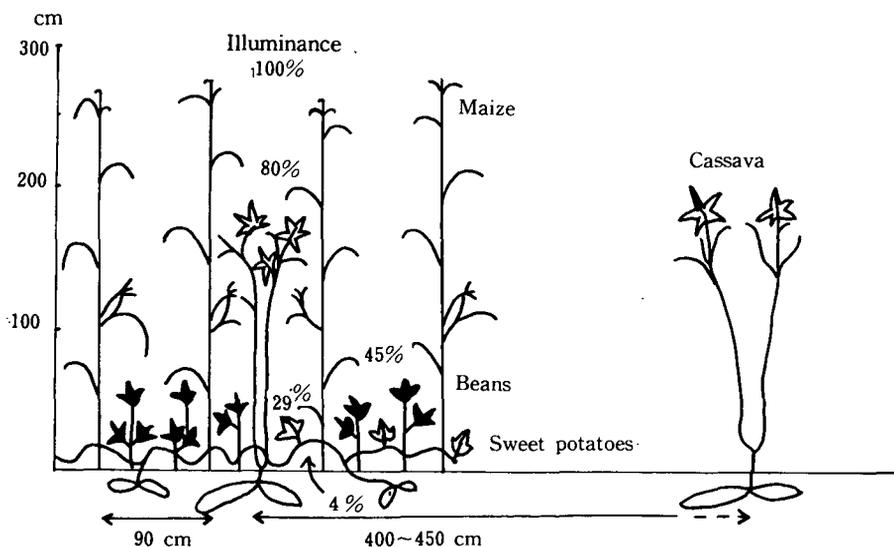


Fig. 6. Crop arrangement and relative illuminance in crop community in Area II.

different kinds of crop were grown during the long and the short rains. For instance, bulrush millet was grown only in the short rains; other cereals like maize and finger millet were grown in both rains. The reason is not known, but it might be because bulrush millet is a quick-maturing crop, which can be harvested in three months or less after sowing even in the short rains.

From the examples given above, the traditional way of farming seemed an effective way to use farmland in terms of solar radiation, soil nutrients, and water.

#### (4) Crop sequence and rotation

It was rare to find farmland fallow, as mentioned before. Permanent cropping was usual. In this section, crop sequence or rotation done over several years as studied from the results of the field survey and from information collected during interviews with farmers will be discussed.

Table 6 shows typical crop sequences or rotation system for each study area. In Area I, the usual crop sequence is continuous cropping, mixed maize and beans, mixed

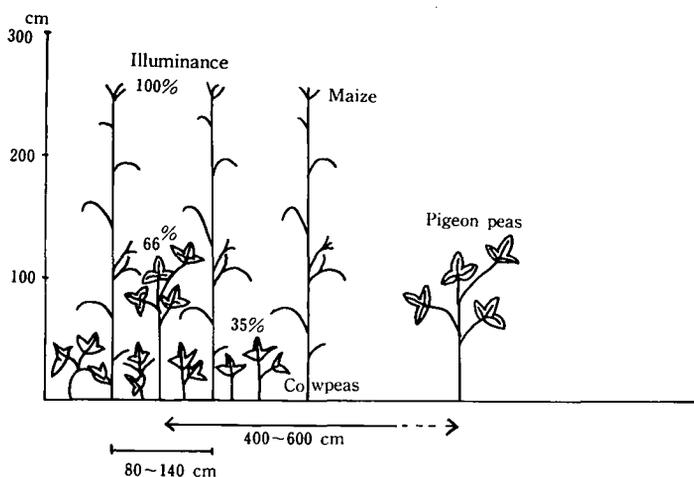


Fig. 7. Crop arrangement and relative illuminance in crop community in Area III.

maize and white potatoes, or the rotation of these mixed croppings. Cropping of maize, beans, or white potatoes alone is rarely observed in this area. When cash crops like tea or coffee are newly planted maize or beans are intercropped between rows of the cash crops during the early stage of growth only so as not to impede the growth of the cash crops.

In Kangaru (Area II), the cropping sequence is more complicated than in Area I because sorghum, cassava, and bananas, which take two seasons to mature are commonly intercropped as staple food crops. The most typical crop sequences are the continuous cropping of mixed maize and white potatoes or of mixed maize and beans, or the rotation of both kinds of intercropping during the rainy seasons. When sorghum and cassava are intercropped with other crops, they are sown at the same time with maize, beans, or both at the beginning of the short rains, and are left in the field to mature during the long rains; the maize and beans are harvested at the end of the short rains. During the long rains, the next maize or bean crop is grown between the rows of sorghum or cassava plants.

The cropping pattern in Areas III and IV in the short rains was nearly the same, with intercropping of cotton or pigeon peas with either mixed maize and cowpeas or bulrush millet and cowpeas. In the long rains, maize and cowpeas are sown between cotton or pigeon peas stands that are left to mature after harvest of the short-rain crops. The crop sequence in both areas is basically a rotation of the kind of crop combination mentioned above. Only a small part of the farming plot is left fallow for several years to recover soil fertility or to conserve the soil water. The crop sequence that includes a fallow period is seldom observed.

In Mavuria (Area V), there are cropping sequence that are similar to those seen in Areas III and IV. The intercropping of maize, cowpeas, and pigeon peas is usually alternated with the intercropping of bulrush millet, cowpeas, and pigeon peas. In this area, however, bulrush millet is never cultivated during the long rains. As in Areas III and IV, the farmland is rarely left fallow.

Bulrush millet is an important crop especially in the semiarid areas because of its drought resistance and of rapid growth maturity. Bulrush millet is harvested by cutting off the heads with small knives. After that the stovers are cut down and they returned to the soil as organic matter or put in banks to protect the land from erosion.

Table 6. Crop sequence in the study areas.

Area	Crop sequence
I	
Gitare, Kiriari	$(Ma=KB \text{ or } WP)^L - (Ma=KB)^S$ $(Ma=KB \text{ or } WP)^L - (WP)^S$ $(Ma=KB \text{ or } WP)^L - (Ma)^S$ $(Ma=KB)^L - (Ma=KB)^S$ $(Ma=KB)^L - (WP)^S$ $(Ma=KB)^L - (Ma)^S$
II	
Kangaru	$(Ma=WP)^L - (Ma=WP)^S - (Ma=KB)^L$ $(Ma=WP)^L - (Ma=WP)^S - (Ma=WP)^L$ $(Ma=WP)^L - (Ma=WP)^S - (Ma=SP)^L$ $(Ma=WP)^L - (Ma=WP)^S - (Ma=KB=Ca)^L$ $(Ma=WP)^L - (\overline{So}=BM=KB)^S \rightarrow (\overline{So})^L$ $(Ma=WP)^L - (Ma=BM=KB)^S$ $(Ma=KB)^L - (Ma=WP)^S - (Ma=KB)^L$ $(Ma=KB)^L - (Ma=WP)^S - (Ma=WP)^L$ $(Ha=KB)^L - (Ma=WP)^S - (Ma=SP)^L$ $(Ma=KB)^L - (Ma=WP)^S - (Ma=KB=Ca)^L$ $(Ma=KB)^L - (\overline{So}=BM=KB)^S \rightarrow (\overline{So})^L$ $(Ma=KB)^L - (Ma=BM=KB)^S$ $(Ma=KB=\overline{Ca})^L \rightarrow (\overline{Ca}=Ma)^S - (Ma=KB)^L$ $(Ma=KB=\overline{Ca})^L \rightarrow (\overline{Ca}=Ma)^S - (Ma=SP)^L$ $(Ma=KB=\overline{Ca})^L \rightarrow (\overline{Ca}=Ma)^S - (Ma=KB=Ca)^L$ $(Ma=\overline{SP})^L \rightarrow (\overline{SP}=Ma)^S - (Ma=KB)^L$ $(Ma=\overline{SP})^L \rightarrow (\overline{SP}=Ma)^S - (Ma=WP)^L$ $(Ma=\overline{SP})^L \rightarrow (\overline{SP}=Ma)^S - (Ma=KB=Ca)^L$ $(\overline{So}=\overline{SP})^L \rightarrow (\overline{So}=\overline{SP})^S$
III	
Gachoka	$(Ma=KB \text{ or } Co)^L - (\overline{Ct}=Ma=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=BM)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=Ma=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=KB=Co)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=So=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=BM)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=So=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=KB=Co)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=BM=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=BM)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=BM=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=KB=Co)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=\overline{So})^S \rightarrow (\overline{Ct}=\overline{So})^L - (Ma=BM)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=\overline{So})^S \rightarrow (\overline{Ct}=\overline{So})^L - (Ma=KB=Co)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=BM)^S \rightarrow (\overline{Ct})^L - (Ma=BM)^S$ $(Ma=KB \text{ or } Co)^L - (\overline{Ct}=BM)^S \rightarrow (\overline{Ct})^L - (Ma=KB=Co)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=Ma=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=BM)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=Ma=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=KB=Co)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=So=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=BM)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=So=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=KB=Co)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=BM=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=BM)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=BM=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L - (Ma=KB=Co)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=\overline{So})^S \rightarrow (\overline{Ct}=\overline{So})^L - (Ma=BM)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=\overline{So})^S \rightarrow (\overline{Ct}=\overline{So})^L - (Ma=KB=Co)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=\overline{So})^S \rightarrow (\overline{Ct})^L - (Ma=BM)^S$ $(Ma=KB=Co)^L - (\overline{Ct}=BM)^S \rightarrow (\overline{Ct})^L - (Ma=KB=Co)^S$

Table 6. (Continued)

Area	Crop sequence
IV	$(Ma=Co \text{ or } GG=PP)^L - (Ma=BM)^S - (Ma=Co \text{ or } GG)^L$
Kithunthiri,	$(Ma=Co \text{ or } GG=PP)^L - (Ma=\overline{So})^S \rightarrow (\overline{So}=Co)^L$
Mbita	$(Ma=Co \text{ or } GG=PP)^L - (Ma=\overline{Ct}=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L$
	$(Ma=Co \text{ or } GG=PP)^L - (Ma=Co=\overline{PP})^S \rightarrow (Ma=Co=\overline{PP})^L$
	$(Ma=Co)^L - (Ma=BM)^S - (Ma=Co \text{ or } GG)^L$
	$(Ma=Co)^L - (Ma=\overline{So}=Co)^S \rightarrow (\overline{So}=Co)^L$
	$(Ma=Co)^L - (Ma=\overline{Ct}=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L$
	$(Ma=Co)^L - (Ma=Co=\overline{PP})^S \rightarrow (Ma=Co=\overline{PP})^L$
V	$(Ma=Co)^L - (\overline{Ct}=\overline{PP})^S \rightarrow (\overline{Ct}=\overline{PP})^L$
Mavuria	$(Ma=Co) - (Ma \text{ or } BM=Co)^S - (Ma=Co)^L$
	$(Ma=Co)^L - (BM \text{ or } So=\overline{PP})^S \rightarrow (\overline{PP}=Ma)^L$
	$(Ma=Co)^L - (BM \text{ or } \overline{So}=\overline{PP})^S \rightarrow (\overline{So}=\overline{PP})^L$
	$(Ct=PP)^L - (Ma=Co \text{ or } BM)^S - (Ma=Co)^L$
	$(Ma=PP)^L - (Ma=Co \text{ or } BM)^S - (Ma=Co)^L$
	$(Ma=PP)^L - (\overline{So} \text{ or } BM=\overline{PP})^S \rightarrow (\overline{So}=\overline{PP})^L$
	$(Ma=PP)^L - (So \text{ or } BM=\overline{PP})^S \rightarrow (Ma=\overline{PP})^L$

Note) Ma, maize; KB, kidney beans; WP, white potatoes; Ca, cassava; BM, bulrush millet; So, sorghum; SP, sweet potatoes; Co, cowpeas; Ct, cotton; GG, green gram; PP, pigeon peas; L, long rains; S, short rains; -, crop sequence; ( )  $\rightarrow$  ( ), two-season crop; =, mixed cropping or intercropping.

Although there are different crop sequences in each area, they consist of the alternation of simple combination of crops. This tendency was stronger in the upper than in the lower areas.

Throughout the study areas, very little farmland rested bush fallow compared to the total area of farmland in use. Some 9 to 27% of the farmland was fallow in the lower areas, and this rate was only 3 to 8% in the upper areas. Bush land for grazing of cattle or other animals was rarely reclaimed to grow food crops even in the lower areas, there was two to four times as much bushland than cropped land. In the upper areas, nepiergrass and kikuyugrass, grown for cattle roughage, often was used as part of the rotation system.

In summary, the crop sequences and the rotation systems in the study areas consist of the repetition of simple crop combination in which the crops are selected for their drought resistance or for their adaptability to mixed cropping. Furthermore, the combination of gramineous and leguminous crops, the general rule in crop combination, is reflected empirically in the crop sequences and the rotation systems of the native farmers.

#### (5) Varieties of main food crops and their cultivation

It was mentioned in the previous section that crops are selected to cope with the climatic conditions, which range from dry to wet in the study areas. Cultivated species of main food crops and their cultivation will be reported on in this section.

##### (i) Maize

Maize is the most important cereal crop in the study areas and also in East Africa as a whole. In the study areas, it is intercropped with beans, cowpeas, or other crops during both the long and short rains. Maize was first introduced to East Africa in the 16th or 17th century by the Portuguese (Acland 1971), but the spread of maize throughout Kenya took place in the last 30 or 35 years. Most of the maize harvested in Kenya is eaten as *ugali*, and some as *irio* (cooked with boiled, mashed potatoes) or as roasted immature maize on the cob. The maize varieties usually cultivated by small-

Table 7. Kinds of improved varieties of maize and time of their introduction.

Area	Kinds of improved varieties of maize	Cultivation rate (%) between composite and hybrid	Year of introduction of improved variety, %* before 1980	General tendency of seed renewal in each area
I Gitare, Kiriari	Katumani composite	0	66	every season
	Hybrid (613, 614, 625)	100		
II Kangaru	Katumani composite	12	25	not every season (every 2~3 years)
	Hybrid (511, 512, 513)	88		
III Gachoka	Katumani composite	100	10	not every season (every 2~3 years)
	Hybrid (511, 512, 513)	0		
IV Kithunthiri, Mbita	Katumani composite	80	10	not renewed
	Hybrid (511)	20		
V Mavuria	Katumani composite	90	30	not renewed
	Hybrid (511)	10		

\* % shows the ratio of farmers who introduced the improved varieties before 1980 among the farmers interviewed during survey.

Table 8. Populations of maize in the fields sampled.

Area	Distance		Plants /hill	Population /ha*
	between rows, m	between hills, m		
I Gitare, Kiriari	0.4 — 0.8	0.4 — 0.5	1~2	30,000—81,200
II Kangaru	0.8 — 0.9	0.4 — 0.5	1~2	22,000—53,000
III Gachoka	0.8 — 1.4	0.45—0.85	1~2	8,500—30,400
IV Kithunthiri, Mbita	0.85—2.0	0.45—0.5	1~2	10,000—45,000
V Mavuria	0.8 — 3.0	0.4 — 0.5	1~2	4,000—33,000

\* Mixed or intercropped with other crops.

scale farmers in the study areas are the white dent-flint grain type. This type looked like the progenies of improved varieties bred according to the breeding programmes of Kenya. Most of the farmers in the study areas came to plant the improved varieties in the past when they suffered from serious droughts, and they use seeds from open-pollinated plants of the improved varieties grown in their own fields. Table 7, based on data from interviews, shows the kinds of hybrids or composite varieties that have been grown and those that are planted to be grown. It shows that the growing of the improved varieties began earlier in the upper areas than in the lower areas. In Area I, more than 66% of the farmers started the cultivation of the hybrid before 1980, and they grow hybrid maize with seeds renewed by seed grower every season to obtain the advantages of hybrid vigor. Plant populations of maize in the lower areas were generally smaller than those in the upper areas, though the size depended on the cropping pattern and varieties, as shown in Table 8. This table also shows that the farmers have adapted their way of farming to the drier climatic conditions. The growth periods of varieties of maize and other crops in the upper and lower areas are given in Fig. 8. This figure shows that the Katumani composite is more suitable in the lower areas than other local varieties because of its early maturity, and the late hybrid varieties are more useful in the upper areas with rainfall ranging between 1,000 and 1,500 mm. Crops, in the lower areas with rainfall less than 800 mm, often suffered from shortages and irregularity of rainfall. In such conditions, maize produced barren plants (Table 9). The table gives the percentage of barren plants in plots sown at different times, in relation to the date of rainfall. There were two adjacent plots, one sown five days after the onset of the rains,

the other sown 17 days after the first sowing. Almost all of the plants were barren in the plot sown later, because there was insufficient rain for about one month after the first rain. Meteorological data on this, however, was not available. Maize cultivation is relatively simple, particularly in the fields of small-scale farmers. The most critical factor affecting maize production, in the lower areas where the duration and amount of rainfall is limited, is usually the sowing period. So, farmers recommend that land

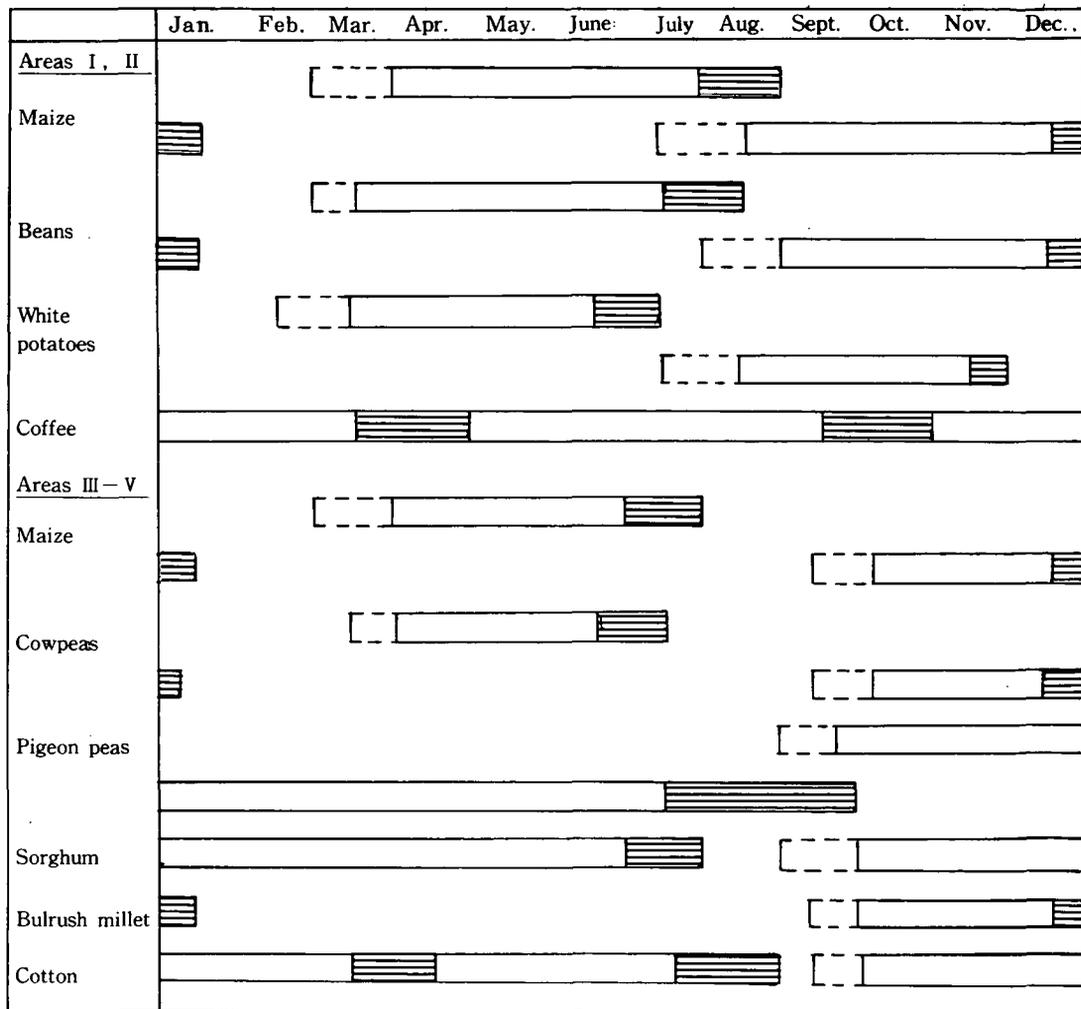


Fig. 8. Cropping season of main food crops and cash crops in the upper and lower areas.

Note) [Dashed line], sowing season; [Hatched area], harvest.

Table 9. Comparison of percentages of barren plants after early and late planting of adjacent plots in Area III.

Plots	Days after first rain	Barren plants, %	Plant height, cm
Early planting	5	30.6	188.9
Late planting	22	100	119.3

preparation and sowing should be done before the onset of the rains or soon after. For this purpose, ox-ploughing is more suitable than hand-ploughing to prepare the land in time. Chemical fertilizers are rarely applied on maize in the lower areas, but dry animal manure that is raked up from *boma* (enclosure for safeguarding cattle at night) is applied on maize whenever possible. A handful of the manure is placed in the hole together with maize seeds, and then they are covered with soil. The only field work the farmers do after planting and before harvesting is weeding, which is generally done twice, and intersowing of some other crops such as beans, cowpeas, or pigeon peas between the rows of maize. In the upper areas, applications of chemical fertilizers and pesticides to the maize is not uncommon. This will be described in another section.

Data on yields were obtained by sampling from 100 m<sup>2</sup> of the fields. Yields are low (Table 10). Yields in the upper areas are said to be higher than in the lower areas, but data on yields are not available, because the harvesting time of maize was missed. In the lower areas, the estimated yield per hectare of farmland varies between 0.23 and 1.9 tons. Barren plants resulting from shortages in soil water and nutrients decrease the yield in maize. The percentage of barren plants was more than 60% in Area V (Mavuria). Matured maize is mostly harvested by hand. In the lower areas, maize plants are cut at 10 to 20 cm above ground and usually shocked for several weeks in the field to reduce the moisture in the grains. Then ears are removed from the stalk and carried home to be dried further in the yard. Maize grains on the cobs or threshed grains are stored in a granary when the moisture content of the grains is low enough. In the upper areas, maize ears are removed from the plants when mature, and then dried on a drying floor prepared in the farmyard. Maize stovers are harvested as feed for cattle soon after the ears are picked off, and the field is plowed or dug to prepare for the next crop.

#### (ii) Sorghum

Sorghum is an important crop in Kenya although it is not cultivated as often as maize in these study areas. Many sorghum varieties, different in shape and color of the grains, glumes, and head types, were seen in the lower areas. Most of the sorghum, which is called *muvia* in the lower areas, is planted at the beginning of the short rains and harvested at the end of the long rains, as a two-season crop. An improved variety that matures in three to four months was also observed. Sorghum was intercropped with a combination of cowpeas, green gram, cassava, or cotton. This crop is common used in cooking *ugali* after the dry grains are ground. The grains as is or coarsely ground grains are used for porridge. Fifteen samples of sorghum were collected from fields and granaries. They showed much variation in spikelets and head types. According to the farmers, they were all indigenous to the area except for one variety. The colors of the grains and glumes included white, pink, orange, brown, and red with intermediate reddish, greyish, and yellowish colors (Table 11).

Harlan and de Wet (1972) and Stemler *et al.* (1977) have developed a simplified classification for *Sorghum bicolor* L. that uses the spikelet character and head type. Samples collected in the study areas were identified as two basic races and four intermediate types with many head types, from compact to loose, in the head index of Harlan and de Wet (1972). The farmers classify these varieties as three types, by origin (native or improved) and by the color of the grain. The improved sorghum is called *gatengu* (or *mutengu*), that with red or orange grains is called *ciagacegethiuri*, and the white grain plant is called *thiriku*. Sorghum heads are usually harvested by hand as they ripen, laid out on a drying floor in the farmyard to dry in the sun, threshed, and stored in a granary. The sorghum yield was not studied, but from information obtained during interviews with farmers, the yield was estimated to be between 500 and 800 kg/ha. The

Table 10. Estimated yields of

Area	Farmer's No.	Variety	Population	Barren plants, %
III Gachoka	8	Katumani progeny <sup>1)</sup>	20,800	20
	12	Local <sup>1)</sup>	39,000	30
IV Kithunthiri	25	Katumani progeny <sup>1)</sup>	9,000	25
	26	Local <sup>2)</sup>	27,700	5
	31	Local <sup>1)</sup>	37,000	54
V Mavuria	32	Local <sup>1)</sup>	28,000	66
	32	Local <sup>3)</sup>	25,000	40
	18	Local <sup>1)</sup>	25,000	30

Notes) 1) Intercropped with cowpeas, 2) pure stand, 3) intercropped with cowpeas

Table 11. Sorghum varieties

Area	Sample No.	Varieties	Head length, cm	Grain size
III Gachoka	850709-2	Local <sup>3)</sup>	17	Small
	850709-3	Local <sup>3)</sup>	18	Small
	850704-3	Local <sup>3)</sup>	21	Medium
	850708-6	Local <sup>3)</sup>	22	Large
	850709-5	Local <sup>3)</sup>	27	Large
	850709-4	Local <sup>3)</sup>	23	Medium
	850709-6	Local <sup>3)</sup>	23	Large
	850702-2	Local <sup>3)</sup>	21	Large
IV Mbita	850718-2	Local <sup>3)</sup>	28	Medium
	850718-3	Local <sup>3)</sup>	14	Medium
	850718-4	Local <sup>3)</sup>	21	Medium
	850718-5	Local <sup>3)</sup>	22	Medium
IV Kithunthiri	850722-1	Local <sup>3)</sup>	19	Large
	850722-2	Local <sup>3)</sup>	33	Large
	850722-3	Improved <sup>4)</sup>	22	Large

Notes) 1, 2, According to Harlan and de Wet (See References); 3, two season variety ;

collection of sorghum varieties showed that the native types with a large variation in many characteristics are still cultivated within limited areas. Problems concerning crop diversity seemed to be present in this area, as will be discussed below in connection with adaptability in traditional farming.

### (iii) Millets

Bulrush millet (*Pennisetum americanum* (L.) Leeke) was next in importance to maize, especially in the lower areas. Cultivation of this crop is said by the farmers to be confined to within the short rainy season, from October to December. I did not observe cultivation of bulrush millet except for their volunteer crops in the long rains, because the survey period was from June to August 1985, but several spike samples were collected from granaries and local markets. According to the farmers, this millet is usually intercropped with maize, sorghum, cowpeas, green gram, pigeon peas, or cotton, and is

maize in the field sampled.

Weight of 100 air-dried ears, kg	Weight of air-dried grain per 100 plants, kg	Ear length, cm	No. of grains per ear	Estimated yield, ton/ha
9.8	7.4	13.0	292	1.22
8.5	6.9	13.4	267	1.88
4.8	3.4	—	198	0.29
7.5	6.2	—	—	1.63
8.0	6.4	—	239	1.08
3.0	2.4	—	—	0.23
6.4	5.3	—	—	0.79
11.8	8.3	—	—	1.46

and pigeon peas.

collected in the study areas.

Grain color	Glume color	Spikelet type <sup>1)</sup>	Head type <sup>2)</sup>
Light brown	Brownish black	Caudatum	6
Reddish brown	Brownish black	Durra-Bicolor	6 ~ 7
Yellowish white	Yellowish brown	Kafir-Caudatum	3
White	Orange	Ginea-Caudatum	5
Grayish white	Brownish black	Guinea-Caudatum	4
Grayish white	Orange	Guinea-Caudatum	4
Grayish white	Orange	Guinea	5
Grayish white	Yellowish white	Caudatum	4
Orange	Brownish black	Guinea-Caudatum	8
Red	Black	Guinea-Kafir	7
White	Black	Caudatum	6
Pink	Reddish brown	Durra-Bicolor	3
Orange	White-pink	Unidentified	3
Yellowish white	White-brown	Durra-Bicolor	4
Yellowish white	Yellowish brown	Caudatum	5

4, one season variety.

also grown alone in pure stands very rarely. By comparison of the shape of caryopsis with the standard of Brunken *et al.* (1977), most of the samples were classified into the 'Typhoides' race, which has the widest distribution in Africa. However, farmers in the Mavuria area classified the millet into three varieties by the maturity period and head shape, as follows: 'Muca Na Vua' (3 months, small head), 'Muthanje' (3 months, medium head), and 'Mugombe' (3.5 months, large head). In the study areas, stems of bulrush millet are often bound and placed along the contours in sloping field to prevent soil erosion, and serve as green manure. They are never used as animal feed because of the bristles in the spikelets. Birds are reported to damage the crop seriously.

Cultivation of finger millet (*Eleusine coracana* Gaertn.) seems to occupy somewhat less hectareage than does bulrush millet, and it is mainly cultivated in the lower areas. It is intercropped with cowpeas, maize, or both in the long and short rains. Field

preparation is most important for this crop because the seeds are very small and are broadcast by hand. The yield in the study areas is low ; it was estimated to be between 300 and 400 kg/ha. The grains are usually ground into flour for cooking *ugali* and whole grains are sometimes used for making porridge or beer.

The palatability of the cereal crops grown in the study areas according to the farmers is in the order of bulrush millet > maize > sorghum > finger millet. Most of the native cereal crops, including bulrush millet, that have been popular and important to the farmers as the staple foods in the past, have gradually been replaced by maize over the past thirty years.

(iv) Leguminous crops

In the study areas, the following leguminous crops were of importance: kidney beans or beans (*Phaseolus vulgaris* L.), cowpeas (*Vigna sinensis* Endl.), pigeon peas (*Cajanus cajan* L. Millsp.), green gram (*Vigna radiata* L.), hyacinth beans (*Dolichose lablab* L.) and lima beans (*Phaseolus lunatus* L.). Beans are very important, especially in the upper areas ; they are usually intercropped with maize in both the long and the short rains. Various types different in growth habit, maturity, and seed character, were seen during the survey period. In kangaru (Area II), some of the farmers showed us eight varieties with different maturity, between two and a half and three and a half months. The local names of the varieties are given in Table 12. The information from the farmers did not always agree concerning the maturity period and other characteristics. There were also large variation in the color, shape, and size of the seeds. Some farmers use a natural mixture of colors and sizes of seeds for sowing, and they usually consume the harvested seed mixture as part of their diet. In the upper areas where the bush type is predominant, beans are usually intercropped with maize or potatoes. In Area III where cultivation is critical because of the hot, dry climate, two types of beans, bush and climbing type, are cultivated. The bush types can be harvested even when the rainy season ends early because of its determinate growth habit, and the climbing types grow and set pods for a long time when the rains continued for long enough, because of its indeterminate growth habit. Therefore, farmers in this area usually plant both types separately or mixed together in the same field. In general, the beans mature earlier than cowpeas, and the cowpeas are more likely to have pod shattering than beans. Therefore, the harvest period of the beans takes only two weeks, while that of the cowpeas takes one month. Cowpeas, which are resistant to drought, are also an important crop, especially in the lowland areas, where they yield more than the beans. A diversity in growth habit and seed color was also observed in the cowpeas. Cowpeas are called *nthoroko* in the

Table 12. Varieties or types of kidney beans grown in Kangaru (Area II).

Local variety	characteristics
Kathiga	red and brown mottled, early
Mwitmania	ivory and brown mottled, early
Karambi	early - medium
Muviki	early - medium
Runi	red, large grain, medium
Loan (= Roan)	medium - late
Gitune	medium - late
Karaki	medium - late
Kathimbi	late
Kithaga	late

lower Embu area. The growth habit can be classified largely into spreading, semi-upright, and erect types. The seeds are white, black, brown, cream, mottled, and spotted. It is of interest that cowpeas, originating in the African continent, are important as a staple food crop while cereals native to the African continent have been replaced by maize, introduced from the American continent.

Cowpeas are intersown by broadcasting between the rows of maize, millet, pigeon peas, or sweet potatoes. The plant population of cowpeas consisted of 16,000 to 130,000 plants with a mean of about 60,000 plants/ha. Pod numbers per plant and seed numbers per pod depended on the growth habit and cultivation of the plants.

The yield varied greatly in each field. Leaves of cowpeas are used as vegetables in Embu as well as the rest of Kenya; they are eaten in soup or as a paste every day. A diversity of color and shape was observed in seeds and pods. There were two types of pods, one was long and straight and the other short and curved. The curved pod was said to yield more than the straight kind in infertile soil conditions, but this was not confirmed in the field in this survey. In the lower areas, four varieties or types were distinguished by the farmers. Their characteristics, however, did not coincide with their names among all farmers. The most serious problem in their cultivation is damage by a parasite plant, *Alectra orobanchoides*, which is called *kiriti* in the local language. The degree of damage to the cowpeas differs depending on the cultivation conditions such as soil fertility. The cowpeas seemed to be more susceptible to such damage in infertile soil, as is shown in Table 13. The farmers do not take measures against the parasite to protect the cowpeas. Mature pods are picked by hand and the pods are dried on the bare ground in the farmyard and are then stored in granaries. Threshing is done by beating the pods with sticks whenever the cowpeas are needed for food. The yield of cowpeas varied considerably from field to field, according to the farmers. Data on yield were not available during this survey. However, the yield was estimated to be between 400 and 1,000 kg/ha, which is higher than for beans grown in the upper areas.

Pigeon peas are called *njugu* in Embu and are cultivated as a famine crop in the lower areas, where they are grown as a perennial crop or a two-season crop. In general, they are intercropped with maize, cowpeas, cotton, or sorghum in rows 2.5 to 6 m apart at the beginning of the short rains. They are left in the field after the one-season crop is harvested, and maize or cowpeas are sown again between the pigeon pea stands. The pods can be picked immature, about five months after sowing; mature pods are usually harvested when they ripen at the end of the long rains.

Table 13. Percentage of cowpeas attacked by the parasitic plant (*Alectra orobanchoides*).

Area	Farmers' No.	Soil/Field condition	Total number observed	Plants damaged	%
IV Kithunthiri	21	Soil fertility, relatively high, (near homeyard)	100	0	0
"	21	Sandy soil	100	6	6
IV Mbita	23	Continuous cropping field of cowpeas	225	57	25.3
IV Kithunthiri	27	Near homeyard	150	1	0.6
"	27	Poor soil	120	59	49.2
"	29	Clay soil	166	7	4.2
"	30	Sandy soil (poor soil)	150	51	34.0
V Mavuria	20	Sandy soil (poor soil)	66	43	65.2

Green gram and hyacinth beans are called *ngina* and *njave*, respectively, in the local language. Both crops used to be grown in Embu as well as in the rest of Kenya in the past, but were not popular at the time of this survey in Embu, especially in the study areas. They were observed in only a few fields.

A wide variation in character, including growth habit, and color of seeds and flowers, was seen in hyacinth beans, but not in green gram. Apart from the leguminous crops mentioned above, only a few stands of lima beans, cluster beans (*Cyamopsis tetragonoloba* (L.) Tanb), jack beans (*Canavalia ensiformis* DC), velvet beans (*Mucuna pruriens* (L.) DC.), and peas (*Pisum sativum* L.) were found in the farmers' gardens. These plants were not of much importance as food crops.

(v) Root crops

Throughout the study areas, the root crops listed in Table 3 are grown. In the lower areas, only some cassava plants, most of which were infected with a virus disease, and some sweet potatoes were observed on the edge of farm fields or home gardens. In the upper areas, white potatoes were an important crop, and cassava and sweet potatoes were also cultivated. Sweet potatoes and cassava are planted in the short rains and only the large mature roots are dug up when needed. Vines of the sweet potatoes are left in the field, so successive growth and rooting takes place if the plants survive the drier season. The potatoes are eaten as a dish called *gitoero*, which is cooked with cassava and taro. White potatoes are grown both in the long and short rains in mixed cropping and in rotation with maize and kidney beans, and are harvested three and four months after planting. Tubers with the mean weight of about 50 g are sown as seed tubers at a distance of 30 cm apart and 60–90 cm between rows. There are three varieties supplied by the Kenya Grain Growers Cooperation Union (KGGCU), Kiers pink, Ninety-nine, and Kenyah akiba. According to the farmers, the yield is about 20 bags of fresh tubers per acre, which was equivalent to 6 to 7.5 tons/ha. In the upper areas, chemical fertilizers and pesticides are usually applied to increase production.

In Kangaru, Gachoka, and Kithunthiri, cooking bananas are also of importance. They are interplanted with root crops such as white potatoes in Kangaru and cassava in the two other areas. Cultivation of cassava and sweet potatoes was less common and that of yam was more common in the upper areas with an elevation of more than 1,500 m. From the growth habit, leaf shape, color of the flesh, and other characteristics, the yam was identified as yellow yam (*Dioscorea cayenensis* Lamk.). Yellow yam has a long history of cultivation in the Embu area, and it grows wild, climbing on the natural vegetation, including trees. Some are twined around the old wilted coffee trees to be eaten as a supplemental food.

Taro and yautia are not extensively grown in the farm fields of the study areas, but they grow wild on the banks of rivers or are grown in riverside fields called *kianda*. They are eaten as a supplemental food in times of scarcity.

(vi) Cash crops

Most of the agriculture in the study areas is small-scale traditional subsistence farming. However, coffee, tea, and cotton are cultivated as important cash crops. They are not old to the study areas. According to Brokensha and Riley (1980), for instance, the growing of cotton was promoted by the Embu Local Council in the lower areas of the Embu District in the 1930's and tobacco cultivation was started by small-scale farmers in the 1950's. Coffee and tea cultivation were promoted by the local government in the 1950's and 1960's in the upper areas.

In the survey, tea cultivation was observed in areas above 1,700 m, and coffee between 1,400 and 1,700 m. Coffee plants grown by small-scale farmers number from 500 to 2,000 plants, which is equivalent to 0.2 to 0.8 ha. The method of planting coffee

seedlings is shown in Fig. 9. Planting holes are prepared three months before planting, and seedlings, which are supplied from coffee-processing firms, are planted into these holes in March. The spacing between coffee trees is generally 2.0 × 2.0 m, 2.3 × 2.3 m, or 2.7 × 2.7 m. During the growth stage, many kinds of chemicals are sprayed onto the trees because there is otherwise damage from various pests and diseases. Fertilizers are applied two or three times and manure once or twice a year to increase the yield.

The farmers said the following insect pests and diseases cause damage to coffee.

Insect pests : scale, berry borer, leaf minor

Diseases : leaf rust, coffee berry disease (CBD)

The following chemicals were commonly found in the farmers' sheds in the upper areas.

Insecticides : Diplerex (effective against maize stalk borer), Labaycide (berry moth), Gusathion (mealybug, scale), Smmition (leaf minor).

Fungicides : Bayleton Copper oxychloride (CBD, leaf rust).

The typical cropping season and cultivation method of coffee in Area I are shown in Fig. 10. Harvesting of coffee is called picking and it is usually done by hand twice a year, March to May and September to October. The mean yield of berries from a seven-year tree is between 10 and 20 kg depending on cultivation and care. In 1984, one kilogram of berries was sold to processing plants for Kenya Shs 3.05/kg.

Tea growing starts later than that of coffee in Area I. In this area, chemicals are never sprayed on the tea bush, but fertilizer and manure are applied once or twice a year. Tips of tea shoots are plucked every 10- to 14-day intervals, and the annual yield varies from field to field, with an average of 1,250 kg/ha. The shoot tips plucked by small-scale farmers are sold to processing plants as a source of cash income.

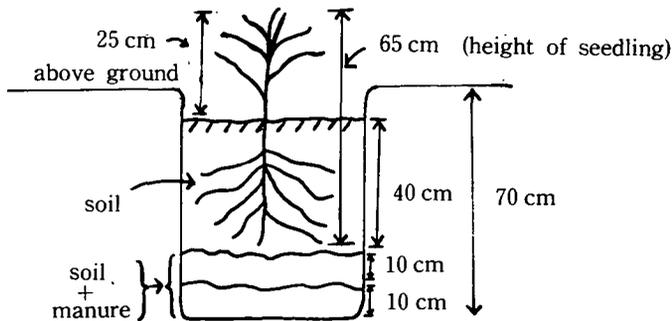


Fig. 9. Method of planting coffee seedlings.

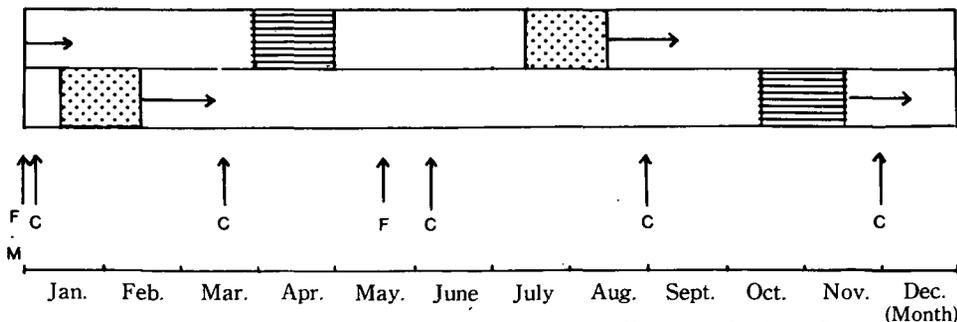


Fig. 10. Typical cropping season and cultivation of coffee trees in Area I.

Note) , flowering; , harvesting; F, fertilizer application; M, animal manure application; C, application of agricultural chemicals.

Cotton is also important as a cash crop, especially in Areas III and IV, which are located in the cotton and marginal cotton zones. Cotton is sown intercropped with maize, sorghum, or pigeon peas in the short rains. Small-scale farmers are furnished with seeds recommended by the Lint & Seed Marketing Board, and they grow the cotton according to technical guidance from this board. For instance, 9 kg of seeds are sown in one hectare of farmland with five seeds in each hole, and then the seedlings are thinned to two plants. Consequently, the population density of the cotton is from 35,000 to 70,000 plants per hectare. Cotton suffers seriously from various kinds of pest and disease damage, so chemicals furnished by the board are sprayed 3 to 6 times even after flowering. Mean yield of seed cotton are said to be about 625 kg per hectare in the study areas.

As was mentioned above, the intensive use of chemicals such as fertilizers, pesticides, and fungicides was observed in cash crop cultivation. These modern techniques in cash crop cultivation have had some effect on the traditional subsistence agriculture that has prevailed in the study areas.

(6) Maintaining land productivity and keeping stock

How to maintain soil fertility is a serious problem for small-scale farmers in the uplands of the tropics. Shifting cultivation or the bush and fallow system, which are still used worldwide, is said to be ideal for traditional agriculture in the tropics if the population density of human is low and the fallow periods are long enough to restore soil fertility.

In the study areas, shifting cultivation had been common among the small-scale farmers 10 to 30 years ago, as mentioned above. At present, continuous cropping (permanent cropping) is becoming common in both the upper and lower areas. Continuous cropping bring about progressive depletion of soil fertility and land productivity. The factors that the farmers believe to limit land productivity are shown in Table 14. In the upper areas, soil erosion is the most serious factor and general infertility comes next. The farmers believe that those two factors are interrelated, for erosion decreases soil fertility and consequently decreases crop yields. This observation is true, because the small-sized cropping in the upper areas is done mostly on slopes as steep as 15-20%. Table 15 gives data from topsoil analysis of the sampled farms of the study areas. In the upper areas (Areas I and II), severe soil acidity of between pH (H<sub>2</sub>O) 4 and 5 was found. Soil acidity in the lower areas (Areas III, IV, and V) was pH (H<sub>2</sub>O) 6 to 7, so it was less severe than in the upper areas. The severe soil acidity in the upper areas probably resulted from leaching of the basic cations by much rainfall and also from application of great amounts of chemical fertilizer (ammonium sulphate). The

Table 14. Factors limiting on land productivity according to farmers.

Area	Total number of farmers	Rank*	% of answering					Total %
			Soil erosion (steep slopes)	Soil infertility	Condition of soil (include stones, sand)	Water-logging	Other	
I and II	14	1st	64.3	28.6	0	7.1	0	100
		2nd	28.6	50.0	14.3	7.1	0	100
III ~ V	32	1st	40.7	46.9	6.2	0	6.2	100
		2nd	34.4	43.8	6.2	6.2	9.4	100

\* 1st, Factor said by the farmers to be the most serious one.

2nd, Factor said by the farmers to be second most serious one.

Table 15. Chemical properties of topsoils in the sampled farms of the study areas.

Area	Field sampled	pH (H <sub>2</sub> O)	C		N	C/N	Ex. cations				
			%				K	Na	Ca	Mg	(mg P <sub>2</sub> O <sub>5</sub> /g)
							(meq/100 g)				
I	Sweet potatoes filed	4.68	3.85	0.350	11.00	0.37	0.15	3.37	1.32	0.016	
	Maize=beans field	4.80	3.32	0.320	10.38	0.48	0.15	2.00	1.09	0.006	
	"	4.43	3.83	0.360	10.64	0.51	0.15	0.87	0.48	0.011	
II	White potatoes field	4.95	2.69	0.220	12.23	1.79	0.15	2.66	1.55	0.024	
	Maize=cowpeas field	5.85	2.68	0.220	12.18	0.79	<0.05	5.36	2.64	<0.001	
III	Maize field	6.41	2.17	0.160	13.56	1.19	0.05	6.13	2.04	0.022	
IV	Cowpeas field	6.75	1.09	0.097	11.24	0.88	0.05	4.01	1.28	0.020	
	"	6.78	0.80	0.075	10.67	0.68	0.05	3.25	1.04	0.033	
	Maize=cowpeas field	5.88	0.66	0.060	11.00	0.56	0.05	1.52	0.56	0.036	
	"	7.11	1.25	0.120	10.42	0.76	0.05	8.05	2.01	0.140	
	Cowpeas field	6.88	0.49	0.044	11.14	0.28	0.05	2.08	0.29	0.053	
	"	6.80	0.53	0.044	12.05	0.20	0.05	2.32	0.31	0.100	
	Maize=cowpeas field	6.16	0.47	0.045	10.44	0.23	0.05	1.24	0.28	0.025	
	Maize field	7.16	1.13	0.100	11.30	0.96	0.05	4.79	1.16	0.022	
	Hyacinth beans field	6.81	0.53	0.050	10.60	0.52	0.05	2.67	0.68	0.002	
	Cowpeas field	6.47	0.46	0.043	10.70	0.48	<0.05	1.52	0.35	0.013	
	"	6.40	0.45	0.044	10.23	0.28	<0.05	1.59	0.40	0.004	
	V	Maize=cowpeas field	7.63	0.80	0.074	10.81	0.61	0.05	3.92	1.09	0.110
		"	7.53	0.54	0.052	10.38	0.44	0.23	2.22	0.71	0.056
		Maize field	5.64	0.46	0.047	9.79	0.64	0.05	1.44	0.72	0.013
		"	5.97	0.68	0.059	11.53	0.72	0.05	2.20	0.80	0.018
Cowpeas field		6.47	0.35	0.033	10.61	0.22	0.05	1.23	0.31	0.026	
Bananas field		5.85	0.36	0.034	10.59	0.40	0.05	0.52	0.28	0.012	
Cowpeas field		6.48	0.32	0.028	11.43	0.20	0.05	0.92	0.27	0.020	
"	6.20	0.81	0.073	11.10	0.56	0.05	2.54	1.11	0.009		
"	6.71	0.43	0.039	11.03	0.39	<0.05	2.00	0.40	0.018		

Note) = means mixed cropping or intercropping.

Table 16. Percentages of farmers who use chemical fertilizer and animal manure in the study areas

Area	Maize		Bulrush millet		Kidney beans		Cowpeas		Whits potatoes		Cotton		Coffee	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M
I	86	67	—	—	0	0	—	—	33	67	—	—	100	100
II	88	100	—	—	13	13	0	13	25	38	—	—	100	100
III	8	92	0	0	0	25	0	25	—	—	0	33	—	—
IV	50	80	0	40	0	40	0	40	—	—	10	30	—	—
V	10	80	0	0	—	—	0	40	—	—	0	0	—	—

Note) F, fertilizer; M, animal manure.

amount of organic matter in the sampled soils was evaluated by the carbon and nitrogen contents of the topsoil and the C/N ratios (Fig. 11). The carbon and nitrogen content of the topsoil of the upper areas were greater than in the lower areas, but the C/N ratios of

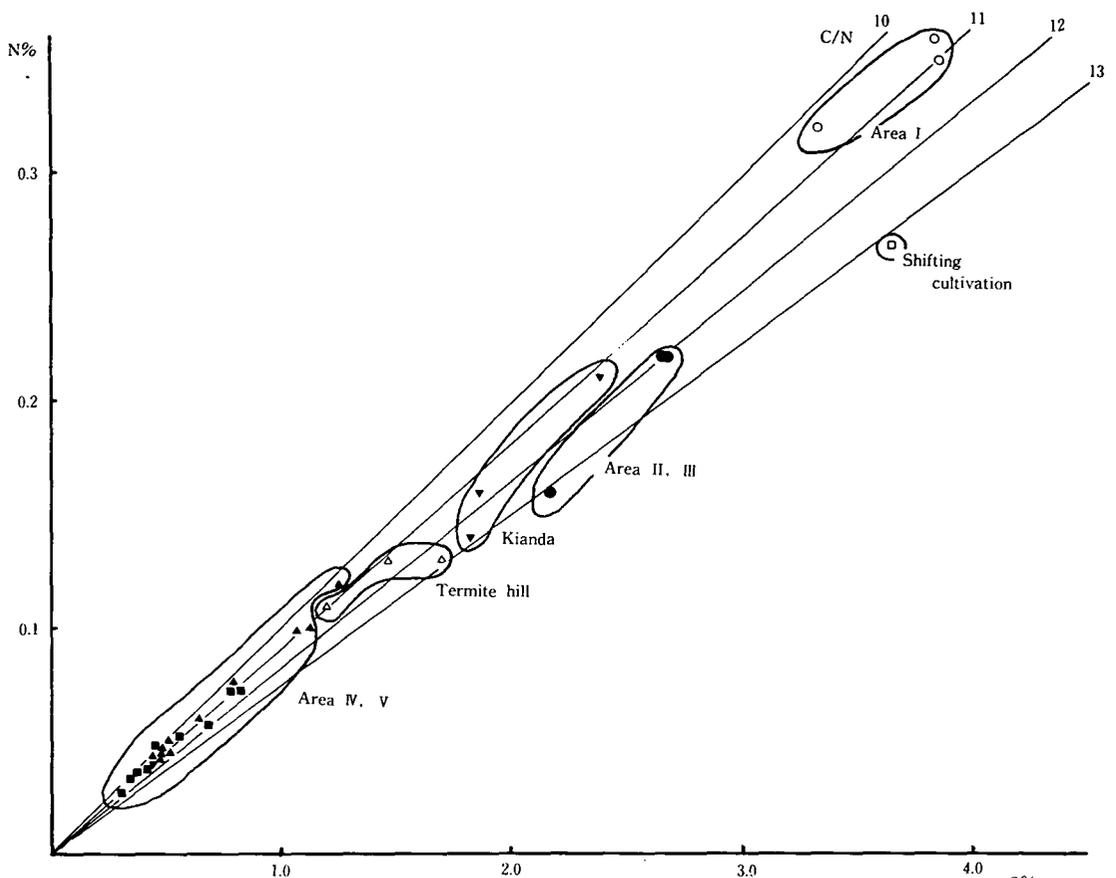


Fig. 11. Carbon and nitrogen contents, and C/N ratios of the sampled soils. C%

Table 17. Size of *boma*, height of animal manure heaps, and number of animals

Area	Farmers' No.	Cattle			Goats and sheep		
		Head	Area, m <sup>2</sup>	Height of heaps, cm	Head	Area, m <sup>2</sup>	Height of heaps, cm
II	37	2	15.0	—	1	—	—
	38	2	20.0	—	4	—	—
	48	3	50.0	—	1	—	—
III	2	24	615.0	5	20	8.7 8.0	5
	3	5	140.0	5	—	—	12
IV	21	21	240.0	9	27	24.0	—
	23	4	21.0	8	10	5.0	11
	24	10	11.0	—	9	—	8
	26	7	91.0	2	22	48.0	—
	28	3	13.0 15.0	9 1.5	7	4.5	13
V	31	5	36.0	0.3	10	11.0	—
	13	4	8.7	—	5	8.4	—
	18	15	32.0	13	13	7.5	22
	19	2	10.6	2	9	6.2	2
	22	7	110.0	8	38	—	—

Table 18. Chemical components of dry animal manure sampled in the study areas.

Area	Farmers' No.	Cattle manure (%)							
		C	N	P	K	Ca	Na	Cl	Si
I	42	20.9	1.73	0.286	1.36	0.400	0.056	0.047	9.80
	42	24.5	1.90	0.308	1.61	0.999	0.158	0.187	8.03
	45	13.2	1.25	0.240	1.61	0.539	0.119	0.111	9.83
II	48	28.0	2.16	0.213	3.53	0.377	0.076	0.620	7.18
I and II : Means		21.65	1.76	0.262	2.03	0.579	0.102	0.241	8.71
III	2	18.7	1.39	0.204	2.22	0.914	0.609	0.259	9.82
	3	9.1	0.86	0.186	1.06	0.750	0.142	0.060	11.40
	7	13.3	1.16	0.245	1.86	0.849	0.126	0.267	12.30
IV	21	12.0	1.12	0.238	1.72	1.340	0.252	0.090	19.00
	22	17.4	1.43	0.248	3.19	1.130	0.125	0.792	13.50
	23	16.6	1.30	0.230	2.12	0.985	0.186	0.229	12.40
	24	7.6	0.58	0.120	1.63	0.776	0.285	0.220	16.40
	26	11.7	1.02	0.336	1.81	2.950	0.788	0.295	12.10
	28	14.0	1.29	0.299	2.86	1.300	0.204	0.434	18.30
	29	20.8	1.30	0.256	2.09	1.730	0.311	0.353	12.50
	31	5.7	0.48	0.112	1.91	0.683	0.583	0.188	20.40
V	13	20.9	1.67	0.268	5.13	0.799	0.469	1.270	15.00
	18	17.4	1.67	0.364	4.00	1.930	0.312	0.460	15.10
	19	18.3	1.35	0.209	3.44	1.280	0.154	0.392	14.10
	32	9.2	0.72	0.146	3.33	0.468	0.385	0.266	21.80
III ~ V : Means		14.18	1.16	0.230	2.56	1.192	0.328	0.372	14.94
Area	Farmers' No.	Goat and sheep manure (%)							
		C	N	P	K	Ca	Na	Cl	Si
II	36	26.9	2.11	0.348	2.29	1.010	0.070	0.217	8.01
III	2	29.5	2.09	0.368	4.54	2.670	0.162	0.729	6.38
IV	21	21.2	1.94	0.475	5.00	3.240	0.298	1.360	10.80
	26	28.5	2.10	0.694	4.73	4.250	0.295	0.963	7.17
	28	14.8	1.58	0.289	4.18	1.450	0.216	0.782	16.60
	29	27.0	2.44	0.483	5.39	3.170	0.240	1.430	8.27
V	18	25.0	2.42	0.410	4.80	2.150	0.219	1.220	12.00
	19	26.6	3.08	0.418	3.56	2.730	0.149	0.513	9.16
	20	21.7	2.11	0.485	4.76	1.520	0.274	1.400	12.60
	32	24.7	1.96	0.440	6.38	1.690	0.281	1.310	9.95
III ~ V : Means		24.33	2.19	0.451	4.82	2.540	0.237	1.079	10.33

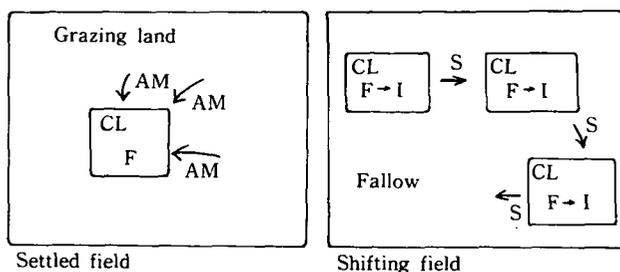


Fig. 12. Soil fertility maintenance by application of manure gathered from livestock and by shifting cultivation.

Note) CL, cropped land ; AM, application of animal manure ; F, fertile soil conditions ; I, infertile soil conditions ; S, shifting.

both areas were about the same, between 10 and 12. Results of soil analysis showed that soil fertility decreases continuously in the absence of fertilization. The maintenance of soil fertility is the sincere concern of the small-scale farmers interviewed especially in the lower areas where most farmers do not apply any chemical fertilizers (Table 16). In cropping lands where no chemical fertilizer is applied, the addition of animal manure is the most effective way to maintain soil fertility and thus to increase the crop yield. According to oral tradition, the numbers of livestock needed to supply enough animal manure for one hectare of farm field is between 12 and 24.

It was reported in an earlier section that cattle, goats, sheep, and chickens are found in areas where mixed farming of crops and livestock is common. The purposes of keeping livestock in the study areas are to earn cash when the need occurs and to produce animal manure for the soil. However, the dependence on livestock is generally greater in the lower areas, where crop production is unstable because of frequent dry spells and infertile soil conditions.

There are various practices for grazing. In the lower areas, for instance, owners of livestock usually graze their animals on their own and on their neighbour's bushland, and animals are driven about 4 to 5 km every day. During the dry season, however, the animals may be driven about 8 km to a watering place. The animals that are grazed in the bushland in the daytime are kept in an enclosure at night that is called a *boma* in the local language. The animals are usually grazed as a communal group of livestock of five or six households of close relatives or neighbouring farmers.

Each member of the group grazes all of the animals of the group for 5 to 7 days. There are usually two *boma* in each household, one for cattle and the other for smaller animals such as goats and sheep. The size of the *boma* was different depending on the size of the herd. The animal manure in the *boma* is applied to farmland once a year, usually in the dry season between August and September. Table 17 shows the *boma* size and the height of the manure piles in the *boma*, by which the amount of animal manure can be estimated. Table 18 lists chemical components of the animal manure sampled in the study areas. These data show that the application of animal manure is an effective procedure to maintain soil fertility, but that the amounts produced by herds of these sizes are not sufficient.

In shifting cultivation, which is said to have been widespread in the study areas 20 to 30 years ago, land rich in organic matter was used to the best advantage by shifting the fields to be cropped. In terms of soil fertility, however, the settled cultivation used now depends largely on animal manure gathered from animals grazed in the bushland and on the range (Fig. 12). Livestock rearing also helps to fill economic needs when crops fail. Thus crop cultivation and livestock rearing complement each other in the mixed farming

system in the lower areas.

## V. Characteristics of the farming technology

The farmers were interviewed about the characteristics of the farming technology that is usually practiced by the farmers in the study areas.

### (1) Intercropping and crop diversification

The prevailing cropping pattern in the study areas is intercropping in which maize is intercropped with beans, cowpeas, or another cereal. Sole cropping is rarely observed in the lower areas, it was found in the fields of farmers who own more farmland than the average. Farmers were asked why they chose intercropping, and the results are shown in Table 19. (i) In the upper areas, 80% of the farmers said the main reason was shortage of farmland. (ii) In the lower areas, however, shortage of farmland was mentioned by 50% of the farmers, about 30% said that intercropping is done to help minimize the risk of crop failure at the time of climatic disasters. (iii) Most of the farmers engaged in sole cropping pointed out that intercropping is inconvenient for cultivating and weeding with animal draught implements. (iv) Some farmers stated that sole cropping may yield more than intercropping under certain field conditions. (v) The major reason for intercropping given by most of the farmers in the study areas was to ensure the production of subsistence food within a given farm with limited input. (vi) Farmers were asked what measures they would take to cope with changes in the natural environment such as a delay in the onset of the rainy season. The responses can be summarized as follows. In the upper areas, 43% of the farmers answered that the cropping pattern or crops to be combined in the ordinary pattern would be switched to another pattern. Fewer than 20% of the farmers gave the same answer in the lower areas. This response in the lower areas indicated a lack of flexibility against environmental stress because the condition of the land is too bad for farming.

The advantages and disadvantages of crop diversification in traditional tropical agriculture, including the subjects of intraspecific diversification and mixed cropping, have been discussed (Chang 1977; Clawson 1985). In general, traditional farmers grow many species of crops in a mixed cropping pattern in order to minimize the risk of crop failure. In this survey, it was found that there were many more kinds of crop combinations in the lower areas than in the upper areas. In the upper areas, however, numerous varieties of the same crop were found in the same field in mixture or in separate cultivation. For instance, eight varieties or types of beans with different maturity period, color, and size of grains were grown by one farmer in Kangaru (Table 12). Moreover, sorghum varieties different in grain and glume color, head type, and maturity period were found within a small area in Gachoka. Under changeable environmental conditions, intra- and interspecific diversification is surely helpful in assuring a secure harvest by shifting growth of each crop or variety through the growth season. However, such diversification will probably decrease gradually with the diffusion of modern standardized technology such as 'the Green Revolution Technology'.

Table 19. Reasons for practicing intercropping reported by farmers.

Area	Total number of farmers	Sole cropping; numbers and (%) of farmers	Inter-cropping; numbers and (%) of farmers	Reasons (percentage of farmers giving this answer)				
				Shortage of farm land	Minimizing risks of crop failure	Shortage of labour	Increase of total yield	Soil conservation
I and II	14	3 (21)	11 (79)	82	18	—	—	—
III ~ V	32	4 (13)	28 (88)	54	29	14	—	4

Table 20. Farming operation necessary for increasing of crop yield.

Area	Total number of farmers	Rank*	Farming operation (percentage of farmers giving this answer)					Land preparation
			Timely planting	Manuring	Weeding	Pest control	Bird driving	
I and II	14	1st	50	43	7	0	0	0
		2nd	14	29	57	0	0	0
		3rd	7	14	14	50	0	14
III ~ V	32	1st	66	9	13	0	0	13
		2nd	19	41	28	0	0	13
		3rd	13	41	38	0	9	0

\* 1st : said by the farmers to be the most important.

2nd : said by the farmers to be the second most important.

3rd : said by the farmers to be the third most important.

## (2) Factors limiting crop production

Factors concerned with crop production and farm work that is essential for the increase in the crop yields are listed in Table 20. The data were obtained during interviews (Table 20).

(i) Timely planting ① Both in the upper and lower areas, timely planting of the crops takes priority over all other work. This is followed by manuring in the upper areas. ② In the lower areas, land preparation and weeding are ranked above manuring. ③ Timely planting is important mainly because the rainfall is very scanty and also because the date of the onset and the end of the rainy season varies considerably from year to year. ④ According to the farmers in the lower areas, the best planting time for short-term crops is usually before the onset of the first rain, so land preparation has to be completed during the dry season.

(ii) Farming implements ① Farming implements are, of course, important part in the carrying on of farm work like ploughing, planting, and weeding. Table 21 shows the kinds and numbers of the farm implements possessed per household in the study areas. ② Most of the farming implements are simple hand-operated tools except for the iron ploughs and wheel barrows. ③ In the lower areas with a clear-cut bimodal rainfall pattern, the time available for land preparation is limited for several days before the onset of rain, so it is difficult to complete land preparation without draught animals and iron ploughs. Ploughing and planting would be delayed without the oxen-plough. ④ In the upper areas, on the other hand, the oxen-plough is not useful because of the small plots and steeply sloped farmland. Not one of the farmers interviewed had an oxen-plough. ⑤ A broad-bladed hoe called a *jembe* is commonly used for tilling the soil both in the upper and lower areas, and weeding was done with a *panga* or *muro*. The tools seemed to be well-suited for use in particular conditions present. For instance, a *muro* is used to make planting holes as well as to weed, and a *panga* has uses other than weeding alone. A *panga* is very convenient for harvesting and sometimes for tilling, especially in the upper areas with unfavorable conditions for cropping. ⑥ In the upper areas, sprayers and ox-carts are possessed by 67% and 33% of farmers, respectively. The sprayer is an indispensable implement in the upper areas where cash crop cultivation is more common than food crop cultivation.

(iii) Manuring ① For land productivity, manuring is an important procedure ; it maintains the soil fertility and also increase the crop yield. Generally there are two ways of manuring in the study areas. One is to apply animal manure (composed of animal fences piled on the *boma* in the lower areas) and the other is to apply chemical

Table 21. Kinds and numbers of farm implements per household.

Area	Iron plough	Jembe	Forked jembe	Panga	Muro	Sprayer	Wheel barrow	Ox cart
I Gitare, Kiriari	0	2	3	6	0.2	0.8	0.3	0.3
II Kangaru	0.1	2.1	3.4	7	0	0.6	0.6	0.6
III Gachoka	0.7	2.6	0.8	3.3	0	0.1	0.1	0.1
IV Kithunthiri, Mbita	0.4	2.7	0.3	2.9	1.9	0.1	0	0
V Mavuria	0.7	2.2	0.4		4.6	0	0	0

Table 22. Application of agricultural chemicals to main food crops and cash crops.

Area	Total number of farmers	Application of agricultural chemicals		Application to each crop (% of farmers)					
		numbers	%	Maize	Kidney beans	Cowpeas	White potatoes	Cotton	Coffee
I and II	14	14	100	79	0	—	43	—	100
III ~ V	32	24	75	16*	3*	9*	—	100	—

\* Includes even one application (not every season).

fertilizers. ② Most of the farmers in the lower areas wanted to apply animal manure not only to maize, but also to crops such as cowpeas, beans, and millet if there was enough animal manure. But application of animal manure is often restricted to fields nearest to the farmer's home because of its scarcity and the lack of carts. ③ Most of the farmers in the upper areas invariably apply animal manure and chemical fertilizer to maize and white potatoes as well as to coffee trees, important cash crop. ④ In the lower areas, only 3% of the farmers (Areas III ~ V) apply a chemical fertilizer to cotton, the only cash crop in these areas. Especially in the lower areas, application of chemical fertilizers does not seem to be profitable because their effects are counterbalanced by the frequent dry spells and soil infertility. ⑤ Compound fertilizers in the proportions of 23-23-0, 20-20-0, or 17-17-0 are commonly used in the study areas. In the upper areas, for instance, most farmers apply as much as 20 to 25 kg of nitrogen and phosphate/ha to maize or white potatoes mixed with leguminous crops as a basal dressing, and some of the farmers apply additional nitrogen at the rate of 10 kg/ha in the form of a straight fertilizer, ammonium sulphate or others, when maize is about 60 cm high. ⑥ Application of large amounts of chemical fertilizers causes severe soil acidity, as mentioned above, and the degree of the soil acidity is accelerated by serious leaching arising from erosion that occurred during the rainy season.

(iv) Agricultural chemicals ① Cash crops seem to have pest problems different from those of local food crops, so almost all farmers spray insecticides and fungicides onto the cash crops, cotton in the lower areas and coffee in the upper areas (Table 22). ② In the upper areas, 79% of the farmers apply pesticides to maize; only 16% in the lower areas have ever applied them. ③ The tendency to use purchased pesticides is stronger in the upper areas than in the lower areas.

(v) Other cultivation work ① Weeding is necessary for high yields, as mentioned above, but it is labourious. ② In general, weeding is done with hand tools such as the *panga* and *muro*, twice for short-term crops and three or four times for two-season crops. ③ The critical period for the first weeding is soon after germination of the crop seeds; timing of the second weeding is different from crop to crop. For instance, weeding is done during the period of maturation for maize. For other crops such as cowpeas, beans, and millet, weeding is done after harvesting by cutting of stovers of the

crops and ploughing of the field; thus, weeding and field preparation for the next cropping season is done at the same time. ④ Bird damage causes serious yield losses, especially in areas where millet and sorghum dominate. In the short rains, the main cultivation season for millet, undivided attention needed from dawn to dusk to keep birds away when the millet reached at a certain mature stage when the birds eat them. ⑤ Bird driving consumed time and manpower, but this is not labourious work. Usually schoolchildren help in this work during the morning hours before school. ⑥ The time required for bird driving often conflicted with the needs of other crops, because it could not be skimmed for even a few minutes. Thus, most of the farmers in the upper areas stopped growing millet in the 1960's when coffee cultivation began because bird driving during the millet maturing period interfered with the harvest of the coffee berries.

(vi) Storage of food products and seeds ① In the semiarid areas, which are always in danger of crop failure, it is indispensable to store grains for food from the good years for survival. In the study areas, the harvested grains are kept in a granary, called an *ikumbi* in the local language. This is usually constructed of timber and bamboo with a thatched roof. ② The temperature inside the granary was 3 to 5°C lower than the outside, and the relative humidity was 5 to 7% higher. ③ Stored food grains were spread with ashes; rarely chemical pesticides like Actellic 1% and Malathion 2% were applied to control weevils. ④ Another problem in grain storage in the study areas is how to store the seeds for the next season without losing germinability. Seeds of crops such as maize, bulrush millet, and sorghum are stored hanging up from the kitchen ceiling in the traditional way. ⑤ Small-scale farmers often could not obtain seeds to be sown for the next cropping because of drought. In this case, the government and missions often supplied seeds for the main food crops free of charge, which gave the farmers the opportunity to obtain improved varieties like the Katsumani composite of maize.

### (3) Measures for maintaining living in droughts

Farmers in semiarid areas were always under the risk of crop failure because of the little rain and their uneven distribution in time. In the interview, they were asked what measures they take in forecasting crop failures because of drought or other disasters unavoidable in their area, in order to survive and maintain their living standard? Their responses, in order of frequency, were as follows (Table 23).

Table 23. Measures for survival of droughts.

Area	Total number of farmers	Measures (% of farmers giving each answer)			
		Food reserves	Rearing livestock	Cultivation of famine crops	Off-farm income
I and II	14	50	—	29	21
III ~ V	32	56	19	13	16

In the upper areas (Areas I and II):

Food reserves > Cultivation of root crops > Off-farm income  
 (yam, sweet potatoes, cassava) (off-farm labor in town)

In the lower areas (Areas III ~ V):

Food reserves > Rearing of livestock > Off-farm income > Cultivation of drought-resistant crops  
 (off-farm labor in town) (finger millet, sorghum)

There was fundamental problem. The crop yield must be increased so that there is enough to put aside for storage, for the yield is still unsatisfactory even in season of good crops.

## VI. Transition from traditional subsistence farming to intensive farming

This study showed that the agriculture in the Embu area is mainly practiced by small-scale farmers as subsistence farming, and that most of the food crops are consumed by the farming families except when there is surplus production. Cash crops like cotton in the lower areas and coffee and tea in the upper areas are also cultivated by small-scale farmers. The ratio of the area cropped with coffee and tea to the total cropped area is about 62% in the upper areas; this is several times higher than the ratio of the area cropped with cotton in the lower areas. It seems, therefore, that a shift from subsistence farming to commercial agriculture has been in progress in the upper areas. In the Embu area, land reform, which began in the 1960's, was carried out vigorously in the 1970's, and now permanent farming is practiced on the family scale in five areas. The traditional system, in which farming has ever done in communal groups, is still used for grazing in the lower areas.

Agricultural production is still dependent on traditional farming technology except for the intensive agriculture sometimes used in coffee cultivation in the upper areas. Failure of the harvest because of unfavorable environmental conditions, especially to uneven rainfall, is unavoidable in the lower areas. In those areas, traditional ways in which farming is highly adapted to the unfavorable environmental conditions through the knowledge and experience of the people are often still used. The crops to be planted in the long or short rains are selected by characteristics as maturity, drought resistance, and so on. Intercropping and crop interspecific or intraspecific diversification, which are popular throughout the study areas, are also adaptation measures taken against unexpected changes in the environment.

Traditional subsistence farming uses techniques characteristic of methods for soil fertility maintenance that mainly depend on a nutrient cycling process in the vicinity of the farmers' own fields (watanabe 1985). In the lower areas, soil fertility in permanent farming is maintained by use of animal manures gathered from animals grazing in the farmers' own and their neighbours' grazing lands or ranges. Another method, which is very rare, is the field to lie fallow for several years. In these ways, agriculture in the lower areas seemed to be characteristic of traditional agriculture that has adapted itself to the given social and natural environments for many generations. The traditional ways, which make effective use of a very small amount of soil water under semiarid conditions, were chosen by the small-scale farmers through their long experience. For instance, banana seedlings are planted 70 to 80 cm under the ground in order to use the underground water, and vegetables and root crops, which require much water, are usually cultivated in *kianda* (riverside fields) to make use of the small amount of water remaining at the riverside even in the dry season.

In the upper areas, where the total size of individual farms is smaller than in the lower areas, it is difficult to supply animal manure to the soil for fertility in the vicinity of the farmers' land because animal keeping consists of only a few livestock and very little or no grazing land. So, chemical fertilizers have to be applied to conserve soil fertility and to continue permanent farming within a given area. This has caused various changes in farming systems and techniques; for instance, it hastened the spread of hybrid maize varieties and encouraged the rate of the renewal of the seeds. It also accelerated the cultivation of cash crops. However, traditional food crops like yams (*Dioscorea* spp.) and hyacinth beans began to suffer seriously from insect pests like scales

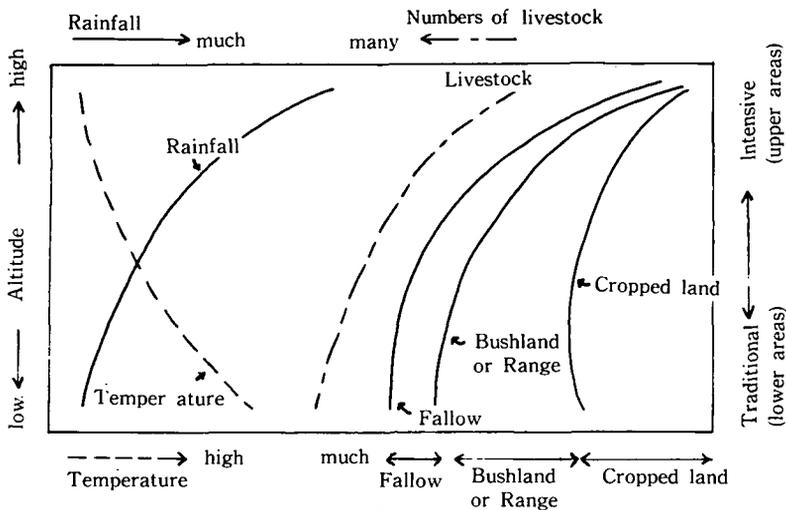


Fig. 13. Process of transition from traditional subsistence farming in the lower areas to intensive farming in the upper areas.

after the cultivation of cash crop like coffee trees was established.

Intercropping with a combination of various crops ensured the small-scale farmers from crop failure, and crop diversity in certain areas made some harvest possible even when natural disasters occurred. However, the introduction of cash crops simplified the kinds of crops in the cropping system and changed agro-ecological conditions, which were highly stabilized by traditional ways. Thus, techniques depending on the continuous application of agricultural chemicals and fertilizers are now being used to stabilize the new agro-ecological conditions that developed with the introduction of cash crops.

A typical transition process from traditional subsistence farming to intensive farming (the so-called modernization process of agriculture) is taking place between the upper and lower areas (Fig. 13).

## VII. Conclusions

This agricultural study was done to identify the actual agricultural conditions and methods of farming used by the small-scale farmers in the semiarid area of the Embu District, Kenya, with relation to agro-ecological factors such as climate and soil.

(1) In the upper areas sited above 1,500 m, which have 1,250~1,500 mm of annual precipitation, so-called intensive farming with the application of chemicals became popular with the cultivation of cash crops like coffee and tea. Improved varieties of the subsistence food crops such as hybrid maize were introduced and they spread with a very high rate of seed renewal. Intensive farming seems to have caused some confusion to the traditional agriculture, which had been well adapted to the agro-ecological and social conditions of the area.

(2) In the lower areas, improved techniques such as application of fertilizers and cultivation of improved varieties were not as popular. These techniques were not very practical for the small-scale farmers because fertilizer is costly and crop yield does not increase in proportion to the amount of fertilizer applied. This is because the uneven and scanty rainfall (less than 800 mm) often does not allow the effects of the fertilizer to appear.

(3) In the lower areas, planting the crop seeds in time for the onset of rains is most important, and land preparation has to be completed during the dry season because production decreases drastically if the planting is too late. Here the problem is that the

small-scale farmers do not own enough farming implements like iron ploughs for land preparation.

(4) The small-scale farmers in the lower areas seem to practice their traditional subsistence farming within the given environmental and economic and social conditions, and the farmers seem somewhat resigned to their own living conditions. Their farming is still primitive and far from sufficient, but one farmer, who was interviewed, had been achieving high crop production by the following ways in a farm in the lower areas.

(i) Land preparation by animal draught plough before the onset of the rainy season. (ii) Restoring soil fertility by application of animal manure produced by a large number of livestock. (iii) Discovery and use of special soils like termite hill soil and of a vein of water under the farmland. (iv) Selection of crop suitable to farmland conditions and use of different cropping systems and crop diversity to minimize crop failure. (v) Application of minimum amounts of chemicals so as not to upset existing agro-ecological conditions.

(5) Improved farming techniques can be integrated in these ways into the traditional ways of farming. First, a better understanding of the ecological basis of existing farming practices should be promoted. It would then be effective to incorporate modernized techniques gradually into the traditional ways based on small-scale mixed farming.

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Plate 1. Mixed cropping of banana and cassava in Gachoka area.



Plate 2. Mixed cropping of maize with cassava, banana, and cowpeas in Kangaru area.



Plate 3. Banana seedling planted 70~80 cm under the ground in Mavuria area.



Plate 4. A granary for keeping the harvested grains in Gachoka area.



Plate 5. Parasitic plant (*Alectra orobanchoides*) which gives the serious damages to cowpeas.

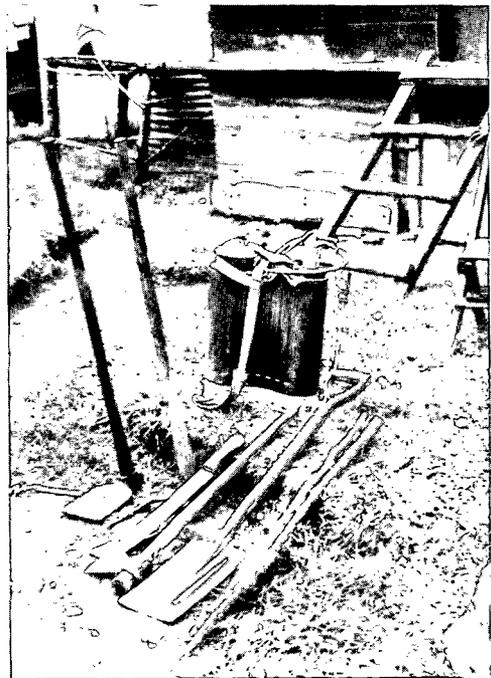


Plate 6. Kinds of farming implements in Kiriari area.



Plate 7. Cultivation of yam (*Dioscorea cayenensis*) in Kangaru area.

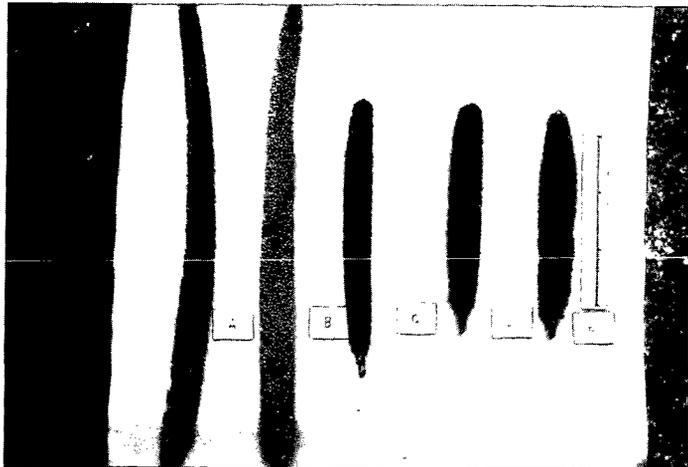


Plate 8. Kinds of bulrush millet varieties collected in Kithunthiri area.



Plate 9. Kinds of cowpeas varieties collected in Mbita area.

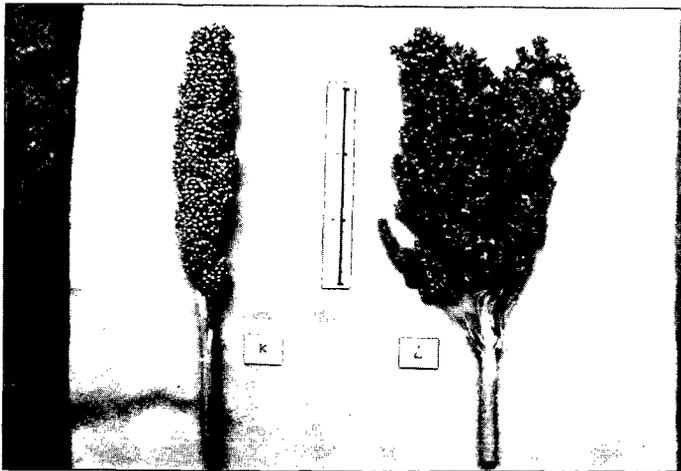
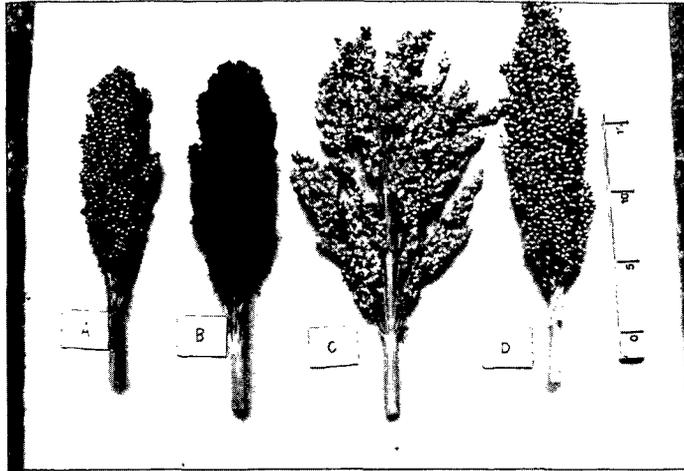


Plate 10. Kinds of sorghum varieties collected in Gachoks area.

## A 2. VEGETABLE CONSUMPTION AND PRODUCTION BY FARMERS

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### I. Introduction

Differences of the agroecology with increase of sea level are clearly visible in the Embu district, located at the foot of Mt. Kenya.

Hirose has already described the differences of the agroecology in this district in the foregoing section.

In this section, the traditional vegetable production and consumption from live stock and millet zone (LM 5) to tea and coffee or coffee zone (UM 1, 2) will be discussed.

The method of survey is the same as Hirose's. Nowadays, the main foods eaten in this district are maize, millet, cowpeas and kindey beans. Table 1 shows the result of a survey of preference for various grains taken among the farmers in the lower and upper lands. They are more fond of eating maize than any other grain. Millet and sorghum are highly preferred in the lower lands, whereas rice and bread are preferred in the upper lands. The main reason why millet and sorghum are preferred in the lower lands is that these crops are traditional to this area. On the other hand, rice and bread are preferred in the higher lands as the purchasing power of the people there is greater due to the

Table 1. Preference for various grains taken among the families in the survey areas

Sub-location	Order of preference							
	Rice				Millet and Sorghum			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
lower lands								
Mavuria	0%	43	57	0	27	18	18	18
Kithunthiri, Mbita	20	10	50	20	10	60	20	10
Gachoka	11	22	56	11	11	56	22	11
upper lands								
Kangaru	0	25	75	0	33	33	33	0
Kiriari, Gitare	25	75	0	0	20	0	60	20

Sub-location	Order of preference							
	Wheat				Maize			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
lower lands								
Mavuria	0%	29	14	67	67	22	11	0
Kithunthiri, Mbita	0	25	25	50	78	11	11	0
Gachoka	17	17	17	49	73	18	0	9
upper lands								
Kangaru	29	0	43	29	80	20	0	0
Kiriari, Gitare	25	25	50	0	100	0	0	0

\* the lower lands : Mavuria, Kithunthiri, Mbita and Gachoka, the upper lands : Kangaru, Kiriari and Gitare

Table 2. The frequency of consumption of animal and plant protein  
a : Animal protein

frequency	lower lands			upper lands	
	Mavuria	Kithunthiri, Mbuita	Gachoka	Kangaru	Kiriari, Gitare
<b>Egg</b>					
every day	2 (families)	0	0	0	2
2~3/week	2	7	4	5	1
1/week	1	2	1	0	2
1/2 weeks	0	0	0	0	0
1/month	1	1	2	0	0
2/year	0	0	0	0	0
1/year	0	0	0	0	0
rare or no	3	2	4	3	0
<b>Chicken</b>					
every day	0	0	0	0	0
2~3/week	2	1	0	0	0
1/week	2	0	3	3	2
1/2 weeks	2	4	0	2	1
1/month	1	3	5	0	1
2/year	1	0	1	0	1
1/year	2	0	1	0	0
rare or no	0	2	1	1	0
<b>Goat and Sheep</b>					
every day	0	0	0	1	0
2~3/week	0	1	1	2	1
1/week	0	0	1	1	2
1/2 weeks	3	1	2	0	0
1/month	0	2	5	0	1
2/year	0	0	0	1	0
1/year	2	0	1	0	0
rare or no	4	6	1	3	0
<b>Beef</b>					
every day	0	0	0	1	0
2~3/week	0	1	1	1	1
1/week	0	0	1	1	3
1/2 weeks	1	0	0	0	0
1/month	0	2	3	0	0
2/year	0	0	0	0	1
1/year	1	0	1	0	0
rare or no	4	6	5	3	0
<b>Fish</b>					
every day	0	0	0	0	0
2~3/week	3	0	0	0	0
1/week	4	0	0	1	0
1/2 weeks	1	0	0	0	0
1/month	0	1	0	0	1
2/year	0	0	0	0	0
1/year	0	0	0	0	1
rare or no	1	8	11	7	3
<b>Milk</b>					
every day	3	5	12	8	5
2~3/week	2	0	0	0	0
1/week	0	0	0	0	0
1/2 weeks	0	0	0	0	0
1/month	0	0	0	0	0
2/year	1	0	0	0	0
1/year	0	0	0	0	0
rare or no	3	4	0	1	0

## b : Plant protein

frequency	lower lands			upper lands	
	Mavuria	Kithunthiri, Mbuita	Gachoka	Kangaru	Kiriari, Gitare
<b>Kidney beans</b>					
every day	0 (families)	1	4	2	3
2~3/week	5	3	7	4	2
1/week	1	1	0	0	0
1/2 weeks	0	1	0	0	0
1/month	0	0	0	0	0
2/year	0	0	0	1	0
1/year	0	0	0	0	0
rare or no	3	4	0	1	0
<b>Cowpeas</b>					
every day	2	3	0	0	0
2~3/week	7	7	7	1	1
1/week	0	0	0	2	0
1/2 weeks	0	0	2	0	0
1/month	0	0	3	0	1
2/year	0	0	0	0	0
1/year	0	0	0	0	0
rare or no	0	0	1	4	3
<b>Green grams</b>					
every day	0	0	1	0	0
2~3/week	6	3	1	1	0
1/week	0	0	2	0	0
1/2 weeks	0	2	0	0	0
1/month	0	2	2	0	3
2/year	0	0	2	0	0
1/year	1	0	0	0	0
rare or no	2	3	2	6	2
<b>Pigeon peas</b>					
every day	0	1	1	0	0
2~3/week	1	7	6	2	0
1/week	0	0	1	0	0
1/2 weeks	0	0	1	0	0
1/month	1	1	1	0	3
2/year	2	0	1	0	0
1/year	0	0	0	0	0
rare or no	5	1	0	6	2

production in that area of cash crops such as coffee, etc. and they can therefore afford to purchase rice and bread. The degree of consumption of animal protein can be seen in table 2-a. Milk is drunk every day by most farm families in both the lower and upper lands, and eggs are an important source of protein for them, being consumed once or twice a week by most farmers.

Chicken, eaten once or twice a month, is another important source of animal protein for them. The meat of goats and cows is not consumed as frequently in the lower lands as in the higher lands. The higher we go, the greater is the consumption of meat. Fish

is eaten once or twice a week in Mavuria where there is a large dam nearby, but it is not consumed at all in the upper lands.

As for the consumption of plant protein, kidney beans are eaten regularly in both the lower and upper lands, though they are consumed somewhat more frequently in the upper lands. Cowpeas, green gram and pigeon peas are consumed more in the lower lands than in the upper lands, since the temperature is too low for these pulses to grow in the upper lands (table 2-b).

This concludes the discussion of the diet of the peoples in the survey area.

## II. Vegetable production and the consumption of vegetables and medicinal plants

### a. Cowpea leaves

As shown in table 3, cowpea leaves are an important vegetable in the diet of the people in the lower lands. In the native language the leaves are called '*nyenyi*' and the seeds are called '*nthoroko*', thus the leaves of the cowpea are distinguished from the seeds. Both *nthoroko* and *nyenyi* are important foods for these people. As the leaves of the cowpea cannot be harvested from July to September in the lower lands the people buy them during this period at the market, which is supplied with leaves from the fields along the river called the '*kianda*' in a later section. The price of a handful of these leaves is about one Kenya shilling, or Twelve Japanese yen (Plate 1).

There is no one particular variety cultivated exclusively for the gathering of cowpea leaves. Some farmers preferred the taste of the purple leaf variety to the greenish one. Others told us that the purple ones were more resistant to drought than the greenish ones, but we cannot scientifically verify that fact in this survey. The climbing variety produces a higher yield of seeds than the bush one.

The nutritional value of the cowpea leaf is shown in table 4. The data indicate that it is higher in nutrients than either cabbage or lettuce. The young pod of the cowpea is rarely eaten. The seeds of cowpea are primarily sown in March or September. The leaves can be harvested one month after the seeds sprout. The plants begin to flower from four to six weeks after sowing, and the seeds are harvested about four weeks after the flowering. Cowpeas mature in about three and a half months (kidney beans require two and a half months, *Dorichos* three and a half months).

Cowpeas originated on the African continent and are therefore well adapted to the high temperatures and dry climate prevalent there, as their roots grow usually deep into the soil. Our measurement in the Mavuria shows that the main root penetrates as deep as twentyfive to thirty centimeters under the soil surface. The results of the survey in the lower lands as to the order of drought resistance of pulses grown in this area as follows: the most drought resistant pulse is the cowpea, followed by the pigeon pea, then the *Dorichos*, and finally the green gram and kidney beans.

In the lower lands the parasite called '*kiriti*' represents a serious problem in the growing of cowpeas. The damage of this parasite is very severe and will be described in detail in a later section titled '*kiriti*'.

In the upper land (about one thousand eight hundred meters) the temperatures are too low for the seed of the cowpeas to mature but they can grow cowpeas therefor the leaves. The seeds are sown from August to October, and the farmers can continue to harvest the leaves until January. However, the seeds of the nonclimbing variety of cowpeas will mature even at one thousand six hundred meters.

As mentioned above, the cowpea is used for seed production and the gathering of leaves for vegetables. Therefore the author thinks that the branching cowpea varieties which bear the most branches are best suited to the purposes of the people in this region, since branching cowpeas produce a greater yield of seeds and the leaf harvest increases

Table 3. The frequency of consumption of vegetables by farmer families

frequency	lower lands			upper lands	
	Mavuria	Kithunthiri, Mbuita	Gachoka	Kangaru	Kiriari, Gitare
<i>Sukuma</i>					
every day	0 (families)	1	2	2	4
2~3/week	0	3	3	2	0
1/week	1	2	2	1	0
1/2 weeks	1	0	2	0	0
1/month	2	0	1	1	0
2/yeay	1	0	0	0	0
1/year	0	0	1	0	0
rare or no	4	4	0	1	0
<i>Cowpea leaves</i>					
every day	9	10	11	4	11
2~3/week	1	1	2	3	2
1/week	0	0	0	1	1
1/2 weeks	0	0	0	0	0
1/month	0	0	0	0	0
2/year	0	0	0	0	0
1/year	0	0	0	0	0
rare or no	0	0	0	0	1
<i>Carrots</i>					
every day	0	1	1	1	2
2~3/week	1	0	1	2	2
1/week	0	1	0	2	0
1/2 weeks	1	0	3	0	0
1/month	1	0	1	0	0
2/year	0	0	0	0	0
1/year	0	0	0	0	0
rare or no	6	8	5	2	0
<i>Kikuyu onions</i>					
every day	6	7	9	7	5
2~3/week	2	1	2	1	0
1/week	0	0	0	0	0
1/2 weeks	0	0	0	0	0
1/month	0	1	1	0	0
2/year	0	0	0	0	0
1/year	0	0	0	0	0
rare or no	0	0	0	0	0
<i>Cabbage</i>					
every day	0	0	0	1	0
2~3/week	1	0	1	1	2
1/week	0	0	3	2	2
1/2 weeks	1	1	2	0	1
1/month	2	1	2	1	0
2/year	2	0	1	0	0
1/year	0	0	1	0	0
rare or no	3	8	1	1	0

Table 4. The nutritional value of the cowpea leaves, pumpkin, leaves, cabbage, *solanum nigrum* leaves (per 100 g fresh weight)

	Protein (g)	Calcium (mg)	Iron (mg)	Beta-Carotene ( $\mu$ g)	Vitamin-C (mg)
Cowpea leaves	4.7	256	10	8,000	90
Pumpkin leaves	6	400	9.3	9,900	130
<i>Solanum nigrum</i> (leaves and stem)	6	300	12	9,000	140
Cabbage	1.7	50	1	100	54

after pinching.

b. '*Mutanga*' (*Citrurus lanatas*)

*Mutanga* is the name of a type of watermelon whose fruit is characteristically not sweet. Similar to the cowpeas, the growing of *mutanga* is limited to the lower lands (Plate 2-a). Its young, mature fruit and young leafy stem are eaten as vegetables. In Kithunthiri and Mbuita it is called *mutanga*, in Mavuria, *metanga*. Cowpea leaves and *mutanga* are two of the few traditional vegetables still grown in these areas. '*Njima*', a dish made from *mutanga* and millet, is a very old one in the lower lands.

The method of growing *mutanga*, which is sown in April or October, is very simple and requires no special techniques. Three to four seeds are sown together in a small hole.

*Mutanga* is commonly sown together with maize or cowpeas. A *mutanga* with small fruit (about one kilogram) will yield about fifty fruits per plant. The harvest of *mutanga* begins three months after sowing the seeds and continues for four months. Two kinds of *mutanga* are cultivated in this area. They are the oblong type (*magunthi* in the native language) and the round type (*cianguri*). The oblong type is the bigger of the two. The fruit weight of the oblong type is over fifteen kilograms (Plate 2-b). It is said that the round type of *mutanga* is older than the oblong type and there are two kinds of seeds color. The seed of the oblong type is redish brown while that of the round type, of which a netted and complicated design runs along the surface of the fruits, is black. Some of the farmers interviewed told us that the Kamba trib often raise *mutanga* and have been growing it from times of old. It is possible to store the mature fruit for eight to ten months. *Mutanga* is the most important vegetable in the diet during the period when the growing of cowpeas is impossible. There is no sweet watermelon in this area.

*Citrullus lanatus*, which originated on the African continent similar to the cowpeas as described above, is one of the crops which is resistant to drought. In Mavuria, even the *mutanga* frequently dries up for lack of water. In the lower lands, people do not grow sweet watermelons, and most of them do not know of their existence. I do not know whether people can grow the sweet watermelon in this area or not, but it may be cultivated sometime in the future. If it is, the root stock of the *mutanga* should be used and the seedlings should be raised in a nursery.

c. '*Sukumawiki*' (*Sukuma*)

The scientific name of sukuma is *Brassica oleracea* var. *acephara*. It is called kale or corad in English. It is eaten every day, for it is an important mineral source in both the lower and upper lands (Table 3).

The *sukuma* originated near the Mediterranean, and it was introduced to Kenya by the Europeans only about a century ago. As shown in table 5, most farmers said that the *sukuma* was the newest vegetable to be cultivated in both the upper and lower lands.

*Sukuma* leaves are picked one by one, then boiled or fried. The taste of the leaves is more bitter than that of cabbage, but the people like the bitterness of *sukuma* leaves.

Table 5. The newest vegetables cultivated in the upper and lower lands

	<i>Sukuma</i>	Cabbage	Carrot	Garden pea	Tomato	Egg plant
Lower lands	64 %*	23	0	3	6	3
Upper lands	64	22	14	0	0	0

\* Percentage of farmers who answered *sukuma* is the newest vegetable.

The *sukuma* will not flower unless it has a period of low temperatures (below ten degrees) for several weeks during the growing season. However, there is no such cold period in the lower lands and therefore the *sukuma* do not flower or, consequently, not produce seeds. In the upper lands it is possible to produce the seeds, although the quantity is small. *Sukuma* seeds are therefore largely imported from Europe. In the lower lands, people must tax their ingenuity to cultivate *sukuma*. Cultivation of *sukuma* in the lower lands is described below.

Most of the farmers grow *sukuma* from seedlings produced in the upper lands, and sold at the market.

In table 6 we can see the survival rate of the *sukuma*, from the seedling to the mature stage. The survival rate of *sukuma* is twenty percent in the lower lands. Of the plants which survive, some grow to over forty centimeters in height, although twenty centimeters is the average height. The *sukuma* is grown either in the *kianda*, in the swampy plots of the fields (called '*kithithinia*' or '*saba*' in the native language), around the cattle corrals (known as '*boma*' in the native language) or on termite hills (Plate 3). Leaves can be harvested from the same plants for a period of six to eight months.

In the lower lands there is what is called '*coro*', a vegetable similar to the *sukuma*. *Coro*, whose scientific name is *Brassica carinata*, is called Abishinian mustard in English. *Coro* originated on the high lands of the African continent, and is therefore better adapted to high temperatures and drought than the *sukuma*. Moreover, it is easier to obtain seeds from this crop than from the *sukuma*. Some of the farmers grow *coro*, in place of *sukuma*, though most people prefer eating *sukuma* leaves to those of *coro* (Plate 4).

If it is possible to develop an improved variety of *coro* whose leaves are as tasty as those of the *sukuma*, more people may begin raising *coro* in the lower lands than *sukuma*.

I believe that *kairan* (*Brassica oleracea* var. *alboglabra*), a vegetable similar to the *sukuma* and cultivated in South East Asia, could be used to improve the *sukuma*, since *kairan* flowers readily in tropical regions.

Let us now look at the cultivation of *sukuma* in the upper lands. Most farmers sow

Table 6. The survival rate of *sukuma* in the lower lands

farmers	survival rate
A	5 %
B	25
C	16
D	66
E	50
F	50
G	0
H	35

Table 7. Plant height and number of nodes of *sukuma* about one year after sowing (in the upper lands)

plant height	Number of nodes
62 cm	95
63	92
65	96

the seeds during the long rainy season, although in areas where irrigation is used they can sow *sukuma* throughout the year. Harvest of the leaves begins two months after sowing. Since the *sukuma*, which dies after flowering, does not flower in this area, most farmers can flowering, does not flower in this area, most farmers can continue harvesting leaves from the same plant for three to four years (Plate 5).

The number of nodes and the plant height of the *sukuma* sown one year ago are shown in table 7. In the upper lands there are both branching and nonbranching varieties of *sukuma*. In the case of the branching variety, leaves can only be harvested for one year, as the branching variety flowers easily in this area.

Growing of *sukuma* in the upper lands is easier than in the lower lands, but there are some problems in growing it, the first being damage from aphids and scales, the second the production of seeds. Growing of *sukuma* in the upper lands is a good example of the utilization of the characteristics of the physiology of the *sukuma*'s flowering in cultivation.

#### d. *Kikuyu onions*

Until now the production of *Alliums* on the African continent has not been introduced to Japan. However, *Alliums* are widely grown in Kenya.

In the Embu district they are consumed daily, though the actual amount consumed everyday is not so great (Table 3). The leaves of *Alliums* in Kenya are more slender and shorter than those of the Japanese welish onions (Plate 6-a, b), and the taste is very hot. Since they rarely bear flowers, they seldom produce fertilized seeds. They are therefore propagated through the dividing of the stands or the bulbil (Plate 6-c). When I tried growing them in Japan, they remained dormant during the summer season and grew in the autumn or spring seasons. I would assume that they belong to the shallot family from the viewpoint of the morphology of the flowers and the ecological characteristics described above. It is said that they were introduced by an Arab into Kenya, although it is not known from which country they came nor how they spread. They are called '*gitunguru*' in the native language, and '*kikuyu onions*' by the Africans when they speak in English. People use *kikuyu onions* in all of their fried dishes. Generally, the growing of *Alliums* in the areas where the temperatures are very high is inferior to the growing of *Alliums* in temperate zones. Therefore, *kikuyu onions* do not grow well in the lower lands in the Embu district where the temperatures are too high. Thus they are trucked to the Embu district from the upper lands, for example Nyeri. The price is very high, two to three onions being sold for one Kenya shilling (seven in Japanese yen). The farmers in the lower lands would very much like to raise *kikuyu onions* themselves and are trying to do so but it is very difficult in this hot climate. Like the *sukuma*, the *kikuyu onions* grow best in the *kianda*, on termite hills and in swampy fields. *Kikuyu onions* are planted during either the long or short rainy season, and the harvest begins one month later.

As stated above, the growing of *kikuyu onions* in the lowlands is very difficult. Therefore I would suggest that the Chinese chive (*Allium tuberosum*) which belongs to the *Allium* genus and is very resistant to high temperatures, be adapted for cultivation in

the lower lands. Although the taste, which is somewhat different from that of the *kikuyu onions*, may not be preferred, I believe the growing of Chinese chive should be tried in this area.

On the other hand, it is not so difficult to grow *kikuyu onions* in the upper lands, although they have the problem of water shortage during the dry season there.

e. Lima beans

People use the powder of the lima seeds with grains in their diet, and while they utilize the young leaves and stems as vegetables. Lima beans are called *mbumbu* in the native language (Plate 7).

They are also called *mbumbu* in the upper lands, where their leaves and stems are eaten.

There are two kinds of lima beans, one being the large seed variety and the other the small. *Mbumbu* is of the later variety.

In this district *mbumbu* is an old crop, although lima beans originated on the new continent.

Seeds of lima beans are sown during the period of the long rainy season, and the stands will survive up to two to three years after sowing. As it is a climbing vine, most farmers grow it up trees which are three to four meters in height. The young leaves and stems are used for cooking the same as with the cowpea leaves. It is said that the taste of seed is similar to that of *Dorichos* beans but the taste of the later is of a higher quality. As with the cowpeas, lima beans are not grown in large numbers. In many cases small numbers of planted on the homestead or on the corners of the fields. They are cultivated more in the upper lands than in the lower lands, as the temperatures in the lower lands are too high to produce seeds. It is very difficult to grow the *Dorichos* beans in the upper lands due to damage from scales, so the farmers there grow lima beans, which are rarely attacked by scales, instead.

The other vine vegetables are *cucurbits* and chayote. In the *cucurbits* genus, *Cucurbita moschata*, *C. pepo* and *C. maxima* are grown in the upper lands, while in the lower lands only *C. moschata* is grown.

f. Other vegetables, medicinal plants

Edible bottle gourds are called '*mungu*' in the native language. The bottle gourds, which are used for bottles, bowls etc., are very bitter and they cannot be eaten. The native people told us that they can distinguish bitter bottle gourds from nonbitter ones by biting the leaves of the seedlings.

The gourd known as '*shunguru*' (Plate 8) has warts on the surface of the fruit and is similar to the wart bottle gourd in Japan. The young fruit of *shuguru* is either fried or boiled.

Table 8. List of weeds utilized as vegetables in the survey areas

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*Managu, Kithi, Mukima, Terere, Karini ka nthia, Buoga, Kanguru, Mukangati, Mukengeria, Ruoga, Kigerema, Gokisi, Kimore, Mathorokwe, Mutengege, Kingóngóya, Kirigirigi, Makumbui, Mukangati, Kingóngó ya, Gicue gue, Gakangati, Mvka uri ibu, Karimi ka nthia, Macuicue, Mategenge, Matamba na ngoa, Girigi, Ndamba na ngaa, Karange, Kiruma audu, Kithugio, Mategenge, Gatandoro, Karini ka nthia, Muthigiriri (tree), Gatandoro, Irunandu, Ndanbana ngae, Ngengeria, Ngangati, Karikanonongwe, Matu ma nthia, Kankanonogue, Kithu kia mbiti, Ngengeria, Murega, Magwata ngonedu, Makuru, Monagu, Makiri, Ndamba na ngoa, Gikiri, Kithu kia mbiti, Mabiubu, Ikrimbui, Ndorimukia, Mariaria, Maboga, Mruroro, Maboga.*

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Table 9. Medicinal plants used in the survey areas

Kinds (local name)	Plant parts for usage	Disease
<i>Mucugu</i>	Root (biting after peeling)	Cough
<i>Mugenbe</i>	Stem (soaking in water)	"
<i>Mucanacama</i>	Stem (soaking in water)	"
<i>Mukinga</i>	Leaf (boiling in water)	"
<i>Murumbawe</i>	Root (boiling in water)	"
<i>Mukura</i>	Stem (chewing)	"
<i>Muhigiriri</i>	Root (boiling in water)	"
<i>Matoo</i>	Stem (boiling in water)	"
<i>Muceneri</i>	Stem (boiling in water)	"
<i>Muba</i>	Leaf (boiling in water)	"
<i>Muikigiriri</i>	Stem (boiling in water)	"
<i>Mutagataga</i>	Root ( ? )	"
<i>Mucugucugu</i>	Root (chewing)	"
<i>Mugaa</i>	Stem ( ? )	"
<i>Mugenbe</i>	? (chewing)	"
<i>Manandu</i>	Leaf (chewing)	"
<i>Muba</i>	Stem (boiling in water)	"
<i>Coffee</i>	Root (boiling in water)	"
<i>Muthata</i>	Stem (boiling in water)	Malaria
<i>Mvingo</i>	Stem (boiling in water)	"
<i>Kithunju</i>	Twig (evaporating)	" , Mumonnia
<i>Mwini</i>	Leaf (boiling in water)	"
<i>Mukinduri</i>	Leaf and root (boiling in water)	"
<i>Mukawa</i>	Root (boiling in water)	"
<i>Muuti</i>	Root (boiling in water)	"
<i>Mukenenga</i>	Stem (boiling in water)	"
<i>Mukingi</i>	Root (boiling in water)	"
<i>Mugia</i>	Root (boiling in water)	"
<i>Mujugairia</i>	Root (boiling in water)	"
<i>Muthigira</i>	Stem ( ? )	" Cough
<i>Muvoru</i>	Stem (boiling in water)	"
<i>Mugirinura</i>	Leaf ( ? )	"
<i>Gakambui</i>	Fruit (boiling in water)	"
<i>Muuti</i>	Root (boiling in water)	"
<i>Murasi</i>	Stem (boiling in water)	"
<i>Mucigara</i>	Root (boiling in water)	"
<i>Muterendu</i>	Leaf (boiling in water)	"
<i>Mugegeti</i>	Root and Leaf ( ? )	"
<i>Mwirungwa</i>	Leaf (soaking in water)*	Stomach ache
<i>Mukururu</i>	Leaf (biting)	"
<i>Muthunthi</i>	Leaf (biting)	"
<i>Mwingwa</i>	Twig (boiling in water)	"
<i>Karikonongwe and Kabobo</i>	Root, Stem (boiling in water)	"
<i>Musee</i>	Leaf (boiling in water)	"
<i>Muuti</i>	Root (boiling in water)	"
<i>Muraba</i>	Leaf (chewing)	"
<i>Karikanonongwa</i>	Root (boiling in water)	"
<i>Makandu</i>	Leaf (boiling in water)	"
<i>Mvaruwa</i>	Stem (boiling in water)	"
<i>Nthoroko</i>	Stem (boiling in water)	"
<i>Muvavai</i>	Root (boiling in water)	"
<i>Mukawa</i>	Root (boiling in water)	"
<i>Muthunga</i>	Root (boiling in water)	"
<i>Mutura</i>	Leaf (chewing)	"
<i>Mutaa</i>	Leaf (chewing)	"
<i>Ngeta</i>	Fruit (boiling in water)	"
<i>Mukanga</i>	Leaf (boiling in water)	"
<i>Mumcnjoro</i>	Root (soaking in water)	Abscess
<i>Ikuno</i>	Root (boiling in water)	Bachache
<i>Ry</i>	Seed (crashing with water)	Mumonnia
<i>Mutanbi</i>	Leaf (boiling in water, drinking with honey)	Rheumatism
<i>Muguruka</i>	Root (boiling in water)	"
<i>Mutuba</i>	Leaf (biting)	Tooth ache
<i>Muariki</i>	Root (boiling in water)	Indigestion
<i>Muthoroko</i>	Root (boiling in water)	"
<i>Menu</i>	Leaf ( ? )	Swelling
<i>Muini</i>	Leaf ( ? )	Skin disease
<i>Njogu ya iria</i>	Leaf (boil)	"
<i>Nwikithia</i>	? ( ? )	Ear disease

*Shunguru* is a very old traditional vegetable in the lower lands, as is the *mutanga*. But now it is very rare in this area and few people even know the name *shunguru*. The fruit is about ten centimeters in length and fifteen centimeters in circumference and the surface of the mature fruit is very hard. The relationship between *shunguru* and bottle gourds should be researched sometime in the future.

In table 8 is a list of the weeds which are utilized as vegetables at present. Nowadays the utilization of weeds is not as common as it used to be, although in ancient times they were used frequently.

The weeds are gathered and eaten during the rainy season but they are hardly utilized during the dry season. We could not see the weeds used in cooking, since our survey was conducted during the period of the dry season. Therefore, I cannot identify their botanical names and will present only a list of the native names of the weeds.

Sometimes the young buds of trees are utilized for vegetables in South East Asia, though they are not so utilized in this area. There are also examples of medicinal plants being utilized for vegetables in South East Asia. But in this area it is a rare that people put the buds of trees or medicinal plants to use as vegetables.

Table 9 shows the list of names of the wild medicinal plants in the native language, how to use them and the names of the diseases for which they are presently used as a cure. People could not survive without the wild medicinal plants in this area.

There are many wild fruits in the lower lands which people eat, but they are not important in their daily diet.

### III. Places of vegetable production in the semiarid zone

#### a. Homesteads

Homesteads are important places for the growing of vegetables in the semiarid zone, that is, the lower lands. The people recycle waste water to irrigate or for growing of vegetables (Plate 9).

Crops produced on the homesteads are indispensable in the daily lives of the people and also serve as a source of food during times of famine.

The growth of the crops occasionally fails due to a shortage of water during a draught, but even more devastating are the locusts which appear in large quantities following a draught and completely devour the crops.

One of the reasons why the tuber crops are grown on the homesteads is that the damage from locusts does not reach the part of the tubers under the soil. Therefore, people can avoid starvation by eating what remains of the tuber.

It is said that by growing crops around the houses it is possible to avoid damage from animals, such as monkeys eating the crops.

The vegetables grown on the homesteads in the lower lands are *sukuma*, cowpeas, sweet potatoes, *kikuyu* onions, tomatoes, chilli, pumpkin, cassava and the other vegetables. They are cultivated on homesteads in the upper lands. *Mutanga*, bottle gourds and *shunguru* are cultivated only in the lower lands, while yams, chayote, potatoes, cabbages and carrots are grown mainly in the higher lands.

In the lower lands pesticides and fungicides are rarely used. I believe the production of vegetables on the homesteads of the lower lands will be of increasing importance in the future. By selecting suitable crops in this area and by rotating crops, damage from soil diseases and insects may be minimized.

In selecting of the kinds of crops to be grown on the homestead, of course the preferences of the people must be taken into consideration, and foods which have been grown in this area from ancient times should be maintained.

b. 'Kianda'

The fields along the rivers are called 'kianda' in the native language. *Kianda* is a very important field for people in both the lower and upper lands.

Table 10 shows the distribution of the kianda in the upper and the lower lands.

The *kianda* are most abundant in the Gachoka region. In Mavuria the rivers run dry during the dry season and therefore most farmers do not have *kianda*. The crops grown in the *kianda* are bananas, sugar cane, sweet potatoes, *sukuma*, tomatoes, *kikuyu onions*, taro, among others.

The distribution of crops grown in the *kianda* can be seen in table 11.

It is said that the soil of the *kianda* is more fertile than that of ordinary fields.

Table 10. Percentage for possessing of *kianda* in the survey areas

	possessing rate
Lower lands	
Mavuria	0%
Kithunthiri, Mbita	25
Gachoka	82
Upper lands	
Kangaru	75
Kiriari, Giatare	80

Table 11. List of crops cultivated in the *kianda* in the survey areas

Lower lands	<i>sukuma</i> , <i>kikuyu</i> , <i>onions</i> , red onions, maize, bananas, <i>Dorichos</i> , sugar cane, sweet potatoes, tomatoes, taro, pumpkin, cowpeas, chilli, cabbage
Upper lands	<i>sukuma</i> , <i>kikuyu onions</i> , maize, bananas, sugar cane, sweet potatoes, tomatoes, taro, pumpkin, <i>mbumbu</i> , cassava, mungo, passion fruit, avogados, yams, pineapples, kidney beans

Table 12. Soil analysis of the *kianda*, termite hills and swampy fields

	pH(HO)	C	N	Ex. Cations				Avail. P (mgP <sub>2</sub> O <sub>5</sub> /g)
				%				
				K	Na	Ca	Mg	
				(meq/100 g)				
I <i>Kianda</i>	7.06	1.87	0.160	1.78	0.35	11.00	3.39	0.001
	6.97	1.83	0.140	0.77	0.82	8.59	3.39	0.001
	6.39	0.45	0.040	0.44	0.05	1.96	0.48	0.025
	6.14	2.39	0.210	2.31	0.05	8.66	2.85	0.003
II Termite hills	7.79	1.22	0.110	1.62	0.05	11.59	1.28	0.031
	7.90	1.74	0.130	1.07	0.05	32.00	2.79	0.360
	8.04	1.46	0.130	0.98	0.05	20.80	1.71	0.058
III Swampy fields	6.88	0.26	0.027	0.15	0.24	0.99	0.33	0.023
	8.17	0.61	0.056	0.28	0.15	4.81	0.39	0.057
	6.10	0.85	0.075	0.93	0.05	1.50	1.13	0.008
	6.80	0.97	0.081	0.81	0.05	5.25	0.85	0.300

The results of soil analysis show that while some of the *kianda* are fertile (table 12), others are not. The *kianda* represent a very important growing area in the lower lands during the dry season.

People can grow cowpeas in the *kianda* in August and September, a time when they cannot be grown in ordinary fields. The size of the larger *kiandas* is ten are while the smaller ones are from one to two are (Plate 10).

The destruction of *kiandas* from tampering with the rivers through the building of dams, etc., could present a serious threat to the people of the this area and it is therefore necessary to take the *kianda* into account when changing the geography of the rivers.

#### c. Termite hills

It is known that the water condition of the soil of the termite hills is very good and the soil is more fertile than that of ordinary fields. The results of soil analysis show that most termite hills are very fertile, and calcium and potassium in particular are more abundant than in ordinary field (Table 12).

The pH value is also slightly higher, seven to eight in most termite hills. Crops are rarely planted near the top of the termite hills. The termite hills are cultivated to about two thirds of their height since water evaporation from the soil is very high near the top of hills and the salinity of the soil therefore increases, causing unfavorable conditions for plant growth. The termite hills used for the growing of crops are limited to those found in the fields.

There are no termite hills in the upper lands. They are found only in the lower lands. The number of termite hills decreases where the soil is sandy, as in areas such as Mavuria.

Among the areas surveyed the greatest number of termite hills were located in Gachoka, Kithunthii and Mbita.

The crop most commonly grown on the termite hills is *Dorichos* beans. *Dorichos* beans, which require very fertile soil, grow well on these hills. As shown in plate 11, the farther *Dorichos* beans are planted from the termite hills, the worse they grow. Frequently, people use the termite hills for the growing of *kikuyu onions*.

Generally farmers use the termite hills which are at least three years old, although in rare cases they use those of only one year. The months for sowing and planting on the termite hills are April and sometimes October. There appears to be no problem of termites eating the crops. In the rainy season termites go up toward the top of the hill, but in the dry season they remain down below. Therefore that is the best season for growing the crops.

#### d. Swampy fields

Mavuria in the lower lands, there are few *kianda* and termite hills. One of the places where vegetables are grown in this area is the swampy areas of the common fields. It is not known why swampy fields exist in the midst of these dry fields. The swampy fields are called '*kithithinia*' (the areas of green plant), '*saba*' (Plate 12).

The results of soil analysis in the swampy fields show that the content of calcium there is higher than in the common fields (Table 12).

*Sukuma*, *kikuyu onions* and other vegetables are grown in the swampy fields. The size of these fields is not very large, generally measuring about one hundred square meters.

These fields are very small, but they are very important for the growing of vegetables in the dry areas.

### IV. Damage from the '*kiriti*' (parasite) and scales

#### a. The occurrence of *kiriti* and its damage

In Mauuria, Kithunthiri and Mbita of the lower lands the damage from *kiriti* is a

Table 13. The soil analysis of infected with *kiriti* and not infected

Area	Condition of sampling field and farmer No.	pH (H <sub>2</sub> O)	C N		Ex. Cations					Avail. P (mg P <sub>2</sub> O <sub>5</sub> /g)
			%		C/N	K	Na	Ca	Mg	
Kithunthiri										
I (No. 21 farmer)	Field without <i>kiriti</i>	6.60	0.45	0.042	10.7	0.52	0.05	1.16	0.44	0.025
	with <i>kiriti</i>	6.22	0.40	0.033	12.1	0.29	0.05	1.19	0.25	0.014
II (No. 27 farmer)	Field without <i>kiriti</i>	7.06	0.57	0.052	10.9	0.29	0.05	2.76	0.34	0.050
	with <i>kiriti</i>	7.03	0.44	0.038	12.0	0.30	0.05	2.92	0.56	0.120
III (No. 31 farmer)	Field without <i>kiriti</i>	6.40	0.45	0.043	10.4	0.39	0.05	1.71	0.44	0.014
	with <i>kiriti</i>	6.36	0.042	0.042	10.0	0.38	0.05	1.58	0.48	0.001
Mubita										
I (No. 24 farmer)	Field without <i>kiriti</i>	6.26	1.00	0.092	10.8	0.77	0.05	3.75	1.21	0.037
	with <i>kiriti</i>	6.73	0.89	0.081	10.9	0.84	0.05	3.98	1.25	0.050

very serious problem of the growing of cowpeas (Plate 13). The scientific name of *kiriti* is *Alectro orokanochooides*.

In some fields of Mavuria as much as fortyfive percent of the cowpea crop was attacked by *kiriti* during the growing season while this figure reached eighty percent in Kithunthiri, *kiriti* have been present since ancient times. The damage from *kiriti* is less in the new fields than in the old ones. Damages from the parasites has increased with continued cultivation of cowpeas in the same fields. *Kiriti* appears in greater numbers during the long rainy season than in the short rainy season. They also do serious damage in the sandy fields.

*Kiriti* appears the cowpeas flower, and are found in greater numbers in the fields of pure stands of cowpeas than in those of mixed cropping.

Some farmers told us that the number of *kiriti* in the fields mixed with maize is greater than in those mixed with millet. However, *kiriti* rarely appear on termite hills. At this point no method of preventing infestation has been discovered. Some farmers told us that the utilization of organic manure in the fields helps reduce the damage by *kiriti*.

The results of soil analysis in fields infected with *kiriti* and those which are not are shown in table 13. The results show that there is no relationship between the occurrence of *kiriti* and fertility of the soil.

#### b. Damage from scales

Crop damage from scales is higher in the upper lands than in the lower lands. Scales are called '*kathua*' in the native language.

It is said that the damage from scales increased immediately after the introduction of coffee to this area, that is, in the 1930's in the upper lands.

Scales do serious damage to coffee, *Dorichos*, yams etc. Before the introduction of coffee to this area *Dorichos* were widely cultivated, but they are now rarely grown in the upper lands. According to the farmers, the growing of *Dorichos* and yams became increasingly difficult three years after coffee was introduced.

Before the introduction of coffee, the main crops in the upper lands were millet, yams and *Dorichos*. At that time the long rainy season was called '*njavi mbura*', which

means 'Dorichos season', and the short rainy season was called 'mbura mwere', which means 'millet season'. The damage from scales is more serious during the short rainy season than during the long one.

The damage from scales to yams is so severe in Kangaru of the upper lands that people can scarcely grow them (Plate 14).

It is a serious problem for the people in the upper lands that the traditional food crops cannot be grown due to the introduction of foreign crops. One possible method of controlling scales might be the introduction of their natural enemies. At any rate it is urgently necessary to survey the present progression of damage by scales. As to the avoidance of damage from scales, people control the scales by scattering ash at the root of the yams or applying fowl droppings to them.

In this survey we cannot clarify scientifically the positive effects of these procedures on scales. However, the farmers told us that these methods work well in controlling of scales.

## V. Conclusion

The production of vegetables in the semiarid regions is very different from that in the humid tropical regions.

First of all, fewer kinds of vegetables are grown in the semiarid regions than in the humid tropical regions. Next, the production of vegetables which can be stored is greater in the semiarid regions. In the semiarid regions which we surveyed during our stay a large number of *mutanga* were grown. In the Decan plateau of India, which is very similar in climate to the semiarid region of Kenya, nonsweet melons and ash gourds are cultivated instead of *mutanga* in India, but in both cases these fruits are ones which can be stored for long periods. There are many kinds of vegetables grown both in the Decan plateau and in Kenya which can be, so to speak, 'stored' on the plant. That is, the leaves can be gathered daily from the plants for a period of months. *Sukuma* and cowpeas are examples of such vegetables in Kenya.

In the Decan plateau the growing of pigeon peas and pumpkin corresponds to that of *sukuma* and cowpeas in Kenya in this characteristic of the vegetable being 'stored' on the plant.

The production of vegetables from the western world is increasing all over the globe, and this tendency can be seen in the Embu district as well. But growing of vegetables from the West is very difficult in the tropical regions, since the vegetables are subject to damage from insects and diseases. Therefore it might be a good idea to establish a method of crop rotation centering around traditional crops.

It is also, of course, necessary to insure the availability of water for irrigation in vegetable production.

As extensive irrigation projects are economically unfeasible at this time, I believe at this point the greatest efforts should be put toward the preservation of current soil conditions.

The data of soil analysis obtained during the course of this survey is very useful in studying methods of preserving soil conditions in this area, particularly in the lower lands.

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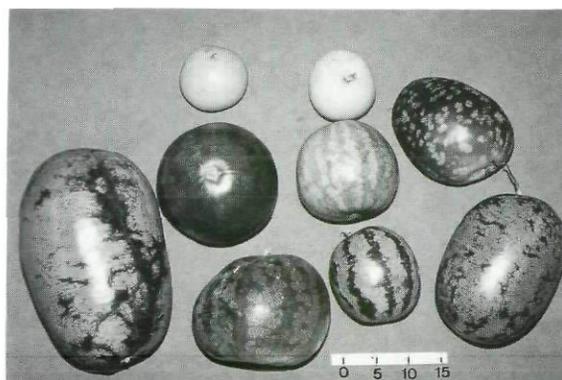
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Plate 1 Cowpea leaves sold at the local market



Plate 2 a : Growing of *mutanga* in the field



b : Various cultivars of *mutanga*



Plate 3 Growing of *sukuma* in the lower lands



Plate 4 *Coro (Brassica carinata)*



Plate 5 Growing of *sukuma* in the upper lands

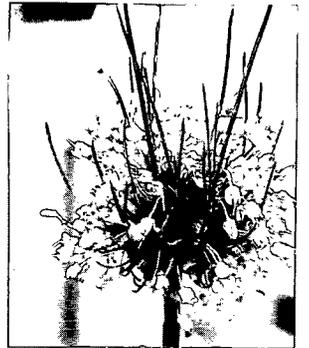


Plate 6 a : *Kikuyu onions* sold in the local market

b : Growing of *kikuyu onions*

c : Bulbils and flowers of *kikuyu onion*



Plate 7 *Mbumbu* (lima beans, *Phaseolus lunatus*)

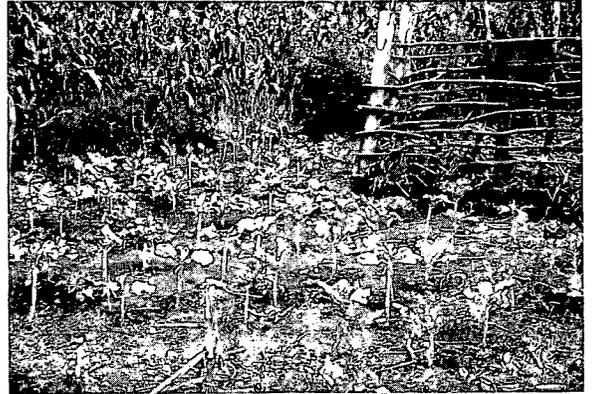


Plate 8 a : Growing of *shungru*

b : The fruit of *shungru*



Plate 9 a : Homestead in the lower lands



b : Homestead in the upper lands

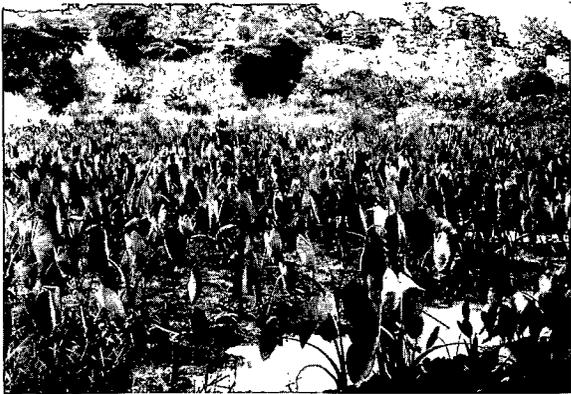


Plate 10 a : The large *kianda*



b : The small *kianda*

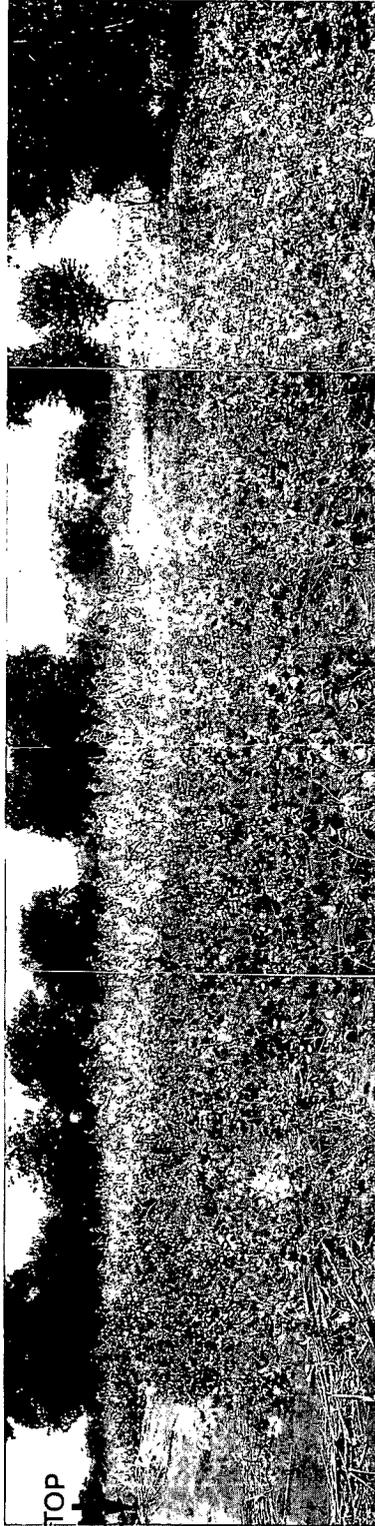


Plate 11 Cultivation of *Dorichos* on the termite hill.  
Growing is good near the termite hill



Plate 12 Growing of tobacco in the swampy field



Plate 13 *Kiriti* is parasitic on cowpeas



Plate 14 Yam damaged by scales

### A 3. ECONOMIC STRUCTURE AND AGRICULTURAL PRODUCTION OF FARM HOUSEHOLDS

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#### I. Introduction

After colonization at the end of the last century, the Kenyan economy has changed greatly. The Embu District is no exception. This district was not included in the so-called "White High Land" area, but as parts of neighboring lands—Kikuyu and Kamba lands—were taken over by the colonial government, both the Embu and Mbere peoples have been affected indirectly by the formation of the White High Land. Compulsory labour, migration of labour, and collection of taxes such as the hut tax and pole tax have directly or indirectly changed the traditional pattern of economic life.

The extension of administration by the colonial government has changed the traditional rural society. Establishment of health facilities and the end of tribal warfare have caused an increase in the African population. The Swynnerton Plan, a development policy for African agriculture in the mid 1950's, has also drastically changed the traditional subsistence economy and agriculture. Land consolidation and registration has had a marked impact on the traditional land tenure system. The lower areas—formerly the Mbere Division—of the Embu District were selected as one of six divisions for the experimental Special Rural Development Plan (SRDP), which started in 1970. The main object of the plan was to increase farm incomes by encouragement of more efficient production of cotton, tobacco, and other minor crops such as castor, Katumani maize, and Mexican 142 beans. Group ranches were stressed for improvement of livestock and beekeeping was also suggested. The subsistence economy in the traditional society has changed in the Embu District during the past fifteen years.

The aims of this chapter are to describe the economic structure of farm households, and to consider the relationship between agriculture now and economic life. It is important to analyze current agriculture from the point of view of farming systems. This chapter analyzes what kinds of economic factors limit increases in agricultural productivity, and how current agricultural production restricts the economic behaviour of farm households. This field survey was the first of its kind to be done for this region, so analysis here is mainly cross-sectional. Based on time-series analysis, a study of the economical and agricultural changes in the Embu District will be left as next step.

Table 1. Number of farm households in the survey  
(June 16~August 31, 1985)

Division	Location	Sublocation	Sample number
Gachoka	Mavuria	Kithunthiri	13
"	"	Mavuria	16
"	"	Mbita	21
"	Mbeti	Gachoka	12
"	"	Kangaru	6
Runyenje' s	Kagaari	Gitare	4
"	Ngandori	Kiriari	2
Total			74

In addition to the 44 farm households mentioned in Chapter 1, for this chapter another 30 farm households were chosen from three sublocations: Mbita, Kithunthiri, and Mavuria of the Mavuria Location (Table 1). All work is assumed to be done with care. However, some data that seem unrealistic have been excluded from analysis. In this chapter, the total of 74 farm households surveyed were divided into two areas for convenience: 1) upper areas where coffee and tea are the main cash crops on most farms, and 2) lower areas where cotton and tobacco are the main cash crops on some farms. Finally, this chapter will examine policy implications for agricultural and rural development in the near future, based on the results of the study.

## II. Income structure of farm households

Income as mentioned here means the total income obtained from the economic activities of farm households for the one year before the day when I visited the farm households for the survey. This survey was done over about two months from July to August, 1985. The period of the survey thus included both the long rains of 1984 and the short rains of 1985. The area surveyed suffered serious damage from drought, especially in the long rain season. Some farm households in the lower areas had no harvest.

### (1) Total income

Table 2 lists the income of farm households. The mean total income of 70 of the farm households was about 14,000 KShs. per year. The four other farm households were excluded because the farmers could not report the amount of income to us. This mean income was thus about 1,200 KShs. per month. The Economic Survey 1984, an economic white paper of Kenya, pointed out that the mean monthly income of employees working for wages was 5,804 KShs. in the private sector, 1,978 KShs. in agriculture and forestry in the private sector, and 6,916 KShs. in the public sector in 1984. That Survey reports that the minimum wage per month was 3,140 KShs. in the upper class, 1,169 KShs. in the middle class, and 612 KShs. in the lower class. Accordingly, the mean income per month of the farm households surveyed was slightly lower than for workers in agriculture and forestry in the private sector, and nearly equal to the minimum wage of the middle class. Because the income of the farm households surveyed here did not include the value of food produced for household consumption on the farm, the real income was higher. The coefficient of variation was 1.54 and dispersion was wide (Tables 3 and 4). The highest income reported was 155,580 KShs., which was three times of the mean income in the farm households surveyed. The farm was in the lower areas. The lowest income was 420 KShs., 3% of the mean. The farm households surveyed included eight headed by school teachers who farm part-time. All of them were in the lower areas. The mean income excluding these households was 12,040 KShs., about 1,000 KShs. per month (Table 5).

In the upper areas, the highest income was 51,156 KShs., the lowest 1,700 KShs. and the mean 17,194 KShs; here, the sample number was small (12 households). In the lower areas, the highest income was 155,580 KShs., the lowest 420 KShs., and the mean 13,418 KShs. The coefficient of variation was 0.87 for the upper areas and 1.7 for the lower areas, so the dispersion of income in the lower areas is wider than in the upper. The mean income of the upper areas was 1.3 times that in the lower areas, so households in the upper areas were richer than in the lower areas in terms of money. When comparison was done with teachers' households excluded, the upper areas had a mean income 1.6 times that in the lower areas.

The income as mentioned here means agricultural income plus off-farm income. In all areas, a mean of 34.4% of income was agricultural and 65.6% of income was off-farm. Excluding the teachers' households, 44% of income was agricultural and 56% of

Table 2. Agricultural and off-farm income

	Agricultural income										Off-farm income (B)	Total income (A) + (B)
	Upland crops	Tree crops	Livestock	Other			Total (A)					
				Beekeeping	Charcoal	Timber						
Total	Sum (KShs.)	139,043.30	115,171.50	13,807.00	1,150.00	3,300.00	339,118.50	645,470.00	984,588.50			
	Number	24	44	11	2	5	64	40	70			
Upper areas	Mean (KShs.)	5,793.50	2,617.50	1,255.20	575.00	660.00	5,298.70	16,136.75	14,065.50			
	% *	(40.9)	(34.0)	(4.1)		(1.0)	(34.4)	(65.6)	(100.0)			
Lower areas	Sum (KShs.)	120,198.30	29,471.50			500.00	157,431.80	48,900.00	206,331.80			
	Number	11	8			1	11	5	12			
Total	Mean (KShs.)	10,927.10	3,638.90			500.00	14,312.00	9,780.00	17,194.30			
	% *	(76.4)	(18.7)			(0.3)	(76.3)	(23.7)	(100.0)			
Total	Sum (KShs.)	18,845.00	85,700.00	13,807.00	1,150.00	2,800.00	181,686.70	596,570.00	778,256.70			
	Number	13	36	11	2	4	53	35	58			
Total	Mean (KShs.)	1,449.60	2,380.60	1,255.20	575.00	700.00	3,428.05	17,044.90	13,418.20			
	% *	(10.4)	(47.2)	(7.6)	(0.6)	(1.5)	(23.3)	(76.7)	(100.0)			

Note \*: This means percentage to Total income. In the parenthesized part, the number mean percentage to Total Agricultural income.

Table 3. Income variance in farm households

	Total households surveyed			Excluding teachers' households	
	All areas	Upper areas	Lower areas	Upper areas	Lower areas
<b>Total income</b>					
Number	70	12	58	50	62
Mean (KShs.)	14,065.50	17,194.30	13,418.20	10,802.20	12,039.40
Variance	4.69	2.22	5.17	5.34	4.80
Standard deviation	21,650.30	14,892.20	22,746.20	23,115.40	21,913.60
Coefficient of variation	1.54	0.87	1.70	2.14	1.82
<b>Agricultural income</b>					
Number	64	11	53	47	58
Mean (KShs.)	5,298.70	14,312.00	3,428.00	3,630.00	5,655.90
Variance	6.89	2.25	1.60	1.76	7.45
Standard deviation	8,299.30	15,010.90	4,005.97	4,190.03	8,631.19
Coefficient of variation	1.57	1.05	1.17	1.15	1.53
<b>Off-farm income</b>					
Number	40	5	35	27	32
Mean (KShs.)	16,136.80	9,780.00	17,044.90	13,685.20	13,075.00
Variance	5.65	4.16	6.33	7.36	6.50
Standard deviation	23,765.10	6,447.40	25,158.00	27,136.60	25,498.20
Coefficient of variation	1.47	0.66	1.48	1.98	1.95

income was off-farm. It was striking that although the areas surveyed were rural, the areas had more off-farm income than agricultural. However, the proportions in the upper areas were 76.3% agricultural income and 23.7% off-farm income. Agricultural productivity in the upper areas was comparatively high. The proportions in the lower areas were 23% off-farm income, which was surprising. Excluding the teachers' households, the proportions were 32% agricultural income and 68% off-farm income. The results suggest that the lower areas depend on off-farm income because of the low agricultural productivity of the area.

## (2) Agricultural income

Agricultural income as mentioned here means income from the sale upland crops, tree crops, livestock, and other farm products and from the sale of things collected on one's own land. Agricultural income also includes income generated from the making of charcoal, and timber (Table 6). Products consumed by the household are not included here, because it would have been difficult to collect data on their quantities.

The income from different enterprises was as follows, in descending order: tree crops, livestock, upland crops, and other. The income from tree crops and livestock accounted for about three-quarters of the total income. The level of commercialization of the upland crops was very low. Dispersion of agricultural income was very wide (Table 7). Each area had a different structure of agricultural income. As mentioned above, the agricultural income in the upper areas accounted for 80% of the total income, and was 76.4% from tree crops and 18.7% from livestock. The main crop were coffee and tea, which strongly support the economy of farm households in the upper areas. Livestock production also contributed to the agricultural economy of these areas, as did

Table 4. Distribution of total income

KShs.	Total income		
	Upper areas	Lower areas	All areas
0~ 2,000	1	12	13
2,000~ 4,000	0	12	12
4,000~ 6,000	2	8	10
6,000~ 8,000	0	8	8
8,000~10,000	1	3	4
10,000~12,000	2	0	2
12,000~14,000	0	3	3
14,000~16,000	0	1	1
16,000~18,000	1	1	2
18,000~20,000	1	1	2
20,000~22,000	1	1	2
22,000~24,000	1	1	2
24,000~26,000	0	3	3
26,000~28,000	0	0	0
28,000~30,000	0	1	1
30,000~32,000	0	1	1
32,000~34,000	1	0	1
34,000~36,000	0	0	0
36,000~38,000	1	1	2
38,000~	1	3	4

Table 5. Agricultural and off-farm income excluding eight teachers' households

	Agricultural income	Off-farm income	Sum
All areas			
KShs.	328,043.00	418,400.00	746,443.00
Share (%)	43.9	56.1	100.0
Mean (KShs.)	5,291.00	6,748.40	12,039.00
Lower areas			
KShs.	170,611.20	369,500.00	540,110.70
Share (%)	31.6	68.4	100.0
Mean (KShs.)	3,412.2	7,390.0	10,802.2

tree crops. A major income source in the livestock sector was milk production. Unlike in the lower areas, as will be pointed out later, the agricultural land area per household was small, and the price of land high. Because of high opportunity cost of land, the land was not used intensively for grazing in most of the upper areas. Exotic high-grade dairy cows have been introduced recently, and are kept in cowsheds, and sometimes grazed in small pastures. The fodder is mainly grass and crops grown on the farmer's own land. When there is not enough self-produced fodder, it is purchased.

Compared with the upper areas, the agricultural income in the lower areas was low, only 24% of that in the upper areas. Probably the low agricultural productivity and income are due to the severe natural conditions in the lower areas. The dispersion of

Table 6. Crops, livestock, and other products sold.

	All areas (74)	Upper areas (12)	Lower areas (62)
<b>Food crops</b>			
Maize	8	5	3
Millet	2	0	2
Beans	1	1	0
Chickpeas	1	0	1
Cow peas	1	0	1
Green gram	2	0	2
Potatoes	2	2	0
Tomatoes	1	0	1
<b>Industrial crops</b>			
Coffee	10	10	0
Tea	4	4	0
Cotton	40	0	40
Sisal	1	0	1
Tobacco	1	0	1
Other	1	1	0
<b>Tree crops</b>			
Avocados	2	2	0
Bananas	4	3	1
Guavas	1	0	1
Lemons	4	1	3
Macadamia nuts	1	1	0
Mangoes	12	2	10
Oranges	4	0	4
Passionfruit	1	1	0
<b>Livestock</b>			
Oxen	22	2	20
Cows	20	4	16
Goats	22	0	22
Chickens	6	0	6
Milk	3	3	0
<b>Others</b>			
Charcoal	2	0	2
Timber	6	1	5
Tree seedlings	1	0	1
Beekeeping	13	0	13
Handicrafts	1	0	1

agricultural income in the areas was not great (Table 7).

Unlike in the lower areas, farmers in the upper areas did not sell honey or charcoal, and timber was sold by only one household. Beekeeping was not observed in the upper areas, but some households could have sold charcoal and timber available to them. The survey showed one farm household that was making charcoal for its own use and sale in the upper areas.

The main upland crops were maize, beans, and cow peas. These crops were sometimes

Table 7. Distribution of agricultural income

KShs.	Agricultural income		
	Upper areas	Lower areas	All areas
0~ 1,000	0	12	12
1,000~ 2,000	1	13	14
2,000~ 3,000	0	5	5
3,000~ 4,000	1	5	6
4,000~ 5,000	1	3	4
5,000~ 6,000	1	3	4
6,000~ 7,000	0	2	2
7,000~ 8,000	0	0	0
8,000~ 9,000	0	0	0
9,000~10,000	1	1	2
10,000~11,000	1	0	1
11,000~12,000	0	1	1
12,000~13,000	0	0	0
13,000~14,000	0	0	0
14,000~15,000	0	0	0
15,000~16,000	0	1	1
16,000~17,000	1	0	1
17,000~18,000	0	1	1
18,000~19,000	0	0	0
19,000~	2	1	3

sold, but few farmers offered them such as bananas, mangoes, and avocados were also sold, but in small amounts only.

The income from different enterprises in the lower areas was as follows : livestock (47.2%), upland crops (32.7%), tree crops (10.4%), beekeeping (7.6%), timber (1.5%), and charcoal (0.6%). The kinds of livestock sold in the one year of the survey were cattle, goats, and chickens in the lower areas, and these were sold by 36 farm households (over 60% of all households). The numbers of households that sold particular kinds of livestock were as follows, in descending order (Table 8) : goats, oxen, cows, and chickens. Livestock enterprises operated under special conditions during the survey period. The long rains in 1984 in particular were insufficient, and there was a serious drought. Crops gave almost no yield and some livestock, mostly cattle, died because of the shortage of water and feed. People sold large livestock to get money to purchase food. In the period immediately after such a serious drought, the price of cereals rises sharply to several times the price in a normal years, but the price of livestock goes down. Thus, although data from a normal year are not available for comparison, it is likely that the livestock income in the survey period was much more than normal. In years without drought, farmers rarely sell cattle except when in urgent need of money (for example, for school fees), but sell small livestock, such as goats, sheep, or chickens.

Of upland crops in the lower areas, cotton was sold by more households than any other crop (40 households, and 65% of all total households). Other upland crops such as maize, millet, and green gram were also sold, but only small amounts. Ten farm households sold mangoes, four sold oranges, and three sold lemons. The "other" kinds of agricultural income mentioned in the tables refers to honey, charcoal, and timber.

Table 8. Distribution of livestock income

KShs.	Livestock income		
	Upper areas	Lower areas	All areas
0~ 500	0	7	7
500~ 1,000	0	7	7
1,000~ 1,500	1	7	8
1,500~ 2,000	2	0	2
2,000~ 2,500	0	4	4
2,500~ 3,000	0	0	0
3,000~ 3,500	0	2	2
3,500~ 4,000	0	2	2
4,000~ 4,500	1	4	5
4,500~ 5,000	0	0	0
5,000~ 5,500	0	0	0
5,500~ 6,000	0	0	0
6,000~ 6,500	0	2	2
6,500~ 7,000	0	0	0
7,000~ 7,500	0	1	1
7,500~ 8,000	0	0	0
8,000~ 8,500	0	0	0
8,500~ 9,000	0	0	0
9,000~10,000	0	0	0
10,000~	0	1	1

These are gathered, not produced. It was of interest that persons in the lower areas were getting money from such activities. Honey gathering has been a traditional subsistence activity from early times, not a cash-earning activity. One farmer in a dry marginal area was growing high-grade maize using chemical fertilizer, bought with funds obtained from honey-gathering.

Only two farm households reported selling charcoal in this survey. However, in general, there seemed to be many households selling charcoal. One serious problem in Kenya is the concentration of population into urban areas, in particular, in Nairobi. The price of charcoal is high because of demand, and the supply areas are distant from Nairobi. Charcoal production is profitable in areas far from the city in spite of the high transport costs. To further encourage charcoal production, expansion of agricultural production cannot be expected in marginal dry land such as in the lower, and cash is needed for payments such as purchases of factory goods and educational expenses in the development of a monetary economy. Therefore, persons living in the lower areas who do not have off-farm employment tend to depend increasingly on gathering activities such as beekeeping, charcoal, and timber production as their major income source. Farmers who depend on gathering activities are usually aged and without much education. They cannot easily obtain non-farm income.

### (3) Off-farm income.

Off-farm income as mentioned here means the income obtained from any economic activities, of any variety, carried out elsewhere than one's land. Off-farm income accounted for about 65% of the total income, and was obtained by 57% of all farmers in all areas surveyed (Table 9 and 10).

It seemed that the dependence for income on agriculture in the upper areas was higher

Table 9. Distribution of off-farm income

KShs.	Off-farm income		
	Upper areas	Lower areas	All areas
0~ 2,000	0	8	8
2,000~ 4,000	1	3	4
4,000~ 6,000	0	1	1
6,000~ 8,000	1	2	3
8,000~10,000	0	2	2
10,000~12,000	0	0	0
12,000~14,000	0	2	2
14,000~16,000	0	0	0
16,000~18,000	1	3	4
18,000~20,000	1	0	1
20,000~22,000	0	1	1
22,000~24,000	0	2	2
24,000~26,000	0	1	1
26,000~28,000	0	0	0
28,000~30,000	0	2	2
30,000~32,000	0	0	0
32,000~34,000	0	0	0
34,000~36,000	0	0	0
36,000~38,000	0	0	0
38,000~	0	4	4

Table 10. Main job of head of household

	Upper areas	Lower areas	All areas
Farming	9	43	52
Other	3	19	22
Teacher	0	8	8
Manual labourer	1	3	4
Shopkeeper	0	3	3
Local official	1	1	2
Vicar	0	1	1
Businessman	0	1	1
Matatu operater	1	0	1
Skilled labourer	0	1	1
Other Farm worker	0	1	1
Total number	12	62	74

than in the lower areas, and the relative proportion of off-farm income was low. However, farmers with only small amounts of land for agricultural purposes could not make their living by farming alone. Only one farm household in the upper areas had income from a secondary job (Table 11). The main job of all of the wives was farming, and none of the wives of householders was farming, and none of the wives had secondary jobs (Table 12).

The lower areas had a different income structure from the upper areas. When the eight households headed by teachers in the lower areas are excluded from analysis,

Table 11. Secondary job of head of household

	Upper areas	Lower areas	Total
None	8	36	44
Farming	3	15	18
Other	1	11	12
Manual labourer	0	3	3
Other farm worker	0	2	2
Businessman	0	2	2
Tailor	0	1	1
Ploughman	0	1	1
Mason	0	1	1
Watchman	0	1	1
Preacher	1	0	1

Table 12. Main and secondary job of wife of householder

	Upper areas	Lower areas	All areas
Main			
Farmer	12	57	69
Teacher	0	2	2
Other	0	1	1
Secondary			
None	12	54	66
Farmer	0	3	3
Manual worker	0	2	2
Retailer	0	1	1

the proportion of off-farm income decreases from 76% to 68%, which is still a relative high dependency on off-farm income. The main job of 70% of the householders was farming. Of the seven householders who were engaged in off-farm activities as their main job and were working away from home, three were teachers and four were not.

The secondary job of the both householder and his wife is important. In the lower areas, 11 of the 43 households had heads who had farming as their main job and who also had a secondary job. These secondary jobs were unstable, being farm work and manual labour, with the exception of two householders engaged in business and one householder who worked as a preacher. When the wife of the householder had a secondary job other than farming, the work was manual labour (two) and retail sale (one).

The survey showed that households in the lower areas seemed to depend on off-farm income because of the low agricultural productivity. The lower areas have been well-known as areas of labour migration to Nairobi and neighbouring towns from early days. Even today, the trend continues (Table 13). The advent of unstable secondary jobs is of interest. In the serious drought of 1984, members of some farm households went to upper areas and other districts to work and get food. This is one countermeasure to a drought.

Households are classified as one of four kinds of farm from the point of view of income in Table 14. In all areas taken together, full-time and second-class had a high percentage of full-time farms (58.4%). In the lower areas, the second-class part-time farms were most common (44.9%).

Table 15 shows the share of income in the upper and lower areas. The proportion of households in the upper areas is smaller than in the lower areas, but share of total and agricultural income is bigger; the share of off-farm income is not. There seemed to be an earning differential between the upper and lower areas.

### III. Economic Structure of Agricultural Production

#### (1) Land tenure and farm size

Kenya has promoted a land policy encouraging private ownership since before independence. In the Embu District as well, a land registration program has been carried out gradually. The program had been completed in the upper areas at the time of the

Table 13. Non-farming jobs of householders

Household No.	main job	Secondary job	Kinds of job	at home	not at home	Place of work	Working days	Wage per day	Total income (KShs.)	Salary per month (KShs.)	Tools
1	○		Shopkeeper	○	○	Kiambere	300	15	180		Panga, Jembe
3		○	Manual labour	○			12		350		
4		○	Tailor				35				
5	○		Manual labour		○	Kiambere	300			1,000	
7	○		Teacher		○	Siakago	270			1,800	
14		○	Ploughman	○			150		150		Plough
15		○	Manual labour	○			20	10	200		Panga
16		○	Mason	○			120	30	3,600		General Tools
17		○	Farm worker	○			290			300	Motor cycle
18	○		Vicar	○			252			1,500	Mill, Car
21		○	Businessman	○						9,000~12,000	
22		○	"	○			120			3,000	
23		○	Manual labour	○			30	10	300		Jembe
31		○	Ploughman	○			6		720		Plough Oxen
34		○	Watchman	○			90			560	
38		○	Manual labour	○		Kangaru	300	20	6,000		Car
39	○		Matatu operation	○			300			800	
41	○		Teacher		○	Mutus	162			2,000	
44	○		Local official		○	Isiolo	300			1,860	
45	○	○	Preacher	○		Kieni	240			1,600	
48	○		Local official	○		Embu	96			3,000	
51	○		Teacher	○		Mbita	240			2,000	
53	○		Teacher	○		Nyangwa	240			2,000	
54	○		Drycleaner	○		Nyayuki				2,400	
55	○		Teacher	○		Mbita	260			2,350	
57	○		Storekeeper	○		Nairobi	279			800	
58	○		Manual labour	○		Kiriguya	210	30	6,300		Panga, Spade
60	○		Farm worker	○						600	
63	○		Teacher	○			240			1,400	
64	○		Teacher	○			198			2,000	
65	○		Labourer	○		Mhita	250			600	Bicycle
73	○		Shopkeeper	○			210				
74	○		Businessman	○						3,000	

Note: Household No. 34, 38, 44, and 45 were in the upper areas and the others are in the lower areas.

Table 14. Farm household numbers by kind of income (%)

Farm	All areas	Upper areas	Lower areas
Full-time	29 (41.4)	7 (58.4)	22 (37.9)
Semi-full-time	6 (8.6)	1 (8.3)	5 (8.6)
1st-class part-time	5 (7.1)	0 (0.0)	5 (8.6)
2nd- " "	30 (42.9)	4 (33.3)	26 (44.9)
Total	70 (100.0)	12 (100.0)	58 (100.0)

Note:  $r$  (ratio of part time) = (off-farm income/total income) × 100.

Full-time  $r=0$ ; semi-full-time,  $0 < r < 10$ ; 1st-class part-time,  $10 < r < 50$ ; and 2nd-class part-time,  $50 < r < 100$ .

Table 15. Share of income between Upper and Lower areas (%)

	Upper areas	Lower areas	All areas
Number of Households	17.1	82.9	100.0
Total income	21.0	79.0	100.0
Agricultural income	46.4	53.6	100.0
Off-farm income	7.6	92.4	100.0

Table 16. Land Cultivated per household (ha, %)

Location	Sublocation	Arable land	Grazing and bushland	Fallow land	Home-stead	Total
Ngandori and Kagaari	Gitare and Kiriari	1.88 (85.5)	0.04 (1.8)	0.20 (9.1)	0.08 (3.6)	2.20 (100.0)
Mbeti	Kangaru	2.52 (94.0)	0.08 (3.0)	0.0 (0.0)	0.08 (3.0)	2.68 (100.0)
"	Gachoka	3.12 (33.6)	5.72 (61.7)	0.28 (3.0)	0.16 (1.7)	9.28 (100.0)
Mavuria	Kithunthiri	1.96 (18.3)	8.40 (78.3)	0.20 (1.9)	0.16 (1.5)	10.72 (100.0)
"	Mbita	2.00 (47.5)	1.96 (46.7)	0.12 (2.9)	0.12 (2.9)	4.20 (100.0)
"	Mavuria	2.16 (26.6)	5.64 (69.4)	0.20 (2.5)	0.12 (1.5)	8.12 (100.0)

survey, but was not yet completed in the lower areas, for which the goal was completion in 1985.

Unlike the upper areas, the lower areas do not promote land consolidation projects, because land fragmentation by inheritance is rare. The land of the farms surveyed had all been registered.

Chapter 1 also mentions the cultivated land of the farms surveyed. In addition to those farms of Chapter 1, 30 more households were surveyed in the lower areas. The survey results are shown in Table 16, in which the pattern is similar to that in Table 2 of Chapter 1. The lower the land, the larger the grazing and fallow land per farm household. Also, the lower the land, the more livestock is kept per farm household. There is a connection between the arable land and livestock keeping; manure from the livestock is used for fertilizer. The swidden system is also still used, but only rarely. It is one of system for the restoration of land fertility with a long fallow period. The lower the land, the lower the population density (Table 17). Accordingly, the acreage of

Table 17. Population and land area of surveyed location in 1985

Location	Total Population	No. of families	Size of holding/ha.
Ngandori	49,979	6,247	1.76
Gaturi North and Gaturi	47,102	5,888	2.52
Kagaari	52,374	6,547	2.33
Kyeni	39,402	4,925	2.05
Mbeti	10,862	1,358	16.19
Municipality	20,596	2,575	0.93
Makima and Karaba	28,981	3,623	14.83
Mavuria	31,183	3,898	16.26
Evurore and Kiangombe	27,582	3,448	12.10
Nthawa	20,769	2,596	14.74
Total	328,830	41,105	

Notes : 1) Population figures adjusted for 1985 at an assumed rate of increase of 3.5% from the 1979 figures as follow :

$$\text{Formula is } P \left(1 + \frac{3.5}{100}\right)^6$$

P=population in the 1979 Census

2) The size of a family is assumed to be eight persons.

3) Ministry of Agriculture, *Emhu District Work Programme for July 1982 to June 1983*, Nairobi, Dec. 1981

Table 18. Variance in the amount of arable land

	All areas	Upper areas	Lower areas
Average (ha)	2.24	2.21	2.24
Variance	12.93	4.80	14.50
Standard deviation	3.6	2.19	3.81
Coefficient of variation	0.64	0.4	0.68

land owned per household is larger. There was, however, a large difference in arable land acreage in the upper and lower areas. The reason is that it is not possible to cultivate large amounts of land with hand tools by family labour in the lower areas. Also, because of the low level of agricultural productivity, there is a tendency to depend on off-farm income. There was large variance in land-holding acreage (Table 18). This was the result of land concentration by wealthy families and local political leader in the days of land registration.

In the upper areas, the price of farm land was high, from 50,000 to 100,000 KShs. (600,000-1,200,000 Japanese Yen) per hectare, and in the lower areas, it was 1,250 to 45,000 KShs. (15,000-540,000 Japanese Yen). There was considerable variance in price in both the upper and the lower areas. Table 19 shows the mean price of agricultural land per hectare. The price in the upper areas (Gitare, Kiriari, and Kangaru sub-locations) was about ten times that in the lower areas.

The existence of a land lease system noteworthy in the lower, although it is not clear that the system appeared because of the unfair land holding system after land registration. In the Gachoka sublocation of the lower areas, one of the farmers surveyed had never owned any land ; his entire farm was rented. However, he had not paid any of the rent in cash or in kind. Such a land lease system was seen in each area. Of the farm surveyed, one household head in the upper areas and eight households in the lower areas

Table 19. Mean price of agricultural land per hectare

Sublocation	Price (KShs.)
Gitare and Kiriari	72,915
Kangaru	78,333
Gachoka	16,250
Kithunthiri	8,125
Mbita	7,025
Mavuria	8,100

were renting a total of 16.2ha of land. Three farmers had leased a total of 2.1 ha of their land. The rent per ha per year was 750 KShs. in the upper areas and 100 KShs. and 625 KShs. in the lower areas. Of the nine farmers renting, only three were paying rent in cash. The other farmers paid the rent in kind. The transition of the land-holding system from clan to private seem to have caused various socio-economic changes. Unequal land holdings and a few landless farmers have appeared. Kenya has one of the highest rate of population growth in the world. In the near future, fragmentation of farmland and the appearance of landless farmers will probably increase.

The change to a private land-holding system has also drastically changed the land use system from swidden or shifting cultivation to sedentary agriculture. With such land use, investment to primitive land-improvement was seen in the lower areas. One typical method is the terracing of sloping land.

#### (2) Economics of cash crop production

As mentioned above, the main cash crop were coffee and tea in the upper areas and cotton in the lower. In addition to these crops, some kinds of agricultural products produced in excess of need for home consumption are sold, but the quantity is small.

Table 20 shows the proportion of land cropped for cash and food (in the lower areas, tobacco was included as a cash crop, but only one farm was growing it for sale). Whereas 63.5% of all cropped land was used for coffee and tea in the upper areas, cotton and tobacco occupied only 22.3% of the total cropped land in the lower areas. Coffee and tea are seldom consumed by the household itself, so agriculture was much more commercial in the upper areas than in the lower. However, in spite of the high level of commercial activities, farms in the upper areas produced most of the food needed for home consumption. The agricultural productivity of the upper areas is much higher than in the lower because of the relatively abundant rainfall and its reliability. Measures to increase land productivity have been taken by farmers themselves, not always just in response to government policies. High-yield varieties of maize and chemical fertilizers were used by most of the small-scale farmers in the upper areas surveyed here.

Cotton which takes almost one year to mature, occupied 22.3% of the total cropped

Table 20. Proportion of land area cropped for cash and food

	Upper areas		Lower areas	
	Coffee and tea	Food crops	Cotton and tobacco	Food crops
Area (ha)	4.0	2.3	13.2	46.1
%	63.5	36.5	22.3	77.7
Numbers of households	5	6	16	42

Table 21. Crop production

	Maize				Cotton	
	Practice		Area		Practice	
	Pure stand	Mixed cropping	Upper areas	Lower areas	Pure stand	Mixed cropping
Cropped area (ha)	15.2	18.3	1.6	31.9	11.2	1.7
(%)	45.4	54.6	4.8	95.2	86.8	13.2
Households	30	14	5	38	16	3

land at the time of the survey. The same fields are used for mixed cropping or inter-cropping. Pure cotton stands were few.

Mixed cropping and inter-cropping are important agricultural practices not only from the point of view of cultivation technology, but also in terms of farm economics and management. There were 13 main kinds of crops (maize, finger millet, sorghum, bananas, beans, cow peas, green gram, pigeon peas, potatoes, cotton, coffee, tea, and tobacco) planted in either the upper or the lower areas. Minor crops and crops on which data about planted area could not be collected were excluded. Of the main crops, coffee and tea in the upper areas and tobacco in the lower areas were never mixed or inter-cropped with other crops. With these three exceptions, crops were generally mixed or inter-cropped with two to four other crops, although pure stands were sometimes seen. There was more intercropping in the lower areas than in the upper areas.

Table 21 shows the cropping modes of maize and cotton. For maize as a staple crop, 45% in the upper areas and 54.6% in the lower one were grown in mixed cropping and in intercropping.

In the Special Rural Development Program, the major object of agricultural development was the introduction of cash crops and the diffusion of cropping by pure stands for these crops. Pure stands are desirable for the introduction of modern inputs like improved seed varieties and fertilizer, and also to promote early planting. In short, pure stands are promoted by extension agents of the government, because they believe that practice of pure stands is more rational. However, the farmer's choice based on rational judgement is that mixed cropping and intercropping are useful in actual practice. This is of importance thing in consideration of the agricultural development of the lower areas in the future. This point will be discussed below.

(i) Tea (green leaves)

Only four tea-growing farms were included in this survey and the data collected on tea production was not extensive (Table 22). In particular, the farmer's gate price of green leaves per kg differed from farm to farm. For example, the price was 7.6 KShs./kg in Farm No. 43; in other farms, it was between 1.1 and 1.2 KShs. Tea leaves are all marketed to the Tea Marketing Board. It was not possible to check the actual price with the Board, so the price reported by the farmers was in this survey.

The Small Farm Survey of 1978 (Farm Management Handbook by R. Jaetzold and H. Schmidt) reported that the mean area planted with tea per farm was 0.3 ha and that the mean yield per hectare was 4,219 kg, with a maximum of 6,250 kg and a minimum of 900 kg. Judging from these data, the yield on farm No. 43 was high, that on farm No. 47 was extremely low, and that on farm No. 46 was near to the mean. The areas planted were 0.3, 0.5, and 0.6 ha, respectively.

One of the most important agricultural processes in tea growing is the picking of green leaves. Most of the labour input involves picking work, which sometime depends on hired labour. The labour input on farm No. 43 by man-day seemed reasonable, but

Table 22. Economics of coffee and tea production

Household No.	Cost (KShs.)				Quantity sold (kg)	Price /kg (KShs.)	Total income (KShs.)	Net income (KShs.)	Area planted (ha)	Yield /ha (kg)	Pay for per day (KShs.)
	Hired labour	Fertilizer and pesticides	Other	Total							
Coffee (herries)											
33	nil	200.00	100.00	300.00	500	1.00	500.00	200.00			0.10
36	nil	600.00	nil	600.00	4,000	"	4,000.00	3,400.00			17.20
37	nil	920.70	nil	920.70	2,070	"	2,070.00	1,149.30			12.10
38	nil	1,270.00	nil	1,270.00	3,900	"	3,900.00	2,630.00			4.80
42					3,589	3.50	12,561.50				
43	90.00	910.00	300.00	1,300.00	5,000	4.00	20,000.00	18,700.00	0.5	10,000	58.47
44	nil	3,000.00	1,500.00	4,500.00	5,100	3.00	15,300.00	10,800.00	0.4	12,750	14.90
45	1,440.00	1,850.00	600.00	3,890.00	10,080	3.15	31,752.00	27,862.00	0.8	12,600	75.87
46		715.00		715.00	2,000	5.60	11,200.00	10,485.00	0.5	4,000	3.68
Tea (green leaves)											
42	2,400.00	1,160.00	nil	3,560.00	1,604	1.20	1,924.80	320.80			3.90
43	504.00	2,000.00	nil	2,504.00	4,600	7.60	34,960.00	32,960.00	0.5	9,200	111.00
46	nil	100.00	nil	100.00	1,200	1.10	1,320.00	1,220.00	0.3	4,000	0.09
47					290	1.10	319.00		0.6	480	

without data for comparison, it could not be evaluated. On this farm, the income for the labour of an adult man per day was about 110 KShs. If the data were all accurate, tea seems to be a profitable crop. However, the data could not be checked.

(ii) Coffee (berries)

The data collected in this survey on the economics of coffee production have limits to their usefulness because of the small sample number and incomplete data, as in the above section.

The Small Farm Survey of 1978 reported that the mean area planted with coffee per farm was 0.3 ha. In this survey, the area planted was between 0.4–0.8 ha per farm. The mean yield of coffee berries per hectare reported in the Small Farm Survey was 9,691 kg, with a maximum of 12,500 kg and a minimum of 2,363 kg. The yield of the farms surveyed here was 4,000 to 12,700 kg. The income for the labour per day was 23.40 KShs., with a maximum of 76 KShs. and a minimum of 0.1 KShs. These data have high dispersal compared with income for agricultural labour per day (about 10 KShs.), but coffee seemed to be a comparatively highly profitable crop.

(iii) Cotton (seed cotton)

The sample number of cotton farms was greater than for tea and coffee farms. However, some error can be expected in a survey based on the questioning of farmers through interpreters. In the Small Farm Survey of 1978, the mean area of cotton planted was 0.5 ha per farm. It was 0.74 ha in this survey; the dispersion was large, between a maximum of 2.6 ha and a minimum of 0.2 ha (Table 23). In the Small Farm Survey, the mean yield per hectare 948 kg with a maximum of 1,400 kg and a minimum of 404 kg. In this survey, the mean was 491 kg with a maximum of 1,500 kg and a minimum of 0 kg. It was a normal (non-drought) year in both 1978 and 1985. If the data do not contain considerable error, the mean yield found in this survey was low compared to that reported in 1978. The reason might be because the sampling area for the Small Farm Survey in 1978 was Siakago, a much more fertile area than the areas sampled in this survey. The income for labour per day had a high disparity with a mean of 8.50 KShs., a maximum of 27.49 KShs., and a minimum of minus 1.92 KShs. The

Table 23. Area planted and yield of cotton (seed cotton)

Household No.	Area planted (ha)	Yield, kg/ha
2	0.6	750
3	0.8	
4	1.6	1,875
5	0.9	825
6	0.4	525
8	2.6	375
9	0.6	600
10	0.6	75
17	0.2	
49	0.4	225
50	0.2	150
55	0.4	
69	0.2	150
71	1.2	
74	0.4	1,650

results suggested that cotton production was unprofitable.

### (3) Livestock production

Table 24 shows the numbers of livestock kept in the upper and lower areas. More cattle and goats were kept per farm in the lower areas than in the upper ones. However, a number of livestock, particularly cattle, died or were sold during the serious drought, so numbers of livestock were no doubt fewer at the time of the survey than is normal. Hereafter, the number of livestock can be expected to increase. Draft cattle and sheep were not found in the upper areas; dairy cows, an improved variety of Holstein, were never found in the lower areas. The upper areas are steep slopes, so ploughs and carts drawn by oxen cannot be used there. In the lower areas, cows of Holstein type cannot be kept because of the high temperatures and feed shortages in dry seasons. The most common variety of cattle is Zebu or a crossbreed between Zebu and Holstein or Jersey. Many chickens were kept in both the upper and the lower areas.

There are three economical aspects to livestock production. The first is the sale of livestock products like milk and meat. As mentioned above, beef cattle and goats were sold to meet the need for cash arising from a serious drought or other disasters in the lower areas. It is generally believed the Mbere people were originally nomadic and that they began farming at the beginning of this century. According to this view, livestock keeping was for the purpose of milk production for home consumption, but not for sale. This people does not eat beef often, although they eat chicken, goats, and sheep. Livestock was important in social customs for ceremonies and as part of dowries. Today's milk production is intended for home consumption in the upper areas; any surplus is sold. There were three milk-selling farms from which data could be collected (Table 25). The data shows that the quantity of milk is fair, but that there is some need to improve yield.

The original reason for keeping livestock in the upper areas would be the same as in the lower areas. However, the development of a monetary economy in the upper areas started much earlier than in the lower areas. Accordingly, the meaning of livestock keeping in the upper changed drastically in early time. Under population pressure, the manner of keeping livestock has changed from grazing to stall-feeding, and new exotic

Table 24. Kinds and numbers of livestock

		Beef cattle	Draft cattle	Dairy cows	Goats	Sheep	Chickens
Lower areas	Total	296	70	2	361	60	578
	No. of households	52	20	1	43	15	57
	Mean	5.69	3.50	2.00	8.40	4.00	10.14
Upper areas	Total	15	0	10	15	0	106
	No. of households	7	0	8	7	0	10
	Mean	2.14	0	1.25	2.14	0	10.60

Table 25. Economics of milk production

Household No.	Cost (KShs.)			Quantity sold (liter)	Price per (liter)	Total income (KShs.)	Home consumption per month (liter)	Number of cows
	Pesticides for ticks and disease	Fodder	Other (transport)					
44	120	3,300	—	3,675	2.50	9,187.50	150	2
45	80	400	—	5,040	1.60	8,064.00	7	1
46	120	—	2,230	720	12.00	8,640.00	—	4

kinds of cows have been introduced into the upper areas. In the future, the change from keeping beef cattle to keeping dairy cows will probably continue, while the pace of the change will slow, because of feed shortages and the high price of dairy cows. The price of cows was 2-3 times that of beef cattle, and some farms keeping dairy cows were buying the feed.

According to our informant, in the lower areas, the supervision of grazing was very important. One person was needed to take care of a herd grazing from morning to evening. Formerly, this was a major task of boys. Nowadays, however, most boys are going to school, and cannot supervise herds every day. As mentioned above, the need for livestock still exists, particularly in the lower areas. However, as livestock keeping does not always earn a high income, young adult men cannot devote their time to herd supervision. Also, the opportunity cost of the work is high. If the income level of the household is high, it is possible to employ a man for this work. A few households surveyed here had such an employee. As was pointed out in Chapter 1, the communal grazing system still existed in the areas farthest from Embu town. However, the system will no doubt disappear completely with further economic change. Dipping of cattle was widespread among the farmers of both the upper and lower areas. This modern method for killing ticks was not expensive.

(4) Use of modern input

Of factors of production other than labour and fixed capital, comparatively new inputs that have been introduced are improved seed, fertilizer, pesticides, and feed (Table 26). As showed in detail in Table 7 of Chapter 1, improved maize was introduced early and nowadays almost 100% of the farms in the upper areas use this seed. On the other hand, improved maize can be seen in the lower areas, but a very few.

In this upper areas, as the land area per farm is very small and the most of the land is occupied by cash crops such as coffee and tea, the area of maize planted as a staple food is small. However, it is not possible to shift to the full commercial production of cash crops in such an economic environment. The only way to increase food production is to improve the land productivity of food crops. Consequently, improved maize has been promoted. the economical effect was considerable. In the upper areas, the number of livestock per farm is small because of feed shortages and so organic manure is insufficient. In consequence, chemical fertilizer is used in fields of coffee, tea, and the improved varieties of maize.

The rainfall is unreliable in the lower areas, so an increased yield of food crops would have little effect. Even when improved varieties of maize is introduced into such a natural environment, a high yield cannot be relied on. Therefore, the successful introduction of high-yield varieties of maize was rare in the lower areas. However, the farmers in the lower areas were interested in the improved varieties of maize. After the most recent serious drought, an improved variety of maize was distributed free by the government. This was not action of the farmers themselves, but two or three farmers surveyed here were using the improved variety of maize and chemical fertilizer by their

Table 26. Use of modern input (Numbers of households)

	Hired labour	Fertilizer	Pesticides	Seeds	Feed
Upper areas (12 households)	3	9	10	4	2
Lower areas (62 households)	8	3	37	1	0
All areas (74)	11	12	47	5	2

own desire to obtain a higher yield. These householder were all young, full-time farmers who were engaged in farming as their only means of support. Thus, intensive farming can appear even under disadvantageous natural and economical conditions in the lower areas.

The main cash crop was cotton in the lower areas and most of the cotton farmers use pesticides in the fields.

(5) Possession of farm tools

The level of farm mechanization was low in both the upper and the lower areas ; the main farm tools were hand-held. They included the *jembe*, fork *jembe*, and *panga* (Table 27). Sprayers were recently introduced. The ox cart is known in the upper areas, but only two farmers own one in the lower areas. Ox carts are seldom used for work on the farm because of the steep slopes of the land. It is used mostly for transportation of products. In the lower areas, the main cash crop was cotton and other agricultural products were seldom sent to market. Accordingly, ox carts were not needed. Wheelbarrows, which are inexpensive, are now used, but at a low rate of introduction.

(6) Ox ploughs

Ox ploughs, the major function of which is to speed up land cultivation, would be useful in the lower areas. To assure early planting is one way to raise yields, particularly in the lower areas. As mentioned above, ox ploughs cannot be used in most part of the upper areas because of the steep slopes and high opportunity cost of the land.

In the lower areas, because land productivity of food crops is generally low, the enlargement of the planted areas is needed to meet the food requirements of families. No farms had an ox plough in the upper areas, but 37% of those in the lower areas owned one. The reply to the question "when did you first obtain a plough" was as follows : "in the 1960's." four farmers answered, twelve answered "in the 1970's." and six answered "in the 1980's." The most common answers to the question "why do you use an ox plough ?" were "to make the work of cultivation easy" and "to loosen the soil."

About 63% (39 farmers) of all farms surveyed did not have an ox plough. Although the farmers fully understood the advantages of ox ploughing, 85% of the farmers without a plough could not buy a ploughing set (a plough and two or four trained oxen). Other reasons for not owning a ploughing set were as follows : the land holding is very small (three farms), the land too sloping (two), the land is stony (one), and the oxen died of drought (two), The price of a plough was 600-700 KShs. not including the oxen

Table 27. Possession of farm tools

	<i>Jembe</i>	Fork <i>jembe</i>	<i>Panga</i>	Sprayer	Ox cart	Ox plough	Wheel- barrow
Upper areas (12 Households)							
Numbers of households	9	11	11	7	6	0	0
Number of tools	21	40	71	8	6	0	0
Mean per household	1.8	3.3	5.9	0.7	0.5		
Lower areas (62 Households)							
Numbers of households	56	29	62	14	2	23	9
Number of tools	166	49	193	14	2	26	12
Mean per household	2.7	0.8	3.1	0.2	0.0	0.4	0.2

needed to pull the plough. Accordingly, poor farmers cannot buy a ploughing set.

Most farmers who did not own a ploughing set did cultivate their land with an plough. Of the 39 farmers who did not own one, 26 hired a plough and two borrowed one. Thus, about 80% of the lower-areas farms used an oxen plough. The mean charge for ox ploughing of one acre was about 240 KShs. This charge was high, considering the cost of acquiring one ploughing set. In some areas, tractor ploughing service is available, but it was not much used because of the high charge.

(7) Use of labour

Table 28, 29, and 30 show the total labour input. Labour as mentioned here means the total labour used for the processes of agricultural production. Labour used for processing is excluded here.

Most agricultural work was done by family labour in both the upper and the lower areas. Family labour includes the labour of men, women, and children (under 16 years old). There was a tendency to depend on family labour more in the upper areas than in

Table 28. Labour use in all areas

	Family			Resident non-family workers			Relatives			Neighbours			Other			Total
	M <sup>1)</sup>	F <sup>2)</sup>	C <sup>3)</sup>	M	F	C	M	F	C	M	F	C	M	F	C	
Total	20,003	29,697	11,134	2,366	300	660	67	359	—	133	429	—	1,214	2,007	—	
Man-unit	20,003	23,757.6	5,567	2,366	240	330	67	287.2	—	133	343.2	—	1,214	1,605.6	—	
Numbers of household	69	74	35	6	1	2	10	21	—	15	24	—	19	30	—	
Total in man-units	49,327.6			2,936			354:2			476.2			2,819.6			5,5913.6
%	88.04			5.24			0.63			0.85			5.03			100.00

Notes : 1) M=Male  
 2) F=Female=0.8 man-unit.  
 3) C=Children aged under 16.=0.5 man-unit.

Table 29. Labour use in the Upper areas

	Family			Resident non-family workers			Relatives			Neighbours			Other			Total
	M <sup>1)</sup>	F <sup>2)</sup>	C <sup>3)</sup>	M	F	C	M	F	C	M	F	C	M	F	C	
Total	5,056	4,942	1,656	576	—	—	6	6	—	22	32	—	378	454	—	
Man-unit	5,056	4,753.6	828	576	—	—	6	4.8	—	22	25.6	—	378	363.2	—	
Numbers of household	11	12	6	1	0	0	2	2	—	2	3	—	4	5	—	
Total in man-units	10,637.6			576			10.8			47.6			741.2			12,013.2
%	88.55			4.79			0.09			0.40			6.17			100.00

Notes : 1) M=Male  
 : 2) F=Female=0.8 man-unit  
 : 3) C=Children aged under 16=0.5 man-unit.

Table 30. Labour use in lower areas

	Family			Resident non-family workers			Relatives			Neighbours			Other			Total
	M <sup>1)</sup>	F <sup>2)</sup>	C <sup>3)</sup>	M	F	C	M	F	C	M	F	C	M	F	C	
Total	14,947	23,755	9,478	1,790	300	660	61	353	—	111	397	—	836	1,553	—	
Man-unit	14,947	19,004	4,739	1,790	240	330	61	282.4	—	111	317.6	—	836	1,242.4	—	
Numbers of households	58	62	29	5	1	2	8	19	—	13	21	—	15	25	—	
Total in man-units	38,690			2,360			343.4			428.6			2,078.4			43,900.4
%	87.13			5.38			0.78			0.98			4.73			100.00

Notes : 1) M=Male  
 2) F=Female=0.8 man-unit  
 3) C=Children aged under 16=0.5 man-unit

the lower ones. The labour input of men and women per household in the upper areas was relatively greater than in the lower ; for children, the pattern was opposite. This means that as labour-intensive crops such as coffee and tea are introduced, more labour input is needed.

There were so-called "live-in agricultural workers" who worked on the farm and lived with the employer's family. Only one farm had such "live-in workers" (two of them) in the upper areas. In the lower areas, there were eight farms with such workers. These workers mostly supervised herds of livestock.

There was a mutual-help system of agricultural work involving relatives and neighbours. The system was used more in the lower areas than in the upper ones. However, this kind of labour accounted for only some 2% of the total labour input in the lower areas.

Casual labour was reported in both the upper and the lower areas, but the upper areas depended more on such labour than lower ones. These casual labourers were mostly employed in harvesting of tea and coffee.

#### IV. Structure of household expenditures

Household expenditures as mentioned here means cash payments for food, fuel, clothing, schooling, transportation, and medical expenses. The items produced and consumed at home were excluded. The survey included cash payment for goods and services purchased made within the year before the date of the survey. The year's total cash payments were divided by 12 months, to give the household expenditure per month. A total of 73 households were interviewed, with 12 households in the upper areas and 61 households in the lower ones.

The mean expenditure of cash per month was 1,132 KShs. in the upper areas and 882 KShs. in the lower areas. As already mentioned, the mean income per month in the upper areas and the lower areas was 1,433 and 1,118 KShs., respectively. Thus, both the upper and the lower areas had a surplus. However, as the survey questions were not perfectly adequate and the sales of livestock were much higher than in normal years because of the recent serious drought, the data here do not indicate the normal state of household economies.

##### (1) food expenditure

Food expenditure amounted to 25.2% of total expenditure in the lower areas and 48.4% in the upper areas (Table 31). The mean food expenditure in cash per farm household per month in the upper and lower areas was 497 and 147 KShs., respectively. The actual cash expenditure on all items were higher in the upper areas than the lower areas except for the expenditure on eggs and milk. The expenditure on meat was much higher. The amount spent on maize, a staple food, was high. It seems that self-sufficiency in food was not complete.

In both the upper and the lower areas, rice was not produced, but about 70% of the farm households purchased rice. Analysis of changes in rice consumption were not possible because of the shortage of data, but it seems that rice consumption is gradually increasing.

Also, in all areas, much sugar was consumed. Sugar cane was grown mainly for home consumption throughout the upper areas and in places in the lower areas. Refined sugar was purchased in shops. Most persons drank milk tea containing much sugar.

##### (2) Other expenditures

One striking item of expenditure other than food was school expenses. School expenses amounted to 13% of total expenditure in the upper areas and 34% in the lower areas. There were two reasons why school expenses in the lower areas were relatively

Table 31. Household expenditures per month

(KShs.)

	All areas		Upper areas		Lower areas	
	Total	%	Total	%	Total	%
Foods	14,936.84	29.0	5,963.10	48.4	8,973.74	25.2
Maize	1,627.50	2.4	450.00	3.6	1,177.50	2.2
Rice	2,411.75	3.6	696.00	5.6	1,715.75	3.1
Meat	6,233.54	9.3	2,304.00	20.5	3,929.54	7.2
Eggs/Milk	1,701.50	2.5	186.00	1.5	1,515.50	2.8
Vegetables	222.00	0.0	—	—	222.00	0.0
Sugar	4,256.75	6.3	1,166.00	9.4	3,090.75	5.7
Tea	877.97	1.3	204.67	1.6	673.30	1.2
Salt	218.64	0.0	77.48	0.0	141.16	0.0
Drinks	506.30	0.0	113.30	0.0	393.00	0.0
Oil	2,406.71	3.6	765.65	6.2	1,641.06	3.0
Soap	2,681.30	4.0	431.63	3.5	2,249.67	4.1
Fuel	2,586.28	3.9	664.00	5.3	1,922.28	3.5
Clothing	8,489.91	12.6	1,733.34	14.2	6,756.57	12.4
Schooling	18,860.78	30.1	1,630.82	13.1	17,229.96	33.5
Transportation	9,108.15	13.6	1,354.99	10.9	7,753.16	14.2
Medical	3,044.12	4.5	578.33	4.6	2,465.79	4.5
Other	1,530.05	2.3	100.00	0.0	1,430.05	2.6
Total		100.0		100.0		100.0

Table 32. Possession of household goods

	Bicycle	Car	Cassette radio	Jiko	Lamp	Motor cycle	Paraffin stove	Radio	Sofa	Thermos flask	Torch	Water tank
Upper areas												
Household (of total 12)	4	1	1	10	10	0	5	7	3	2	11	7
Number	5	1	1	14	30	0	5	7	4	5	19	13
Lower areas												
Household (of total 62)	16	1	4	30	59	3	19	38	13	8	44	24
Number	16	1	4	39	114	3	25	41	17	13	74	45

high. In those areas, there were few lower secondary schools, and farmers' houses scattered. Most students lived in dormitories. Dormitory charges were included in the school expenses.

Parents in the lower areas in particular were enthusiastic about the education of their children because of the low productivity of agriculture. Their choice of education as an investment seems to be both natural and reasonable. In some household, they never ate meat or sugar, having cut down on their family expenditures to educate their children.

Table 32 lists household goods possessed in both the upper and the lower areas. The income level in the upper areas was higher than in the lower, and this was reflected in the

general plenty in terms of household goods.

## V. Conclusions

This chapter mainly analyzed the economic structure of farm households and the relationship between the current farming systems and the economic environment. The results and some policy implications are summarized as follows :

(1) Economic analysis shows that agricultural production was more active in the upper areas than the lower ones. This was an expected result because the natural environment in the upper areas (in particular, the stability and the absolute quantity of rainfall) was more suitable to agricultural production than in the lower areas. Although sufficient data for a detailed analysis could not be collected, but it seemed that cash crops such as coffee and tea were profitable. The natural environment for agricultural production in the lower areas was quite severe. Serious droughts are not rare in this region. The profitability of cotton, which is the main cash crop in the lower areas, was low.

(2) Food production was sufficient for home consumption in the upper areas. Land for cropping was very limited of cash crop production, but improved technology has been introduced to raise the land productivity. These modern technologies include a high-yield varieties of maize and the use of chemical fertilizers. It seems that food shortages will not occur in the upper areas in the near future. On the other hand, food production in the lower areas was unsatisfactory. The lower areas have natural environment factors that cause serious droughts. People living there has devised several ways to cope with serious droughts.

(3) Countermeasures to confine the damage of a drought to a minimum are migration to find work and the sale of livestock, timber, charcoal, and honey. Thus life is made possible in severe circumstances. It is of historical interest to find why the Mberé people live under such severe natural conditions, but this is not immediately relevant to this study.

(4) All of Kenya had a serious socio-economic environment, the problems of which include high population growth unemployment, and poverty. Both the upper and the lower areas are affected directly or indirectly by those problems. With the limited employment opportunities in the non-agricultural sectors, young persons leaving school cannot easily find employment. Segmentation of land cannot be allowed because of land holdings are already small, particularly in the upper areas. Some persons who with to own land must move to the areas where land is relatively plenty. However, large areas of land are needed there for a farm because of the low productivity of land with currently used agricultural technology.

(5) The economy of both the upper and the lower areas has been affected by the development of commercialization. The upper areas have always managed to cope with new economic environments. However, the agriculture of the lower areas is less satisfactory than that of the upper areas under changing economic circumstances. It is important for persons in the lower areas to find a sufficient source of income, in particular.

(6) Some farmers have now begun to use improved agricultural input such as high-yield varieties of maize and chemical fertilizers in the lower areas. The change from sifting cultivation to intensive agriculture has just begun in the lower areas. It can be expected that the numbers of farmers who use improved input will increase under the limited economic conditions. However, there is a limiting factor to effects to establish stable agricultural production. The limiting factor of the agricultural development of the lower areas is water. To improve agricultural productivity stably, water resources must be found and used efficiently.

(7) In the lower areas, one measure to raise the income of households is to improve method suitable for their natural environment scientifically : for example, to improve livestock and grass suitable for semi-arid natural conditions, to develop tree resources, and to improve traditional beekeeping practices. In the upper areas, it is desirable to improve or introduce other cash crops that have higher land productivity and higher effect of labour absorption.

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## B. STUDIES OF THE KENYAN SOILS

The purpose of this study undertaken in Kenya by a group of soil scientists was two-fold: 1) characterization of volcanogenous soils, and 2) estimation of the fertility status of the soils in the study area of the agronomists. The report consists of the following five sections.

B 1. Description of the sample soils.

B 2. Chemical and mineralogical characterization of soils derived from volcanic ashes.

B 3. Characterization of humic substances in soils derived from volcanic ashes.

B 4. Chemical characteristics of Kenyan Nitosols.

B 5. Fertility status of cultivated soils in villages in the Embu District.

In accordance with the purpose, the area covered by the group was limited. Thus, the reader should note that the results reported herein may not be applicable to other areas and other types of soil in Kenya.

## B 1. DESCRIPTION OF THE SAMPLE SOILS

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To characterize volcanogenous soils, volcanic ash soils or Ando and Ando-like soils were collected at different sites where they were known to occur. Reference was made to soil maps and soil survey reports made available by the Kenya Soil Survey. The group of Japanese scientists was guided and assisted by the staff of the Kenya Soil Survey in the field work.

Nitosols were studied in some parts of the Kiambu and the Embu Districts as a kind of old, weathered volcanogenous soils of agricultural importance. The soils are used for different crops depending on the elevation, so samples were taken at different elevations and locally at different positions on a slope. These soils had developed on dissected volcanic plateaus and were derived mostly from old ash, tuffs, and basic volcanic rocks such as olivine basalt and nepheline phonolite.

To estimate the fertility status of soils in the areas studied by the group of agronomists, a few profile samples and a number of surface and subsurface soil samples were taken. The latter were collected by the agronomists.

Soil profiles are described below in two groups: K-1 through 20 are described in detail, and K-21 through 43 are described in brief. Of the profiles described, K-12 through 14, K-36 through 38, and K-42 and 43 are the profiles taken in the villages studied by the group. The sampling locations of K-1 through 43 are shown in Fig. 1. For the surface and subsurface soil samples collected by the agronomists, only the number of samples for each location is given below.

Zone	Sampling Location	No. of Samples		
		Surface	Subsurface	Total
I	Gitare, Kagaari/Runyenjes	3	3	6
II	Kangaru, Mbeti/Gachoka	3	1	4
III	Gachoka, Mbeti/Gachoka	4	5	9
IV	Kithunthiri, Mavuria/Gachoka	17	17	34
	Mbita, Mavuria/Gachoka	5	5	10
V	Mavuria, Mavuria/Gachoka	11	11	22
	Sum	43	42	85

### *Description of the profiles studied in Kenya*

Profile No. K-1

(850619) Kijabe

Location : Roadside of Rte 104, 56.5 km from Nairobi, Kijabe, Kiambu District, Central Province

Parent material : Volcanic ash

Londform : Ridge part of gently undulating volcanic plateau

Local relief : 4%

Vegetation : Plantation (ca. 15 yrs) of cypress spp.

Elevation : 2550 m

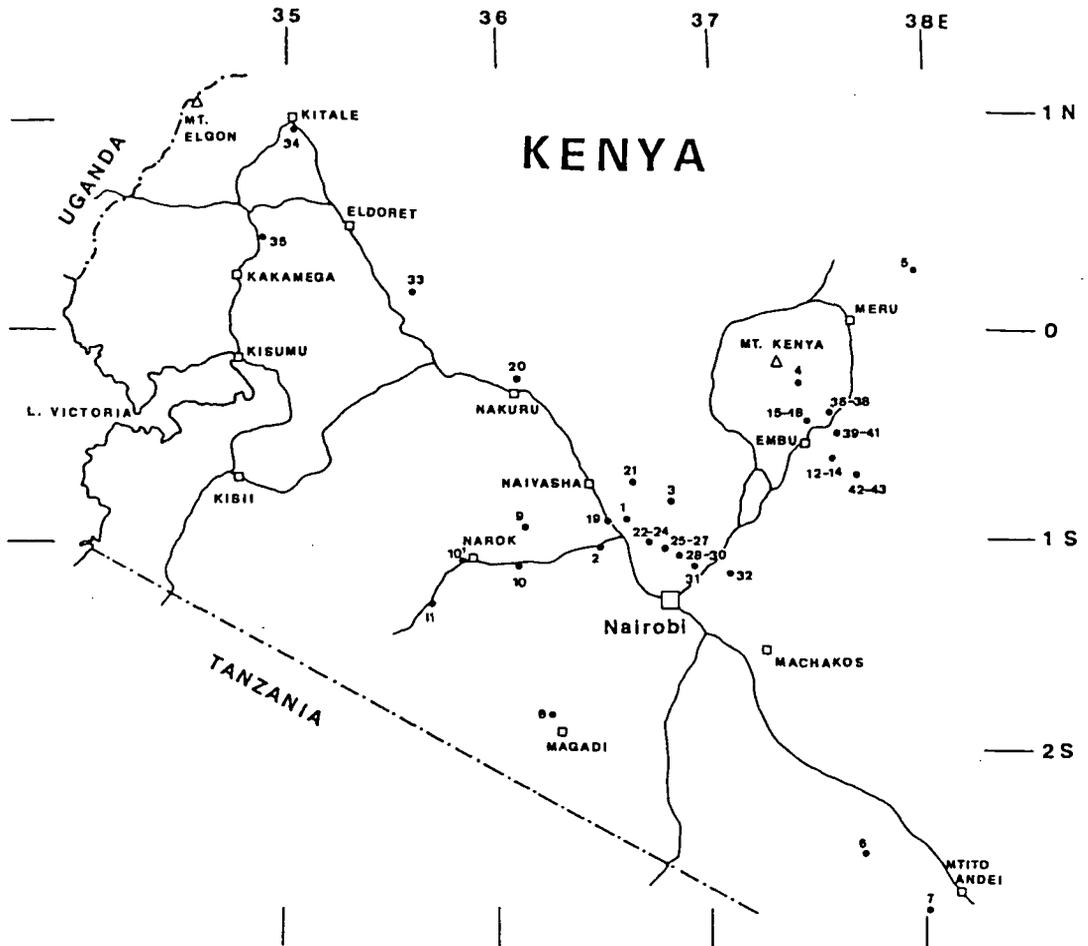


Fig. 1. Map showing the distribution of the soil sampling sites in Kenya

- |        |          |    |  |
|--------|----------|----|--|
| A 11   | 0- 20    | cm | Brownish black (7.5 YR 2/2, moist) loam ; moderate fine crumbs ; very friable ; clear smooth boundary to                           |
| IIA 12 | 20- 35   | cm | Brownish black (10 YR 2/2, moist) loam ; weak to moderate fine to medium subangular blocky ; very friable ; clear wavy boundary to |
| IIC    | 35- 45   | cm | Brown (10 YR 4/4, moist) sandy loam ; weak medium subangular blocky ; very friable ; clear wavy boundary to                        |
| IIIA1b | 45- 65   | cm | Brownish black (10 YR 2/2, moist) clay loam ; moderate fine to medium subangular blocky ; friable ; gradual smooth boundary to     |
| IIIA3b | 65- 80   | cm | Dark brown (7.5 YR 3/4, moist) clay loam ; moderate fine to medium subangular blocky ; very friable ; gradual smooth boundary to   |
| IIIB1b | 80-105   | cm | Brown (7.5 YR 4/4, moist) clay loam ; weak medium subangular blocky ; friable ; gradual smooth boundary to                         |
| IIIB2b | 105-130+ | cm | Dull reddish brown (5 YR 4/4, moist) light clay ; moderate fine subangular blocky ; slightly firm ; thin clay films on ped faces   |

Remarks : 1. Rooting reaches to 1 m.

2. The pit was formerly under the forest, but presently it is just outside due

- to felling of the trees.
3. Material very similar to IIC material occurs as a lens in IIIA 3 b.
  4. Krotovina-like dark-colored spot (10-15 cm) occurs in IIIB 1-IIIB 2 boundary.
  5. Mollic Andosol (Kenya), Typic Eutrandept (USDA)

Profile No. K-2

(850620) Mt. Suswa

Location : 16.5 km from A 104/B 3 junction on Narok Rd.

Parent material : Volcanic ashes and pumices

Landform : Very gently undulating on the rift valley bottom

Local relief : Level

Vegetation : Short grasses and bushes (whistling thorn trees) and a few tall trees (yellow fever thorn trees) along wadis

Elevation : 1650 m

Al	0- 20	cm	Dark brown (10 YR 3/3, moist) silt loam with common pumiceous gravels ; moderate medium granular ; very friable ; clear smooth boundary to
IIC 1	20- 74	cm	Olive brown (2.5 Y 4/4, dry) silt loam with common pumiceous gravels ; very weak fine granular ; loose ; abrupt smooth boundary to
IIIC 2	74- 82	cm	Grayish olive (5 Y 6/2, dry) consolidated sand ; breakable between fingers ; hard ; abrupt smooth boundary to
IIIC 3	82- 97	cm	Grayish olive (5 Y 6/2, dry) loamy sand ; single grains ; loose ; abrupt smooth boundary to
IVC 4	97-129	cm	Gray (7.5 Y 5.5/1, dry) sand ; single grains ; loose ; abrupt smooth boundary to
VC 5	129-144	cm	Pumice layer (grain sizes ranging from 5 to 20 mm) with sandy material very similar to IVC 4 ; single grains ; very loose ; abrupt smooth boundary to
VIC 6	144-200	cm	Yellowish brown (10 YR 5/6, dry) sandy clay loam ; moderate medium subangular blocky ; slightly firm.

- Remarks : 1. Described on a dry river channel wall ca. 4 m high.
2. A 1 is a recent alluvial deposit by sheet flow. In the vicinity a thicker alluvial deposit is seen overlying above IIC 1.
  3. IIIC 2 is not continuous and thins out. This is probably formed by consolidation of IIIC 3 material by some unknown mechanism.

Profile No. K-3

(850621) Gituamba

Location : Gituamba Agricultural Station, Muranga District, Central Province

Parent material : Volcanic ashes

Landform : Dissected piedmont plain of Aberdare Range

Local relief : Gently sloping (4%) to NE, on a ridge

Vegetation : Cultivated (maize, beans, sugarcane), but nearly abandoned with many grasses and bushes, conspicuously with ferns.

Elevation : 2100 m

A 1	0- 18	cm	Dark reddish brown (5 YR 3/3, moist) loam ; weak fine to medium subangular blocky ; very friable ; clear smooth boundary to
A 3	18- 47	cm	Dark reddish brown (5 YR 3/4, moist) clay loam ; moderate fine to medium subangular blocky ; friable ; clear wavy boundary to
Bt	47- 85	cm	Dark reddish brown (5 YR 3/6, moist) light clay ; moderate medium subangular blocky ; friable ; thin continuous clay films on ped faces and channel walls ; clear smooth boundary to
IIAb	85-105+	cm	Dark reddish brown (5 YR 3/4) light clay ; moderate medium subangular blocky ; friable.

- Remarks : 1. Rooting is frequent to the bottom of A 3.

2. Even in Bt horizon few carbonized materials are seen, suggesting some disturbances.
3. Humic Andosol (Kenya).

Profile No. K-4

(850622) Mt. Kenya Lodge

Location : 1.5 km before Meru Mt. Kenya Lodge (20km from the gate of Forest Station),

Chogoria Track

Parent material : Volcanic ash and lapiri

Landform : Foothlope of Mt. Kenya

Local relief : Sloping to N, 15%

Vegetation : Bamboos and tall evergreen trees with hanging mosses

Elevation : 2850 m

A 1	0- 32	cm	Brownish black (7.5 YR 2/2, moist) clay loam with common semi-rounded gravels and pebbles (~ 4 cm) : moderate fine subangular blocky breaking into fine granular ; friable ; clear smooth boundary to
IIC	32- 57	cm	Bright brown (7.5 YR 5/8, moist) loamy sand with common fine gravels ; partly weak medium subangular blocky and partly single grained ; partly firm and partly loose ; abrupt smooth boundary to
IIIAb	57- 68	cm	Black (7.5 YR 2/1, moist) and reddish brown (5 YR 4/8 to 5/8, moist) clay loam ; moderate medium subangular blocky ; very friable ; abrupt wavy boundary to
IVB2b	68-120	cm	Brown (7.5 YR 4/6, moist) light clay ; moderate medium to coarse subangular blocky ; friable ; thin continuous clay films ; clear smooth boundary to
IVB3b	120-130	cm	Bright brown (7.5 YR 5/8, moist) light clay ; moderate medium to coarse subangular blocky ; friable ; thin continuous clay films ; clear smooth boundary to
VC1b	130-142	cm	Dark reddish brown (5 YR 3/6, moist) light clay with few weathered pumice or rock fragments ; few fine Mn concretions ; moderate medium subangular blocky ; very friable ; thin continuous clay films ; abrupt smooth boundary to
VIC2b	142-180+	cm	Irregularly laminated yellowish brown (10 YR 5/6, moist) and yellowish gray (2.5 Y 4/1, moist) sandy clay loam ; weak coarse subangular blocky ; very friable (partly firm blocks) ; thin continuous clay films.

- Remarks :
1. Described on a road cut.
  2. IIC can be traced along the cut and the present relief.
  3. IIIAb has black colored part and red colored part irregularly intermingled. The origin of this feature is not known.
  4. Probably A 1 is a colluvial deposit.
  5. VIC 2 b is somewhat similar to *imogo*.

Profile No. K-5

(850623) Nyambeni Hill

Location : 7 km E from the junction north of Maua on the road to Meru National Park, Nyambeni hill.

Parent material : Basaltic lava and ash (?)

Landform : Lava plateau

Local relief : Nearly level

Vegetation : Grasses and bushes

Elevation : 1400 m

A 1	0- 16	cm	Dark reddish brown (5 YR 3/2, moist) light clay ; moderate fine
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- subangular blocky breaking into fine crumbs ; friable ; clear smooth boundary to
- A 3 16- 43 cm Dark reddish brown (5 YR 3/2, moist) light clay with few small pebbles ; moderate to strong fine subangular blocky ; friable gradual smooth boundary to
- B 2 43- 70 cm Dark reddish brown (5 YR 3/3, moist) heavy clay with few small pebbles ; moderate to strong fine subangular blocky ; friable ; thin patchy clay films ; diffuse smooth boundary to
- B 3 70-120+ cm Dark reddish brown (5 YR 3/3, moist) heavy clay with few small pebbles ; moderate fine subangular blocky ; friable ; thin patchy clay films.

Remarks : 1. Described on a road cut.  
2. Phaeozem or Ando-Luvic Cambisol (Kenya)

Profile No. K-6  
(850625) Chyulu-1

Location : Foot of Elmau Hill, Chyulu Range, Kajiado District

Parent material : Chyulu ash and cinders

Landform : Very gently undulating plain with thick blanket of volcanic ejecta

Local relief : Nearly level

Vegetation : Short grasses (*Themeda trianda*) with very few trees

Elevation : 1150 m

- A 1 0- 15 cm Dull yellowish brown (10 YR 4/3, dry) loam with few fine cinders ; moderate fine to medium crumbs ; very friable ; clear smooth boundary to
- A 3 15- 28 cm Dark brown (10 YR 3.5/3, dry) sandy loam with few fine cinders ; powdery and weak fine crumbs ; loose ; clear smooth boundary to
- B 1 28- 40 cm Dull yellowish brown (10 YR 5/3, dry) sandy loam with few fine cinders ; powdery and weak fine crumbs ; loose ; gradual smooth boundary to
- B 2 40- 60 cm Dull yellowish brown (10 YR 5/3, dry) sandy loam with few fine cinders ; powdery and weak fine crumbs ; loose ; clear smooth boundary to
- B 3 60- 70 cm Dull yellowish brown (10 YR 5/3.5, dry) sandy loam with common fine cinders ; powdery and weak fine crumbs ; abrupt smooth boundary to
- C 1 ca 70- 90 cm Dull yellowish orange (10 YR 6.5/3, dry) lime cemented cinders (variable color inside)
- C 2 90-120+ cm Cinder layer with various colors and sizes (mostly below 5-6 mm)

Remarks : 1. Described in a pit previously surveyed (Kenya Soil Survey Observation No. 182/1-44).

Profile No. K-7  
(850626) Chyulu-2

Location : Past Devil Mountain away from Chyulu Gate of Tsavo West National Park, Chyulu Range

Parent material : Volcanic ash and cinders

Landform : Foot of a volcanic cone

Local relief : Sloping (10 degree)

Vegetation : Grasses and bushes

Elevation : 1200 m

- A 1 0- 30 cm Brownish black (10 YR 3/2, dry) gravelly sandy loam with many cinders ; weak fine to medium crumbs ; loose ; abrupt smooth boundary to

- IIC 1 30- 42 cm Gray (5 Y 4/1, dry) gravelly sand with many cinders ; single grains ; loose ; abrupt wavy boundary to
- IIC 2 42-150 cm Dull yellow orange (10 YR 6/4, dry) gravelly sandy loam with many cinders ; powdery and weak fine crumbs ; loose; slightly cemented by lime at depths between 130-150 cm ; abrupt smooth boundary to
- IVC 3 150-180+ cm Fresh cinder layer, thinly coated by lime.
- Remarks : 1. Described on a road cut.  
2. KSS Observation No. 182/4-80.

Profile No. K-8

(850627) Magadi

Location : Foot of Nytkia Escarpment, Magadi

Parent material : Fluvial deposits derived from volcanic ash

Landform : Alluvial plain

Local relief : Level

Vegetation : Short perennial grasses, few wild sorghum and ciperus

Elevation : ca. 700 m

- A 1 0- 20 cm Dull reddish brown (5 YR 4/4, dry) light clay ; moderate to strong fine subangular blocky ; friable ; gradual smooth boundary to
- A 3 20- 50 cm Dark reddish brown (5 YR 3/4, slightly moist) light clay ; moderate to strong fine subangular blocky ; friable to slightly firm ; abrupt smooth boundary to
- IIC 1 50- 58 cm Orange (7.5 YR 6/8, slightly moist) silty clay loam ; weak medium blocky breaking into fine platy with 5 YR 3/4 clay on the surface of some plates ; friable ; abrupt smooth boundary to
- IIC 2 58- 65 cm Reddish brown (5 YR 4/6, slightly moist) sandy loam ; weak medium blocky breaking into medium platy ; friable ; abrupt smooth boundary to
- IVC 3 65- 78 cm Reddish brown (5 YR 4.5/8, slightly moist) fine sandy loam ; weak medium blocky breaking into medium platy ; very friable ; abrupt smooth boundary to
- VC 4 78- 90 cm Parallely intercalated reddish brown (5 YR 4.5/8) and dark reddish brown (5 YR 3/4) light clay ; moderate to strong medium to coarse platy ; friable to slightly firm ; abrupt smooth boundary to
- VIC 5 90-120 cm Dull reddish brown (5 YR 4/3, slightly moist) light clay ; moderate to strong medium subangular blocky breaking into medium platy ; firm ; patchy Mn films on ped faces.

- Remarks : 1. Small termite nest in A 1.  
2. From IIC 1 to VIC 5 fine lamination is more or less visible, which appears as the platy element in the structure.

Profile No K-9

(850701) Mau

Location : Enooseiya (just south of a primary school), 16 km N of Nairagi Enkare, Mau Escarpment

Parent material : Volcanic ash

Landform : Narrow dissected ridge

Local relief : Nearly level

Vegetation : Lawn

Elevation : 2850 m

- A 11 0- 12 cm Brownish black (7.5 YR 2/2, moist) sandy loam with dull yellow orange (10 YR 7/2.5) loamy sand and nearly continuous lenses at the bottom of the horizon ; moderate very fine crumbs and somewhat powdery ; friable ; clear smooth boundary to
- IIA 12 12- 39 cm Brownish black (7.5 YR 2/2, moist) clay loam ; strong fine to

			medium crumbs ; friable ; clear smooth boundary to
IIIA13	39- 52	cm	Brownish black (10 YR 3/1, moist) sandy loam ; moderate fine subangular blocky ; very friable ; clear smooth boundary to
IIIA 3	52- 63	cm	Brownish black (10 YR 3/2, moist) sandy loam ; weak fine subangular blocky ; very friable ; clear wavy boundary to
IIIC	63- 91	cm	Grayish olive (7.5Y 4/2, moist) sandy loam ; single grains ; very friable ; clear wavy boundary to
IVA1b	91-137	cm	Black (7.5YR 2/1, moist) light clay ; moderate to strong fine subangular blocky ; friable ; clear smooth boundary to
IVA3b	137-150+	cm	Brownish black (7.5 YR 2.5/2, moist) light clay with few weathered pumice particles ; moderate fine subangular blocky ; friable.

- Remarks : 1. Described in the same pit as KSS Observation No.133/ 3 -11.  
 2. The loamy sand material at the bottom of A11 horizons is widely traceable along the present land surface at least in the ridge part of the topography. It is presumably a recent ash deposit.  
 3. IIIA13 and IIIA 3 horizons are presumably the same ash deposit as IIIC, but stained by humus.

Profile No. K-10  
 (850702) Narok-1

Location : 2 km S of Ntumele at 26 km East of Narok  
 Parent material : Volcanic ash and tuff  
 Landform : Level volcanic plateau south of the Mau Range  
 Local relief : Nearly level  
 Vegetation : Grasses and bushes  
 Elevation : 2050 m

A 1	0- 28	cm	Brown (7.5YR 4/4, nearly dry) clay loam ; weak to moderate fine subangular blocky ; friable ; diffuse smooth boundary to
A 3	28- 57	cm	Brown (7.5YR 4/4, moist) clay loam ; weak fine subangular blocky ; friable ; diffuse smooth boundary to
B 2	57- 83	cm	Dark brown (7.5YR 3.5/4, moist) light clay ; weak to moderate fine subangular blocky ; friable ; thin patchy organ (7.5YR 2/2) : clear smooth boundary to
IIAb	83-110+	cm	Mixed brownish black (7.5YR 2/2, moist) and dark brown (7.5Y 3.5/4, moist) light clay ; moderate medium subangular blocky breaking into strong fine black subangular blocky ; friable with medium blocky peds but firm with fine blocky peds ; slightly calcareous (fine powdery efflorescence of lime on some peds).

- Remarks : 1. Described in the same pit as KSS Observation No. 147 / 1 - 3.  
 2. Faunal activity (ants, termites) are seen to IIAb as nests.

Profile No. K-10'  
 (EAK 35) Narok-2

Location : 3 km west of Narok town on the road to Masai Mara  
 Parent material : Volcanic ash  
 Landform : Flat to very gently undulating volcanic plain  
 Local relief : Level  
 Vegetation : Short grass with bushes  
 Elevation : 1950 m

A1	0- 20	cm	Dark brown (7.5YR 3/2, moist) clay loam ; massive falling apart to weak very fine subangular blocky structure ; friable when moist, sticky and plastic when wet ; slightly calcareous ; clear smooth boundary to
B 21	20- 60	cm	Dark brown (7.5YR 3/2, moist) sandy clay ; massive falling apart to weak very fine crumbly structure ; friable when moist, sticky and

- IIB 22 60- 90 cm plastic when wet ; slightly calcareous ; diffuse smooth boundary to Dark brown (7.5YR 3/2, moist) clay loam ; massive falling apart to weak fine to medium subangular blocky structure ; firm when moist, sticky and plastic when wet ; moderately calcareous, diffuse smooth boundary to
- IIB 3 90-145+ cm Horizon composed of concretionary mass of weathering tuff-calcareous.

Remarks : 1. Described by Kenya Soil Survey staff as KSS No. 146/2-4 .  
2. Analyses were done at ISRIC by Mizota.

Profile No. K-11

(850 02) Loita Plain Planosol

Location : 0.6 km southeast from the main road (C 12) to Maji Moto

Parent material : Tuff and ash

Landform : Very gently undulating plain (Loita plain)

Local relief : Level

Vegetation : Sparse short grasses and few bushes

Elevation : 1900 m

- A 11 0- 14 cm Brown (7.5YR 4/3, nearly dry) silty clay loam with very few fine concretions ; moderate fine to medium subangular blocky ; firm ; clear smooth boundary to
- A 12 14- 24 cm Brown (7.5YR 4/3, moist) light clay with few to common (increasing downwards) manganiferous concretions and nodules ; weak fine subangular blocky ; friable ; abrupt smooth boundary to
- A 2g 24- 43 cm Grayish yellow brown (10 YR 6/2, moist) gravelly sandy clay loam with profuse concretions and nodules (~10 mm) with few large nodules (~10 cm) at the bottom of the horizon ; single grains ; readily breakable ; abrupt irregular boundary to
- B 2tg 43- 60 cm Brownish black (7.5YR 2/2 moist) heavy clay with common nodules (~40 mm) ; strong fine angular blocky ; friable ; thin continuous clay films and pressure faces ; clear wavy boundary to
- B 3c 60- 80+ cm Hard pan layer with various colors (10 YR 7/2 -7.5YR 3/2) ; very coarse platy ; extremely hard

Remarks : 1. The hard pan is clearly a product of secondary induration, as it contains some concretions Local surveyors call it a duripan.  
2. The pan layer breaks into platy unit with crusts with relatively soft yellowish brown colored interior.  
3. Planosol (Kenya)

Profile No. K-12

(850708) Gachoka-1

Location : Gachoka Sublocation, Mbeti Location, Gachoka Division, Embu District

Parent material : Phonolites on Precambrian basements

Landform : Dissected upland

Local relief : Sloping mid-slope position

Vegetation : Maize and cowpeas

Elevation : 1250 m

- Ap 0- 20 cm Dull reddish brown (5YR 4/3.5, dry) light clay with few quartzite and weathered gravels ; weak medium subangular blocky ; hard to very hard ; abrupt smooth boundary to
- B 1 20- 35 cm Dull reddish brown (5YR 4/7 dry) light clay with few nodules (~10 mm) ; weak medium subangular blocky ; friable to slightly firm ; clear smooth boundary to
- B 2 35- 60 cm Reddish brown (5YR 4/7, slightly moist) light clay with few nodules

- (increasing downwards) ; weak medium subangular blocky ; slightly firm ; abrupt smooth boundary to
- X 1 60-120 cm Reddish brown (5YR 4/8, moist) light clay with abundant nodules and few angular and rounded quartzite pebbles ; single grains ; loose ; clear smooth boundary to
- X 2 120-150+ cm Reddish brown (5YR 4/8, moist) light clay with many nodules ; single grains ; loose.
- Remarks : 1. X1 and X2 are *murram* layers consisting of nodules and concretions of 5-10 mm size.
2. The *murram* layer is underlain by weathered rocks at about 200 cm.

Profile No. K-13

(850709) Gachoka-2

Location : Same as K-12

Parent material : Same as K-12

Landform : Same as K-12

Local relief : Level (on ridge)

Vegetation : Maize

Elevation : 1270 m

- Ap 0- 18 cm Dull reddish brown (5YR 4/4, dry) sandy clay loam with very few fine gravels ; weak medium subangular blocky ; friable ; clear smooth boundary to
- A 3 18- 25 cm Dark reddish brown (5YR 3/3, dry) sandy clay loam ; weak fine subangular blocky ; firm ; very compact ; clear smooth boundary to
- B 1 25- 40 cm Reddish brown (5YR 4/6, dry) sandy clay loam ; moderate fine subangular blocky ; firm ; very compact ; gradual smooth boundary to
- B 21 40- 60 cm Reddish brown (2.5YR 4/8, slightly moist) sandy clay ; moderate fine subangular blocky ; friable ; compact ; gradual smooth boundary to
- B 22 60- 85 cm Reddish brown (2.5YR 4/8, moist) sandy clay ; moderate fine subangular blocky ; friable ; diffuse smooth boundary to
- B 3 85-150+ cm Reddish brown (2.5YR 4.5/8, moist) sandy clay ; weak to moderate medium subangular blocky ; very friable.

- Remarks : 1. A 3 and B 1 are very compact and very hard ; B 21 is compact and hard.
2. Cutans are not observable but channel walls are coated by clay films.

Profile No. K-14

(850709) Gachoka-3

Location : Same as K-12

Parent material : Same as K-12

Landform : Same as K-12

Local relief : Gently sloping (upper-slope position)

Vegetation : Grasses and bushes

Elevation : 1260 m

- A 1 0- 12 cm Reddish brown (5YR 4/6, dry) light clay ; moderate fine subangular blocky and powdery ; partly hard, partly loose ; very compact in the lower half of the horizon ; clear smooth boundary to
- A 3 12- 25 cm Reddish brown (5YR 4/6, dry) light clay ; moderate fine subangular blocky ; hard ; very compact ; abrupt smooth boundary to
- B 1 25- 40 cm Bright brown (7.5YR 5/6, dry) light clay ; moderate fine subangular blocky : hard ; very compact ; gradual smooth boundary to
- B 2 40- 53 cm Bright brown (7.5YR 5/6, slightly moist) light clay ; weak fine subangular blocky ; slightly firm to friable ; clear smooth boundary to

- B 3 53- 80 cm Bright brown (7 5YR 5/8, moist) light clay ; weak fine subangular blocky ; friable ; clear smooth boundary to
- C 80-130+ cm Bright brown (7. 5YR 5. 5/8, moist) light clay ; weak fine subangular blocky ; very friable.

Remarks : 1. Very few, very fine concretions (~ 1 mm) are found throughout the profile, which are black and mostly breakable between nails.  
2. No *murrans*.

Profile No. K-15

(850710) Kiriari-1

Location : 100 m north of Kiriari Girls Secondary School, Kiriari Sublocation, Runyenjes Division

Parent material : Basalt and volcanic ash

Landform : Dissected ridge on footslope of Mt. Kenya

Local relief : Level on ridge

Vegetation : Maize

Elevation : 1800 m

- A 1 0- 20 cm Dark reddish brown (5YR 3/4, moist) light clay ; moderate fine granular ; very friable ; abrupt smooth boundary to
- B 2t 20- 40 cm Dark reddish brown (5YR 3/6, moist) light clay ; moderate fine subangular blocky ; friable ; medium continuous clay films on ped faces ; clear smooth boundary to
- B 31 40- 93 cm Dark reddish brown (2. 5YR 3. 5/6, moist) light clay ; strong coarse blocky breaking into weak to moderate medium subangular blocky ; friable ; medium patchy clay films ; gradual smooth boundary to
- B 32 93-110 cm Dark reddish brown (5YR 3/6, moist) light clay ; strong coarse blocky breaking into weak to moderate medium subangular blocky ; friable ; medium patchy clay films ; clear smooth boundary to
- B 33 110-150+ cm Reddish brown (2 5YR 4/8, moist) light clay with few basaltic rock fragments ; strong coarse blocky breaking into moderate fine subangular blocky ; friable

Remarks : 1. Basaltic rock fragments, though very few, are present in B 33 horizon.  
2. Krotovinas are found in B 31 and B 32.

Profile No. K-16

(850710) Kiriari-2

Location : Same as K-15

Parent material : Same as K-15

Landform : Same as K-15

Local relief : Sloping, upper slope position

Vegetation : Maize-tea transition

Elevation : 1780 m

- Ap 0- 23 cm Dark reddish brown (5YR 3/6, moist) light clay ; weak fine granular ; very friable ; clear smooth boundary to
- A 12 23- 50 cm Dark reddish brown (5YR 3/6, moist) light clay ; moderate medium subangular blocky ; very friable to friable ; clear wavy boundary to
- B 50-130+ cm Reddish brown (5YR 4/6, moist) light clay ; strong coarse blocky breaking into moderate fine subangular blocky ; friable ; medium patchy clay films.

Remarks : 1 Ap appears to be a recent deposition on the original soil surface.

Profile No. K-17

(850710) Kiriari-3

Location : Same as K-15

Parent material : Same as K-15  
Landform : Same as K-15  
Local relief : Sloping, lower slope position  
Vegetation : Coffee-tea transition  
Elevation : 1750 m

A 0- 68 cm Dark reddish brown (5YR 3/5, moist) light clay ; weak fine granular ; very friable ; clear irregular boundary to  
B 68-150+ cm Reddish brown (5YR 4/6, moist) light clay ; strong coarse blocky breaking into moderate fine subangular blocky ; friable ; medium patchy clay films.

Remarks : 1. A is a recent deposition containing many charcoal fragments and some reddish subsoil materials.

Profile No. K-18  
(850710) Kiriari-4

Location : Same as K-15  
Parent material : Local alluvium  
Landform : Same as K-15  
Local relief : Level on valley bottom  
Vegetation : Maize  
Elevation : 1720 m

Ap 0- 20 cm Dark reddish brown (5YR 3/5, moist) clay loam ; weak fine subangular blocky ; friable ; clear smooth boundary to  
Cg 20- 50+ cm Dull yellowish brown (10YR 5/3, moist) and brownish black (10YR 3/1, moist) light clay ; common bright brown (7.5YR 5/8) filmy and fine tubular mottles : weak medium subangular blocky ; friable.

Remarks : 1. Close to a stream in the valley bottom.  
2. Ground water level at 50 cm.

Profile No. K-19  
(850720) Mt. Longonot

Location : 11 km from A 104/B 3 junction on Naivasha road  
Parent material : Volcanic ashes and pumices  
Landform : Very gently undulating on the rift valley bottom  
Local relief : Level  
Vegetation : Short grasses with bushes  
Elevation : 1920 m

A 11 0- 13 cm Dark brown (10YR 3/3, moist) silt loam with common pumice gravels ; gradual smooth boundary to  
A 12 13- 33 cm Dark brown (10YR 2/3, moist) silt loam with common pumice gravels ; gradual clear boundary to  
A 13 33- 51 cm Olive brown (2.5YR 4/4, dry) silt loam with common pumice gravels ; clear smooth boundary to  
IIC 51- 61 cm Gray olive (5Y 6/2, dry) yellowish white pumice (5 - 20 mm in diam.) ; abrupt smooth boundary to  
IIIA b 61- 78 cm Gray (7.5YR 5.5/1, dry) sand ; single grain ; loose  
IV C 95-150 cm Gray (7.5YR 5/1, dry) sand ; single grain ; loose  
VA b 180-230 cm Brown (10YR 6/6, dry) loam ; weak subangular blocky

Profile No. K-20  
(850721) Menengai Crater  
Location : Menengai crater picnic site

Parent material : Volcanic ashes and pumices  
 Landform : Ridge part of Menengai crater rim  
 Local relief : Level  
 Vegetation : Eucalyptus plantation (5 to 10 m high)  
 Elevation : 2100 m

A 11	0- 11	cm	Dark brown (10YR 3/3, moist) clay loam ; strong, medium granular ; very friable ; gradual smooth boundary to
A 12	11- 34	cm	Dark brown (10YR 3/3, moist) clay loam ; coarse granular ; friable to slightly firm ; clear irregular boundary to
A 13	34- 50	cm	Dark brown (10YR 3.5/3, moist) clay loam with few pumices ; strong medium granular ; friable to slightly firm ; clear smooth boundary to
IIA 3	50- 65	cm	Dull yellowish brown (10YR 4/3, moist) clay loam ; medium fine granular ; clear smooth boundary to
IIB	65- 86	cm	Brown (10YR 4/4, moist) clay loam ; weak fine granular and medium subangular blocky ; clear smooth boundary to
IIC	86-100+	cm	Brown (10YR 4/4, moist) clay loam with common pumices (yellowish 5-20 mm in diam.) ; weak fine subangular blocky ; friable

Profile No. K-21

1. Sample No. : KY 183-192
2. Profile name and date of sampling : South Kinangop, Aug.23, 1985
3. Soil classification : Solodic Planosol
4. Location and altitude : southern fringe of South Kinangop plain, 2 km south from Magumu settlement. 2690 m.
5. Parent materials : ashes and other pyroclastic rocks of recent volcanoes
6. Physiographic position : plateau
7. Topography of surrounding : high-level structural plain
8. Microtopography : artificial ridges 15 cm high, 100 cm wide, in order to improve drainage condition, but no effect
9. Vegetation around the plot : grass (90%), potatoes, wheat, vegetables
10. Land use at the plot : grazing
11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 0-2%
14. Drainage class : imperfectly drained
15. Remarks : \* deep very dark greyish brown, mottled, firm, clay abruptly underlying a thick topsoil of friable silty clay loam  
 \* box sampling 0-125 cm

Profile No. K-22

1. Sample No. : KY 110-113
2. Profile name and date of sampling : Kamahendu-ridge, Aug. 22, 1985
3. Soil classification : Humic Andosol
4. Location and altitude : 5 km southeast from Mweri village along the local main road which connect Ruiru town with Kijabe. Local name is Kamahendu : 2200 m.
5. Parent materials : volcanic ashes
6. Physiographic position : broad ridge
7. Topography of surrounding : undulating to rolling
8. Microtopography : flat
9. Vegetation around the plot : tea (40%), grass (30%), vegetables (30%)
10. Land use at the plot : tea
11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%

14. Drainage class : well drained
15. Remarks : \* well drained extremery deep, dusky red to dark reddish brown, friable clay, with an acid humic topsoil  
\* auger sampling

Profile No. K-23

1. Sampling No. : KY 155-163
2. Profile name and date of sampling : Kamahendu-slope, Aug.22, 1985
3. Soil classification : Humic Andosol
4. Location and altitude : 150 m east and 5 m down along the slope from the Kamahendu-ridge pit, 2195 m.
5. Parent materials : volcanic ashes
6. Physiographic position : broad gentle slope
7. Topography of surrounding : undulating to rolling
8. Microtopography : slightly sloping (5%)
9. Vegetation around the plot : tea (30%), grass (30%), vegetable (30%)
10. Land use at the plot : tea
11. Erosion : slight rill erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : well drained
15. Remarks : \* complete box sampling (0 -112.5 cm)

Profile No. K-24

1. Sampling No. : KY 106-109
2. Profile name and date of sampling : Kamahendu-valley, Aug.22, 1985
3. Soil classification : Mollic ndosol
4. Location and altitude : 100 m east and 10 m down along the slope from the Kamahendu-slope pit, 2185 m.
5. Parent materials : volcanic ash
6. Physiographic position : broad valley bottom
7. Topography of surrounding undulating to rolling
8. Microtopography : slightly sloping (5%) but colluvial deposition
9. Vegetation around the plot : vegetable (70%), banana (10%), etc. (20%)
10. Land use at the plot : cabbage and banana
11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : moderately well drained
15. Remarks : \* auger sampling

Profile No. K-25

1. Sample No. : KY 102-105
2. Profile name and date of samling : Kamuchege-ridge, Aug. 22, 1985
3. Soil classification : Mollic Ando-Nitisol
4. Location and altitude : 7 km east and about 200 m down along the Ruiru-Kijabe road, village name Kamuchege, 2000 m.
5. Parent materials : volcanic ash, Tertiary basic igneous rocks such as olivine basalts, nepheline phonolite, and older basic tuffs
6. Physiographic position : broad ridge
7. Topography of surrounding : rolling
8. Microtopography : flat
9. Vegetation around the plot : tea (30%), food crops (maize, potatoes, 20%), coffee (20%), vegetable (10%), grass (20%)
10. Land use at the plot : maize, potatoes, beans, banana
11. Erosion : slight rill erosion
12. Stoniness/Rockiness : nil

13. Slope gradient : 2-8%
14. Drainage class : well drained
15. Remarks : \* extremely deep, dusky red to dark reddish brown, friable clay with a mollic top soil  
\* auger sampling

Profile No. K-26

1. Sample No. : KY 168-177
2. Profile name and date of sampling : Kamuchege-slope, Aug. 22, 1985
3. Soil classification : Humic Nitisol
4. Location and altitude : 100 m south and 20 m down along the slope from the Kamuchege-ridge plot 1980 m.
5. Parent materials : same as Kamuchege-ridge
6. Physiographic position : concave slope
7. Topography of surrounding : rolling to hilly
8. Microtopography : -
9. Vegetation around the plot : -
10. Land use at the plot : tea and coffee
11. Erosion : moderate to severe sheet erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 8-30%
14. Drainage class : well drained
15. Remarks : \* extremely deep dusky red to dark reddish brown, friable clay with acid humic top soil  
\* complete box sampling 0-125 cm

Profile No. K-27

1. Sample No. : KY 98-101
2. Profile name and date of sampling : Kamuchege-valley, Aug.22, 1985
3. Soil classification : Eutric Nitisol
4. Location and altitude : 100 m south and 50 m down along the slope from the Kamuchege-slope; at the center of U-shaped valley, 1930 m.
5. Parent materials : same as Kamuchege-ridge
6. Physiographic position : valley bottom
7. Topography of surrounding : rolling to hilly
8. Microtopography : flat
9. Vegetation around the plot : -
10. Land use at the plot : banana vegetable
11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : moderately well drained
15. Remarks : \* transitional from coffee to tea zone  
\* auger sampling

Profile No. K-28

1. Sample No. : KY 94-97
2. Profile name and date of sampling : Nyaga-ridge, Aug.21, 1985
3. Soil classification : Eutric Nitisol
4. Location and altitude : opposite side of Nyaga primary school along the Ruiru-Kijabe road, 1700 m.
5. Parent materials : soils developed on Tertiary basic igneous rocks such as olivine basalts, nepheline phonolite, older basic tuffs included
6. Physiographic position : broad ridge, volcanic footridges
7. Topography of surrounding : undulating to hilly
8. Microtopography : flat
9. Vegetation around the plot : maize (40%), coffee (40%), banana, vegetable (20%)
10. Land use at the plot : maize
11. Erosion : slight sheet erosion

12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : well drained
15. Remarks : \* extremely deep, dusky red to dark reddish brown, friable clay with mollic topsoil  
\* dense distribution of small (less the 0.5 ha) farms  
\* auger sampling

Profile No. K-29

1. Sample No. : KY 147-154
2. Profile name and date of sampling : Nyaga-slope, Aug.21, 1985
3. Soil classification : Eutric Nitisol
4. Location and altitude : 100 m north and 30 m down along the slope from the Nyaga-ridge plot, 1670 m.
5. Parent materials : same as Nyaga-ridge
6. Physiographic position : halfway down the slope
7. Topography of surrounding : undulating to hilly
8. Microtopography : sloping
9. Vegetation around the plot : -
10. Land use at the plot : coffee and maize
11. Erosion : moderate gully erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 10-20%
14. Drainage class : well drained
15. Remarks : \* complete box sampling (0-100 cm)

Profile No. K-30

1. Sample No. : KY 90-93
2. Profile name and date of sampling : Nyaga-valley, Aug.21, 1985
3. Soil classification : Eutric Nitisol
4. Location and altitude : 300 m north and 70 m down along the slope from the Nyaga-slope pit, 1600 m.
5. Parent materials : same as Nyaga-ridge
6. Physiographic position : concave foot slope near to valley bottom of Ruiru river
7. Topography of surrounding : undulating to hilly
8. Microtopography : slightly sloping
9. Vegetation around the plot : -
10. Land use at the plot : banana and coffee
11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 2 - 8 %
14. Drainage class : moderately well drained
15. Remarks : \* auger sampling

Profile No. K-31

1. sample No. : KY 178-182
2. Profile name and date of sampling : Ruiru estate, Aug.20, 1985
3. Soil classification : Eutr c Nitisol/Iron stone soil/Nito-Rhodic Ferralsol
4. Location and altitude : 6 km northwest from Ruiru town along Ruiru-Nyaga road, 1480 m.
5. Parent materials : Tertiary basic igneous rocks as olivine basalts, nepheline phonolites, older basic tuffs included
6. Physiographic position : plateau
7. Topography of surrounding : undulating
8. Microtopography : slightly concave slope
9. Vegetation around the plot : coffee 80%, grass and tree 20%
10. Land use at the plot : coffee estate, sprinkler irrigation
11. Erosion : nil
12. Stoniness/Rockiness : Iron stone layer (local name *murrām*) up to 7.5 cm diameter

from 40 cm -100 + cm depth

13. Slope gradient : 0 - 5 %
14. Drainage class : moderately well drained
15. Remarks : \* shallow, yellow red to dark yellowish brown, friable, gravelly clay over petroplinthite, *murrum* layer  
\* box sampling (difficult), 0-62.5 cm

Profile No. K-32

1. Sample No. : KY 164-167
2. Profile name and date of sampling : Juja estate, Aug.20, 1985
3. Soil classification : Pellic Vertisol, stony phase
4. Location and altitude : 18 km east from Ruiru town Juja estate, 1480 m.
5. Parent materials : Tertiary basic igneous rocks such as olivine basalts, nepheline phonolites, older basic tuffs included
6. Physiographic : plateau
7. Topography of surrounding : flat with dissected river side
8. Microtopography : flat
9. Vegetation around the plot : sisal (30%), grass (69%), maize (10%)
10. Land use at the plot : grazing ; orange and vegetable by irrigation
11. Erosion : nil
12. Stoniness/Rockiness : olivine basalt-nepheline phonolitic rock and stone layer up to 30 cm (or more) diameter, from 30 cm - 100 + cm depth
13. Slope gradient : 0-2%
14. Drainage class : Imperfectly drained
15. Remarks : \* very deep, dark gray to black, firm to very firm, bouldery and stony, cracking clay  
\* box sampling 0-62 5 cm, rock collection

Profile No. K-33

1. Sample No. : KY 81-84
2. Profile name and date of sampling : Tinderet, Aug.15, 1985
3. Soil classification : Mollic Nitisol
4. Location and altitude : South fringe of Elgyo escarpment, 50 km south east from Eldoret city 2500 m.
5. Parent materials : Tertiary basic igneous rocks such as olivine basalts nepheline phonolites
6. Physiographic position : volcani footridge
7. Topography of surrounding : undulating to hilly
8. Microtopography : broad ridge
9. Vegetation around the plot : wheat, barley, maize, grazing, forest
10. Land use at the plot : wheat and maize
11. Erosion : slight rill erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 2 - 8 %
14. Drainage class : well drained
15. Remarks : \* extremely deep, ducky red, friable, clay  
\* auger sampling

Profile No. K-34

1. sample No. : KY 77-80
2. Profile name and date of sampling : Kitale, Aug.14 1985
3. Soil classification : Nito-Rhodic Ferralsol
4. Location and altitude : 6 km south from Kitale city, along the main road. 1800 m.
5. Parent materials : old volcanic ash and undifferentiated basement system rocks
6. Physiographic position : lower-level upland
7. Topography of surrounding : gently undulating
8. Microtopography : slightly convex, very broad ridge
9. Vegetation around the plot : maize

10. Land use at the plot : maize
11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 2 - 8 %
14. Drainage class : well drained
15. Remarks : \* very deep, red to dark red, very friable to friable, clay

Profile No. K-35

1. Sample No. : KY 85-89
2. Profile name and date of sampling : Malava, Aug.14, 1985
3. Soil classification : Humic Nitisol
4. Location and altitude : 30 km north from Kakamega, the side of main road, 1700 m.
5. Parent materials : Tertiary or older basic igneous rocks as basalts, nepheline phonolites, etc., basic tuffs included with some mixing of basement granite
6. Physiographic position : upper middle-level upland
7. Topography of surrounding : undulating
8. Microtopography : broad ridge
9. Vegetation around the plot : maize, forest
10. Land use at the plot : maize (poor)
11. Erosion : rill erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 2 - 8 %
14. Drainage class : well drained
15. Remarks : \* extremely deep dark reddish brown to dark red, friable, clay, with an acid humic top soil  
\* auger sampling

Profile No. K-15

1. Sample No. : KY 193-202
2. Profile name and date of sampling : Kiriari-ridge, July 10, 1985
3. Soil classification : Humic Nitisol
4. Location and altitude : 18 km north from Embu town, Kiriari girl's secondary school, 1800 m.
5. Parent materials : Tertiary basic igneous rocks such as olivine basalts, nepheline phonolites
6. Physiographic position : volcanic foot ridge
7. Topography of surrounding : rolling to hilly
8. Microtopography : ridge, convex almost flat
9. Vegetation around the plot : tea (50%), coffee (30%), maize (10%), grass (10%)
10. Land use at the plot : corn and coffee
11. Erosion : rill erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : well drained
15. Remarks : \*complete box sampling 0-125 cm  
\*profile description by K. Kyuma

Profile No. K-16

1. Sample No. : KY 70-73
2. Profile name and date of sampling : Kiriari-slope maize/tea, July 10, 1985
3. Soil classification : Humic Nitisol
4. Location and altitude : 150 m northeast and 20 m down along the slope from the pit of Kiriari-ridge, 1780 m.
5. Parent materials : same as Kiriari-ridge
6. Physiographic position : convex slope
7. Topography of surrounding : -
8. Microtopography : border road, between maize and tea fields
9. Vegetation around the plot : -

10. Land use at the plot : maize and tea
11. Erosion : gully erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 5-15%
14. Drainage class : well drained
15. Remarks : \*pit sampling 0-120 cm  
\*description by K. Kyuma

Profile No. K-17

1. Sample No. : KY 203-212
2. Profile name and date of sampling : Kiriari-slope coffee/tea July 10, 1985
3. Soil classification : Humic Nitisol
4. Location and altitude : 150 m northeast and 30 m down along the slope from the pit of Kiriari-slope maize/tea, 1750 m.
5. Parent materials : same as Kiriari-ridge
6. Physiographic position : convex slope
7. Topography of surrounding : -
8. Microtopography : the lowest part of the sloped coffee field right up the neighbouring tea field
9. Vegetation around the plot : -
10. Land use at the plot : coffee and tea
11. Erosion : gully erosion except in well grown tea garden
12. Stoniness/Rockiness : nil
13. Slope gradient : 20-30%
14. Drainage class : well drained
15. Remarks : \*complete box sampling 0-125 cm  
\*profile description by K. Kyuma

Profile No. K-18

1. Sample No. : KY 74-76
2. Profile name and date of sampling : Kiriari-valley, July 10, 1985
3. Soil classification : Humic Gleysol
4. Location and altitude : 70 m northeast and 30 m down along the slope from the pit of Kiriari-slope coffee/tea, 1720 m
5. Parent materials : same as Kiriari-ridge
6. Physiographic position : U-shaped valley bottom
7. Topography of surrounding : -
8. Microtopography : small valley plain, 10-20 m wide
9. Vegetation around the plot : -
10. Land use at the plot : grazing (grassland), maize
11. Erosion : nil, but periodical flooding?
12. Stoniness/Rockiness : nil
13. Slope gradient : 5-10%
14. Drainage class : poorly drained
15. Remarks : \*colluvial deposition of poor acid surface soils of Kiriari-slope coffee/tea, may result in this kind of poor soil.  
\*profile description by K. Kyuma

Profile No. K-36

1. Sample No. : KY 230-239
2. Profile name and date of sampling : Gitare-ridge, July 15, 1985
3. Soil classification : Humic Nitisol
4. Location and altitude : 4 km north from Runyenjes, 1580 m.
5. Parent materials : Tertiary basic igneous rocks such as olivine basalts, nepheline phonolites ; older basic tuffs
6. Physiographic position : volcanic footridges
7. Topography of surrounding : rolling
8. Microtopography : broad ridge
9. Vegetation around the plot : coffee (50%) maize (20%), tea (10%), vegetable,

fruits (20%)

10. Land use at the plot : coffee, maize, sweet potato, tea
11. Erosion : gully erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 5-10%
14. Drainage class : well drained
15. Remarks : \*complete box sampling 0-125 cm  
\*very thin top soil

Profile No. K-37

1. Sample No. : KY 65-69
2. Profile name and date of sampling : Gitare-slope, July 15, 1985
3. Soil classification : Eutric Nitisol
4. Location and altitude : 150 m southwest and 30 m down along the slope from the pit of Gitare-ridge, 1550 m.
5. Parent materials : same as Gitare-ridge
6. Physiographic position : convex slope
7. Topography of surrounding : -
8. Microtopography : contour bunding to prevent erosion 40 cm high, 50 cm wide and 100 m interval.
9. Vegetation around the plot : -
10. Land use at the plot : coffee
11. Erosion : gully and sheet erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 10-20%
14. Drainage class : well drained
15. Remarks : \*sampling from pit 0-150 cm

Profile No. K-38

1. Sample No. : KY 240-249
2. Profile name and date of sampling : Gitare-valley, July 15, 1985
3. Soil classification : Eutric Nitisol
4. Location and altitude : 150 m southwest and 30 m down along the slope from the pit of Gitare-slope, 1520 m.
5. Parent materials : same as Gitare-ridge
6. Physiographic position : valley bottom
7. Topography of surrounding : -
8. Microtopography : slightly concave slope
9. Vegetation around the plot : -
10. Land use at the plot : coffee, grass, maize, banana
11. Erosion : gully erosion
12. Stoniness/Rockiness : basaltic phonolitic rocks, deeper than 100 cm.
13. Slope gradient : 5-10%
14. Drainage class : imperfectly drained
15. Remarks : \*complete box sampling 0-125 cm

Profile No. K-39

1. Sample No. : KY 213-222
2. Profile name and date of sampling : Ugweri-ridge July 16, 1985
3. Soil classification : Rhodic Ferralsol/Eutric Nitisol
4. Location and altitude : 11 km south from Runyenjes, 1310 m.
5. Parent materials : basalts (Nyambeni Series)
6. Physiographic position : volcanic plain, convex broad ridge
7. Topography : undulating
8. Microtopography : slightly convex, almost flat
9. Vegetation around the plot : maize (10%) coffee (30%), sunflower, mango tree, grass
10. Land use at the plot : maize, sunflower, coffee

11. Erosion : nil
12. Stoniness/Rockiness : nil
13. Slope gradient : 0-5%
14. Drainage class : somewhat excessively drained
15. Remarks : \*dark reddish brown, clay, very hard when dry, friable when moist  
many fine to medium pores.  
\*complete box sampling 0-125 cm

Profile No K-40

1. Sample No. KY 60-63
2. Profile name and date of sampling : Ugweri-slope July 16, 1985
3. Soil classification : Rhodic Ferralsol/Eutric Nitisol
4. Location and altitude : 100 m north and 3 m down along the slope from the Ugweri-ridge pit, 1307 m
5. Parent materials : same as Ugweri-ridge
6. Physiographic position : volcanic plain, halfway of convex slope
7. Topography of surrounding : -
8. Microtopography : slightly convex slope
9. Vegetation around the plot : -
10. Land use at the plot : maize
11. Erosion : slight rill erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : somewhat excessively drained
15. Remarks : \*sampling from pit 0-150 cm

Profile No. K-41

1. Sample No. : KY 223-229
2. Profile name and date of sampling : Ugweri-bottom, July 16, 1985
3. Soil classification : Rhodic Ferralsol, iron stone phase
4. Location and altitude : 100 m north and 3 m down along the slope from the Ugweri-slope, near swampy bottomland, 1304 m.
5. Parent materials : same as Ugweri-ridge
6. Physiographic position : volcanic plain concave slope near (5 m) swampy bottomland
7. Topography of surrounding : -
8. Microtopography : concave slope
9. Vegetation around the plot : -
10. Land use at the plot : coffee
11. Erosion : slight sheet and rill erosion
12. Stoniness/Rockiness : iron-manganese stone layer deeper than 60 cm
13. Slope gradient : 2-8%
14. Drainage class : imperfectly drained
15. Remarks : \*box sampling 0-87.5 cm

Profile No. K-42

1. Sample No. : KY 52-55
2. Profile name and date of sampling : Kiritiri-top, July 17, 1985
3. Soil classification : Ferric Arenosols
4. Location and altitude : 2 km east from Kiritiri town, 1150 m.
5. Parent materials : basement gneisses, and quartzites
6. Physiographic position : lower middle-level uplands, broad top of ridge
7. Topography of surrounding : undulating
8. Microtopography : flat
9. Vegetation around the plot : banana (20%), pea (30%), cotton (30%), maize (10%), grass
10. Land use at the plot : banana garden
11. Erosion : nil

12. Stoniness/Rockiness : nil
13. Slope gradient : 0-5%
14. Drainage class : Somewhat excessively drained
15. Remarks : \*reddish brown loamy soil, enough moisture deeper than 50 cm  
\*auger sampling

Profile No. K-43

1. Sample No : KY 56-59
2. Profile name and date of sampling : Kiritiri-slope, July 17, 1985
3. Soil classification : Cambic Arenosols
4. Location and altitude : 200 m west and 3 m down along the slope from the Kiritiri-top pit, 1147 m.
5. Parent materials : same as Kiritiri-top
6. Physiographic position : convex slope
7. Topography of surrounding :
8. Microtopography : near the lower limit of farmland lower part of the toposequence occupied by grass. Bottomland has outcrops of gneiss and quartzite
9. Vegetation around the plot :
10. Land use at the plot : pigeon pea and cotton
11. Erosion : gully and sheet erosion
12. Stoniness/Rockiness : nil
13. Slope gradient : 2-8%
14. Drainage class : somewhat excessively drained
15. Remarks : \*grayish brown loamy sand  
\*auger sampling

## B2. CHEMICAL AND MINERALOGICAL CHARACTERIZATION OF SOILS DERIVED FROM VOLCANIC ASHES

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### I. Introduction

Soils derived from volcanic ashes occur in association with the major global tectonic zones of the world. Volcanic ash soils are named Ando soils, Andosols or Andepts and occupy more than 124 million hectares, or 0.84% of the world's land surface (Leamy et al., 1980). A review of studies throughout the world showed that the most distinctive property of soils derived from volcanic ashes in cool to temperate and humid climates is the presence of active forms of aluminum in an aluminum-humus complex, and of allophane and imogolite (Wada, 1985).

In Kenya, volcanic activity has occurred in and around with the Great Rift Valley Systems in East Africa in the early Tertiary to Recent eras. Thick volcanic ash deposits have been found on the hills and footslopes of Nyambeni Hills, Mt. Kenya, Chyulu Range, Aberdare Range, and around the Great Rift Valley regions, which are characterized by a high alkali content (Baker et al., 1971). Because of suitable climatic conditions, the soils of the volcano regions are intensively cultivated and hence the areas are highly populated (up to 800 persons/km<sup>2</sup>). Nevertheless, few systematic studies have been made on the chemistry and mineralogy of these soils. Wielemaker and Wakatsuki (1984), Wakatsuki and Wielemaker (1985), and Mizota and van Reeuwijk (1986) have studied some selected soils derived from volcanic ashes in Kenya. In spite of the resemblance in field morphology common to soils developed on volcanic ashes, the soils studied have very unusual properties, typified by low content of active forms of aluminum. Whether the unusual properties are derived from a local petrological influence of parent volcanic materials or from other specific weathering environments is not known. Diverse pedo-environmental conditions have been observed in Kenya (Sombroek et al., 1982), so there is a base for a systematic study of soil development on volcanic ashes in different bioclimatic conditions.

This study extends work described elsewhere (Mizota and van Reeuwijk, 1986, van der Gaast et al., 1986). Soil samples were collected from areas in humid to dry climates, and the petrology of the parent volcanic materials was from basic basaltic to acidic trachytic. Emphasis was placed on the effects of these factors on the development of active aluminum in the weathering of volcanic ashes.

### II. Materials and methods

#### (1) Soil samples

Twelve pedons developed on Quaternary volcanic ejecta were selected through reference to a soil map and agro-climatic zone map of Kenya (Sombroek et al., 1982; Tables 1-1 and 1-2). A description and site information about the pedons are given in Chapter B-1. The pedons were in humid (Zone I) to dry (Zone VI) areas. The mean annual rainfall is from 450 to 2700 mm and the mean annual air temperature from 12 to 22°C. Zone I, II, and part of III were udic in the Soil Taxonomy classification (Soil Survey Staff, 1975), part of III, all of IV, and part of V were ustic, and part of V and all

Table 1-1. Analysis of Soil Samples

Agro-ecological zone <sup>a)</sup>	Pedon	Depth (cm)	Horizon	pH		Total carbon (%)	Oxalate Al (%)	Bulk density (g/cm <sup>3</sup> )	P-retention (%)
				H <sub>2</sub> O	KCl				
I-6	Gituamba (K-3)	0-16	A1	5.2	3.7	13.1	2.2	0.70	100
		16-28	A3	5.0	4.1	8.6	2.3	0.68	100
		28-47	B1	4.8	4.4	7.5	2.6	0.68	99
		47-130+	B2	4.8	4.5	5.4	4.0	0.85	99
I-5	Mt. Kenya Lodge (K-4)	0-32	A1	5.8	4.7	15.2	1.4	0.54	82
		32-57	II C	6.5	5.3	0.7	1.2	1.09	71
		57-68	III Ab	6.9	5.4	10.5	5.9	—	100
		68-120	IV B2b	7.4	5.7	10.4	7.8	0.40	99
		120-130	IV B3b	6.1	5.6	2.0	2.5	—	99
		130-142	V C1b	6.2	6.2	0.5	2.1	—	98
		142-180+	VIC2b	6.4	6.3	0.3	2.0	0.47	80
II-2	Nyambeni Hills (K-5)	0-16	A1	5.9	4.9	3.9	1.4	1.01	73
		16-43	A3	7.0	5.1	3.3	1.4	0.94	76
		43-70	B2	6.8	5.2	2.4	1.4	0.89	78
		70-120+	B3	6.8	5.4	1.7	1.5	0.92	80
II-6	Kijabe (K-1)	0-17	A1	6.7	6.1	10.0	1.1	0.70	64
		17-41	AB	7.1	6.2	4.3	1.0	0.85	63
		41-49	B1	7.1	5.9	1.8	1.0	0.85	61
		49-75	II A1	6.3	5.2	4.5	0.8	0.93	62
		75-105	II B1	6.3	5.3	4.0	2.6	0.82	89
		105-140+	II B2	6.2	5.1	2.9	3.6	0.83	92
V-2	Chyulu-1 (K-6)	0-15	A1	6.7	5.9	3.1	1.0	1.05	40
		15-28	A3	7.1	6.4	1.8	1.1	1.10	56
		28-40	B1	7.2	6.5	1.5	1.2	1.16	66
		40-60	B2	7.4	6.6	1.6	1.6	1.15	71
		60-70	B3ca	7.9	7.2	1.4	2.1	—	74
		70-180	C2cax	9.1	7.6	0.7	1.1	—	48
V-2	Chyulu-2 (K-7)	0-30	A1	7.1	5.8	3.5	0.7	0.96	25
		42-150	III A1	7.8	5.9	4.8	2.0	0.85	69
III-6	Menengai (K-20)	0-11	A11	6.6	4.9	6.0	0.6	—	52
		11-34	A12	6.2	4.4	5.6	0.5	0.56	50
		34-50	A3	6.0	4.5	4.3	0.7	—	61
		50-65	II A1b	6.1	4.4	3.6	0.9	—	69
		65-86	II B2b	6.3	4.6	2.5	1.2	0.47	77
		86-110+	II Cb	6.8	4.7	1.6	0.5	—	60
III-7	Mau (K-9)	0-12	A11	7.2	6.5	10.0	0.1	0.60	12
		12-39	II A12	7.2	5.7	5.6	0.6	0.91	38
		39-52	III A13	7.5	5.9	2.7	0.5	1.01	35
		52-63	III A3	7.4	5.8	1.7	0.4	1.08	28
		63-91	III C	7.7	5.8	0.5	0.1	1.11	12
		91-137	IVA1b	7.4	5.7	3.8	0.3	0.83	28
IV-4	Narok-1 (K-10)	137-150+	IVA3b	7.6	5.7	2.6	0.3	—	28
		0-28	A1	7.1	5.2	3.2	0.2	0.96	20
		28-57	A3	7.1	5.5	2.3	0.2	0.86	19
		57-83	B2	7.5	5.6	1.5	0.2	1.00	17
V-5	Narok-2 (EAK-35)	83-110+	II Ab	7.5	5.8	1.4	0.2	1.05	19
		0-20	A1	6.7	5.8	2.3	0.2	—	31
		20-60	B21	7.0	5.8	0.7	0.3	—	28
		60-90	II B22	7.3	6.3	0.4	0.2	—	19
VI-1	Magadi (K-8)	90-145+	II B3	7.9	7.0	0.1	0.1	—	22
		0-20	A1	7.3	5.9	2.1	0.2	1.13	18
		20-50	A3	7.5	5.7	1.0	0.2	1.09	18
		50-58	II C1	7.2	5.8	0.6	0.1	—	17
		58-65	III C2	7.4	5.7	0.3	0.1	1.12	11
V-5	Mt. Longonot (K-19)	65-78+	III C3	7.5	5.9	0.4	0.1	1.09	15
		0-13	A11	6.5	5.0	3.6	0.2	0.90	22
		13-33	A12	6.9	5.2	3.8	0.2	0.93	23
		33-51	A13	7.3	5.5	2.1	0.2	0.85	22
		61-78	III A1	6.8	5.5	1.4	0.2	0.86	22
		95-150	IV C	7.5	5.5	0.1	0.1	—	1
		180-230	V A1	7.3	6.1	1.0	0.2	—	16

<sup>a)</sup> Cited from Sombroek et al. (1982)

Table 1-2. Analysis

Agro-ecological zone <sup>*)</sup>	Pedon	Depth (cm)	Horizon	Exchangeable bases (me/100g)				
				Ca	Mg	K	Na	Sum
I-6	Gituamba (K-3)	0-16	A1	0.0	0.0	0.3	0.1	0.4
		16-28	A3	0.0	0.1	0.2	0.1	0.4
		28-47	B1	0.0	0.0	0.2	0.1	0.3
		47-130+	B2	0.2	0.3	0.1	0.1	0.8
I-5	Mt. Kenya Lodge (K-4)	0-32	A1	2.2	0.4	0.6	0.1	3.3
		32-57	II C	0.8	trace	0.2	0.1	1.1
		57-68	III Ab	1.3	0.2	3.2	7.9	12.6
		68-120	IVB2b	1.6	trace	6.7	5.5	13.8
		120-130	IVB3b	1.2	trace	5.0	3.6	9.8
		130-142	VC1b	1.0	trace	0.3	0.2	1.5
		142-180+	VIC2b	1.4	trace	0.1	0.2	1.7
II-2	Nyambeni Hills (K-5)	0-16	A1	8.4	4.1	0.4	0.1	13.0
		16-43	A3	9.7	3.9	0.3	0.3	14.2
		43-70	B2	9.7	3.4	0.2	0.1	13.4
		70-120+	B3	8.2	3.2	0.2	0.1	11.7
II-6	Kijabe (K-1)	0-17	A1	33.0	4.1	1.5	0.1	38.6
		17-41	AB	19.5	3.5	0.9	0.0	23.9
		41-49	B1	8.6	2.5	0.7	0.0	11.8
		49-75	II A1	14.7	4.9	1.6	0.0	21.2
		75-105	II B1	15.8	4.3	2.6	0.1	22.9
		105-140+	II B2	7.8	3.1	3.9	0.1	14.9
V-2	Chyulu-1 (K-6)	0-15	A1	16.8	4.5	4.0	0.6	25.9
		15-28	A3	19.9	6.4	3.7	0.5	30.5
		28-40	B1	25.7	8.5	4.5	0.8	39.4
		40-60	B2	29.9	10.6	3.8	1.1	45.3
		60-70	B3ca	37.3	23.3	5.5	2.8	68.9
		70-180	C2cax	24.8	21.9	13.2	38.6	98.5
		0-30	A1	21.6	4.4	5.4	4.1	35.5
V-2	Chyulu-2 (K-7)	42-150	III A1	46.6	12.2	7.4	4.2	70.4
		0-11	A11	14.2	5.0	7.4	3.4	30.0
III-6	Menengai (K-20)	11-34	A12	11.8	2.6	5.0	3.3	22.7
		34-50	A3	12.0	2.8	5.4	4.0	24.2
		50-65	II A1b	9.3	2.3	3.7	1.2	16.5
		65-86	II B2b	9.1	2.2	4.5	1.4	17.2
		86-110+	II Cb	9.0	2.3	4.8	1.4	17.5
		0-12	A11	34.8	6.1	2.8	0.2	43.9
III-7	Mau (K-9)	12-39	II A12	16.9	2.3	6.0	4.8	30.0
		39-52	III A13	12.5	1.1	6.6	12.4	32.6
		52-63	III A3	8.4	0.5	1.5	0.9	11.3
		63-91	III C	3.4	0.2	3.6	2.3	9.5
		91-137	IVA1b	20.2	3.8	13.4	11.1	48.5
		137-150+	IVA3b	9.2	5.0	7.2	4.5	25.9
		0-28	A1	16.4	4.8	4.0	0.4	25.6
IV-4	Narok-1 (K-10)	28-57	A3	19.0	6.0	4.2	2.1	31.3
		57-83	B2	17.9	5.1	3.9	2.5	29.4
		83-110+	II Ab	16.8	5.1	5.0	2.5	29.4
V-5	Narok-2 (EAK-35)	0-20	A1	17.6	2.3	2.9	0.4	23.1
		20-60	B21	20.0	2.0	6.3	2.0	30.3
		60-90	II B22	19.1	2.2	9.8	1.7	32.9
VI-1	Magadi (K-8)	90-145+	II B3	21.8	2.2	6.0	0.8	30.7
		0-20	A1	28.2	6.0	7.3	trace	41.5
		20-50	A3	27.4	4.5	5.0	trace	36.9
V-5	Mt. Longonot (K-19)	50-58	II C1	24.7	3.9	3.9	trace	32.5
		58-65	III C2	18.4	2.7	3.1	trace	24.2
		65-78+	III C3	21.2	2.8	3.3	trace	27.3
		0-13	A11	13.5	3.8	3.0	0.2	20.5
		13-33	A12	19.3	4.0	3.3	0.3	26.9
V-5	Mt. Longonot (K-19)	33-51	A13	15.2	5.0	4.5	0.4	25.1
		61-78	III A1	13.1	7.3	8.0	1.0	29.4
		95-150	IV C	1.9	0.4	0.9	0.4	3.6
		180-230	VA1	13.8	1.3	4.2	4.8	24.1

<sup>\*)</sup> Cited from Sombroek et al. (1982)

<sup>\*\*)</sup> Abbreviation : Qz=quartz, Fd=feldspars, Gb=gibbsite, Kn=kaolin, Magh=maghemite, Hm=hematite, VG=volcanic glass, Mc=mica, LS=layer silicates.

of Soil Samples

Exchange-able Al (me/100g)	< 2 μm		>50 μm fractions (%)	P <sub>2</sub> O <sub>5</sub> (ppm)		Minerals in** 2 ~ 20 μm
	(%)	pH disp.		Total	Available	
I-6 4.9	31	4	trace	6,270	12	Qz >>> Fd
3.4	54	4	trace	7,850	0	Qz >>> Fd
2.2	—	—	—	6,253	0	—
0.7	45	4	trace	—	—	Qz >>> Fd
—	10	4	28	4,871	40	Fd >>> Qz
—	—	—	—	1,080	10	—
I-5 —	41	4	7	3,301	6	Qz, Fd >> Gb
—	—	—	—	5,315	0	—
—	43	4	15	2,167	0	Gb > Fd >> Qz
—	—	—	—	1,901	0	—
—	14	4	21	1,371	0	Fd > Gb
—	64	10	1	9,790	53	Qz > Kn, Magh, Hm > Fd, Gb
I-2 —	—	—	—	8,427	29	—
—	—	—	—	7,946	26	—
—	73	10	1	8,512	16	Qz > Kn, Magh, Hm > Fd, Gb
—	20	10	—	7,048	43	Fd
—	—	—	—	3,530	0	—
II-6 Lijabe —	—	—	—	3,189	0	—
—	26	10	—	4,672	0	Fd
—	—	—	—	4,259	0	—
—	19	10	—	—	—	Fd
—	15	10	—	9,244	577	VG
—	—	—	—	8,390	227	—
—	—	—	—	7,861	152	—
V-2 K-5 —	17	10	—	7,976	194	VG
—	—	—	—	6,749	87	VG
—	23	10	—	—	—	VG
—	7	10	72	5,762	396	Fd, Qz, Mc
K-7 —	30	10	26	6,508	79	Fd
—	40	10	13	1,950	10	Fd > LS >> Qz
III-6 —	—	—	—	2,971	4	—
—	—	—	—	2,862	4	—
—	49	10	12	3,366	0	Fd >> LS, Qz
—	—	—	—	2,238	0	—
—	—	—	—	1,070	0	—
—	7	10	38	5,676	162	Fd > Qz
—	—	—	—	4,482	68	—
—	—	—	—	2,637	9	—
IV-7 —	7	10	54	1,713	18	Fd
—	—	—	—	850	34	—
—	23	10	24	2,910	0	Fd
—	—	—	—	2,080	6	—
—	34	10	13	6,415	1,486	Fd
—	—	—	—	6,027	928	—
—	—	—	—	3,406	497	—
—	40	10	9	2,517	206	Fd
—	29	10	—	—	—	Fd
—	—	—	—	—	—	—
V-5 —	16	10	—	—	—	—
—	33	10	—	—	—	Fd
—	47	10	0	3,548	933	Fd >>> Qz
—	—	—	—	3,747	612	—
—	—	—	—	1,591	186	—
—	—	—	—	1,184	223	—
VI-1 —	32	10	5	1,353	199	Fd >>> Qz
—	26	10	30	4,364	23	Fd
—	—	—	—	2,486	12	—
—	—	—	—	1,911	4	—
V-5 —	40	10	12	1,529	9	Fd
—	—	—	—	636	26	—
—	36	10	17	1,490	20	Fd >>> Qz

of VI were aridic. The main parent volcanic material from Nyambeni Hills, Chyulu Range, and Aberdare Range (in the eastern parts of Kenya) were basic basaltic, but those from places associated with Rift Valley floor volcanoes were acidic peralkaline trachytic (Baker et al., 1971, Wielemaker and Wakatsuki, 1984). An outline of the sample sites is given in Fig. 1. Extraneous rock fragment materials other volcanic ejecta were not found in the pedons studied.

Very little information is available for estimation of the absolute ages of soils and volcanic ash deposits in Kenya, although many  $^{14}\text{C}$  ages relevant for dating fluctuations in lake levels in the Nakuru, Elementaita, and Naivasha basins have been reported (Butzer et al., 1972). Stratigraphic correlation and the physical appearance of ash deposits around the soil survey areas in this study indicated that the last, most recent volcanic ejecta derived from Mt. Longonot in the Rift Valley floor and the southern cinder cones of the Chyulu Range. The ages of two soil humic acid preparations from the A horizons buried by gray colored key ash ejecta from Mt. Longonot were  $2350 \pm 130$  and  $3090 \pm 140$  years (Chapter B-3, Appendix).

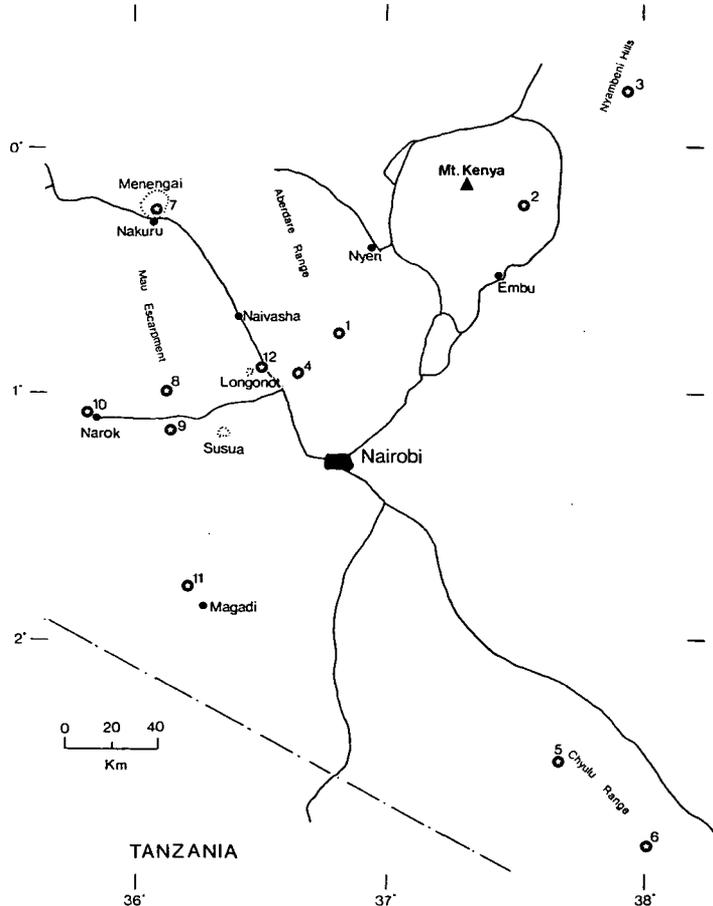


Fig. 1. Sampling sites (closed star mark).

- 1 = Gituamba, 2 = Mt. Kenya Lodge, 3 = Nyambeni Hills, 4 = Kijabe, 5 = Chyulu-1, 6 = Chyulu-2, 7 = Menengai, 8 = Mau, 9 = Narok-1, 10 = Narok-2, 11 = Magadi, 12 = Mt. Longonot

The sample materials were collected from different horizons of the pedons and brought to Kenya Soil Survey of the National Agricultural Laboratories, Nairobi. Soil samples were air-dried and shipped to Japan.

## (2) Analysis of soil samples

Triplicate, undisturbed ring samples (volume, 100 cm<sup>3</sup>) were collected in the field for calculation of bulk density. No correction was made for the gravel content (larger than 2 mm in diameter). The following analytical procedures were used: total carbon content of soil, dry combustion method; pH (KCl, H<sub>2</sub>O), 1:2.5 suspension; exchangeable Ca, Mg, K, and Na, NH<sub>4</sub>OAc extraction and either atomic absorption spectroscopy (or both); exchangeable Al, *M* KCl extraction and atomic absorption spectroscopy; P-retention, method of Blakemore et al., 1981; acid-oxalate-soluble Al, method of Blakemore et al., 1981; total phosphorus, HF-HClO<sub>4</sub> digestion and molybdovanadate colorimetry; and available phosphorus, 2.5% acetic acid extraction by the method of Sekiya (1976). The last two items were analyzed by Miss K. Kusuhara as part of her graduation thesis at the Faculty of Agriculture, Kyushu University.

## (3) Analysis of clay and silt minerals

Five to ten grams of samples of fine earth was first washed with *M* NaOAc buffer solution (pH 5) to remove CaCO<sub>3</sub> and to saturate the samples with Na ions. Then treatment with hydrogen peroxide (15%, v/v) on a hot electric plate and sonic wave treatment with 25-KHz output for 20 min were done. The suspensions were caused to disperse at pH 4 or 10 by the addition of small amounts of dilute HCl or NaOH, the choice depending upon the major clay minerals (Table 1-2). Clays (less than 2 μm in equivalent spherical diameter) were repeatedly collected by sedimentation, decantation, and sonic wave treatment. The clay collected were flocculated by the addition of saturated NaCl and stored as dilute suspensions in a polyethylene bottle. A 5-mL portion of the clay suspension was centrifugally washed with 5-mL portions of water-methanol (1:1), methanol-acetone (1:1), and then acetone, and the dry clay weight was measured.

The clay mineralogical composition was estimated by a combination of several methods. First, the active constituents in the clays were dissolved by selective dissolution with acid-oxalate. Second, insoluble clay constituents were studied by instrumental analysis. Details of the analytical procedures are described below. Wet clay sediment from the suspension equivalent to 100 mg of dry clay was shaken on a reciprocal shaker for four hours in the dark in 100 mL of 0.2 *M* ammonium oxalate-oxalic acid (pH<sub>3</sub>.0). Four drops of 0.2% "Accofloc N-100" (Mitsui Cyanamide Limited Company, Tokyo) solution was added, vigorously shaken for 30 seconds, and centrifuged for 5 min at 3000 rpm. The clear supernatant was analysed for Si, Al, and Fe. Si was colorimetrically assayed with silico-molybdate (Weaver et al., 1968), and Al and Fe by atomic absorption spectroscopy. Clay residues in the centrifugal tubes were recovered by several washings with *M* NaOAc buffer (pH 5) and treated again with 15% hydrogen peroxide on a hot electric plate to remove "Accofloc". The resulting clay suspensions were used for X-ray diffraction analysis in the oriented state, for which Mg- and K-saturated specimens were employed. Glycerol solvation and heating were applied to these clay samples. The formamide test was used for differentiation of halloysite (7 Å) from kaolinite (Churchman et al., 1984). Extraction with dithionite-citrate-bicarbonate (DCB) was done by the method of Tokashiki and Wada (1972). The dissolved constituents were also analysed for Si, Al, and Fe by the same procedures as for acid-oxalate. Polycarbonate centrifugal tubes were used to avoid Si contamination from the tube wall. The KBr disc method was employed for infrared spectroscopy, where 1.5 mg of a dry clay sample was mixed with 600 mg of KBr. A small drop of clay dispersion was dried on a collodion grid and observed under an electron microscope (JEM 100B) at a direct magnification of

50,000 times. Silt fractions (2 to 20  $\mu\text{m}$  in diameter) were separated from the residues after clay separation. Minerals in the silt fractions were identified by X-ray powder diffractometry with Co K alpha radiation.

### III. Results and discussion

#### (1) Physical and chemical properties

Results of the analysis of the soil samples from twelve pedons are shown in Tables 1-1 and 1-2, where the pedons are arranged in the order of decreasing amounts of acid-oxalate-soluble aluminum from the surface horizons. There was a clear climosequential tendency in the changes in the physical and chemical properties of the soils. With decreasing annual rainfall from Zone I to Zone VI, the pH ( $\text{H}_2\text{O}$ , KCl) and status of the exchangeable bases of the soil samples markedly increased. The reverse was observed for total carbon, acid-oxalate-soluble aluminum, and P retention. Bulk density did not change in any definite pattern. With the exceptions of the Gituamba and Mt. Kenya Lodge soils from areas of higher rainfall, in which the chemical properties are the same as those of volcanic ash soils in Japan (Inoue, 1986) and in some other countries, all of the soil samples had fairly low to very low amounts of active aluminum soluble in acid-oxalate solution. The data suggest that greater rainfall where the downward leaching of soluble elements is prevailing favour the development of active aluminum in the weathering of volcanic ashes. Large amounts of exchangeable K and Na were noted among the exchangeable bases. Such a large exchangeable K content explains why the application of K fertilizer is not common in Kenya. The parent volcanic materials in the Kenya Rift Valley systems are alkaline (Baker et al., 1971, Wielemaker and Wakatsuki, 1984). The gradual release of the alkali elements through weathering of primary volcanic materials, even in advanced stages of pedogenesis as in the Mt. Kenya Lodge and Nyambeni Hills soils, result in high levels of exchangeable K and Na.

#### (2) Mineralogical properties

In silt fractions, quartz, feldspar, layer silicates, and oxides and hydroxides of Fe and Al were observed (Table 1-2). The quartz content was greatest in soils from humid zones (Gituamba and Nyambeni Hills and buried horizons of Mt. Kenya Lodge). Since fine-grained quartz was not found in the drier, younger soils, the quartz was of extraneous origin, probably from eolian dust as found in Hawaii (Jackson et al., 1971) and in Japan (Mizota and Matsuhisa, 1985).

Table 2-1 gives a summary of clay minerals analysis. Acid-oxalate treatment selectively dissolves aluminum in combination with humus, allophane, imogolite, and ferrihydrite (Wada, 1977). The amounts of acid-oxalate-soluble constituents differed more from pedon to pedon than within one pedon. The Si/2Al ratios of the soluble constituents were low, from 0.19 to 1.13. The soluble  $\text{SiO}_2$  content was from 0.4 to 6.5 %, which was much less than soluble  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$ , so allophane was not a main clay constituent of these clay samples. There is a tendency for the whole oxalate-soluble content to be higher in soil clays from the humid zones (Zone I and II). Generally, the level of the oxalate-soluble  $\text{SiO}_2$  was low in the surface horizons of the pedons, but increased with increasing depth. Humus-aluminum was a major form of active aluminum in the surface horizons.

Table 2-2 shows the results of dissolution treatment with DCB of some selected clay samples. The amounts of DCB-soluble iron (7 to 12%) were greater than those of iron soluble in acid-oxalate solution, indicating the presence of crystalline iron oxide mineral in the clays. The reverse was observed for soluble aluminum. Except for a soil clay from Mau IIIA3 horizon, the DCB-soluble  $\text{SiO}_2$  content was greater than that soluble in acid-oxalate. Using chemical dissolution analysis together with difference infrared

Table 2-1. Clay mineral analysis of acid-oxalate-soluble and -insoluble constituents.

Agro-ecological zone	Clay	samples	Acid-oxalate-soluble constituents					Si/2Al	Acid-oxalate insoluble constituents**
			Content*	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub>	Total		
I-6	Gituamba	A1	20	0.8	5.4	7.7	13.9	0.25	Vt-Ch, Kt, Gb, Qz
		A3	27	2.8	6.5	9.2	18.5	0.73	Vt-Ch, Gb>Kt, Qz
		B2	32	3.1	11.6	7.3	22.0	0.45	Vt-Ch, Kt, Gb
I-5	Mt. Kenya Lodge	A1	29	0.5	4.5	15.3	20.3	0.19	Vt-Ch>Fd>Gb, Kt, Qz
		IIIAb	62	5.3	22.4	14.9	42.6	0.40	Vt-Ch>>Gb, Kt>Qz
		IVB3b	32	2.3	9.1	10.7	22.1	0.43	Gb>>Fd, Qz, Vt-Ch, Mc, Kt
		IVC2b	51	5.4	15.7	14.2	35.3	0.58	Gb>>Fd
II-2	Nyambeni Hills	A1	17	0.6	3.3	8.0	11.9	0.31	Kt>>Vt-Ch, Mc
		B3	17	0.9	3.3	7.3	11.5	0.46	Ht(7Å), Kt>>Mc>Vt-Ch
II-6	Kijabe	A1	29	1.3	8.3	10.5	20.1	0.27	POP>Fd
		IIA1	26	1.5	5.1	11.0	17.6	0.50	POP>Fd
		IIB2	47	6.5	15.8	9.8	32.1	0.70	POP>Fd
V-2	Chyulu-1	A1	25	1.4	6.5	9.4	17.3	0.37	POP
		B2	29	2.3	8.0	9.7	20.0	0.49	POP
		C2cax	17	1.5	5.9	4.6	12.0	0.43	POP
V-2	Chyulu-2	A1	29	2.3	6.8	11.1	20.2	0.57	POP>>Vt-Ch, OS
		IIIA1	32	2.8	8.0	11.5	22.3	0.59	POP, Ht/2: 1
III-6	Menengai	A11	22	1.3	2.5	11.2	15.0	0.88	Ht(7Å, 10Å)>Kt, Mc
		IIA1b	22	1.6	3.2	10.0	14.8	0.85	Ht(10Å>7Å), Kt, Mc
III-7	Mau	A11	13	0.6	3.1	5.5	9.2	0.33	OS>>Vt-Ch, Fd
		IIIA3	32	2.7	8.5	10.6	21.8	0.54	Fd>OS, Ht (10Å)
		IVA1b	18	1.1	2.8	8.3	12.2	0.67	Fd, OS>Ht (10Å)
IV-4	Narok-1	A1	9	0.5	1.5	4.5	6.5	0.57	Ht/2: 1, POP, OS, Fd
		IIAb	8	0.6	1.1	3.7	5.4	0.93	Ht/2: 1, POP, Fd
V-5	Narok-2	A1	22	0.7	4.2	9.9	14.8	0.28	POP
		IIB22	22	0.9	4.7	9.7	15.3	0.32	POP
		IIB3	22	1.1	4.7	9.0	14.8	0.40	POP
VI-1	Magadi	A1	4	0.5	1.1	1.1	2.7	0.77	Ht/2: 1>POP, Fd
		IVC3	4	0.6	0.9	1.2	2.7	1.13	Ht/2: 1, POP>Fd
V-5	Mt. Longonot	A1	11	0.6	2.0	5.0	7.6	0.51	POP, Ht/2: 1>Fd>OS
		IIIA1	7	0.5	1.3	2.9	4.7	0.65	POP, Ht/2: 1>Fd>OS
		VA1	3	0.4	1.0	0.5	1.9	0.68	POP, Ht/2: 1>Fd

\*. (Sum of oxalate-soluble SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Fe<sub>2</sub>O<sub>3</sub>) × 1.45.

\*\* Abbreviations: Kt=kaolinite, Vt-Ch=vermiculite-chlorite intergrades.

Mc=mica, Ht=halloysite, Fd=feldspars, Gb=gibbsite, Qz=quartz.

POP= complex minerals giving broad XRD reflection bands between 32 to 7Å, Ht/2: 1= randomly mixed layer minerals of halloysite and 2: 1 clays, OS=opaline silica.

spectra and X-ray diffraction analysis, Wielemaker and Wakatsuki (1984) and Wakatsuki and Wielemaker (1985) emphasized the presence of poorly ordered siliceous iron oxide minerals in volcanic ash soils in younger weathering stages in the central and western regions of the Rift Valley of Kenya. The Si/2Al ration (corresponding to SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>

Table 2-2. Chemical analysis of dithionite-citrate-bicarbonate-soluble constituents.

Clay samples		SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub> (%)	Total	Si/2Al
Kijabe	A1	2.0	3.7	11.9	17.6	0.92
	IIB 2	2.3	6.1	13.6	22.0	0.64
Chyulu-2	A1	3.8	2.3	12.2	18.3	2.80
Mau	A11	1.4	1.7	6.8	9.9	1.40
	IIA 3	2.2	3.2	12.4	17.8	1.17
	IVA1b	1.9	1.2	11.5	14.6	2.69
Narok-1	A1	2.8	0.6	7.5	10.9	7.92
Narok-2	A1	3.3	1.1	5.3	9.7	5.09
Mt.	A11	2.8	0.8	7.9	11.5	5.94
Longonot	IIIA1	3.3	0.7	7.3	11.3	8.00

molar ratios) of the dissolved constituents from ten clay samples examined in this study were from 0.6 to 8.0 which was comparable to those (0.8 to 23) reported by Wielemaker and Wakatsuki (1984) and Wakatsuki and Wielemaker (1985). Somewhat greater amounts of SiO<sub>2</sub> dissolved in DCB solution may have resulted from higher pH of the reaction in DCB solution (pH 7.3). The dissolution analysis of clays with DCB showed that the high siliceous iron oxides (Wielemaker and Wakatsuki, 1984) or proto-ferrihydrite containing Si (Wakatsuki and Wielemaker, 1985) are not major clay constituents of soil clays derived from volcanic ashes in Kenya.

Acid-oxalate insoluble constituents were crystalline layer silicates, crystalline aluminum, iron oxides, and primary minerals and they accounted for the major parts of the clays (Table 2-1). Again, the mineral composition of the insoluble fractions differed more from pedon to pedon than within one pedon. Considerable amounts of vermiculite-chlorite intergrades associated with abundant gibbsite were observed in clays from the Mt. Kenya Lodge samples, in which quartz predominated in the silt fractions (Table 1-2). The presence of substantial amounts of gibbsite in the clay and silt fractions of the Gituamba and the buried horizons of Mt. Kenya Lodge pedons indicated that the soils were undergoing severe desilication. Kaolinite and halloysite were identified in clay samples from the Nyambeni Hills and Menengai pedons. The clay mineral composition of some soils developed in dry soil was complicated. Halloysite randomly interstratified with 2:1 layer silicates was the main clay constituents in soil clays from Narok-1 and Magadi pedons. The other soil clays had very diffuse broad X-ray diffraction bands from 32 to 7 Å. Figure 2 shows X-ray diffraction patterns of Mt. Longonot surface clays treated with acid-oxalate. Their diffractograms had a very high background, particularly in the lower angles. Discrete 00 $l$  reflections were not observed in the diffractograms, even after the various chemical treatments. Low-angle X-ray diffraction with controlled relative humidity and high-resolution electron microscopic studies indicated that the clays mainly consist of curly smectite (van der Gaast et al., 1986).

### (3) Native phosphorus fertility

Phosphorus is an essential nutrient for higher plants. Many studies have showed that the native phosphorus fertility of volcanic ash soils developed in humid and temperate climates like Japan is very low due to strong leaching of silicon and bases, resulting in high activities of aluminum and iron. Heavy applications of phosphorus fertilizer is required to maintain high crop yields on such soils (Shoji, 1983).

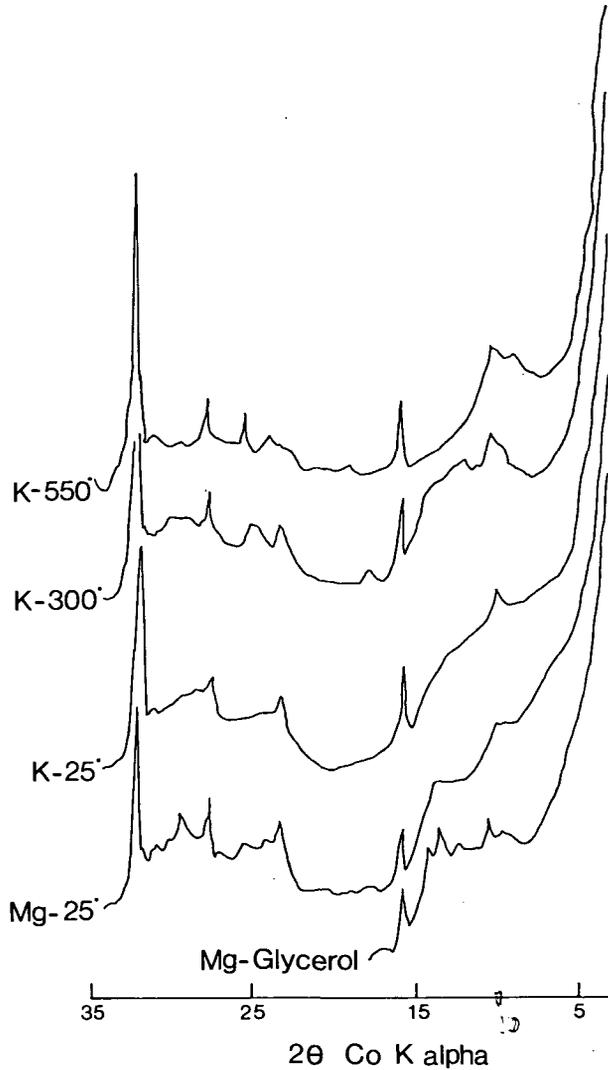


Fig. 2. X-ray diffraction patterns of a clay sample from Mt. Longonot A 1 horizon.

On the other hand, subsistence crops growing on farmers' fields of volcanic-ash-derived soils in Kenya, particularly in the western regions of the Rift Valley, have very good yields, in spite of the annual applications of chemical fertilizer being rare in these regions. The phosphorus is a yield-limiting nutrient in the Kisii soils (Wielemaker and Boxem, 1982). Some field experiments have been done to test the effects of P fertilizer application for different crops in different regions. Table 3 shows an example of a field trial carried out in the Kisii regions (Wielemaker and Boxem, 1982). The data show that the response of maize to P application is very different among the soils examined, and that the soil derived from volcanic ashes or soils admixed with volcanic ashes have very high natural fertility, so that the response of maize to P application is slight. Table 4 shows that P fertilizer application to maize, sorghum, wheat, and barley in the farmers'

Table 3. Effects of phosphate fertilizer application on yield of hybrid maize in Kisii areas (data cited from Wielemaker and Boxem, 1982).

Soils (FAO-Unesco system)	Parent materials	Grain yield (ton/ha)*		Rate of yield increase(%)
		No treatment	Treated**	
Mollic Nitosols	Quartz diorite	0.6	2.2	267
Humic Nitosols	Granite	1.3	2.2	69
Luvic Phaeozems	Rhyolite	4.5	6.0	33
Mollic Nitosols	Basalt	4.5	5.7	27
Mollic Nitosols	Felsite with volcanic ash admixture	7.5	8.5	13
Luvic Phaeozems	Volcanic ash	9.2	9.3	1

Remarks. \*. Rate of nitrogen fertilizer application on all plots was 60 kg N/ha.

\*\* . 50 kg/ha was applied.

Table 4. Effects of phosphate fertilizer application on yield of cereal crops in farmers' fields of various regions of Kenya (data cited from Jaetzold and Schmidt, 1982).

Province	Number of trials	Crop	Range of grain yield(ton/ha)		Rate of yield increase(%)
			No treatment	Treated*	
Nyanza	4	Maize	2.3-3.5	3.1-4.1	17-39
	4	Sorghum	1.3-2.7	2.1-2.7	0-57
Western	3	Maize	4.1-5.0	5.0-6.1	26-32
	3	Sorghum	0.5-1.0	0.7-1.4	33-45
Rift Valley	9	Maize	2.9-4.0	3.5-5.2	13-30
Central	4	Maize	3.4-4.7	4.7-5.7	17-31
Eastern	2	Maize	2.6-2.9	3.4-3.6	26-30
"Njoro" and neighbouring regions	7	Wheat	0.7-3.6	1.1-3.9	0.9-47
	7	Barley	1.2-3.9	1.4-4.5	7-36

\*. Rate of phosphate application (P kg/ha) was 60 kg for maize, 40 kg for sorghum, 20 kg for wheat and barley.

fields in various regions of Kenya is not marked. The experimental fields used for the trials by Jaetzold and Schmidt (1982) included both those used long-term for cultivation and newly reclaimed land. Soil types or parent materials of the soils used for the experiments were not described in their report. The soil maps available, however, show that the soil of these provinces are classified as Andosols or soils admixed with volcanic ashes (Sombroek et al., 1982). Of course, the response of field crops to P application can be changed by environmental factors other than soil conditions. Nevertheless, these earlier field experiments indicate that soils derived from volcanic ashes in central and western Kenya have fairly high natural fertility in terms of soil phosphorus. The higher levels of native soil phosphate available to crops may be the reason.

The total  $P_2O_5$  content of 54 soil samples was from 636 to 9244 ppm, with a mean of 4230 ppm (Table 1-2). The values were higher than those (900 to 4900 ppm) reported for the surface horizon samples of uncultivated Ando soils of Japan and were comparable to those of samples from soils used for intensive cultivation (2200 to 6900 ppm; Wada, 1986). There was a tendency for the total  $P_2O_5$  content to be higher in the surface horizons than in the subsurface horizons.

The available  $P_2O_5$  content, which was evaluated by successive extraction with 2.5%

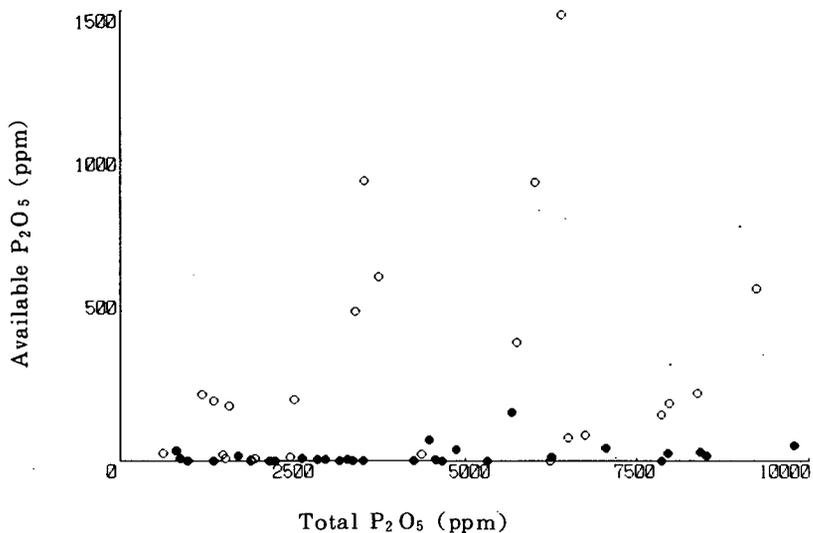


Fig. 3. Relationship between the total and available P<sub>2</sub>O<sub>5</sub> content of soil samples. Closed and open circles indicate the soil samples from the agro-ecological Zones I, II, and III as a group and Zones IV, V, and VI as the other group, respectively.

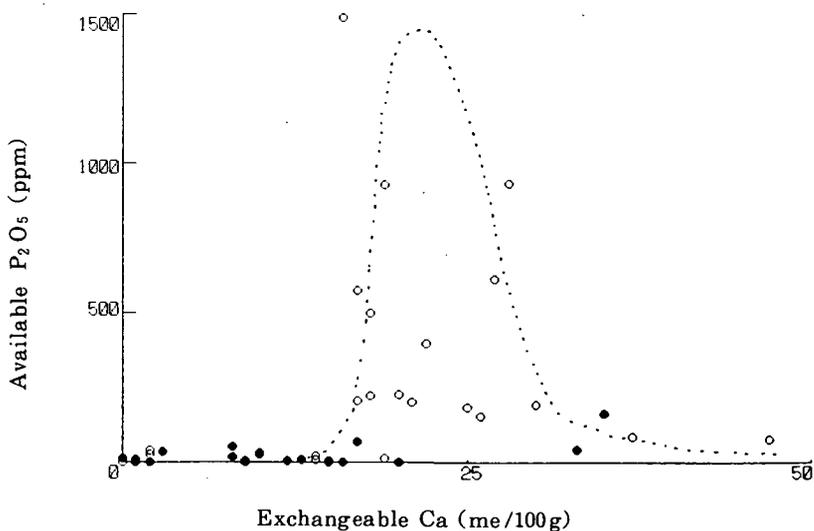


Fig. 4. Relationship between exchangeable Ca and available P<sub>2</sub>O<sub>5</sub> contents of soil samples. Symbols are as in the legend of Fig. 3.

acetic acid and *M* NH<sub>4</sub>Cl solution, was from 0 to 1486 ppm (Table 1-2). Sekiya (1976) showed that the procedure selectively extracts phosphates bound with Ca ion, which are readily available to crops. The available P<sub>2</sub>O<sub>5</sub> content was higher in the surface horizons than in the subsurface horizons. Soils developed with drier moisture regimes had higher

level of available  $P_2O_5$ . There was little available  $P_2O_5$  in the subsurface horizons from the Gituamba, Mt. Kenya Lodge, Kijabe, and Menengai pedons. S. Mugambi (unpublished data) found in a field trial at the Gituamba Agricultural Experimental Station that P applied together with lime causes 160% increase in the grain yield of hybrid maize, much more than values shown in Tables 3 and 4.

Figure 3 shows the relationship between the total and available  $P_2O_5$  contents of soil samples. The soil samples are shown as being divided into two soil groups according to the agro-ecological zones of the landscape (Zones I-III in one group and IV-VI in the other). The correlation between the total and available  $P_2O_5$  contents was low ( $r < 0.004$ ).

Figure 4 shows the relationship between the exchangeable Ca and available  $P_2O_5$  content of the soil samples. A range of high available  $P_2O_5$  centered on soil samples with exchangeable Ca of 10 to 35 me/100 g soil. The data indicate that a "medium" range of exchangeable Ca content of soils favours the formation of Ca-phosphate soluble in 2.5% acetic acid and  $M NH_4Cl$  solutions. Very high such available  $P_2O_5$  content in some surface horizons developed from volcanic ashes under drier conditions, particularly in soils from the western regions of the Rift Valley, which explains the slightness of the response to application of P by crops is shown in Table 3 and 4. A high concentration of available  $P_2O_5$  content in the surface or near surface horizons (or both) implies that phosphorus was recovered through biological absorption.

#### IV. Conclusions and summary

Twelve pedons developed on Quaternary pyroclastic deposits in areas of the Great Rift Valley in Kenya were analysed for their chemistry and mineralogy. Their agro-ecological zones were from I (humid) to VI (dry). Their petrological nature was from acidic peralkaline trachytic to basic basaltic. Climosequential changes in soil properties were observed in an order from Zone I to VI, which zones are classified by a balance of rainfall and evapotranspiration. The moisture regimes under which the soils developed were reflected in the status of exchangeable bases of soils. Soils that developed in Zones I and II were characterized by abundant active forms of aluminum in complexes with humus and in lesser amounts in allophanes. Towards the drier zones, the content of active forms of aluminum decreased greatly. Instead, authigenic layer silicates with a very complicated composition increased. In some soils from dry regions, curly smectite, which had very weak basal reflections but distinct hko reflections because of poor layer stacking, was identified as the major weathering product. Covariant relations of fine-grained quartz and 2:1-2:1:1 layer silicates in soils from high elevations (and higher rainfall) indicated the eolian dust origin of these minerals. The effects of the petrological nature of the parent volcanic ashes on weathering were not studied because of the limited distribution of definite types of volcanic ashes.

An unusually high level of available phosphorus was found in soils from drier climates, particularly in the western regions of the Rift Valley. The laboratory data about the available phosphorus content well substantiated the high native soil phosphorus fertility of the soils, as evidenced by field trials.

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### B 3. CHARACTERIZATION OF HUMIC SUBSTANCES IN SOILS DERIVED FROM VOLCANIC ASHES

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#### I. Introduction

There have been many studies of the humic substances in the Japanese Ando soils (or Kurobokudo), for the very high content of organic matter and the strong black color of these soils have attracted much interest in soil science. Recently there was a group study of the Japanese Ando soils, in which 25 of the Kurobokudo pedons were studied thoroughly and characterized. The general characteristics of the humic substances of Japanese Ando soils are summarized from the study by Arai *et al.* (1986) as follows:

1) The total carbon content was  $10.17 \pm 6.07\%$  in the A horizon. In the A horizon, 50~90% was an alkali-soluble fraction (HE/HT), the percentage of humic acid in the soluble fraction (PQ) was 20~90%, the color coefficient of the humic acid ( $\Delta \log K$ ) 0.5 to 0.8, and the relative color intensity of the humic acid (RF) 20 to 160. The humic acid was of the A type (18/25), B type (4/25), P type (2/25), or Rp type (1/25). The acidic functional group of the humic acid was in the range of 3 to 7 me/g, and the C/N ratio was 8 to 22.

2) The type of humic acid in the Kurobokudo was thus predominantly of the A type, and it was influenced by the vegetation.

3) The carbon content was correlated with the amount of aluminum and iron components. The nature of the humus was independent of the chemical properties of the soil.

4) The carbon content of the volcanic ash soils was apparently correlated to climatic and other factors.

As shown in the previous sections the Kenyan soils of volcanic ash origin are similar to the Japanese Ando soils in their morphology but their chemical and mineralogical characteristics are generally not. In this paper we compare the humus characteristics of Kenyan volcanic ash soils with those of Japanese Ando soils.

As an appendix, carbon dating data will be given for two humic acid preparations extracted from buried A horizons of the Kenyan volcanic ash soils.

#### II. Materials and Methods

Samples: The following 14 samples taken from 11 volcanic ash soil profiles were examined in this study. Three buried A horizons (-B) are included for comparison.

K-1	Kijabe-A	A11 horizon (0-20 cm)
	Kijabe-B	III A1b horizon 45-65 cm)
K-3	Gituamba	A1 horizon (0-18 cm)
K-4	Mt. Kenya Lodge-A	A1 horizon (0-32 cm)
	Mt. Kenya Lodge-B	IIIAb horizon (57-68 cm)
K-5	Nyambeni Hill	A1 horizon (0-16 cm)
K-6	Chyulu-1	A1 horizon (0-15 cm)
K-7	Chyulu-2	A1 horizon (0-30 cm)
K-8	Magadi	A1 horizon (0-20 cm)
K-9	Mau-A	A11 horizon (0-12 cm)
	Mau-B	IV A1b horizon (91-137 cm)
K-10	Narok	A1 horizon (0-28 cm)
K-19	Mt. Longonot	A11 horizon (0-13 cm)

K-20 Menengai Crater A11 horizon (0—11 cm)

Four samples from two profiles of Japanese Ando soils in the San-in district were also examined together with the Kenyan samples for comparison.

J-5	Sanbesan-1	A11 horizon (0—18 cm)
	Sanbesan-2	A12 horizon (18—40 cm)
J-7	Daisen-1	A11 horizon (0—18 cm)
	Daisen-2	IIA12 horizon (18—58 cm)

Methods: The method of Kumada *et al.* (1967) for humus compositional analysis was used to study the characteristics of the humus. In this method, soil humus is extracted first with 0.1 N NaOH and then with 0.1 M  $\text{Na}_4\text{P}_2\text{O}_7$  (SPP). Both of the extracts are acidified to fractionate humic acid and fulvic acid. With an alkaline solution of humic acid, the UV and visible light absorption curve is obtained. The carbon contents of the soil, the extract, and fractionated humic and fulvic acid are measured by a  $\text{KMnO}_4$  oxidation method. The following measurements and computations are made to characterize humic substances:

HE/HT	Percentage of extracted humus carbon in the total carbon
PQ	Percentage of humic acid carbon in extracted carbon
fHa	Percentage of NaOH extractable humic acid carbon in the total humic acid carbon
fFa	Percentage of NaOH extractable fulvic acid carbon in the total fulvic acid carbon
$\Delta\log K$	Color coefficient, $\log K_{400} - \log K_{600}$ , where K is the absorption coefficient at 400 or 600 nm
RF	Relative color intensity, $K_{600}/(\text{ml of } 0.1 \text{ N } \text{KMnO}_4 \text{ consumed by } 30 \text{ ml of humic acid solution used in making of the absorption spectrum}) \times 1,000$ .

The type of humic acid is identified by means of the scheme of Kumada *et al.* for humic acid classification based on the spectroscopic properties of humic acid solution, i.e.

$\Delta\log K$  and RF. The higher the RF value and the lower the  $\Delta\log K$  value, the more highly humified the humic acid is. Type A humic acid is in the most advanced stage of humification, followed by type B, type P, and type Rp in descending order.

### III. Results and Discussion

The results of the compositional analysis are given in Table 1. The figures for total carbon (HT), extracted carbon (HE), humic acid carbon (Ha), and fulvic acid carbon (Fa) are given for 1g of oven-dried soil. The value of carbon given in the table in milliliters of 0.1 N  $\text{KMnO}_4$  consumed can be roughly converted to milligrams of carbon by multiplication by 0.45. The total carbon content (HT) of Kijabe-A (K-1), Gitumba (K-3), Mt. Kenya Lodge-A (K-4), and Mau-A (K-9) was particularly high, like that of the Japanese Kurobokudo from Sanbesan and Daisen. The carbon content of the other soils was much less, mostly because of poor vegetation and lesser weathering of soil materials, both reflects the drier climate.

The percentage of extractable carbon in the total (HE/HT) was from 67 to 90% for the Kenyan soils, except for one sample (Chyulu-1) with 57%. The range was generally comparable with that for the Japanese Ando soils.

In the Kenyan soils, the percentage of humic acid in the extractable fraction (PQ) was almost always higher for the NaOH extract than for the SPP extract; this was not true for the Daisen (J-7) and Sanbesan-2 (J-5-2) samples.

However, the greatest difference was in the fHa and fFa values and the type of humic acid. fHa and fFa are calculated on the assumption that the NaOH extract contains freely existing soil humic substances, either unbound or only weakly bound to sesquioxides, and that the SPP extract contains humic substances firmly bound to calcium. Very high values for fHa and fFa, indicating the dominance of NaOH-extract-

Table 1. Humus Composition in Some Kenyan Volcanic Ash Soils and Japanese Ando Soils (Kurobokudo)

Soil Sample No. and Name	HT m/	HT m/	HE/HT%	Ext*	Ha m/	Fa m/	PQ %	$\Delta$ log K	RF	Ha-PQ Type	fHa 0+2 %	fHa %	
Kenyan Volcanic Ash Soils													
K-1 Kijabe-A	259	199	76.9	1	90.8	64.2	58.6	0.738	42.0	B	62.1	73.3	84.9
				2	33.0	11.4	74.4	0.531	103	A			
K-1 Kijabe-B	75.8	60.9	80.3	1	31.8	11.3	73.8	0.589	113	A	76.2	68.8	78.1
				2	14.5	3.18	82.0	0.509	148	A			
K-3 Gituamba	310	249	80.1	1	126	113	52.9	0.715	46.3	B	53.4	95.1	97.1
				2	6.55	3.33	66.3	0.638	58.6	B			
K-4 Mt. Kenya Lodge-A	268	187	69.8	1	91.7	86.8	51.4	0.610	58.7	B	51.3	95.7	95.6
				2	4.11	4.04	50.5	0.515	66.4	P			
K-4 Mt. Kenya Lodge-B	193	142	73.8	1	71.3	54.8	56.5	0.571	120	A	57.5	86.9	90.5
				2	10.7	5.65	65.1	0.497	137	A			
K-5 Nyambeni Hill	67.2	45.4	67.4	1	18.4	18.8	49.5	0.617	78.5	B	50.9	79.9	84.4
				2	4.63	3.47	57.2	0.575	99.5	A			
K-6 Chyulu-1	60.9	34.8	57.1	1	18.1	7.47	70.8	0.592	79.6	B	74.8	69.5	85.2
				2	7.94	1.30	85.9	0.512	113	A			
K-7 Chyulu-2	65.7	47.3	71.9	1	24.9	9.39	72.6	0.643	64.7	B	77.0	68.3	86.2
				2	11.5	1.50	88.5	0.488	126	A			
K-8 Magadi	36.1	26.3	72.8	1	12.9	3.84	77.0	0.671	67.6	B	82.0	59.6	81.2
				2	8.71	0.89	90.7	0.544	115	A			
K-9 Mau-A	225	152	67.9	1	74.0	40.0	64.9	0.773	36.4	Rp	69.3	70.0	85.4
				2	31.7	6.83	82.3	0.675	57.7	B			
K-9 Mau-B	67.4	60.2	89.4	1	43.1	5.20	89.2	0.556	146	A	89.3	80.0	80.6
				2	10.7	1.25	89.5	0.496	158	A			
K-10 Narok	61.9	46.6	75.3	1	30.2	10.7	73.9	0.618	92.4	A	74.8	86.5	90.9
				2	4.71	1.07	81.5	0.583	105	A			
K-19 Mt. Longonot	62.0	50.6	81.6	1	29.7	14.5	67.2	0.597	72.2	B	69.6	84.4	94.7
				2	5.48	0.81	87.1	0.493	106	A			
K-20 Menengai Crater	106	79.2	74.4	1	38.3	32.4	54.2	0.633	56.7	B	55.8	86.6	92.6
				2	5.93	2.59	69.6	0.510	91.5	A			
Japanese Ando Soils													
J-5 Sanbesan-1	159	145	91.3	1	96.4	45.3	68.0	0.539	98.3	A	68.2	97.4	98.2
				2	2.57	0.82	75.8	0.517	98.0	A			
J-5 Sanbesan-2	328	238	72.6	1	190	43.1	81.5	0.518	130	A	81.4	98.0	97.5
				2	3.83	1.12	77.4	0.493	133	A			
J-7 Daisen-1	271	231	85.0	1	180	42.5	80.9	0.523	132	A	80.8	96.8	95.8
				2	6.03	1.85	76.6	0.481	135	A			
J-7 Daisen-2	289	250	86.5	1	213	32.6	86.7	0.522	140	A	86.5	98.3	96.8
				2	3.68	1.07	77.5	0.473	150	A			

\* Extractant; 1—0.1 N NaOH, 2—0.1 M Na-pyrophosphate

table humus, are typical of Japanese Ando soils in general, and for the Sanbesan and Daisen samples used in this study in particular. This is a reflection of the highly leached, acidic soils and of the importance of aluminum as a binding and stabilizing agent of humic substances. fHa and fFa values were generally lower for the Kenyan samples suggesting that the soils are less leached. This was seen from the pH values of the sample soils in the preceding section. Only samples from Gituamba and Mt. Kenya Lodge-A had high values of fHa and fFa. Both of these samples were taken from the wettest part of Kenya and had the lowest pH values (5.2 and 5.8, respectively) of the samples examined.

In Japan the type of humic acid as identified by  $\Delta$ log K and RF is often used as a criterion for distinguishing Kurobokudo from other soils. As shown in Table 1 and

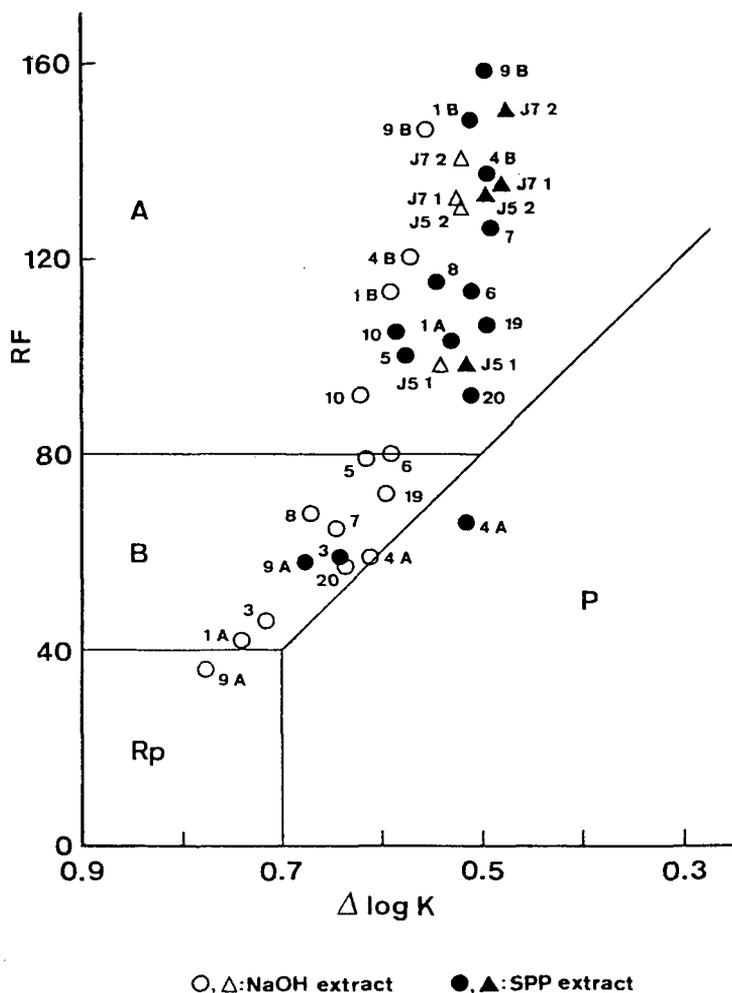


Fig. 1 Classification of Humic Acids according to the Kumada's Scheme

Fig.1, the Kurobokudo samples examined in this study, Sanbesan (J-5) and Daisen (J-7), have type A humic acid in both the NaOH and SPP extracts. This is typical of Japanese Ando soils. Generally, type A humic acid occurs in Ando soils and in calcareous soils with dominance of SPP-soluble humus such as chernozems or rendzinas. Conversely, the humic acid extracted with SPP tends to be more highly humified. This was true for the Kenyan samples, most of which had type A humic acid in the SPP extract, and type B in the NaOH extract. Except for Narok (K-10), the samples with type A humic acid in both NaOH and SPP extracts were all buried A horizons: Kijabe-B (K-1), Mt. Kenya Lodge-B (K-4), and Mau-B (K-9).

As stated above, the humic substances of Japanese Kurobokudo or Ando soils are characterized by the following two properties :

1. The type of humic acid is mostly A for both NaOH and SPP extracts.
2. The values of fHa and fFa are invariably high ; that of PQ is generally high.

In reference to these two items, none of the Kenyan samples were very similar to

Japanese Ando soils in their humic substance :

1) Gituamba (K-3) and Mt. Kenya Lodge-A (K-4), which conformed more exactly to the concept of Ando soils with their occurrence in a high rainfall zone, morphology, low soil pH, high carbon content, high active alumina content high phosphorus retention, etc., also had high values of fHa and fFa, but their humic acid type was B/B (i.e., B for the NaOH extract and B for the SPP extract) and B/P, respectively. The PQ values for total extract were also among the lowest.

2) Buried soil, Kijabe-B (K-1), Mt. Kenya Lodge-B (K-4) and Mau-B (K-9) had type A/A humic acid but their fHa and fFa values were not always high, particularly for Kijabe-B. The pH values of these soils were also quite high : 6.3, 6.9 and 7.4, respectively. Yet for the pH, these fHa and fFa values seemed to be too high for Mt. Kenya Lodge and Mau. Probably this apparent discrepancy comes from the high alkali ion saturation in their exchange complex, reflecting their alkali-metal-rich parent material.

3) Narok (k-10) was the only surface soil among the samples examined that had the humic acid type A/A and relatively high fHa and fFa values, the characteristics similar to those of Ando soil humus. But, unlike ordinary Ando soils, it had a high pH (7.1), with high Ca saturation in its exchange complex, a low level of organic matter, a low active alumina content, and a low phosphorus retention. This soil cannot be regarded as an Ando soil, although it is called mollic Andosol in the Kenyan soil classification. At the same time it is not a chernozem or rendzina (presently Mollisols), because the NaOH extractable humus is much too high.

As mentioned in the introduction of this section, there are some Kurobokudo soils that have type B or type P humic acid in their alkali extract. Gituamba (K-3) and Mt. Kenya Lodge-A (K-4) samples may be grouped together with these unusual Japanese Ando soils, taking into consideration the similarity of their chemical characteristics, including the high percentages of fHa and fFa, to the Japanese Kurobokudo.

The rest of the surface soil samples of the Kenyan volcanic ash soils had moderately humified humus with type B/A humic acid. The generally low fHa and fFa values along with other chemical characteristics may be caused by the low degree of weathering of the parent ashes and cinders under the dry climatic conditions. The alkali-rich parent material might have something to do with the differences of the Kenyan volcanic ash soils from Japanese Ando soils

The highly humified buried soil humus in Kijabe-B (K-1), Mt. Kenya Lodge-B (K-4), and Mau-B (K-9) could be a result of humification after burial, in which the less humified periphery of humus would be preferentially decomposed, leaving a more humified nucleus. But the question of the stabilizing agent for the humus remains unexplained for these buried soils had high pH, a low active alumina content, and a relatively low calcium content.

#### IV. Summary

The humus characteristics of 11 A 1 horizons and three buried A horizons from 11 pedons of Kenyan volcanic ash soils were studied. Four Japanese Kurobokudo samples taken from two profiles in the San-in district were also examined for comparison. The method of Kumada *et al.* for humus compositional analysis was used with successive NaOH and Na-pyrophosphate extractions. The results showed that none of the Kenyan volcanic ash soils had humic substances exactly the same as those in Japanese Ando soils. Two characteristics of humus of Japanese Ando soils, i.e., highly humified humic acid (type A) and the predominance of alkali-extractable humus, were not present simul-

taneously in any of the Kenyan samples. Most of the surface soil samples had type B humic acid for their alkali-extractable humus, whereas the buried soil samples were in a more advanced stage of humification with type A humic acid. Most of the Kenyan soil samples had a lower proportion of alkali-extractable or unbound humus than the Japanese Ando soils.

For the Kenyan soils with a humus content as high as the Japanese Ando soils, but without as high a level of active alumina, the question remains as to what the agent that stabilizes the high amount of humus is.

#### Acknowledgements

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#### Appendix: Carbon Dating of Some Humic Acid Preparations.

Two humic acid preparations were studied by  $^{14}\text{C}$  dating to estimate the age of the Kenyan volcanic ash soils.

The humus of the following two buried A horizon samples were extracted with NaOH and the humic acid was precipitated by acidification with sulfuric acid.

K-1	Kijabe	IIIA1b horizon (45-65 cm)
K-9	Mau	IVA1b horizon (91-137 cm)

The humic acid was purified by repeated dissolution into NaOH and precipitation by acidification twice. Finally the humic acid preparation was washed with water until it started to disperse.

After being air-dried and pulverized about 3 to 4 g of the preparations were sent to Gakushuin University for carbon dating. The results were as follows:

Code No.	Preparation	Age in B.P. (years before 1950)
GaK-12997	Kijabe Humic Acid	$2,350 \pm 130$ (400 B.C.)
Gak-12996	Mau Humic Acid	$3,090 \pm 140$ (1,140 B.C.)

The error term corresponds to one standard deviation of beta-ray counts.

According to the carbon dating there was a time gap between the Kijabe buried A horizon and Mau buried A horizon. As there are no other references available concerning the date of formation of Kenyan volcanic ash soils, these data cannot be discussed now, and cross-correlation among various horizons and layers of different profiles cannot be made.

## B 4. CHEMICAL CHARACTERISTICS OF KENYAN NITOSOLS

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### I. Nitosols and Nitisols in Kenya

To quote from the legend of the soil map of the world compiled and published by FAO-Unesco (1974), Nitosols "show a movement of clay within the profile but have diffuse horizon boundaries and a deeply stretched clay bulge, and generally show a low clay activity. Because of their favorable physical properties and their often higher fertility, especially when derived from basic rock, these soils are separated from the Ferralsols." They are the soils called Reddish-Brown Lateritic Soils in the 1949 U.S. soil classification system.

The name "Nitosols" originated from the characteristic shiny ped faces of these soils (Latin *nitidus*, meaning shiny, bright, lustrous). According to Sombroek *et al.* (1982), however, this characteristic was not adequately defined in the criteria for Nitosols in the key to the soil units (FAO-Unesco, 1974), and, therefore, the term has been used to cover a range of soils without shiny ped faces and soils with a deep, coarse-textured A horizon over a fine-textured B horizon.

Concerning the characteristics of Nitosols in Kenya, Sombroek *et al.* (1982) report that. "In Kenya, Nitosols *sensu stricto* are very extensive. In view of their extent and their importance for agricultural production a more strict definition was applied. To distinguish these more narrowly defined soils from the Nitosols as used by FAO-Unesco, they are called *Nitisols*. Nitisols are defined as having the following characteristics :

1. An argillic B horizon with a high clay content (more than 40%) and a moderate to low silt percentage (silt/clay ratio less than 0.35) ; the requirement of sufficient clay increase within a vertical distance of 30 cm may be waived if all of the following characteristics are present ;
  2. A gentle clay bulge extending beyond 150 cm depth and only a gradual increase in clay % from A to B horizon (clay % ratio B/A horizon usually between 1.0 and 1.2) ;
  3. Many shiny ped faces, especially in the deeper B horizon (more than 10% of the surface area), which cannot or can only partly be ascribed to illuviation argillans ;
  4. Moderately to strongly developed, very fine to medium angular blocky structure (polyhedral) ;
  5. Very friable to friable when moist ;
  6. High aggregate stability (practically no water dispersible clay in horizons with low organic matter content) ;
  7. Clay activity (excluding organic matter content) of less than 24 me/100 g.
- The typical Nitisols are well-drained, dark red or dark reddish brown, extremely deep (often 3-6 m), friable, fine clayey (60-70% clay) soils. They appear to have a relatively high specific surface and the dry fine earth usually shows a degree of magnetism."

It is pertinent here to quote another statement by Sombroek and Muchena (1978) concerning "nitic" or "nito-argillic" horizons proposed to separate "Nitisols" within the framework of the U.S. Soil Taxonomy. Elements listed by these authors for the definition of the horizon are the following :

1. well-drained, deep (more than 150/180 cm from surface) ;

2. a high clay content throughout (more than 40%, if not 50%), with a fair to low percentage of silt (silt/clay ratio less than 0.35?);
3. gentle clay bulge if any; no or only gradual increase in texture from A to B (ratio less than 1.2?) and no or only slight decrease from B to C (less than 20% within 50 cm);
4. only gradual decrease in organic matter content down the profile (little color change from A to B, no bleached sand grains);
5. well-defined blocky structure (moderate fine polyhedral);
6. friable when moist (but hard when dry);
7. high aggregate stability (practically no water-dispersible clay in the horizons with low organic matter content; structure index more than 90);
8. fair to high permeability and moisture storage per unit of volume, associated with rather low bulk density (lower than 1.4);
9. many shiny ped faces throughout the B and the C horizons, which cannot or can be only partially associated with illuviation argillans in thin sections. Micro-morphology would be essentially conglutinated (Eswaran), with many very thin coatings of weak birefringence in the voids and within the S matrix, in the latter occurring around the primary polyhedral structure elements (stress cutans, helped by electromagnetic orientation?);
10. high percentage of free iron (more than 5%, if not 10%; dithionite extraction) and free aluminum (more than 1%, if not 2%), and relatively high percentage of amorphous sesquioxides (more than 0.5% for both Fe and Al; oxalate extraction);
11. high specific surface of the sesquioxides (more than 100 if not 150 m<sup>2</sup>/g) and of the total soil mass (more than 50 m<sup>2</sup>/g?);
12. silicate clay minerals mainly kaolinitic, but metahalloysite and poorly crystallized materials often present (more than 20%?);
13. colors of low value and chroma (4/4 or less); often hue 10 R or 2.5 YR, but sometimes yellower;
14. cation exchange capacity at pH 7 often between 16 and 24 me/100 g clay, but may be lower or higher;
15. amount of weatherable minerals in the fine sand fraction usually rather small (less than 10%?).

Associated characteristics: distinct magnetism, H<sub>2</sub>O<sub>2</sub> effervescence, relatively high Ti percentage (1-2% or more).

## II. Experimental

The above quotations describe the characteristics of Nitisols that occur in the eastern African countries in general, and in Kenya in particular. Therefore, we will discuss only some of the chemical characteristics that were found in laboratory analyses of the Kenyan soil samples taken in this study.

In the description of the soil samples given in B 1, the term *Nitisols* was adopted, as long as the field observations conformed to the characteristics quoted above. The Nitisol profiles are the following:

- |      |                      |
|------|----------------------|
| K-15 | Kiriari, ridge       |
| K-16 | Kiriari upper slope  |
| K-17 | Kiriari, lower slope |
| K-25 | Kamuchege, ridge     |
| K-26 | Kamuchege, slope     |
| K-27 | Kamuchege, valley    |
| K-28 | Nyaga, ridge         |

K-29	Nyaga, mid-slope
K-30	Nyaga, foot slope
K-33	Tinderet
K-35	Malava
K-36	Gitare, ridge
K-37	Gitare, slope
K-38	Gitare, valley

Of these, K-15, the Kiriari (ridge), was one of the most typical Nitisols and has a complete profile description in B1.

The sample soils were analyzed for moisture, pH (H<sub>2</sub>O), pH (KCl), total carbon, total nitrogen, exchangeable cations, exchangeable (Al + H), and available phosphorus in air-dried fine earth. The C/N ratio and effective CEC (ECEC) were also computed, the latter being the sum of exchangeable bases and exchangeable Al + H. The methods of analysis were described in B 5.

The analytical data of the following six profiles that were situated on a nearly level, broad ridge and thus regarded as sedentary in origin are taken up for discussion.

K-15, Kiriari  
K-25 Kamuchege  
K-28, Nyaga  
K-33, Tinderet  
K-35, Malava  
K-36, Gitare

The mean and standard deviation, and the minimum and maximum, of each item of analysis are given in Table 1 for the surface or A horizon, and for the third horizon from the top, or a subhorizon within the B horizon.

The moisture content reflects the field moisture conditions, which are, in turn, influenced by climate and the soil. Being located at high altitudes (1580 m at Gitare through 2000 m at Kamuchege), all of the sample profiles developed under a humid climate. Nitisols are rich in clays. Thus, the moisture content was naturally quite high. The higher moisture content in the B horizon could be a result of clay translocation.

These soils were strongly leached, the pH (H<sub>2</sub>O) often being below 5 with a generally high exchangeable Al level. However, exchangeable bases were quite depleted. The relatively high level of exchangeable K may be attributable to the alkali-rich parent rocks.

The organic matter content was quite high, particularly in the B horizon, resulting in a very gradual decrease in organic matter down the profile. This was compatible with the results of Sombroek and Muchena (1978). The C/N ratio remained in a reasonable range throughout the profile, signifying a normal process of organic matter decomposition.

The ECEC was low for the high clay and organic matter contents. The low activity of the clay fraction was one of the characteristics of Nitisols. On the average, Al saturation based on ECEC was a little over 20% in the B horizon, but in some of the profiles, e.g. Kiriari and Malava, it exceeded 60% in the subsoil, a level said to be critical for Al toxicity

Available phosphorus was very low throughout the profile, always below 10 ppm as P<sub>2</sub>O<sub>5</sub>, or below 4 ppm as available P. As the phosphorus sorption capacity can also be quite high for Nitisols, amendment of the phosphorus level should be the first concern in soils to be used for the growing of crops.

The data and discussion here are preliminary but generally in line with what has been reported about the chemical nature of Nitisols. More detailed studies on the

Table 1. Chemical characteristics of the Kenyan Nitosols

	Surface (A) horizon				Subsurface (B) horizon			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Moisture, %	17.8	6.0	8.4	24.0	22.6	4.3	16.5	29.3
pH (H <sub>2</sub> O)	5.1	0.6	4.4	5.8	5.1	0.6	4.5	6.0
pH (KCl)	4.5	0.4	3.9	5.1	4.4	0.4	4.0	5.2
TC, %	3.2	0.8	2.4	4.5	2.2	0.4	1.6	2.7
TN, %	0.28	0.09	0.18	0.39	0.19	0.04	0.15	0.25
C/N	11.8	1.6	10.4	14.7	11.5	2.5	8.9	15.4
Ex. Ca, me/100 g	3.62	3.11	0.19	8.19	2.55	3.26	0.05	8.54
Ex. Mg	1.22	0.90	0.19	2.41	1.01	1.03	0.11	2.28
Ex. K	1.41	1.18	0.09	2.80	0.74	0.87	0.02	2.18
Ex. Na	0.12	0.05	0.05	0.15	0.12	0.05	0.05	0.15
Ex. Al+H	1.16	1.39	0.11	3.49	1.30	1.08	0.10	2.78
ECEC	7.52	4.05	2.83	13.7	5.70	4.19	2.18	13.2
Av. P <sub>2</sub> O <sub>5</sub> , mg/g	0.004	0.004	0.00	0.009	0.003	0.003	0.00	0.007

chemical, mineralogical, and micromorphological properties must be done to draw a clearer picture of the Kenyan Nitosols. There appears to be particularly little information available about the fertility status of these soils. Although they look magnificent, with a deep profile and excellent physical properties, the acidity strong enough to cause Al toxicity, the extremely low phosphorus level, and the low activity or low nutrient holding capacity of the clay fraction are all indicative of the disappointingly poor quality of Nitosols as a medium of crop growth. There should be keen concern about this aspect of Nitosols in future research.

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## B 5. FERTILITY STATUS OF CULTIVATED SOILS IN VILLAGES IN THE EMBU DISTRICT

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### I. Description of the Villages

The villages studied by the group of agronomists were in the vicinity of Embu town. The general environmental conditions of the study area were described by S.Hirose in his paper (A 1). Here only brief descriptions of each village are quoted from that paper.

Zone	Sublocation	Location/Division	Altitude, m	Agro-ecological Zone*
I	Gitare	Kagaari/Runyenjes	1600-1850	Tea and Coffee or Coffee Zone (UMI, 2)
II	Kangaru	Mbeti/Runyenjes	1400-1500	Marginal Coffee Zone (UM 3)
III	Gachoka	Mbeti/Gachoka	1200-1250	Cotton Zone (LM 3)
IV	Kithunthiri	Mavuria/Gachoka	1100-1200	Marginal Cotton Zone (LM 4)
V	Mbita	Mavuria/Gachoka	1100-1200	Livestock and Millet Zone (LM5)
	Mavuria	Mavuria/Gachoka	1100-1200	

\* Jaetzold and Schmidt, 1983

In the following discussion the names of these six sublocations are used to denote the villages studied. Areas I and II are sometimes called the "upper" areas, and areas III, IV, and V are collectively called the "lower" areas.

### II. General Soil Conditions

Soil conditions are very diverse in the study area. The upper areas were dominated by Nitosols, whereas the lower areas were poorer in its soil resources, having Ferralsols with *murram* and Arenosols. More or less detailed descriptions are available on the following profiles taken in the study area (see B1) :

Profile No.	Sublocation	Soil Classification
K-12	Gachoka	Ferric Cambisol
K-13	Gachoka	Eutric Cambisol
K-14	Gachoka	Eutric Cambisol
K-36	Gitare	Humic Nitosol
K-37	Gitare	Eutric Nitosol
K-38	Gitare	Eutric Nitosol
K-42	Kithunthiri	Ferric Arenosol
K-43	Kithunthiri	Cambic Arenosol

Nitosols in the upper areas were derived from old basic volcanic ejecta, whereas Cambisols and Arenosols in the lower areas were derived from basement rocks such as gneisses and quartzites. Strongly weathered basement rocks had become *murram* or ironstone soils. In some places in Gachoka, basement rocks were overlain by phonolite (Gachoka).

### III. Materials and Methods

The general soil fertility status of the study area was assessed with many surface and subsurface soil samples collected by the group of agronomists during field studies of

crops and farming systems. The number of sample soils collected and analyzed later by the soils group was given earlier for each village (see B 1).

Most of these soils were taken from fields planted to maize, cowpeas, or both ; potatoes, bananas and coffee were also seen in the upper areas. *Dorichos*, a legume, was planted selectively on termite mounds in the lower areas.

Some of the soil samples were taken from a *Kianda*, a low-lying, well-watered land close to a stream. The inhabitants of the region seem to be well aware of the advantages of such a terrain for the growing of vegetables.

In Mavuria, another evidence of the awareness of farmers of conditions of the terrain was noted. In some places, there were wetter spots within a generally dry field. The soil texture was very sandy, so such wet spots were particularly advantageous for crop cultivation and the farmers were making full use of them. Soils were sampled with this in mind.

All of the sample soils were air-dried and passed through a 2-mm sieve to prepare air-dried fine earth. The following items were analyzed :

Field soil moisture	105 °C oven-drying
pH (H <sub>2</sub> O)	soil-to-water ratio of 1 : 2.5
Total carbon and nitrogen	Dry combustion method with NC-analyzer
Exchangeable Ca and Mg	pH 7, 1 N NH <sub>4</sub> OAc extraction and atomic absorption spectrometry
Exchangeable K and Na	Same extraction, flame photometry
Exchangeable Al + H	1 N KCl extraction, titration with NaOH
ECEC	Sum of exchangeable bases and Al + H
Available phosphorus	2.5% acetic acid extraction, colorimetry (mainly Ca-P form)

#### IV. Results and Discussion.

The results of analysis are given in the tables. Table 1 shows the mean and standard deviation of each item of analysis by village and by soil depth, i.e., for surface and subsurface layers. Generally, no great differences were found between the surface and subsurface layers, whereas considerable differences were found among the villages.

Moisture data reflected the field moisture conditions as influenced by the climate and nature of the soil. Gitare and Kangaru, situated above the altitude of Embu town, were much wetter and thus had a higher field moisture. The upper areas also had more clayey soils belonging to the Nitosol group, which had higher moisture than the Ferralsols and Arenosols prevalent in the lower areas.

As reported elsewhere, for example, by Kawaguchi and Kyuma (1977), the soil organic matter is correlated with climate and soil texture ; TC and TN were higher in the upper areas and lower in the lower areas, being particularly low in Kithunthiri and Mavuria where sandy soils were prevalent. The C/N ratio was from 10.5 to 12.6, the normal range of variation for cultivated soils.

The pH and base status were, as expected, naturally lower in the upper areas where there is more rainfall than in the lower areas. The soils in the lower areas were neutral in soil reaction and rich in bases ; those in the upper areas were strongly acidic and high in exchangeable Al. The effective cation exchange capacity (ECEC) is the sum of exchangeable bases and exchangeable Al. Some soils with high pH may contain free calcium carbonates, which seems to be one reason for the relatively high ECEC for sandy soils in Kithunthiri and Mbita. The soils in the upper areas had low ECEC relative to their high contents of clay and organic matter, because of the strong acidity

The method used here to assay available phosphorus was suitable for assessment of Ca-bound phosphorus. The available phosphorus level was low in the acid soils of the

Table 1 Means and Standard Deviations of Fertility Characters of Kenyan Soils by Locations

Location & Layer	No. of Samples	Moisture %		pH(H <sub>2</sub> O)		TC %		TN %		C/N		Ca me/100 g		Mg me/100 g		K me/100 g		Na me/100 g		Al + H me/100 g		ECEC me/100 g		Av-P P <sub>2</sub> O <sub>5</sub> mg/g	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gitare, Runyenjes Surface Subsurf.	6	21.8	3.44	4.72	0.43	3.48	0.29	.328	.023	10.6	0.28	1.54	0.99	0.74	0.38	0.33	0.15	0.15	0.00	2.10	0.80	4.85	0.66	.009	.004
	3	21.4	3.68	4.64	0.19	3.67	0.30	.343	.021	10.7	0.31	2.08	1.25	0.96	0.43	0.45	0.07	0.15	0.00	1.54	0.78	5.18	0.87	.011	.005
	3	22.2	3.96	4.81	0.64	3.29	0.12	.313	.015	10.5	0.29	1.00	0.14	0.51	0.16	0.20	0.02	0.15	0.00	2.66	0.17	4.51	0.08	.007	.001
Kangaru, Gachoka Surface Subsurf.	4	10.4	7.18	5.36	0.48	2.64	0.22	.215	.017	12.3	0.07	3.83	1.35	2.14	0.53	0.92	0.61	0.10	0.06	0.62	0.59	7.61	0.96	.009	.011
	3	12.5	7.26	5.25	0.52	2.74	0.09	.223	.006	12.3	0.09	3.59	1.54	2.01	0.56	1.09	0.60	0.12	0.06	0.77	0.62	7.58	1.18	.012	.012
	1	4.36	-	5.69	-	2.33	-	.190	-	12.3	-	4.57	-	2.53	-	0.39	-	0.05	-	0.16	-	7.70	-	.001	-
Gachoka, Surface Subsurf.	9	5.86	2.39	7.09	0.56	1.67	0.38	.134	.029	12.5	0.99	4.87	3.67	2.55	0.96	1.18	0.56	0.36	0.39	0.05	0.02	9.02	3.78	.013	.011
	4	5.56	1.96	7.06	0.57	1.77	0.40	.143	.024	12.4	1.16	4.24	3.74	2.53	1.05	1.34	0.45	0.32	0.36	0.06	0.03	8.48	4.04	.016	.013
	5	6.10	2.89	7.12	0.63	1.59	0.40	.127	.033	12.6	0.97	5.37	3.98	2.57	1.02	1.06	0.65	0.40	0.45	0.05	0.02	9.45	3.98	.011	.001
Kithunthiri, Gachoka Surface Subsurf.	34	0.85	1.07	6.69	0.70	0.76	0.51	.067	.041	11.2	1.96	5.94	8.88	0.93	0.92	0.45	0.27	0.05	0.02	0.10	0.15	7.47	9.79	.066	.101
	17	0.66	0.84	6.71	0.65	0.80	0.57	.072	.050	11.0	0.77	5.65	8.54	0.86	0.85	0.50	0.30	0.05	0.00	0.06	0.03	7.12	9.55	.061	.087
	17	1.04	1.25	6.66	0.77	0.73	0.47	.062	.032	11.5	2.69	6.23	9.45	0.99	1.00	0.40	0.24	0.06	0.02	0.13	0.21	7.82	10.3	.071	.115
Mbita, Gachoka Surface Subsurf.	10	1.25	1.24	6.72	0.57	1.46	1.02	.124	.077	11.4	0.95	6.45	5.99	2.09	1.88	0.98	0.62	0.05	0.00	0.13	0.17	9.70	8.03	.059	.094
	5	1.16	1.31	6.83	0.75	1.68	1.32	.139	.097	11.6	1.13	8.00	8.28	2.49	2.57	0.99	0.75	0.05	0.00	0.09	0.07	11.6	11.0	.080	.135
	5	1.34	1.31	6.61	0.35	1.23	0.66	.108	.057	11.3	0.85	4.90	2.49	1.69	0.97	0.98	0.55	0.05	0.00	0.17	0.23	7.78	3.87	.038	.026
Mavuria, Gachoka Surface Subsurf.	22	0.63	0.71	6.65	0.79	0.59	0.21	.054	.018	10.7	0.72	2.70	1.63	0.71	0.36	0.54	0.26	0.08	0.06	0.08	0.17	4.11	1.78	.075	.103
	11	0.38	0.70	6.71	0.71	0.59	0.18	.055	.015	10.6	0.58	2.65	1.55	0.69	0.26	0.51	0.18	0.08	0.06	0.05	0.03	3.97	1.70	.071	.076
	11	0.87	0.66	6.59	0.90	0.59	0.25	.054	.020	10.8	0.86	2.75	1.78	0.74	0.45	0.56	0.33	0.08	0.06	0.11	0.24	4.24	1.93	.079	.129
Upper Area Surface Subsurf.	10	17.3	7.63	4.98	0.54	3.14	0.50	.283	.062	11.3	0.89	2.46	1.60	1.30	0.84	0.56	0.48	0.13	0.04	1.51	1.02	5.95	1.61	.009	.007
	6	17.0	7.11	4.94	0.48	3.20	0.55	.283	.067	11.5	0.89	2.83	1.50	1.49	0.73	0.77	0.52	0.13	0.04	1.16	0.76	6.38	1.61	.011	.008
	4	17.7	9.47	5.03	0.69	3.05	0.49	.283	.063	10.9	0.91	1.90	1.79	1.01	1.02	0.25	0.10	0.13	0.05	2.03	1.26	5.31	1.59	.005	.003
Lower Area Surface Subsurf.	75	1.44	2.05	6.73	0.70	0.91	0.65	.079	.050	11.3	1.53	4.93	6.63	1.21	1.17	0.63	0.45	0.10	0.17	0.09	0.15	6.97	7.56	.061	.095
	37	1.17	1.85	6.77	0.65	0.96	0.75	.083	.058	11.1	0.94	4.92	6.71	1.21	1.31	0.66	0.46	0.09	0.14	0.06	0.04	6.94	7.88	.061	.086
	38	1.70	2.22	6.70	0.75	0.87	0.54	.074	.042	11.4	1.95	4.94	6.65	1.22	1.04	0.61	0.44	0.11	0.19	0.12	0.20	6.99	7.34	.061	.104
Whole Samples	85	3.30	6.02	6.52	0.89	1.18	0.96	.103	.084	11.3	1.47	4.64	6.30	1.22	1.13	0.63	0.45	0.10	0.16	0.26	0.58	6.85	7.12	.055	.090

Table 2 Means and Standard Deviations of Fertility Characters of Kenyan Soils by Field Conditions

Condition & Layer	No. of Samples	Moisture %		pH(H <sub>2</sub> O)		TC %		TN %		C/N		Ca me/100 g		Mg me/100 g		K me/100 g		Na me/100 g		Al + H me/100 g		EC/EC Mean SD		Av-P P <sub>2</sub> O <sub>5</sub> mg/g		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean
Whole Samples	85	3.30	6.02	6.52	0.89	1.18	0.96	1.03	0.084	11.3	1.47	4.64	6.30	1.22	1.13	0.63	0.45	0.10	0.16	0.26	0.58	6.85	7.12	0.055	0.090	
Ordinary Surface	71	3.08	6.47	6.37	0.84	1.10	1.00	0.98	0.09	11.0	0.93	3.34	3.26	1.00	1.01	0.52	0.31	0.07	0.05	0.29	0.63	5.22	4.22	0.052	0.083	
Subsurf.	36	3.26	6.80	6.38	0.87	1.21	1.13	1.07	0.97	11.1	0.88	3.47	3.90	1.05	1.18	0.56	0.32	0.07	0.05	0.24	0.51	5.39	5.13	0.051	0.071	
	35	2.90	6.20	6.36	0.82	0.98	0.86	0.88	0.79	11.0	1.00	3.20	2.48	0.95	0.82	0.48	0.30	0.06	0.05	0.35	0.75	5.05	3.10	0.053	0.094	
Kianda Surface	8	4.24	2.91	6.78	0.48	1.61	0.73	1.136	0.62	11.7	0.95	5.20	3.92	2.58	1.31	1.22	0.73	0.38	0.42	0.05	0.01	9.43	5.04	0.012	0.013	
Subsurf.	4	3.89	2.79	6.64	0.45	1.64	0.83	1.138	0.71	11.8	0.91	5.08	4.11	2.53	1.39	1.33	0.87	0.32	0.36	0.05	0.01	9.29	5.39	0.010	0.011	
	4	4.59	3.41	6.93	0.53	1.58	0.74	1.135	0.63	11.6	1.13	5.33	4.35	2.64	1.44	1.11	0.67	0.45	0.51	0.04	0.01	9.56	5.49	0.015	0.015	
Termite Surface	6	4.59	2.61	7.99	0.16	1.53	0.29	1.116	0.26	13.6	3.87	19.3	14.6	2.04	0.68	1.12	0.58	0.07	0.04	0.12	0.03	22.6	14.8	0.146	0.170	
Subsurf.	3	4.04	2.95	7.91	0.13	1.47	0.26	1.123	0.12	11.9	1.29	18.0	25.6	1.93	0.78	1.22	0.35	0.05	0.00	0.12	0.02	21.3	16.1	0.150	0.183	
	3	5.14	2.72	8.06	0.18	1.58	0.37	1.109	0.38	15.4	5.18	20.6	16.9	2.14	0.72	1.01	0.82	0.08	0.06	0.13	0.05	24.0	16.9	0.143	0.197	
Mavuria, Gachoka																										
Dry Part Surface	14	0.49	0.58	6.45	0.75	0.54	0.20	0.050	0.17	10.6	0.70	2.30	1.30	0.73	0.42	0.53	0.25	0.05	0.00	0.10	0.21	3.70	1.59	0.055	0.096	
Subsurf.	7	0.17	0.16	6.54	0.82	0.53	0.19	0.050	0.17	10.6	0.57	2.06	0.92	0.68	0.33	0.48	0.18	0.05	0.00	0.05	0.04	3.32	1.30	0.041	0.040	
	7	0.82	0.68	6.36	0.90	0.54	0.23	0.050	0.19	10.7	0.85	2.53	1.64	0.78	0.31	0.57	0.32	0.05	0.00	0.15	0.30	4.08	1.86	0.069	0.013	
Wet Part Surface	8	0.86	0.89	7.00	0.79	0.68	0.22	0.062	0.17	10.9	0.78	3.41	1.98	0.69	0.26	0.55	0.28	0.12	0.08	0.04	0.01	4.82	1.97	0.110	0.113	
Subsurf.	4	0.75	1.15	7.02	0.84	0.68	0.10	0.063	0.09	10.8	0.65	3.68	2.03	0.71	0.08	0.57	0.17	0.12	0.09	0.04	0.01	5.12	1.88	0.124	0.101	
	4	0.96	0.71	6.99	0.86	0.67	0.31	0.060	0.24	11.0	0.99	3.14	2.20	0.68	0.38	0.54	0.39	0.12	0.09	0.04	0.02	4.52	2.30	0.097	0.137	

upper areas. Among the soils in the lower areas, the sandy soils of Kithunthiri Mbita and Mavuria were richer in phosphorus than soils in Gachoka with relatively more clay and organic matter, probably because the soils in Gachoka were more weathered.

Table 2 gives the variation in soil fertility status by field condition. As stated earlier, the inhabitants of this area were keenly aware of field conditions that bring about a difference in crop production. The upper half of the table compares the ordinary upland conditions with those of *Kianda* and termite mounds. *Kianda* had more organic matter and bases than ordinary upland soil, which are reasons for its being preferred by the farmers. It seemed to be inferior in the amount of phosphorus available.

Termite mounds were unusual because of their particularly high Ca and available phosphorus. Their high pH indicated the occurrence of free calcium carbonate, which gave too high an ECEC. The organic matter content was also relatively high, but the C/N ratio suggested that the organic matter had remained relatively undecomposed.

The lower half of Table 2 compares the dry and wet parts of fields in Mavuria. Wet parts occurred in spots in generally sandy and dry field. The cultivators took advantage of the wetness in their cropping practices. The higher moisture content of the wet part was evident, but the difference was not extreme. The base status and amounts of organic matter and available phosphorus all were slightly more favorable in the wet part of the field, but again the difference was not marked. Thus, from all these aspects, the differences in the analytical results were not great, but under critically dry conditions the slight advantage of the wet part could give rise to a strikingly different crop performance.

## V. Summary

Soil samples from cultivated fields in the villages surveyed by the group of agronomists were analyzed to assess their fertility status. The results were tabulated, first of all to compare different villages. There was a clear difference between the upper areas (zone I and II) and the lower areas (zone III, IV, and V) as described by Hirose (A1). Higher clay and organic matter contents were the advantages and strong acidity and little available phosphorus were disadvantages associated with the soils in the upper areas. Roughly speaking, the opposite was true for the soils in the lower areas.

The soil fertility of particular terrain features, such as *Kianda* and termite mounds, which are preferred by local farmers for cultivation of certain crops, were studied. In general, the preference by the farmers had a sound base.

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