COFFEE PRODUCTION IN MACHAKOS DISTRICT

A CASE STUDY OF MATUNGULU LOCATION

BY

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A thesis submitted in part fulfilment for the Degree of Master of Arts (Agricultural Geography) in the University of Nairobi

1981

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D E C L A R A T I O N

This thesis is my original work and has not been presented for a degree in any other University.

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ABSTRACT

This thesis is about small farm sector coffee production in Matungulu location of Machakos District, Kenya. Until about 1935 coffee growing in Kenya was by law restricted to the large farms owned by Europeans settlers and the Africans were not allowed to grow it. After 1935, a few "selected" African farmers in Meru, Embu and Kisii Districts were "allowed" to grow restricted acreages of coffee on a trial basis. It was only after the Swynnerton Plan which was launched in 1954 that coffee was introduced in "African Land Areas" in relatively faster and greater scale than ever before.

In recent years, the small farm sector has outstripped the estate sector in terms of hectarage under coffee and total production. To-day over 50 percent of the Kenya coffee intended for the export market comes from the small farm sector. The average productivity per hectare for this sector is generally lower than the estate sector, implying that there are constraints or inefficiencies, which consistently keep the yields low. In case of Machakos District, however, the productivity per hectare of the small farm sector is slightly higher than the estate sector, indicating that there is still a potential for the small scale

sector, indicating that there is still a potential for the small scale farmers to increase their yields in similar situations. This should be possible given more agricultural inputs, effort and efficiency. It would thus enable the small farm sector to make a significant contribution to Kenya's export earnings as well as raising both the farm incomes and living standards of the rural population.

This study investigates the main physical, biological and socio-economic factors influencing small farm coffee production in Matungulu location, an area of high ecological potential, consisting almost exclusively of small scale farmers. The study has revealed that the success of coffee production depends on the understanding of certain agronomic practices, such as the importance of diseases, pests and weed control, soil quality maintainance, the availability of labour and working capital.

The results of the study also reveal that a poor correlation exists between coffee yields and physical parameters. Conversely, a significant correlation between yields and socio-economic parameters is established. A step-wise multiple regression model employed in the study yielded the following results: First, both Income and Investment accounted for 73.1

percent of the variation in coffee yields in 1978. Secondly, both variables explained 76.1 percent of the differences in yields in 1979. On the basis of the study, it was concluded that most of the variation in coffee yields are attributed to socio-economic rather than physical variables.

The socio-economic factors exercising constraints on coffee production include inadequate agronomic practices, poor extension services, lack of credit for investment, labour shortages at critical times, and a poor transportation network. Even then, the study reveals that the small scale coffee farmers in the Matungulu area are comparatively more prosperous than their counter parts in the non-coffee growing parts of Machakos District. Even though the benefits from the cash-crop economy boosted by coffee are obvious in the study area, and indeed, the highland zone of Machakos District, the widespread displacement of food-crops by coffee has led to food shortages in the district. This has given rise to frequent famines and increased vulnerability of the local population. In view of this problem, it is recommended that the small scale farmers in the study area should be encouraged to produce adequate food alongside their cash crops, to feed their families. This would bring about greater self-sufficiency as far as food production is concerned and reduce its dependence on variations within the environment as well as the fluctuations in the international coffee prices.

ACKNOWLEDGEMENTS

I would like to acknowledge most gratefully the help of the German Academic Exchange Service (DAAD) for having awarded me a 6 month German Language and post-graduate scholarship at Staufen Goethe Institute and Giessen University respectively in West Germany. Similar thanks go to the University of Nairobi and the Faculty of Graduate Studies and Research - McGill University - Canada for admitting me into their Graduate programmes. I must offer most sincere thanks to the Department of Geography at Nairobi and McGill Universities and the Canadian International Development Agency (CIDA) whose graduate contract enabled me to study, analyse and write up my thesis whilst gaining experience in teaching particularly at the University level. Likewise I owe unrefundable debt to Professors F.F. Ojany and T.R. Moore of Nairobi and McGill Geography departments without whose efforts this graduate programme would not have been a success.

I would like to express my gratitude to Prof. R.S. Odingo of the Department of Geography, University of Nairobi for introducing me to Agricultural Geography and guiding me through the subject matter of this thesis.

I am also indebted to Prof. T.R. Moore of McGill

University, Montreal Canada who untiringly read and corrected my manuscript. My thanks also go to Dr. P.V.X. D'Costa of the Department of Soil Science University of Nairobi for his guidance and advice especially on the soils of my study area.

Thanks are due to Dr. Klaus Grenzebach of Giessen University, West Germany, for his encouragement and whose special course on Aerial photograph Interpretation has enabled me to apply aerial photographs to land-use studies.

For their contribution directly or indirectly, I would like to thank Professors, J. Bird, T.L. Hills, S.H. Olson, N.J. Enright, J.T. Parry of McGill University and Celia Nyamweru of Kenyatta University College; Dr. A.G. Ferguson and Messrs D.A. Obara, Ngau, Wegulo (University of Nairobi) and Miss Lois McNeil, Messrs J. Merchant Nurse, and Lionel (McGill University) for their encouragement and constructive criticisms.

I wish to express my sincere gratitude to the following: The Coffee Research Station at Ruiru, Kenya; Ministry of Agriculture Library (Kilimo House); The District and Divisional Agricultural Offices at Machakos and Kangundo respectively; Matungulu Growers Co-operative Society's Head-quarters at Tala; The Meteorological Station at Dagoretti for providing me with the

relevant data for my thesis; the Director of Surveys of Kenya and Mines and Geology Department for allowing me to purchase aerial photographs, topographical sheets and the geology map of the study area; and finally, the National Agricultural Laboratories (NAL) at Kabete and Department of Soil Science for providing me with the soil map of the study area as well as carrying out the mechanical and chemical analyses of my soils.

I owe a special word of thank to Miss Tyra Shaheed (Trinidad) who typed the greatest part of my manuscript with remarkable skill and accuracy, Mrs Mary Adamba and Mr. Samson Otieno (Nairobi) who completed the task with equal efficiency. Similar thanks go to Mr. Abel Sen, a Senior Cartographer and Miss Dominique Papion, an undergraduate student, Geography Department McGill University for the production of the graphic illustrations in this thesis.

My final thanks go to my wife Janet for her help in data collection, vegetation classification of my study area. I record my heartfelt gratitude to her for her encouragement constant patience and for taking care of my children Kiende, Lilian and Mutiso while I was away in West Germany and Canada.

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CHAPTER 1

INTRODUCTION; THE PROBLEM AND ITS RELEVANCE

1.1 Background to Study

Machakos District of Kenya (Fig. 1) lies within the foreland plateau between the Eastern Rift Valley and the Nyika plateau and is a home of 1 million Machakos-dwelling Akamba.* It is not known precisely when the Akamba settled in Machakos District. However, written records show that the Machakos Hills appear to have been little used until the Akamba moved into the area probably during the seventeenth century. Akamba tradition agrees that their ancestors came to the Machakos area through its south-eastern fringe - Makueni and Nzaui.

The Akamba were apparently once a compact group occupying the region now called Ulu, and they consider Mbooni hills as the point from which they settled Kitui and other areas. They also consider themselves to have been hunting and agricultural people who learnt about cattle on trading expeditions and brought them with ivory. Traditionally the main crops are sorghum (*sorghum vulgare*), maize (*Zea mays*), and millet (*Eleusine coracana*). The most popular legume is pigeon pea (*Caj-*

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* The Akamba occupy two administrative districts of the Eastern Province in Kenya viz Machakos and Kitui.

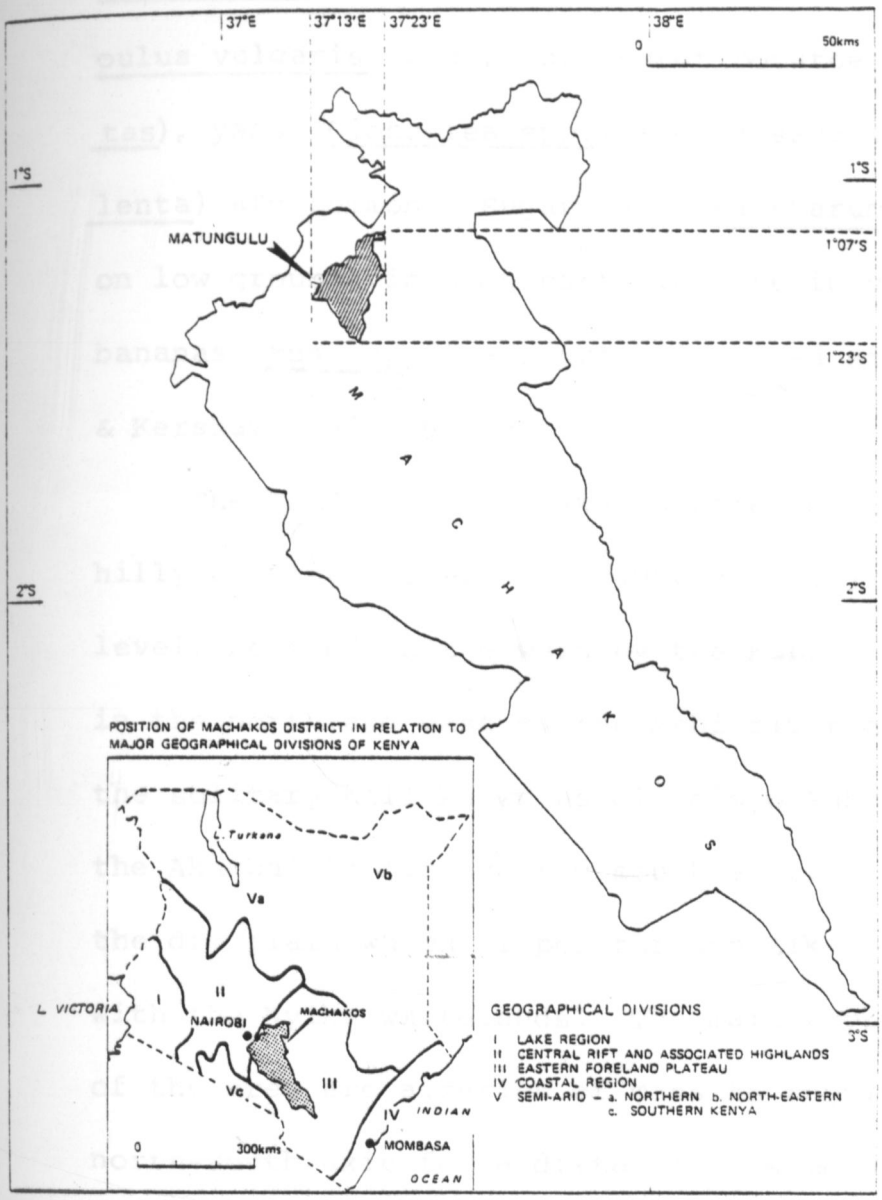


Fig. 1 : Position of Matungulu in Machakos District of Kenya.

anus cajan), and there are other types of beans (Phaseoulus vulgaris) and peas. Sweet potatoes (Ipomoea batatas), yams (Dioscorea spp.) and cassava (Manihot elsculenta) are common. Sugar-cane (saccharum spp.) is grown on low ground, in some parts in pits in valleys, and bananas (Musa spp.) are grown in mixed stands (Middleton & Kershaw, 1978, 68-69).

The land which the Akamba came to is largely a hilly country 1219-2133 m (4000-7000 ft) above the sea-level, bounded in the west by the Kapiti and Athi plains, in the north and east by the Athi river and curves round the solitary hill known as Ol Doinyo Sabuk (Kyanzavi to the Akamba) to flow to the south-east, and in the south the dry plain which slopes through Kikumbuliu to merge with the Nyika wastelands. The main physical features of the area are a series of massifs running on a roughly north-south axis for a distance of some ninety-six kilometres including the massifs of Kangundo, Iveti-mua, Mbooni (place of buffalo and associated with good soil and plentiful water) and Kilungu. They consist in the most of a series of relatively narrow ridges with very steep sides rising to about 609 m (2000 ft) above the surrounding country and reaching an elevation of 1828-2133 m (6000-7000 ft) above sea level (Munro, 1972, 11).

Machakos is a marginal district from an agricul-

tural point of view and presents a number of problems of adjustment. The earliest problems to attract the attention of the government and scholars were those associated with overstocking, soil erosion and later over-population. More recent studies have focused on the adjustment to environmental risks such as drought (Porter: 1965; Mbithi and Wisner 1972); soil erosion; (Moore: 1979; Barber, Moore, Thomas 1979); consequences of population pressure such as land shortage (Owako: 1969; Odingo 1971: 162; Anzagi and Bernard: 1976); nutritional status (Mbithi and Wisner, 1974; Medical Research Centre, Nairobi 1974-1980+); water supply (Silberfert 1976). Owako (1969: 77) observes that the first three problems become interwoven, and presented almost insoluble agrarian problems in the 1930's and 1940's; they owed much to both physical and human factors. The question is when did the Machakos agrarian problems begin? What were the actual causes? Of great importance is, how is the Machakos agrarian problem related to the current study?

The author does not propose to give a detailed discussion of the origins of 'Machakos Problem', but on the contrary, will briefly confine himself to discussing and elucidating those aspects of the problem which may have no direct influence on coffee production, but

which affected the introduction of coffee; availability of high-potential land to the Akamba and distribution of population in Machakos.

The coming of the British settlement in Machakos in 1894 and subsequent creation of the Reserves in 1906 forced the Akamba to adapt their economy to an area roughly half its original size. This move affected the Akamba in roughly five ways as reported by Phil O'keefe and Wisner (ed. 1977: 201) and Mutiso (1977: 41)

(a) these settlers established very large ranche in Athi, Kapiti and Yatta plains, reducing the Akamba pasture by one-half.

(b) settlers' arable farms in Mua Hills and Ol Donyo Sabuk accounted for at least a fifth of the Akambas' high potential land.

(c) the population of both animals and people in the reserves increased in some areas beyond the "critical population density". Like in other reserves in the country this led to shortage of grazing areas, soil deteriorati and marginal productivity.

(d) population pressure and expropriation of lan by the settlers had forced the Akamba down out of the hill masses of Mbooni, Kilungu, Iveti, Kalama, Mukaa, and Mbitini and into the lowlands which lay in between.

(e) the presence of the European settlers in Machakos hills may account for late re-intro- duction of coffee to the African areas.

In the meantime, it is important to note that under the conditions mentioned above - settler imposed overstocking, lack of able-bodied men, heavy tax-burdens - the pioneering Akamba in the lowlands found it hard going. The famine of 1924 (as Phil O'keefe and

Wisner: 1977 point out) marked the emergence of marginality and famine vulnerability which has maintained its hold to the present. The concept of marginal environment is therefore very significant in the assessment of the utilization of Machakos' agricultural resources. This point becomes even of great importance when one realizes the fact that the land of high potential - with rainfall of over 889 mm (35 inches) - occupying only 9.9 percent* of the total land in Machakos is found mainly within the central hill masses, which in terms of administrative locations include parts of Matungulu**, Kangundo, Mitaboni, Kalama, Mbooni, Kilungu and Mbitini. From the foregoing, it is no wonder that heavier concentration (relative to sparsely populated lowlands) are to be found around ecologically favourable spots of the central hill masses of Machakos

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* Assessment of Machakos agricultural potential by the use of rainfall as the main criteria is discussed by F.N. Owako in his article "Machakos Land and Population Problem" in Ominde S.H. (ed.): STUDIES IN EAST AFRICAN GEOGRAPHY AND DEVELOPMENT p. 178-179, 1971 Owako states "expressed in terms of total percentage of the land, it can be seen that only 9.9% of the district falls within high potential zone. The rest i.e. 54.2% and 35.8%, fall within the medium-potential and rangelands (low potential respectively). The medium potential and rangelands have fairly high chances of crop failure.

** The current study centres on Matungulu location of Machakos district.

such as Matungulu-Kangundo, Iveti-Mitaboni-Mua hills; Kiimakimwe, Kilungu-Mukaa and Mbooni. Faced with ever increasing human population and hectarage under coffee on one hand and reduced acreage under food crops and rather limited high potential land on the other, the high land zone of Machakos might be facing a more serious agrarian problem - a point pursued further later on in this chapter.

1.2 Introduction of Coffee in Machakos District

The introduction of coffee in Machakos district in the early fifties provided an effective modern, external linkage to reduce the famine vulnerability of a few Akamba, while the majority were pushed into marginality (O'keefe, and Wisner 1977: 207).

Arabica (Coffea arabica) and perhaps first intensively cultivated in the Yemen, is actually a native of Ethiopia, where it grows wild, or "spontaneously" in the forests of Kaffa, Illubador, Gemu-Gofa and perhaps Sidimo provinces, mainly in the south west of the country. Brown and Cocheme (1969: 229). As Brown and Cocheme (1969) state "the name 'coffee' is perhaps derived from 'kaffa', particularly when given the Arabic pronounciation 'O'ahwa' (Kahwa)".

Coffee was originally brought to Kenya by French Missionaries from South India and Ceylon. It was first planted in Machakos District at the Scottish

Mission - Kibwezi in 1893 and was subsequently abandoned when the mission moved to Kikuyu. In 1903, the Austin' mission started a plantation in Nairobi. It was from this area in Kiambu that coffee spread to other adjoinin districts.

Until about 1935, the coffee Industry was predominantly in the hands of European settlers and the Africans were not allowed to grow coffee. The grounds for resistance were that the introduction of African coffee growing would spread disease, damage the good name of Kenyan coffee, make difficult the prevention of theft from European estates, and reduce the supply of labour to European farms (Heyer et al 1976: 193). Even when coffee was allowed to be grown on experimental basis, in 1933, great care was taken to ensure that the first thre districts - Embu, Meru and Kisii were far removed from European growing areas. The proximity of Machakos highland (just adjacent) to the European settlers at Mua hills and Ol-Donyo Sabuk area, is felt by the author to be one of the main reasons for later reintroduction of coffee in Machakos district.

It was only after the Swynnerton Plan in 1954 that coffee was introduced in African areas in a relatively faster and greater scale than ever before. In the case of Machakos district the first trials were made at Ngelani on Iveti-Mitaboni hills in 1950 - sixty years after the first introduction of coffee at Kibwezi in 1893! This was followed by Kangundo in 1952 and Matungu

in 1953 and later in Mbooni in 1955. Most of the coffee grown in Kenya is of Arabica variety (coffea arabica).

1.3 The Place of Coffee in the Kenyan Economy

Today in Kenya, coffee stands high in foreign earning capacity. It is the most important single cash-crop and contributes more than 30% of the total foreign exchange earnings. For example, in 1978, coffee earned Kenya K£104 million out of the total value of gross market production of agriculture and livestock of K£ 317,318,000 (Statistical Abstract 1978: 104). Its importance in the Kenyan economy is reflected by the fact that it was in the recent past described as black gold of Kenya at the height of its trade boom.

Until very recently, new food crops such as maize, beans, and peas had occupied a greater portion of the cultivated land than coffee in Machakos highland. Today, coffee is grown almost to the exclusion of other food crops. Will this new agricultural development add something to the so-called "Machakos Agrarian problem"?

Coffee is by far the most important cash crop in the highland zone of Machakos and indeed the entire District. "It represents the valuable crop in all divisions of Machakos District except the southern Yatta divisions (Min. of Agr. Mks. dist. Ann. report. 1961-65)* (see Table 1). Its importance arises mainly from its cash-value. Hence, coffee is the major cash-income earner

* Ministry of Agriculture, Machakos District, Annual report.

for most of the small-scale farmers in the central hill-masses of Machakos district. In 1976 coffee earned K£ 2,630,222.65 in Machakos District. (Min. Agr. Mks. Ann. Rep. 1976).

On a locational basis, Matungulu has maintained its second position in the district in terms of number of coffee plants and credit attraction. For instance, between 1956 and 1960 there were 29,521 coffee plants in Matungulu, 79,299 in Kangundo and only 8,818 and 3,128 in Kikima (mbooni) and Iveti respectively (Min. Agr. Mks. Ann. Rep 1956-60). Similarly in 1977 Co-operative Production Credit Scheme (C.P.C.S.) loans were granted to the 13 societies in Machakos - Matungulu received Ksh. 1,700,000 Kangundo Ksh. 740,000/-, and Kikima (Mbooni) Ksh. 240,000 (Min. Agr. Mks. Ann. Rep. 1977). The ever increasing production of coffee led to the split in early 1960's of the former Kangundo/Matungulu Coffee Growers Co-operative Society into the present Kangundo Coffee Growers Co-operative Society and Matungulu Coffee Growers Co-operative Society. Perhaps the greatest landmark in Matungulu coffee production is the Ksh. 9 million multi-storey Co-operative Society's Bank and offices at Tala, Matungulu.

TABLE 1

Contribution by individual crops to District, Gross Income in 1976.

Crop	District Income (Ksh.)
1. Coffee	2,630,222

Crop	District Income (Ksh.)
2. Sisal	213,317
3. Fruits (Mangoes, Citrus, Papaya etc.)	105,000
4. Tomatoes	57,181
5. French beans	55,409
6. Cotton	34,775.5
7. Peppers & Chillies	33,000
8. Onions	16,658
9. Cabbages	15,719
10. Sugar cane	14,032
11. Sunflower	7,260
12. Tobacco	1,758
13. Castor Oil	1,184

Source: Ministry of Agriculture: Machakos District, Annual Report 1976: pp. 74.

1.4 Choice of the Study Area

This study attempts to investigate the main physical, biological and socio-economic factors which influence small-scale coffee production in Matungulu Location of Machakos District - Kenya. The terms small-scale and small-holder are used interchangeably, as are estate and plantation. The study was inspired by four main considerations.

The first consideration, and worth quoting at length is that "detailed studies of small regions are required for development planning and the rural geographer should concern himself with such studies. This is not to suggest that geography is the only discipline which can contribute in this way but it is a discipline which is well suited to the practical needs of rural areas in Africa at the present time. Studies of this type can result in practical suggestions as to how pro-

gress might be made. There is an urgent need for research with practical applications in Africa; research in rural geography should be focussed on the problems and solutions of these problems (Taylor: 1969: 274)."

The second is that coffee has no competing cash-crop in the highland zone of Machakos and Matungulu Location in particular. It is also the major cash income earner for most of the small-scale farmers. Consequently, due to its prominence, it is assumed that farmers take the factors that influence its production seriously. Hence, background knowledge on some physical, biological and socio-economic factors influencing coffee production in the area would be an asset to the farmers. A similar implication of this is that coffee is destined to remain for a long time to come the basis of Matungulu economy and indeed that of the highland zone of Machakos and, therefore, an important object of governmental planning and policy. The question to ask at this juncture is "does coffee justify or deserve the attention given to it nowadays in the highland zone of Machakos, and Matungulu Location in particular?"

The third consideration is that a perusal of the prevailing literature on coffee reveals that no similar study has ever been carried out in this area. Indeed,

many scholars and of varied disciplines and institutions have carried out researches in this Northern Division of Machakos District. However, none of them has ever attempted to explore the influence of physical, biological and socio-economic factors on coffee production on a local level as was postulated at the beginning of this section. For instance, Mbuvi, Van de Weg and Braun (1974) at the request of the Medical Research Centre (M.R.C.), Nairobi, carried out a site evaluation in the North Western part of Machakos district - covering only half of the current study area. They do admit that their present mapping (scale: 1:50,000) is a preliminary one based on aerial photo interpretation and some field observations (surface and several augerholes). No samples were taken except for certain areas where salinity and alkalinity problems were suspected (Mbuvi, Van de Weg, Braun 1974: 1).

M.R.C. is currently carrying out a longitudinal study on morbidity and mortality of a number of childhood diseases in this area. Their study aims at the collection of demographic and medical data among two population groups of 5,000, each in different ecological setting and therefore not necessarily involved in coffee production. For example, Simion Onchere, an agr-

icultural economist, attached to M.R.C. aims at studying the impact of agriculture on the nutrition of the family. Likewise, Kitulu (1980) has been carrying out an economic analysis of observed divergences from agro-chemical recommendations in coffee small-holdings in Machakos district. Kitulu's study is an example of the economist approach to one of the factors that influence coffee production - agro-chemical use - and doesn't necessarily address itself to physical factors such as nutrient status of the soils which are considered to be critical in coffee production.

Perhaps the most recent and rather detailed soil suitability study in the area is that of Sketchley, et (1978: I). Their report outlines the characteristics, distribution, and adaptability of the soils so that it can be managed efficiently and properly. Groupings of the soils were made according to their hazard of use and potential for production of food and fibre. As in other works cited above, little attempt is made to identify the main physical, biological and socio-economic factors influencing coffee production. This study is, therefore, an attempt to fill this gap.

The fourth and last consideration is the impact of the cash-incomes from coffee on the recent areal expansion of coffee and the subsequent change in 'rural development'.

Higher prices paid to the farmers have led to a tremendous increase in coffee planting almost to the

exclusion of food crops and at the expense of quality. As elsewhere in Kenya, the coffee farmers of the highland zone of Machakos district have improved their lot economically much more than their counterparts on non-coffee growing areas. This point becomes more apparent when one compares the socio-economic lifestyles of people living in wetter , rich volcanic soils - west of Kanzalu range and Kangundo hill with those living in comparatively drier and poorer sandy loams east of Kanzalu range - Mbiuni and Mwala locations. As Bernard (1969: 21) remarks in the case of the coffee belt of Mer district of Kenya - the coffee belt of the highland zone of Machakos has become a region of major economic growth New markets, schools, have been built throughout the ar road network has been improved greatly and more than 11 small factories for processing coffee in Matungulu alone have been constructed now employing several hundred workers permanently.

The areal expansion of coffee has led to direct decrease in hectarage under food crops in this part of Machakos - a feature which has been found around Chogori in Meru. "Not unexpectedly, the outcome of this process is a decrease in diet standards, a pattern noted by othe research workers as being common elsewhere in the world where high value cash crops have been introduced (Bernar and Walter: 1971)." It becomes understandable from the foregoing that this study also attempts to describe the effects of the coffee economy upon highland dwelling

Akamba life and landscape and pinpoint some of the impli cations these changes might have for agriculture in Machakos and other comparable Kenyan districts. The rol of small scale agricultural sectors in socio-economic development of our country cannot be underestimated. Fo instance, over half of the Kenya coffee is produced by the small-scale sector. On national scale, Kitulu (1980 15) states that 'in 1978, the small holder sector pro- duced 737.7 kg per hectare which is slightly higher than 50 percent of the estates yield of 1319.5 kg per hec- tare... Machakos District, for instance, though a low potential coffee growing area produced 1511 kg per hecta in that year which was nearly double the national averag of (844 kg per hectare) of small holder coffee growers.' If the praiseworth development is true of Matungulu Loc- ation, it can therefore be assumed that the small-scale farmers of Machakos and those of Matungulu in particular have a potential to produce more with more capital, effo and efficiency.

1.5 Objectives and Scope

The current study is a general assessment of the factors that influence small-scale coffee production in Matungulu Location - Machakos District of Kenya. In this context, coffee belongs to a sector classified by Hills (1970-79) as "cash crop and subsistence, cash crops now becoming the primary objective of cultivation." The author picks on coffee because of its dominant role in

the Kenyan economy in general, and to the livelihood of the highland zone Akamba of Machakos District.

A quick look at Fig. 1a will reveal a summary of the main physical, biological and socio-economic factors which are considered to influence small-holder coffee production in the study area. In the light of the above stated problem, the objective of the current study together with the embodied hypotheses will attempt to:

1.5.1 analyze the physical, chemical and biological factors and their potential in influencing coffee production in Matungulu Location

1.5.2 describe the farm population characteristics related to the sources of labour for coffee production to determine whether or not labour is a critical factor in coffee production in Matungulu Location

1.5.3 determine the proportion of land under coffee in each individual farm in relation to the proportion under food crops and hence find out whether or not increase in coffee production has led to direct decrease in hectarage for food crops

1.5.4 examine the influence of price considerations on the areal expansion of coffee to determine whether or not the areal expansion of coffee plants has been a direct result of good prices paid to the farmers.

1.6 HYPOTHESES:

Newman (1973) saw hypothesis as a statement between two or more phenomena worded so that the direction of relationship can be tested. The current study has one general hypothesis which is further sub-divided into two specific ones. This hypothesis which will be tested is referred to as 'null hypothesis' (symbolized as H_o) as

contrasted with the 'research hypothesis (H_1) that is set up as alternative to H_o

1.6.1 H_o Selected physical, biological and socio-economic factors do not significantly influence the small-scale coffee production in Matungulu location, and the observed differences in yield are due to chance variation

1.6.2 H_1 Physical, socio-economic factors significantly influence the small scale coffee production in Matungulu location

Specific hypotheses:

(a) 1.6.3 H_o Selected physical, chemical and biological factors do not significantly influence the small scale coffee production in Matungulu location and the observed differences in yield are due to random variations

1.6.4 H_1 Physical, chemical and biological factors significantly influence the small scale coffee production in Matungulu location

(b) 1.6.5 H_o Socio-economic factors do not significantly influence the small-scale coffee production in Matungulu location, and the observed differences in yield are due to random variations

1.6.6 H_1 Socio-economic factors significantly influence the small-scale coffee production in Matungulu location.

If the result will lead us to reject the H_o at .05 level of significance and accept H_1, we may confidently begin to look for reasons why those variations in coffee yield exist.

1.7 Organization of Study

It would be difficult to discuss in a detailed manner the organizational framework of the current study here. In this brief section, the contents of the chapters are

outlined fairly broadly.

The first chapter i.e. Introduction - the problem and its relevance, begins with a brief overview of the study area in the historical context. The Akamba, the nature of their economy and early settlement in the stu area are discussed. The effects of colonial economic imposition on the Akamba society are very briefly reviewed, particularly as they impinged on the introduction of coffee, availability of high potential land to the Akamba and the subsequent distribution of the popul ation in Machakos.

The place of coffee in the Kenyan economy is under scored. Its contribution to the total export earnings is shown. Important to note is the fact that the small scale sector has by far outstripped the estate sector both in terms of hectarage under the crop and total production although productivity per hectare is generally low. More emphasis is put on the role of coffee to the highland-dwelling Akamba, where the crop has no competing substitute and remains now and for a long time to come the major cash-income earner for the majority of the small-scale farmers.

Four reasons are advanced to justify the choice of the study area. They range from the importance of detailed studies of small regions, place of coffee in the livelihood of the Akamba living on the highland zone of Machakos district; absence of studies confining themselves to the investigation of the physical, biological

and socio-economic factors influencing the small-holder coffee production in the study area to the impact of the cash-incomes from coffee on the areal expansion of coffee and the subsequent change in the rural development.

The objectives and the scope of the current study are outlined in this section. The objective of the study is to investigate the main physical, biological and socio-economic factors influencing coffee production. For easier understanding of these factors, a conceptual model is provided in Fig. 1a.

Literature Review is a section that - discusses in a rather detailed manner some physical, biological and socio-economic factors which influence coffee production. This literature review is wide and diverse drawn from as near as the Coffee Research Foundation, Ruiru, Kenya to as far afield as tropical and sub-tropical regions. Such a literature review is thought to be the basis of understanding the controls on coffee production. Additionally, it will assist the evaluation and analysis of the field data of the current study.

Chapter two - "Environmental Setting" - presents a general survey of both physical and human resources in relation to coffee production in Machakos District and Matungulu Location in particular. In this chapter, the geographical location of the study area, the geology and soils; physiography and drainage; climate, hydrology

and vegetation and population and land-use are also examined.

Chapter three deals with "research and methodology" In this chapter the sources, nature, method of data collection and analyses are discussed. Finally, the type of research limitation arising out of availability, nature, collection and analysis of the field data are outlined.

Chapter four - "Physical Environment as a Factor in Coffee Production". Here, the analysis of the mechanical and chemical content of the soils from the coffee plots with a view to evaluating the potentiality of the physical environment for coffee production are presented. Similarly, the influence of the biological factors (such as disease/pests and weeds) in relation to coffee production are also examined.

In the fifth chapter i.e. "Human Environment as a Factor in Coffee Production", is a broad one covering a wide range - social, economic and agronomic variables which are thought to influence small-holder coffee production. Our hypotheses will be mainly tested here. By now it is apparent to us that coffee yields are the product of the interaction of both physical and human factors. An attempt to arrive at a multiple-solution fo coffee production will be sought by testing the first hypothesis in a multiple regression model. This specifi model is the step-wise regression model.

The last chapter comprising of "summary, conclusions, and recommendations" in relation to small-holder coffee production in Matungulu Location is presented. The purpose of this conclusion is two-fold

(a) to assess the success and failures of small-scale coffee production in Matungulu Location. The shortcomings of the present agronomic, controlling agencies will be pinpointed. Consequently, recommendations will be made with a view to increasing the physical and economic yields of coffee thereby contributing to the National Income of Kenya and raising the living standards of the small-scale farmers of Machakos District and Matungulu Location in particular.

(b) for academicians, the study is intended to stimulate their interest for further study in the area of agricultural geography. Their contribution is hoped to fill the gaps left by the current study.

1.8 Conceptual Definitions:

1. The term "influence" as used in this study has a dual meaning. It includes those physical and human factors that can lead to direct or indirect increase or decrease in coffee yields.

2. Numerous definitions have been offered for "environment" (Strahler et al, 1973 ; Monkhouse, 1976; Obara, 1976). According to the last author, the concept of this term embraces both physical and human factors. This broad definition of environment has been used throughout this thesis. Included in the physical attributes of the 'environment' are such ecological factors as climate, soils, diseases/pests and weeds. Similarly, the human attributes of the environment will include such socio-

economic factors as farm population characteristics (e.g. age, education status, labour sources etc.); land-tenure, credit availability; coontrolling and marketing institutions, to mention but a few.

3. In Kenya there are two types of farms: small farms and large farms. Views on what is a small or large farm vary greatly. This problem arises out of the fact that what is considered as a small or large farm in Kenya may be quite different in another country. Most of the definitions have been based on farm size. The Central Bureau of Statistics (1978) define 'small farms' as those ranging from 0.2 to 12 hectares. However, the lower farm size limit contained in this definition is considered too low a limit in the economic sense, and in any case, although in this study there were farms as small as 0.4 ha, a lower limit of 0.4 hectares was found to be more acceptable. In contrast, 'large farms' are even more difficult to define. According to the Central Bureau of Statistics quoted above, large farms are those averaging 700 hectares, though there are some outside this range.

4. The term 'rural development' has been defined in various ways by numerous researchers. For the purpose of this study, this term is used to refer to a broad set of action programmes aimed at the alleviation of rural poverty thereby uplifting the standard of living of the rural population. This could be achieved through the

improvement of both physical and human infrastructural facilities. Considered as necessary components of 'rura development' are improved: public health and nutrition; recreational facilities; education system; housing, water and power supply; network of research and extensio services; equitable distribution of agricultural inputs and transportation of farm produce; increase and stabil-ization of farm incomes; creation of employment opportu-nities; and marketing, banking and credit facilities.

1.9 Literature Review:

The literature review shows that little has been studie physical, biological and socio-economic factors influen-cing coffee production in Matungulu Location, and indeed Machakos District. Nonetheless, there is abundance of literature on this subject in Kenya and other tropical and sub-tropical countries, the review of which can pro-vide a sound starting base for the current study.

Several studies have indicated that Arabica coffee is grown in areas whose mean annual rainfall varies from 890 to 1800 mm (Erneholm: 1976: 33; National Coffee Poli Plan 1969: 3; Coffee Research Foundation 'CRF' 1978: 2). Serious droughts may cause a drastic reduction in overal productivity, and where coffee is grown under conditions of minimum rainfall, mulching is essential to conserve moisture and to suppress weeds (Acland 1974; Seifa: Dagg 1968: 68).

Studies on the relationship between temperature and coffee growth have shown that temperatures which are too high cause very rapid growth which result in overbearing and exhaustion. Temperatures which are too low often result in stunted growth. The maximum day temperature normally should not exceed 30°C (90°F) and the night temperature should not fall below 7°C (45°F) CRF 1978: 2).

It is worthwhile to mention that light intensity has been found to be very useful in coffee production. Writing on this physiological aspect of coffee farming, Seifa points out that the highest yields and the most rapid growth rate are obtained in plantations exposed to full light. However, there are certain limits, which if not respected can cause difficulties and even harm.

Studies by Maitha (1974) and CRF Technical Circular No.42, (1978) point to the fact that altitude is important for its direct influence on climatic conditions. The optimum climatic conditions for coffee growing are found around 1700 m (5,500 ft) above sea level. Consequently, most of the coffee growing areas east of the Rift Valley are within the altitude range of 1,500-19000 m (4800-6, 200 ft).

Another important factor in a healthy coffee growt is the moisture regime. It has been found that knowledge of the plant responses to different moisture regimes is very important as it is on the basis of such kno ledge that a sound recommendation on irrigation for the optimal use of water for the best performance of the cro can be made, and wastage of irrigation water can be avoi ded. Kurma (1979: 9,15) notes that it appears coffee trees do not suffer up to a soil moisture regime of 55 percent field capacity (F.C.), both in respect to absorption of the major elements, viz. NPK and Carbon assimilation. Therefore, it has been suggested that irrigation is not needed until the soil moisture drops down to this level which, in terms of soil moisture deficit, may be 150 mm (6 inches).

Coffee cultivation requires relatively deep (at least 1 m), friable, open textured and permeable soil of good drainage and aeration with slightly acidic soil reaction (pH) (Michori and Kimeu: 1980). pH affects the solubility of the minerals. Most minerals are more soluble in acid soils than in neutral or slightly alkaline soils. The soil pH can also influence plant growth affecting the activity of beneficial micro-organisms. For example, the bacteria that decompose soil organic matter, and thus release nitrogen and other nutrients for plant use, are also hindered by strong acidity, Donah Miller and Shickluna 1977: (116-117).

The Coffee Research Foundation recommends that the optimal soil pH in $CaCl_2$ be in the range of 4.4 - 5.4. (CRF: 1977). The previous optimal range was considered as being within the range of pH 5.3 - 6.0. The change in recommendation may be a function of the analytical method used. For most soils, the pH in $CaCl_2$ is usually 0.5 to 1 pH units lower than the pH in H_2O; so their earlier recommendation may be a function of this. Moreover, the CRF states that, the determination of the excess exchangeable acidity (Hp) will in future be limited to soils with pH values of 5.0 and below. The actual Hp values, however, have not changed, as there was no change involved in the method of analysis for Hp.

Soil texture and structure have been found to be important physical properties which influence coffee production. Together, these properties help determine not only the nutrient supplying ability of the soil solids, but also the supplying of water and air, so important to plant life (Brady 1974: 40).

A better understanding of the influence of both physical and chemical properties of the soils in coffee plant growth can only be acquired if the basic physiology is known. Even the effectiveness of the fertilizers and manures can be looked in the light of the morphology of the root and shoot of the coffee plant. The plant has a rather particular system of roots, with shrubby roots which are spread over the surface of the

THE STRUCTURE OF COFFEE ROOTS

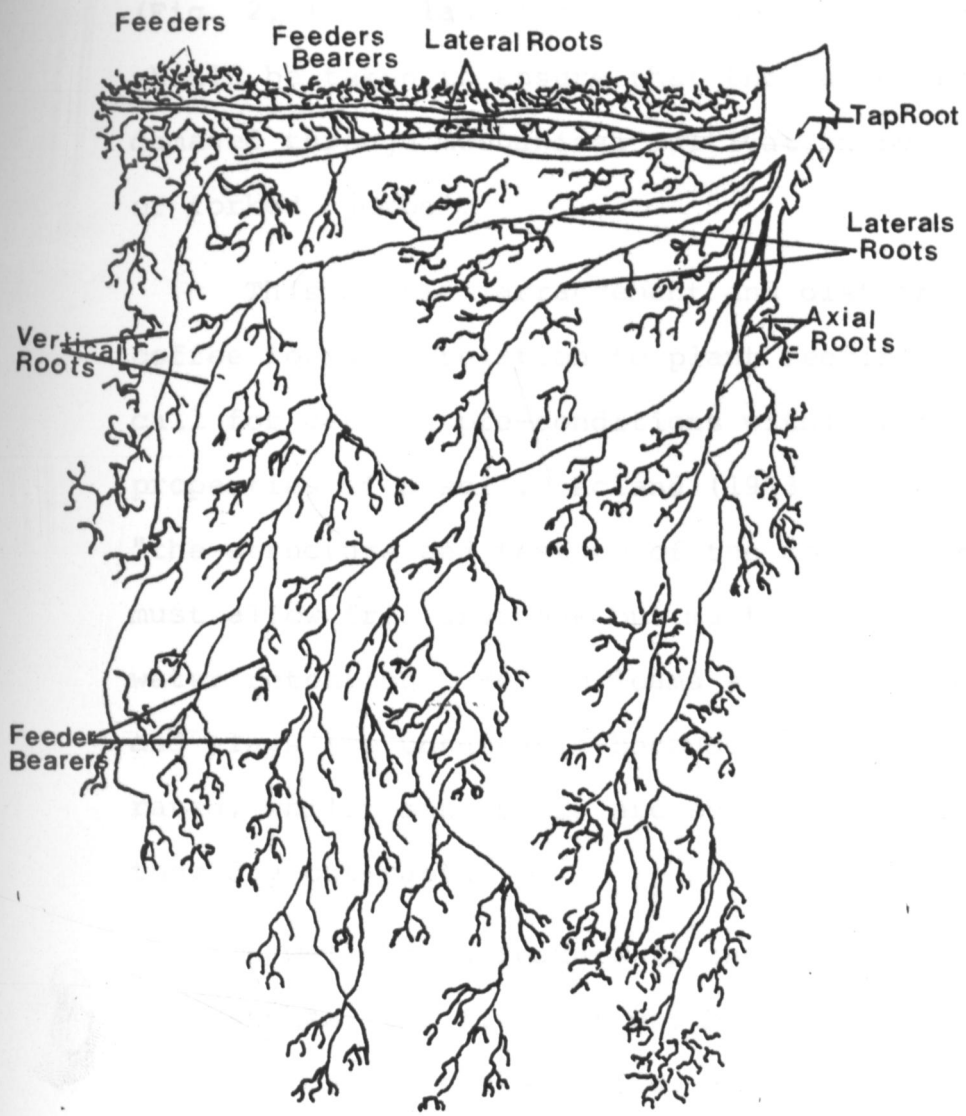


Fig 2 This diagram shows the morphology of Arabica coffee roots

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Source: Kenya Coffee Vol. 44, No. 519 (1979)

soil serving mainly as anchorage; there are also absorbing roots which are to be found in the top layers of the soil and which are the main feeding roots forming a surface mat or plate seldom deeper than 1 ft (0.3 m). (Fig. 2,). Acland (1973: 60) notes that great care should be taken to ensure that the feeder roots are not damaged through mechanical cultivation by either 'Jembe' or forked 'jembe'.

This spatial arrangement and distribution of the coffee roots in relation to plant feeding requirement call for certain pre-conditions within the physical properties of a soil. Acland (1973: 64) asserts that "the structure and texture of the soil and topography must allow free drainage but must also allow reasonable water retention. Medium loams are ideal; heavy loams and clays are unsuitable because they are poorly aerrated, whilst sand soils are equally undesirable because they dry out rapidly."

A well known feature is the existence of two types of branches, the first of which is orthogeotrophic, commonly called suckers (fig. 3) which grow vertically - a type of growth which only produces further vegetative growth and which as Acland (1973: 61) notes rarely produce flowers on the main stems. The second type of branches is called plagiogeotrophic, commonly called primaries and are placed at 45^{o} - 90^{o} in relation to the main axis. These branches are usually called latera

THE PHYSIOLOGY OF COFFEA ARABICA FEATURES

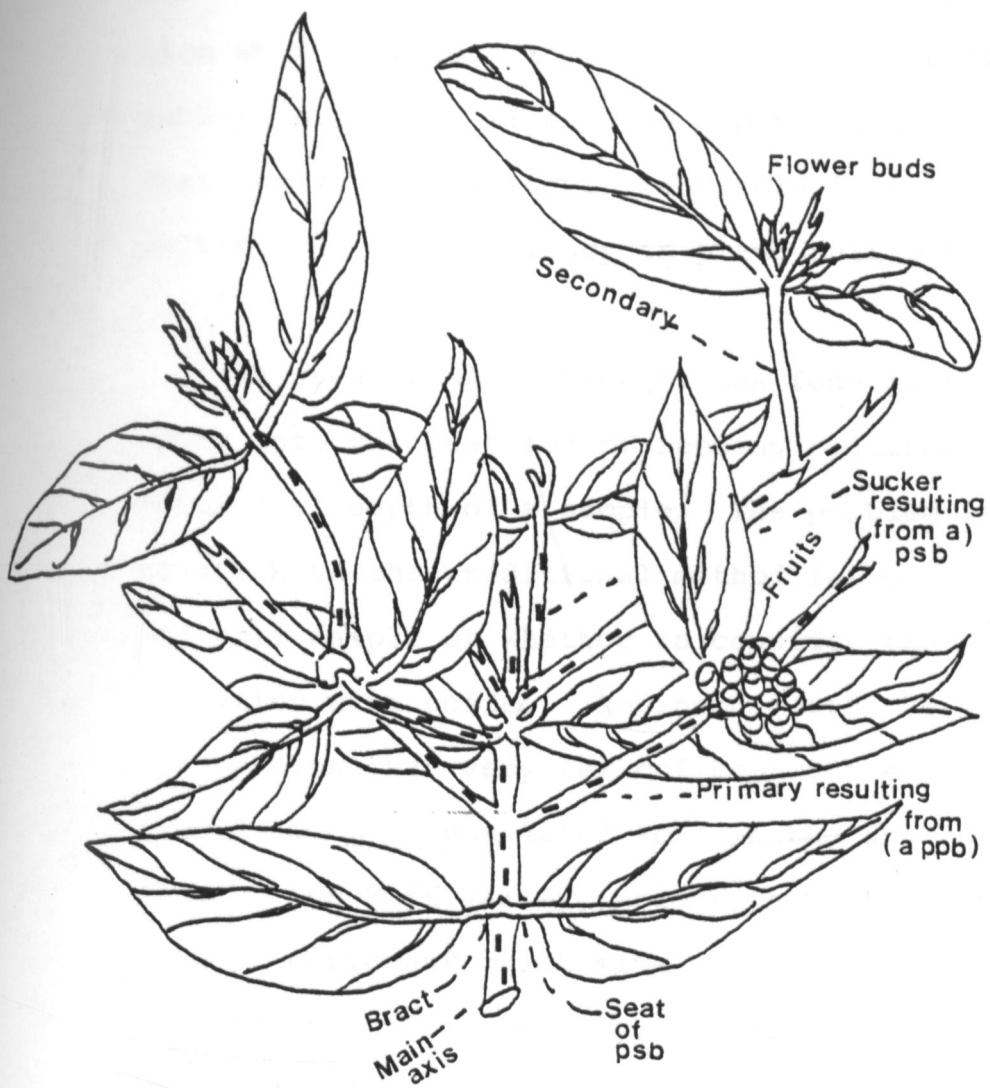


Fig 3 This diagram shows salient features of morphology of coffea arabica

p^{sb} = Potentioal Sucker buds

p^{pb} = Potential Primary bud

Source: Kenya Coffee Vol. 44. No.519 (1979)

Other morphological aspects of coffee plants include buds, and stems and fruit development. These aspects will become more relevant to coffee production when we relate them to some agronomic practices such as pruning. It is also important to mention that leaves play a significant role in helping detect sufficiency or deficiency in plant nutrient.

A great deal of thought has fone in the recent years into the question of feeding requirements and hence soil depth of a sample. The problem is whether to stick to the traditional method ie. 0-15 or 0-20 cm top soil sample or whether to consider the specific situation with coffee. Robinson (1968 75-78) is of the opinion that very few coffee roots exploit the top soil 5-10 cm of unmulched soil in the dry coffee areas east of the Rift Valley, unless there is a semi-permanent or permanent mulch site within the drip cycle and just beyond. Consequently, it seems (to him) rather pointless to analyze this soil as an index of fertility and probable that soil between 10-40 cm or 50 cm will be a suitable index. On the other hand, however, the Coffee Research Station (CRS), Ruiru, Kenya in the Technical Circular No. 23 (July 1979: 2) on "routine soil analysis advisory service for coffee growers" state that the farmer should take separately a soil core to a depth of 0-15 cm (0-6"), representing the top soil, and one at 15-50 cm (6-18")representing the sub-

Coffee is an important consumer of macro-nutrients Nitrogen (N), Phosphorus (P), Potassium (K) Calcium (Ca and Sulphur (S) and a considerable amount of the micro-nutrients such as zinc (Zn), Copper (Cu), Manganese (Mn), Iron (Fe) and Molybdenum. "Insufficien supply of either macro or micro-nutrients can cause considerably lowering of yields. In practice, macro-nutrient deficiencies such as those of N,P,S or K are more widespread than those of micro-nutrients and it is found that the most economic yields are obtained from overall dressing of all these". The critical levels below which deficiencies can be expected as communicated to the author by the National Agricultural Laboratories, Kabete, Kenya are:

Potassium	-	0.2-0.4 m.e. % depending whether the crop is a low or high feeder.
Calcium	-	2.0 - m.e %
Magnesium	-	1.0 m.e %
Manganese	-	0.1 m.e %
Phosphorus	-	20 ppm
Nitrogen	-	2.0 %

Broadly, the division between macro-nutrients and micro-nutrients is based on the quantities in kg/ha of these elements required by plants. Micro-nutrients are required in quantities of 2-3 kg/ha compound, or le whereas the majority of the macro-nutrients are require

in quantities one hundred times as large. Insufficient supply of either macro or micro-nutrients can cause considerable lowering of yields. (CRS: 1977)

Studies on yield responses of Arabica coffee to fertilizers in Kenya have shown that the magnitude of the response is largely governed by the supply and demand balance of nutrient within the soil - plant systems and the environmental factors such as climate, pests, and diseases (Oruko 1975/76: 12).

The use of compound fertilizers involving NPK in coffee in Kenya was recommended by Mehlich in 1968. One of the main advantages of compound fertilizers NPK over the straight N, P and K fertilizers is that it may save labour by reducing very substantially the man-hour required for applying these nutrients separately. The importance of labour cost saved in this way need not be stressed Oruko (1975/76: 26). The commonly used fertil are: Ammonium Sulphate Nitrate (A.S.N.), Calcium Ammoni Nitrate (C.A.N.), Ammonium Sulphate (A.S.) and Urea. The conditions of their use and rates of application depend on the soil reaction (pH) and the amount of the crop estimated in the current season. In soil with pH less than 4.4 C.A.N. (Calcium Ammonium Nitrate)

is recommended being nearer to neutral than the other forms of single nitrogen fertilizers. If the pH is above 5.4, ASN or AS which are acid forming are recommended. However, for optimum growth and cropping the coffee tree required adequate levels of Nitrogen at all times but the roots can only take up nitrates when the soil is moist. During the periods of heavy rainfall any nitrate which is not taken up immediately is leached through the soil below the rooting zone of the coffee. It is therefore recommended by CRS that the annual requirement of Nitrogen fertilizer has to be split into at least four equal applications, instead of three in high rainfall areas and where coffee is irrigated. The timing for the application of Nitrogen fertilizer is illustrated by the table 2 below:

Table 2

Rift Valley and West of Rift: One wet season	East of Rift: two wet seasons		
	Meru District	Other Districts	
		Irrigated Coffee	Non-Irrigated Coffee
March	April	January	April
May	May	April	May
August	November	May/June	November
November	December	November,	

Source: CRS: Tech. Circ. No.29, 1977 p.3.

It is important to note that organic fertilizers have additional advantages over the chemical fertilizers. They are generally cheaper and most of them can be obtained locally, hence, more readily available to the farmer for use. Secondly, continued use of organic fertilizers increases the organic matter content of the soil thereby improving not only the water - and cation-holding capacity of the soil but its tilth. This is practically important in eroded soils where most of the fertile top-soil has been washed away and the physical properties of the soils adversely affected.

Closely associated with soil sampling with regard to nutritional requirements of the coffee plant is the Leaf Analysis. Michori and Kimeu (1980: 81-82) suggest that both the soil and Leaf Analysis Advisory Services are the most valuable practical and direct contributions the chemistry section of the Coffee Research Station offers to the Coffee Growers through fertilizer recommendations based on analysis results. Leaf Analysis determines the general nutritional status of the trees (diagnosis of visual and latent deficiencies). This analysis is, therefore, advantegeous to farmers to conduct both soil and leaf analysis. But they are faced with constraints which range from lack of capital and extension services to implement the recommended fertilizer programme; lack of transport facilities to deliver their samples to CRS in

time and good analyzable condition; and lack of scientific knowledge on the economic use of fertilizers.

The role of weed and disease/pests in coffee production cannot be underestimated. Weeeds are plants which grow where they are not wanted. In coffee which is a monoculture crop, anything growing other than trees is principally weed (Kenya Coffee: 1979: 19). It has been found that high yields could be obtained provided that weed growth is controlled during wet seasons. Weed control reduces competition with the coffee for both water and plant nutrients. This seasonal problem has led to rapid adoption of herbicides being used on estates and considerable interest in this technique in certain small-scale farming areas in which there is a serious seasonal shortage of labour.

Some of the pests that attack coffee are Leaf Miner (Leucoptera spp.); Green Scales (Coccus alpi Star Scales (Asterolecanium coffeae), Thrips (Diarthrot

coffeae), Antestia Bug (Antestiopsis spp.), Kenya Mealy-bug (Planococcus kenyae), Giant Looper (Ascotis selenari reciprocaria) and Berry Borer (Hypothenemus hampei) to mention but a few. The most serious diseases of Coffea arabica in Kenya are the Coffee Leaf Rust caused by 'Hemileia vastatrix' B. and Br., Coffee Berry Disease (CBD) caused by 'Colletotrichum in coffeanum' Noack 'sensu' Hindorf, and Bacterial blight (Elgon/Solai dieba caused by Pseudomonas syringae Van Hall (Okoga: 1978: 22 Coffee Berry disease is by far the most dangerous coffee disease. It increases with heavy rain which dilutes greatly the residual fungicidal cover on the sprayed tree Generally, CBD can effectively be controlled by timely application of fungicides during wet weather. However, research is still under way as to finding other more effective methods of controlling the diseases as was stated in the most recent CRF Technical Circular No. 43 of 1979.

Mulching and pruning are considered as good agronomic practice in coffee production. A study by Fernie (1968:55) show that in any intensive system of culture, pruning must play a large part. The reasons for pruning are to exercise crop contr to maintain bean size, to facilitate harvesting, pest and disease control.

Agricultural education and training on the part of the farmer are the key elements in the whole process o agricultural change and achievement of rising levels of

rural prosperity. However, in Kenya like many parts of tropical Africa a high proportion of the farmers are ill terate. While this feature does not mean that the farme are not receptive to new technological innovations it sh be understood that "modern agriculture, even in its simp aspects requires the imparting of some technical knowled for which the printed word serves a most useful purpose. The planting of new varieties of seed and the associated of fertilizers or spray for disease and pest control may well require simple printed instructions to supplement advice of extension workers. Simple records become esse tial when sales and purchases, and possibly credit are i volved in an increasing sophisticated agriculture. The local cooperative will issue receipts for produce delive It becomes necessary to be able to understand weights an measures if the farmer is not to run the risk of being c tinually cheated (Wilson 1970: 148)". To this end appro priate training programmes must be developed catering bo for education of farmers and their wives. The education the women can be very useful since the bulk of the farm in Tropical Africa is done by them.

Agricultural research and extension services can play an extremely important role in the process of agri- cultural development. "Agricultural research involves th application of science and technology to all aspects of agricultural production. Through patient and systematic work in the laboratory and experimental station, new high yielding varieties of crops ... are evolved, serious pest

and diseases are brought under control, ... many ways and of increasing the productivity and profitability of farming are studied and tested (Wilson 1970: 145-146)".

Research findings have very little meaning if they don't eventually reach the farmer. It is for this purpos that Wilson (1970: 146) states that "agricultural extensi services have been developed in most countries. The exten sion worker, at farm or village level, forms the most impo tant link in the chain of communications between the resea worker and the farmer ... In order to achieve anything the extension staff, must first win the confidence of the farm and be able to demonstrate convincingly that the adoption new practices are worthwhile. He needs to have sufficient education and training to understand the reasons underlayi the improvements he advocates and explains and demonstrate them to the farmer. He should also be capable of understa the peculiar problems of the farmer and communicating thes back to the research worker".

Yet, the steady improvement of the small-scale agr ture cannot be achieved without the co-operative societies rural Kenya. The importance of the cooperative movement i the Kenyan economy is evidenced in the current Government Development Plan 1979-1983 where co-operatives are seen as vehicle for promoting economic growth, alleviation of rura poverty and hence raising living standards of the majority the people in the rural areas. About one half of the acti cooperative societies are primary marketing societies wher their functions include collecting, processing and transpo

ting produce, providing farm input and supplying seasonal credit as well as marketing hire-service and advisory function. "Most primary societies concentrate on one crop. In 1977 these small-holder co-operatives handled nearly 50% of marketed milk (Current Development Plan, 1979-1983)".

Co-operatives are very important in the broad structure of the small-scale agricultural modernisation. The success and failure of small-scale agriculture is reflected in a way through the operations and organizational structure of the co-operative societies. The problems facing co-operative societies are many and diverse ranging from administrative, financial, social to political. Co-operative societies have come under severe criticism by many people from varied quarters of our society. Members of co-operatives have pointed out how they get cheated by those who weigh and process their products such as milk and coffee (Mungai, 1980: 8). Corruption has ruined some co-operative societies in the study area, and some farmers have started to lose interest in looking after coffee.

Co-operative officials arrange with the suppliers of the chemicals, fertilizers and machineries and they are given a certain percentage of money which would be reflected in the invoices of the society. The society would foot the bill as if every single penny was used to purchase the property of the co-operative society when in actual fact a very good amount of money is given to these corrupt members of the committee. (Coffee Peasant, 1981: 7)".

"Another serious constraint facing co-operative societies is the shortage of qualified and experienced personnel to supply general management skills. The standard of management have been found to be poor because of a lack of business acumen, lack of knowledge of co-operative principles among the members and low standards of integrity among the staff of the movement - a factor which has been defended by Livingstone and Ord (1968) on the basis that "since producer marketing co-operatives bring together farmers and not traders, there will be a lack of business management and a lack o accounting expertise since full time farmers will find it difficult to spare time for the acquisition of these

skills" (Livingstone & Ord: 1968).

The methods of land acquisition for any purpose vary with communities and it is the methods by which land is acquired or disposed off by the people in a community that is described as land tenure system (Oboh 1976: 16). Agronomists, planners and land tenure 'experts' have often argued that African land tenure constitutes the single most crucial constraint to agricultural development in independent Africa (Ogendo 1975: 152). Types of land tenure can foster or hinder agricultural modernisation. In general, individual landownership tend to encourage the farmers in farm planning and allocation of factors of production. Even within this setting, other problems such as land fragmentation due to physical, social, cultural and economic reasons such as inheritance and buying and selling compound the problem. Land fragmentation has both pros and cons. On the one hand it helps to spread the environmental risks over the number of fragments and seen in this context, the farmers' eggs are not in one basket. On the other hand, however, land fragmentation can be a hindrance to efficient farm development. The scattered parcels belonging to one farmer pose problems of effective management of the farm, loss of time and en-

ergy spent in getting to the scattered units. Hills, Iton and Lundgren (1972: 88) point out that "the provision of infrastructural facilities such as roads, water etc. become problems to local government when farm fragmentation exists. Official surveys of any kind also have their difficulties multiplied by fragmentation. Officers of the agricultural Extension Service see fragmentation as a hindrance to the efficient dissemination of information on farming techniques and a break on the rate of demonstration, problem solving and essential field inspection." This, like many other problems, will require time and much effort to solve.

Environmental perception can be a very important factor in understanding the way an African views his habitat and the subsequent use of it. Bernard and Walter (1971: 5) write "... knowing what individuals in a culture think and feel about their surroundings leads to insights about their decision making and their wider spatio-territorial behavior. This in turn can be used as a basis for planning rational and efficient use of resources and for creating culturally acceptable systems of spatial organisation... Moreover, since perceptual differences of the environment are basic

aspects of the human condition that have been neglected, they certainly should be investigated more thoroughly if for no other reason than to eliminate ignorance and improve inter-cultural communications."

Ruthenberg (1976: 265) states that "manual labour is by far the most important input in coffee production. The level of coffee output per hectare is closely related to the level of labour input, since the extra work that is involved in applying intensive husbandry techniques may result in substantial increases in quantity and quality. The coffee National Policy (1969) adds that in small-holder, one family can manage ¼ hectare without hiring labour, however, on large coffee holdings or farms with several important enterprises, there may be a considerable employment of labour on a monthly basis or on a 'contract' basis for weeding and pruning the coffee. Odingo (1979: 93) rightly points out that "one must first and foremost look at the family contribution before looking at the additional labour to supplement family resources". Labour is therefore, a critical factor in coffee production.

Although this review of literature has by no means been complete, it would be worthwhile to ask ourselves one more question: What motivates the farmer to plant

coffee? Wallace, Belshaw and Brock (1973:156) have supplied perhaps the main answer to the question; they argue in the case of Bugisu Coffee farmers, that the rising prices in post 1945 period were the major determining factor in decisions of most of the farmers to extend their coffee acreage. This was generally at the expense of production standards and quality over this period.

CHAPTER 2

ENVIRONMENTAL SETTING

2.1 Geographic Location of the Study Area

Machakos District lies within the foreland plateau between the Eastern Highlands of the Rift Valley and the Nyika Plateau, (Fig. 1, p. 2). It forms an elongated stretch of country, running from the Athi Plains in the north-west to the Athi-Tsavo rivers' confluence in the south-east. Covering an area of 5476 sq. miles (6555 km^2)* the district tapers south-eastwards between longitudes 36° 53'E and 37° 51'E in the northern parts and longitudes 37° 56'E and 38° 31'E in the south-east. Latitudinally, it stretches between 0° 47'S and 3° 0'S (Owako 1969: 1). Matungulu Location, the largest and most populous location of the Northern Division lies roughly on the north-western corner of the district (Fig. 1, p. 2). The geographic co-ordinates are approximately 37° 13' and 37° 23'E and 1° 07' and 1° 23'S.

For administrative purposes, Machakos District is divided into seven divisions, namely Northern, Central, Eastern, Western, Southern; Makindu and Yatta, with 28

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* Authors figures inserted.

locations each of which is further sub-divided into sub-locations (Population Census: 1979). Administratively, Matungulu is divided into 11* sub-locations, namely, Katheka, Kingoti, Kambusu, Sengani, Kyaume, Nguluni, Katine, Kawethei, Kalandini, Kianzabe and Kibogo. (See the Administrative Map, fig. 4) The latest census, taken in August 1979 shows a population of 76,326 in Matungulu.

Machakos town with a population of 84,322 (ie. 8.3% of the 1 million in the district) is the main administrative, commercial and cultural centre. It is accessible by an excellent tarmac road some 64 km from Nairobi.

Tala and Kangundo townships situated in Matungulu and Kangundo locations and with a population of 1067 and 5710 respectively, are the main administrative, commercial centres. Like Machakos, Tala and Kangundo are linked to Nairobi by an excellent tarmac road some 67 km away. Tala is situated on a relatively flat plain 1524 m above the sea-level at the junction of Nairobi, Thika and Kangundo roads. Kangundo, on the other hand, is situated on the footslopes of Kangundo Hill at about 1585 metres above the sea-level, about 3 km south-east of Tala. The District Office, Divisional Agricultural Office, Hospital and Police Station are situated in Kangundo.

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* Note that in January, 1979 three new sub-locations were created viz, Kalandi, Kianzabe and Kibogo. Due to lack of well-defined boundaries among these newly created Matungulu sub-locations, and the fact that the last two, cover mainly the estates (out of scope of this study), the current confines itself to the pre-1979 locational boundaries. Consequently, most of the efforts of the study are directed to the first eight sub-locations, the home of all small-holder coffee growers of Matungulu location.

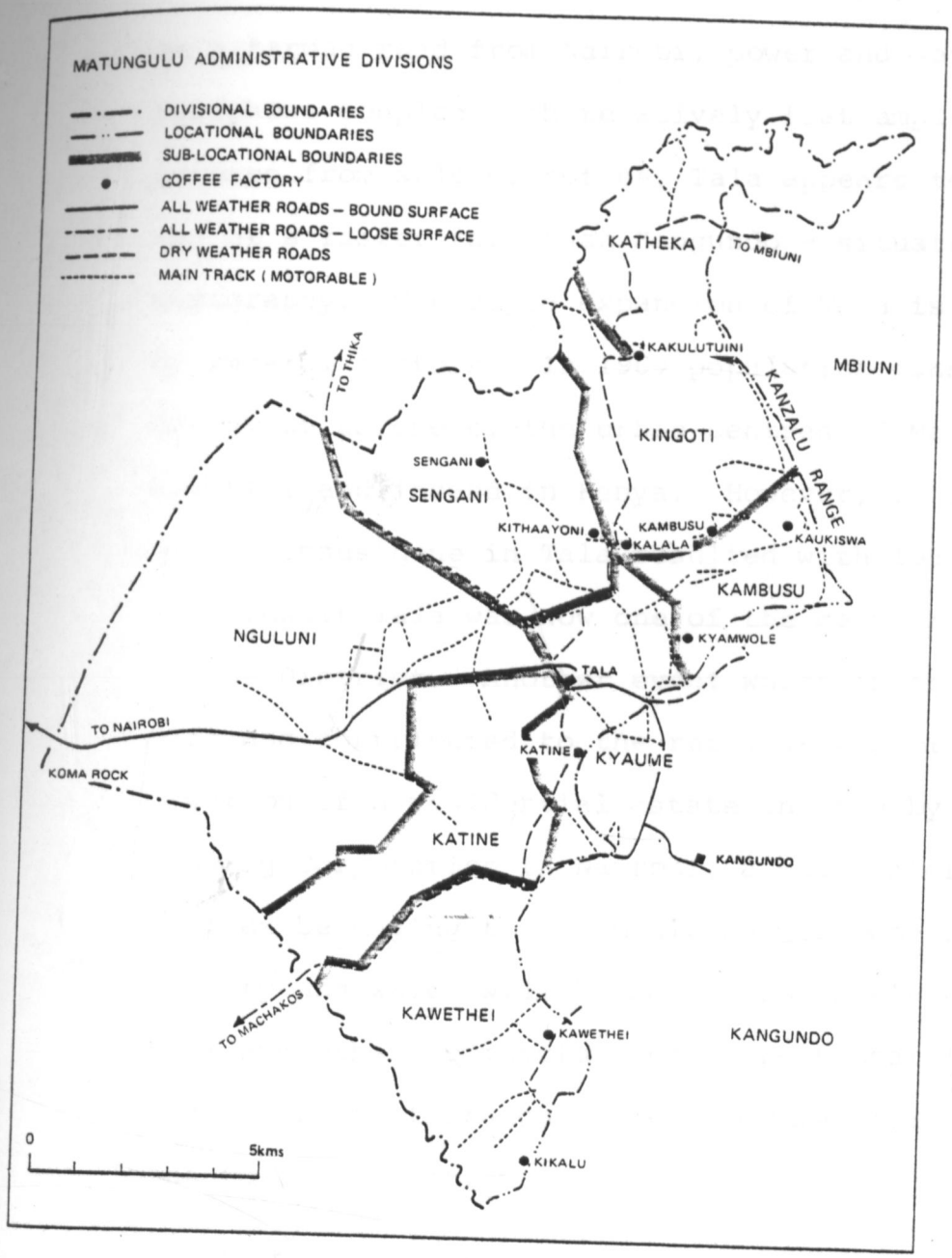


Fig. 4: MATUNGUNLU: Admnistrative map.

With the coming of infrastructural facilities such as a tarmac road from Nairobi, power and water supply, telephone coupled with relatively flat ample land, cash-incomes from sale of coffee, Tala appears to be expanding at a faster rate than Kangundo - situated on a hill topography. The rapid expansion of Tala is evidenced by several factors. In 1969 population census Tala did not exist as one of the urban centres of Machakos District, and indeed in Kenya. However, in 1979 a population census done in Tala resulted with 1067 people and as a result Tala was now one of the main urban centres of the District. Another event which in the recent past has contributed to the rapid growth of Tala is the erection of a residential estate in Tala by the National Housing Corporation in Nairobi, a multi-storey building complex belonging to Matungulu Farmers Co-operative Society and which will house the society's offices, bank and other commercial and recreational functions, and a permanent branch of Kenya Commercial Bank serving the rural population.

2.2 Geology and Soils

The geological foundation in which the present day relief of the district rests, fall into three major rocks, namely, the Basement System (or Basement Complex Rocks as they are at times called), Tertiary Volcanics and Sediments and Pleistocene Volcanics, (Owako 1969: 11) Most of the hills in Machakos District are formed of

granitoid gneisses, the main features being the horse-shoe shaped mass of Machakos Hills, (Fig. 5, Geology Map of Matungulu), Kanzalu Range and Kangundo Hill, Mua-Iveti-Mitaboni and Mbooni Hills, Kalama-Iyuni Mumandu Range and Upete and Mbitini Hills and the smaller hills such as Koma-Rock, Matuu and Kongoni (Mukengesya) (Morgan: 1965; Fairburn: 1963).* It should be noted that Ol Donyo Sabuk, one of the prominent hills in the area is composed not of granitoid gneisses but of metamorphosed basic intrusive rocks (metadolerite). Ol Donyo Sabuk is an impressive, solitary hill which rises to a height of over 2133 m (7000 ft), about 609 m (2000 ft) above the general level of the surrounding plain.

The Kapiti phonolite (Upper Miocene) is a dark grey to black lava bearing prominent pale feldspar (anorthoclase) phenocrysts five or 7.6 cm long, together with waxy looking crystals of nepheline about 1 cm across. It is important to note that Kapiti phonolite is in many parts underlain by an extensive Tertiary Volcanics and Sediments. The pyroclastics, otherwise known as tuffs of trachytic nature, are the most abundant of the volcanic rocks, forming a thick widespread series of variable deposits in both the Thika and Lukenya regions.

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* In preparation of this summary the author has drawn from the above mentioned sources and bears full responsibility for any misinterpretations.

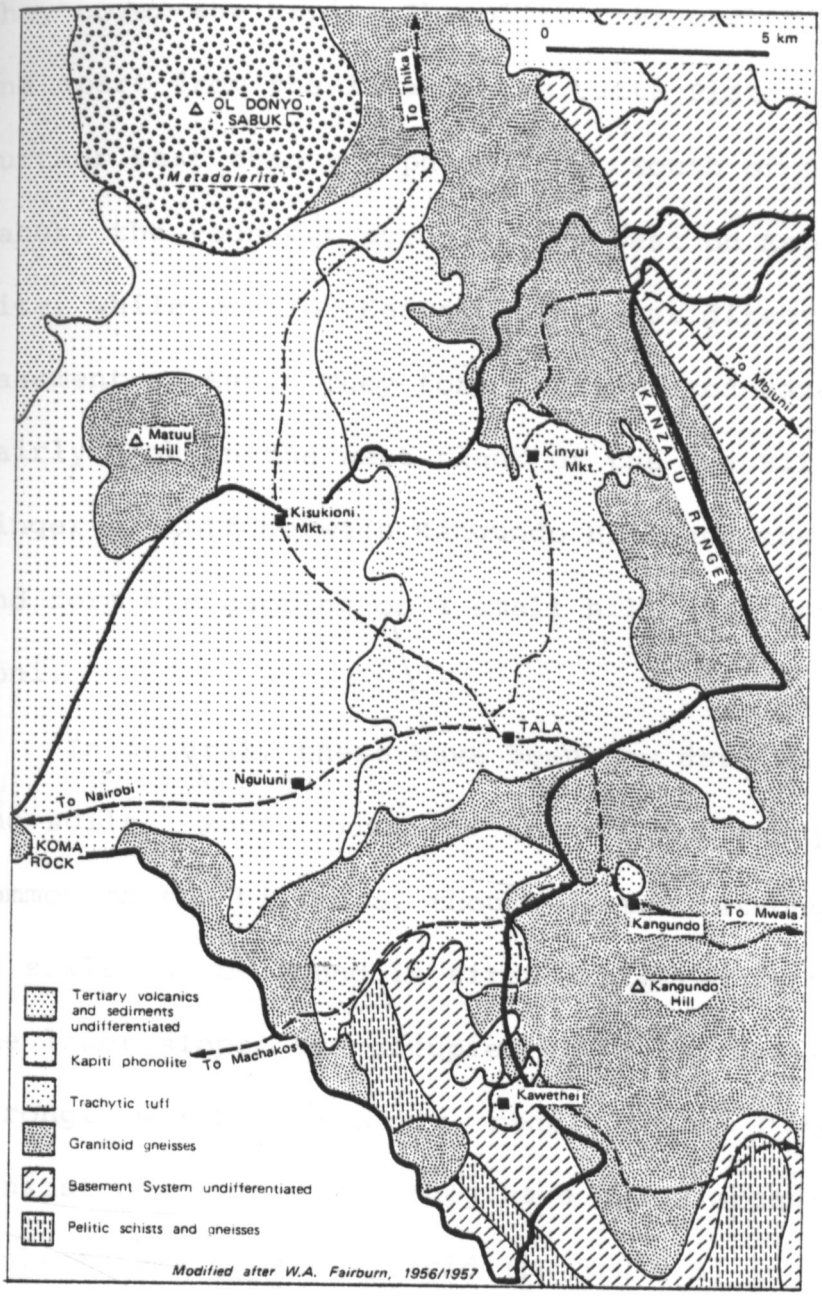


Fig. 5: Geology Map of Matungulu.

They cover the Kapiti Phonolite over much of the area and apart from the lava on the Yatta Plateau, are found further east than the phonolite. South of Ol Donyo Sabuk, the youngest pyroclastics rest on Kapiti phonolite, while west of Kanzalu they rest directly on the Basement system. They form the isolated band of tuff fairly high on the west flank of the Mua Hills, the small finger of tuff between Kangundo Hill and the Mua Hills and form the capping on a small hill just west of Maboloni.

In general, there have been few detailed studies of the soils. Rock, outcrops and shallow sandy soils are common on the hilltops, though deeper, strongly weathered soils can be found in sites protected from erosion. The lower slopes are occupied by, deep, well-drained, strongly weathered soils, reddish-brown clayey, with a ha consistency when dry. They have a low organic matter content, are generally acid (pH 5.0-6.5) in the surface horizons, and have a low nutrient status. Deep colluvial and alluvial soils occur on the footslopes and around drainage-ways. Petroplinthite (murram) and quartzite stone lines can occur at depths of about 1 m, and become exposed when the over lying soil has been eroded. Vertisols occurs in depressions, and though they have a

high nutrient status than the other soils, they are difficult to work. Most soils of the Machakos district can be classified as Ferralsols (Oxisols), Luvisols (Alfisols), Acrisols (Ultisols) Arenosols, Entisols and Vertisols (vertisols) (Moore 1979: 420-421). These soils are derived mainly from Pre-Cambrian gneisses and schists and, generally are of low fertility (Barber, Thomas and Moore 1979: 219).

In summary, the geology of the area west of Kanzalu Range and Kangundo Hill (fig. 5), is mainly of volcanic origin - trachytic tuffs and Kapiti phonolite, the upper slopes being underlain by biotite gneisses of Basement Complex (Sketchley, et al, 1978: 49). Old inselbegs that were not quite covered by the lava flows jut above the plains for example, Koma-Rock; Ol Donyo Sabuk is a meta-dolerite which may well be a dyke of a large intrusion (Ojany and Ogendo: 1973).

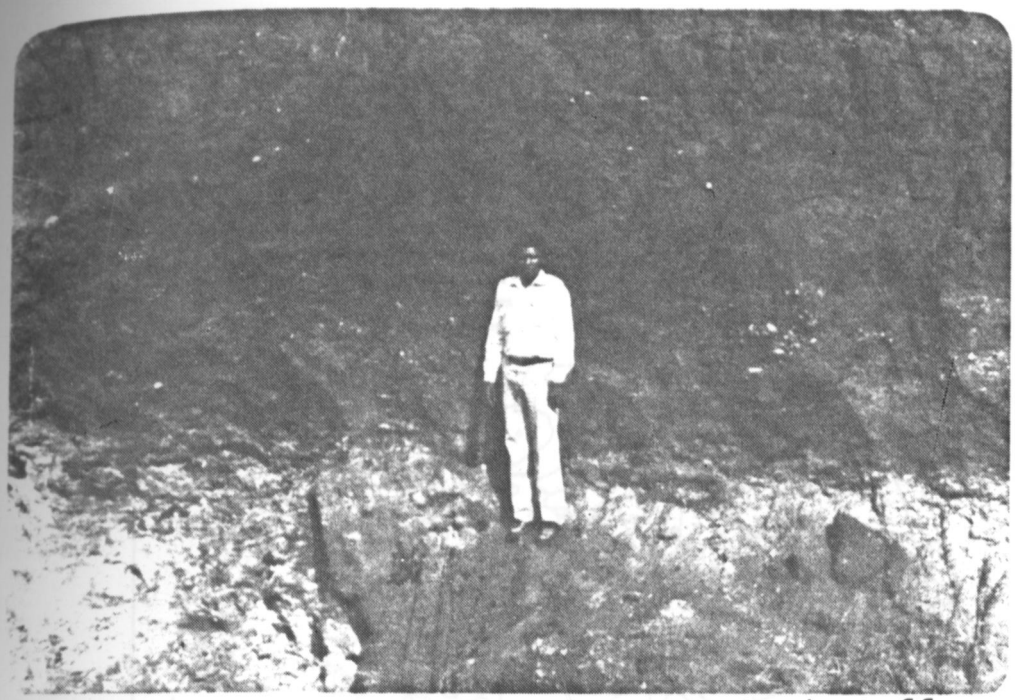
The relatively broad, flat plain to the south-west and north-west of Tala is a zone of complex soils with variable drainage conditions, depth, colour and texture. The soils range from dark-red loams, black to dark-grey clays, dark-grey compacted loamy sand soils (covering Tala township) to red friable clays with laterite horizon clearly visible between Tala and Chief Uku dam

along Tala Nairobi-road.

A good example of trachytic tuff is the western slope of Kanzalu Range, an area stretching from Kinyui market to the north, passing slightly north-east and east of Tala township to Kangundo Hill to the south-east (Plate 1.). The accompanying soils (see fig. 6) are well-drained, deep red friable clays which are on a moderately steep to gentle hill slope and which is the basis of Matungulu-Kangundo small-scale coffee productio

On the other hand, the geology of the area east of Kanzalu Range comes under the Basement System - mainly undifferentiated bounded gneisses. These are metamorphic rocks of various composition, less resistant to erosion than quartz rich, granitoid gneiss forming the Kanzalu Range and the Kangundo Hill. The accompanying soils on these rocks are red to brown and with varying textures (Mbuvi, et al 1974: 3).

The hilly character of the Kanzalu-Mango ranges and Kangundo Hill give rise to a variation in soil conditions. Generally, the soils range from rocks near to hilltops, over red loams and clays on the steep to gentle slopes and to black cotton soils near the valley bottoms. Shallow, well-drained stony soils and stony



Plate]: A deep Soil profile of trachytic tuff near Kangundo.

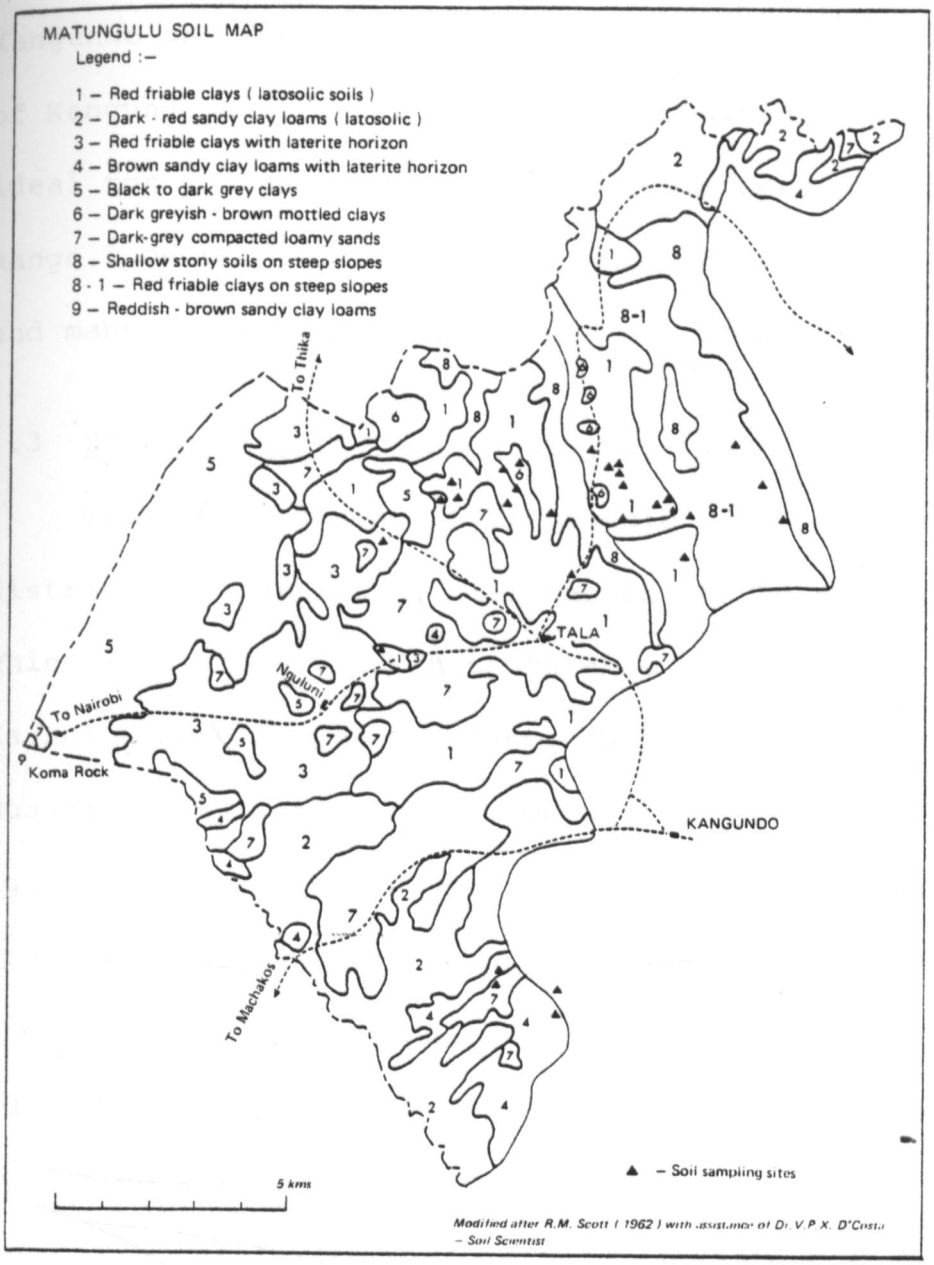


Fig. 6: Matungulu Soil Map

outcrops appear on the tops of Kanzalu-Mango Ranges, Kangundo and Kyevaluki Hills. The gentle hill slopes of Kangundo Hill including Kakuyuni, Kivani, Kitwii are ideal for coffee growing just as those west of Kanzalu Range. On the valley bottoms, sugar-cane, arrow-root and many other water based crops are found.

2.3 Physiography, Drainage and Hydrology

The most striking physiographic unit of Machakos district is a series of hill masses at the centre stretching in a roughly north-south axis with Ol Donyo Sabuk, Kanzalu-Mango Ranges and Kangundo Hill to the north; Mua-Mitaboni-Iveti-Kiima Kimwe at the middle; and Kilungu-Mukaa-Kiu - in the south (Fig.7), . The central hill masses cover an area of about 10,000 km^2 in the Machakos district and reach an altitude of about 2000 m and drop to a series of plains separated by steeper slopes (Moore: 1979: 419).

These hills are visible for miles and command a superb contrasting view of the surrounding grassy high plains of Athi-Kapiti to the west and north-west. Dominantly acacia low-lying plains occur to the east and south-east sloping gently to Athi-River and broken by occasional hills and rivers.

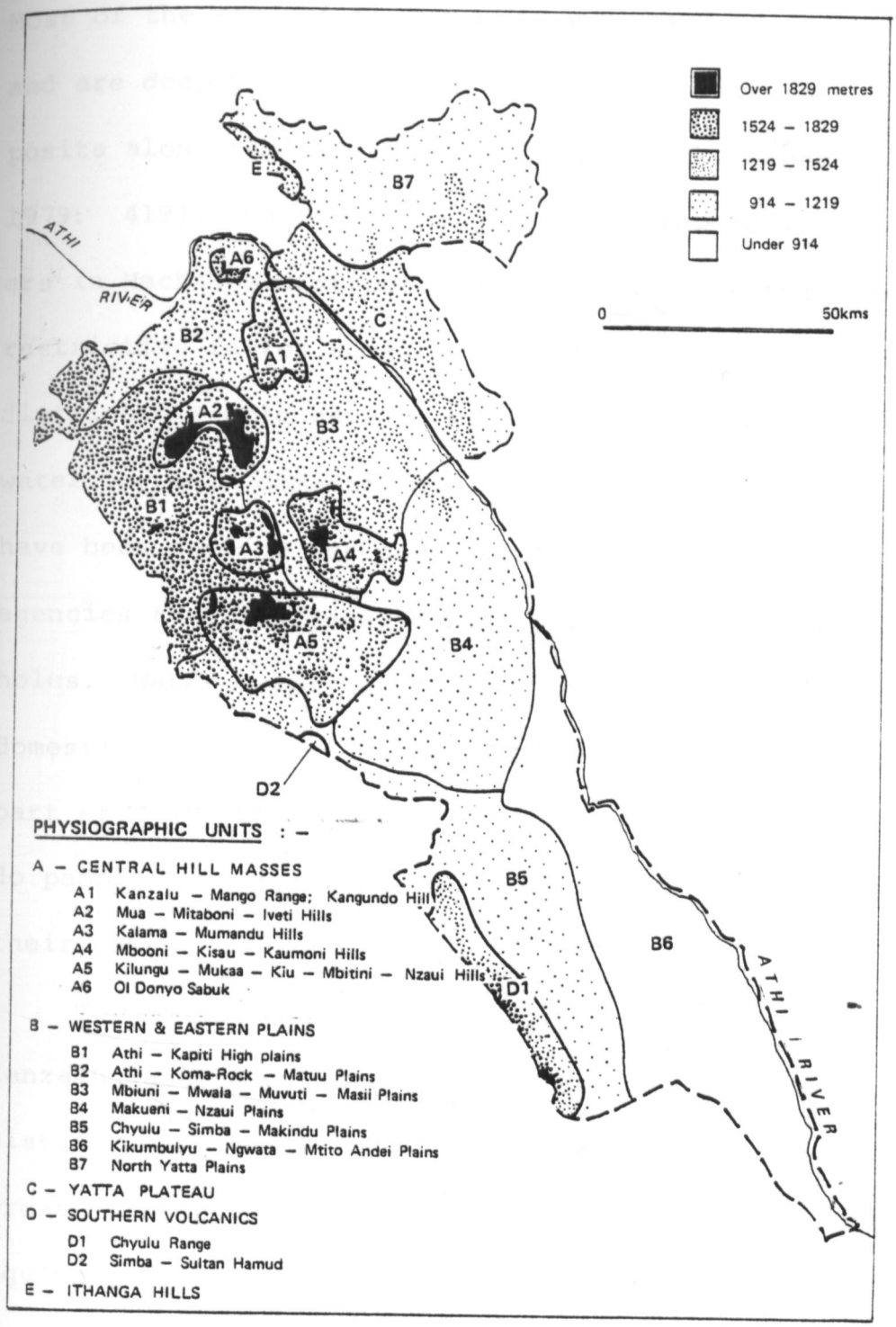


Fig. 7: Machakos Physiographic Units

The overall drainage pattern is from west to east. Most of the streams flow during only part of the year and are deeply incised down to bedrock, with sandy deposits along their floor and between rock ledges (Moore: 1979: 419). On the whole, there are few permanent rivers in Machakos district. Surface water is the main restrictive factor to agricultural development in the district. People have to walk long distances to fetch water for both domestic use and their livestock. Efforts have been made by our government and through foreign agencies to build dams, boreholes, water tanks and water holes. Water supply provided in this manner is used for domestic, livestock and irrigation purposes. For most part of the coffee growing zone of Matungulu and Kangundo people have dug wells some ten metres deep or more at their homes.

Topographically, the steeper slopes of the Western Kanzalu Range and Kangundo Hill, to the north-west of the district, are gently rolling out towards a comparatively broad, flat plain on which Tala township, and Kisukioni, Nguluni, Syanthi and Kawethei shopping centres are located (Fig.8.). The altitude of this relatively broad, flat land unit ranges from 1219 to 1524 m. West of Kanzalu Range the topography is hilly with rounded

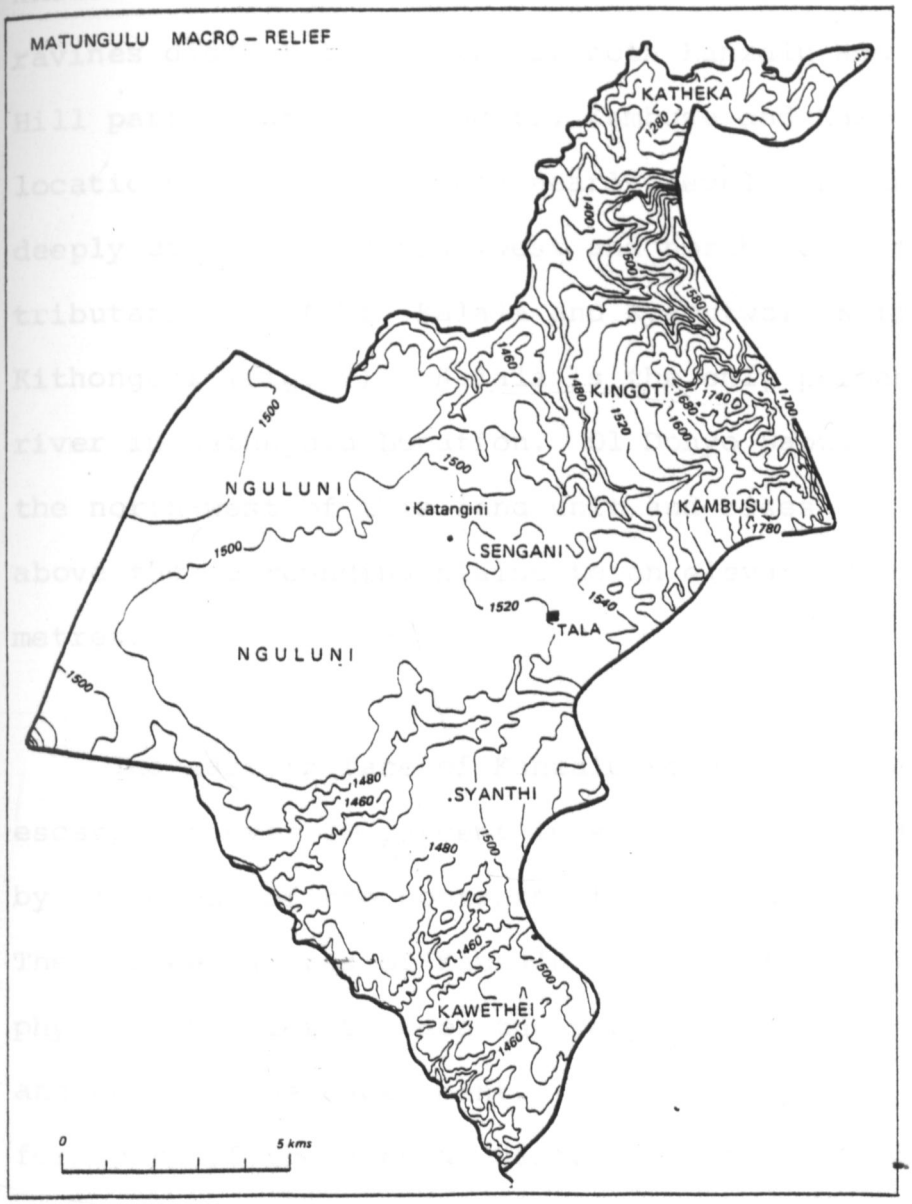


Fig. 8: Matungulu: Macro-relief

knolls and concave slopes. Deep to very deep (7 m) ravines dissect the slopes of both Kanzalu and Kangundo Hill particularly in Kingoti, Kambusu and Kawethei sub-locations (Plate 2). This nearly level land unit is deeply dissected by east-west and north-south flowing tributaries of Athi, Kalala and Kyamutwoi, Katine and Kithongoni (fig. 9). Kalala is the only permanent river in Matungulu Location. Ol Donyo Sabuk is to the north-west of this land unit and rises 750 metres above the surrounding plains to an elevation of 2145 metres.

The eastern face of Kanzalu Range is a very steep escarpment over 30 percent in some parts as witnessed by closeness of the contours (fig. 8) and plate 3). These steep slopes of Kanzalu escarpment form a natural physical barrier between the people living to the east and west of the escarpment. The Mbiuni plains which form part of the general eastern plains of Machakos District are not extensive. They lie between the Kanzal Range and the phonolitic Yatta Plateau and drained by Athi River together with its tributaries. This is a west and south-west drainage pattern most of it starting from Kanzalu Range. At the centre of these plains is a depression.



Plate 2: Aerial view of the northern part of Matungulu location (photography reproduced by permission of the Director of Surveys, Survey of Kenya).

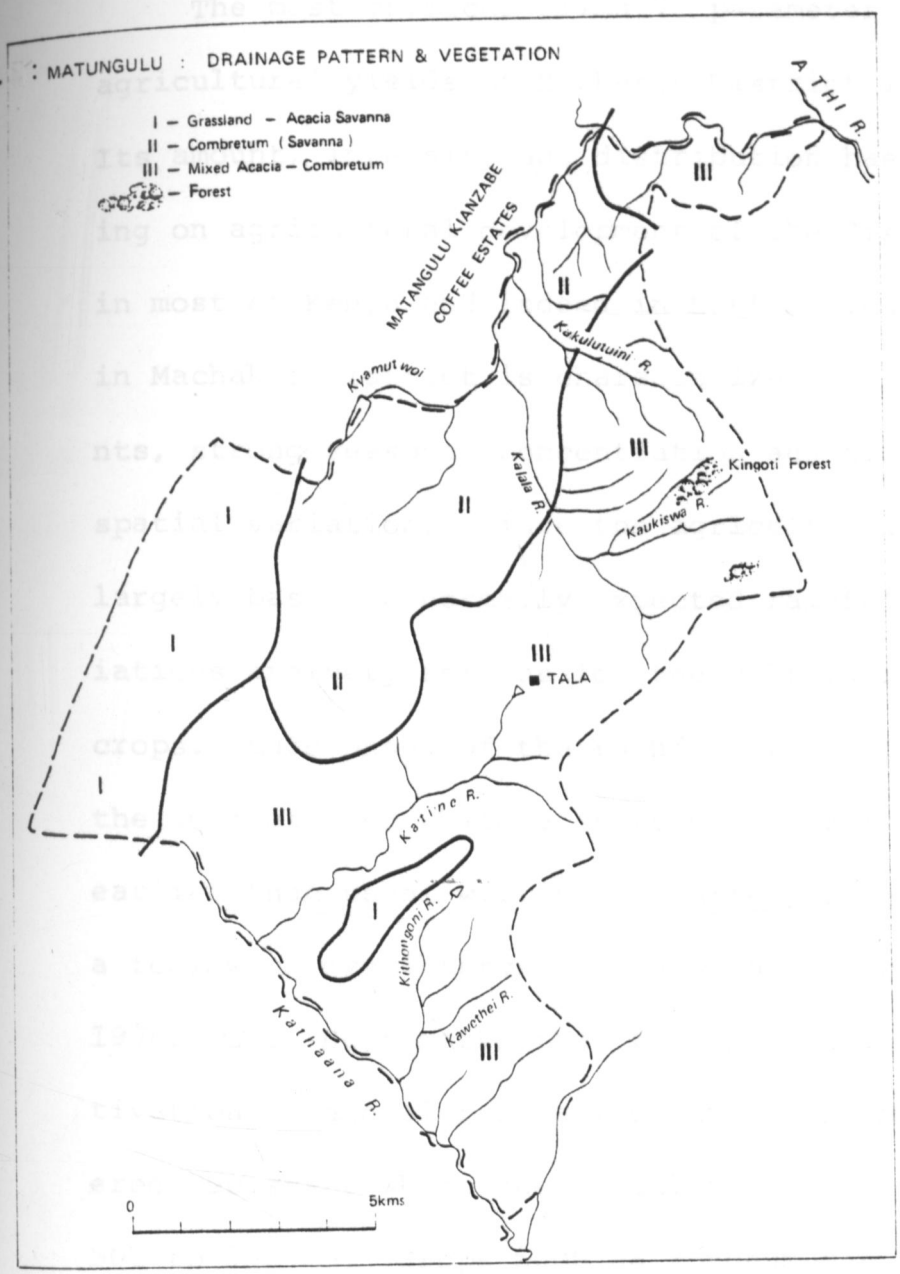


Fig. 9 : Matungulu: Drainage Pattern and Vegetation.

2.4 Climate, Vegetation and Landuse

The most critical climatic parameter that influences agricultural yields of Machakos District is rainfall. Its amount, intensity and distribution has great bearing on agricultural development of the district. Like in most of Kenya and indeed in East Africa, the rainfall in Machakos District is characterized by low total amounts, strong seasonal concentration and high temporal and spatial variation. Since the agricultural calendar is largely based on normally expected rainfall, these variations are very serious for the cultivation of annual crops. Late onset of the rainfall will often result in the loss of seed while a start of the rainfall which is earlier than usual will cause farmers to sow early and a following dry interval may destroy the crop (Niewolt 1978: 2). He remarks that for most forms of crop cultivation an annual rainfall of about 750 mm is considered necessary where the annual rainfall is between 500 to 750 mm. Crops such as sorghum may still be grown but the risk of droughts is large and most of these are devoted to a mixed type of farming based on crops and animal husbandry. Where the annual rainfall regularly remains below 500 mm only pastoral activities can be carried out unless other sources of water such as bore-

holes, reservoirs, or rivers are available.

In terms of spatial distribution of the mean annual rainfall of over 750 mm only about 1/3 of the Machakos District receives this amount as evidenced by 762 isohyet (Fig. 10). This isohyet encloses the central hill masses of the district a factor which appear to coincide with relief (Fig. 7) , high densities of population and the 'coffee zone' which approximates the shape of the central highlands. The mean annual rainfall amount in the district varies from about 900-1270 mm on the hill masses; 762-1016 mm on the Eastern plains; 381-635 on the south-eastern plains (Kikumbulyu Plains) and 457-635 mm on the Athi-Kapiti plains (Owako: 1971: 177). In a district such as the one understudy Owako (1969: 39-40) warns "for agricultural purposes, it is important to think in terms of mean seasonal totals rather than in terms of mean annual totals. But even then, as had been pointed out by Samson (1954) a knowledge of the mean mothly rainfall is of limited value in determining the agricultural potentiality of a given area for means do not take into account losses by run-off, evaporation and transpiration by plants and the distribution of rainfall during the growing season." From the climatological point of view, aridity is the

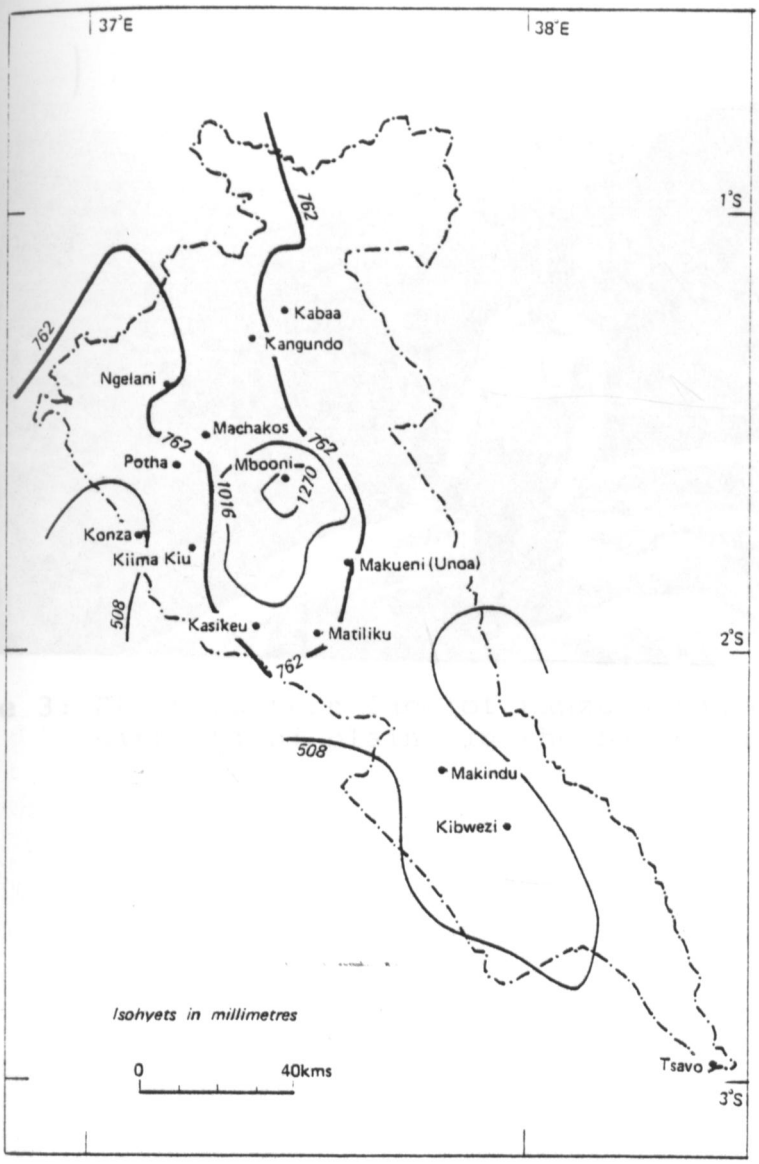


Fig. 10 Machakos – Mean annual rainfall

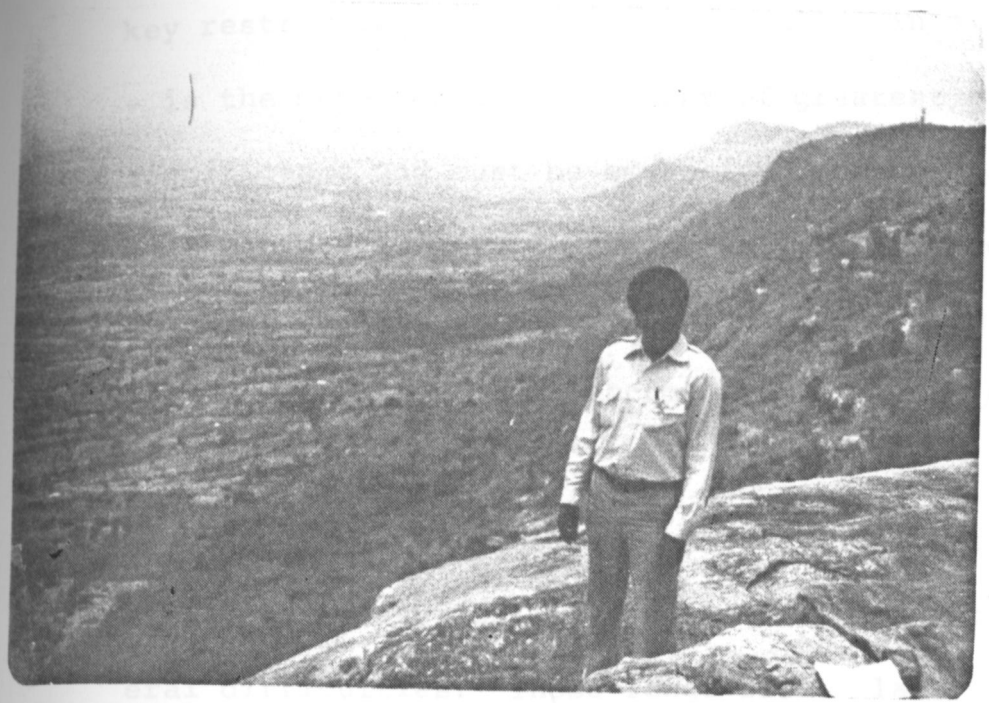


Plate 3: Steep eastern face of Kanzalu range with Mbiuni plains in the background.

key restricting factor; thus rainfall - in all aspects - is the meteorological element of greatest economic significance and must be emphasized in any study of the environment and natural resources. This is reflected in the availability of meteorological data; more statistics of rainfall having been accumulated than any other element (Morgan 1965: 20).

However, in the case of Machakos district working of a detailed reliability of rainfall has met with several difficulties. These range from: lack of an even distribution of the rainfall stations - most of them being concentrated on, and west of the central hill masses - leaving the eastern and south-eastern plains with very few stations; lack of careful collection and continuity of rainfall data in some stations; absence of reliable data out of which evapotranspiration (E_T), soil water balance and hence available water capacity/ Index for plant requirements could be computed. There is no alternative but to accept the uncertain errors to which these factors may lead. It will suffice to say that almost 30 percent of the District lies within the semi-arid eco-climatic zone (iv) which is characterized by an average annual rainfall of 500 to 800 mm (Government of Kenya, 1979) and an available water index of 31

to 45 percent (Woodhead, 1970). The available water index represents the amount of annual rainfall available for transpiration as a percentage of the annual evaporation. The rainfall is distributed into two approximately equal rain seasons, with peaks in April, May and November/December. The distribution is unreliable as shown by Braun (1977) in a study of rainfall probability (Barber, Thomas & Moore 1979: 219). The strong seasonal concentration of rainfall in two peaks (most of it falling in the first month), high intensity, low infiltration rates of the soils and hence great surface run-off have been found to be one of the main causes of soil erosion in the district.

It is worthwhile to devote some space on the rainfall and distribution of Matungulu Location in the north-western part of the District so as to establish the base for the coffee economy of the area. As was the case of the district in general, more emphasis is still put on rainfall rather than other climatic parameters, may be partly due to the presence of few stations recording temperature - a point to be discussed a little later on. A short glance at diagram fig. 11 still shows a strong seasonal concentration of the rainfall around short rains (Nthwa) October to December and long rains

MATUNGULU MONTHLY MEAN RAINFALL FOR 1978 AND FOR 38 YEAR

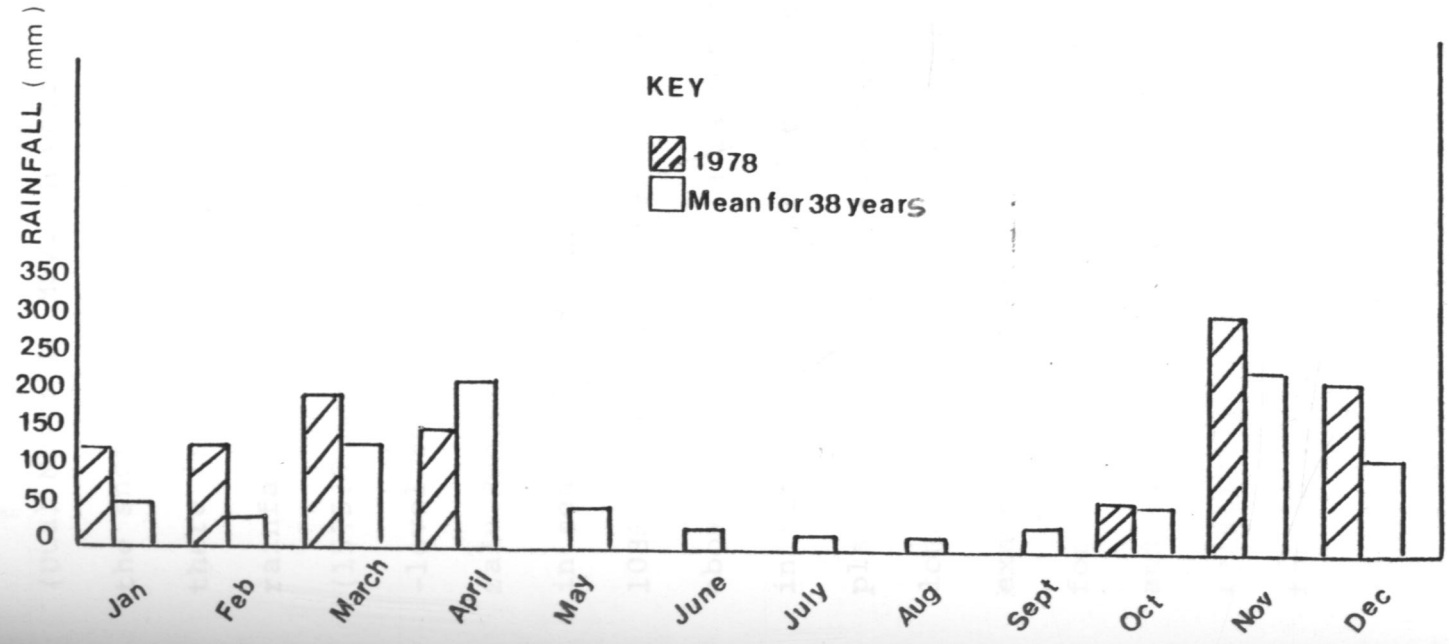


Fig. 11: This diagram shows mean monthly rainfall for 38 years and the annual rainfall for 1978

(Uua) March to May. However, there is a tendency of the short rains to continue into January. In general, there is little variation in both seasonal and annual rainfall means of 1086 mm and 1072 mm for Matungulu (1575.7 metres) and Kangundo (1576 metres) above the sea -level respectively and located to the west of the Kanzalu Range. However, there is a marked difference both in seasonal and annual rainfall means between Matungulu 1086 mm and Mbiuni 992 mm, the latter being 1227.2 metres above the sea-level, a factor which might be explained in terms of altitudinal differences between the two places. A similar trend has been noticed when the long term means are taken into consideration. For example, the long term means of 29, 31, and 20 years for Matungulu, Kangundo and Mbiuni produced 987.4, 1009.9 and 741.8 millimeters respectively. There is also a relatively small variation between mean monthly rainfall for 38 years and the annual rainfall of Matungulu as illustrated in the diagram (Fig. 11). As was pointed out in chapter one, Matungulu meets the altitudinal and rainfall requirements for coffee production, that is over 1500 meters and 890 millimeters of rainfall.

The annual potential evaporation (E_o) at Matungulu and Kabaa is estimated to be in the order of 2100 mm and

1800 mm respectively (Woodhead, 1968). The ratio average rainfall/E_o then is 36% for Kabaa and 55% for Matungulu which puts these sites in ecological zones IV (close to V) and III (close to II) respectively (Woodhead, 1970) and Survey of Kenya, 1970). The boundary between zones IV and III is thought to coincide roughly with the Kanzalu Range ie. east of the range is IV and west is III (Mbuvi, Van de Weg and Braun: 1974: 2). Basing their argument on unpublished material (being prepared by Braun) they state that the probability that the rainfall during a rainy season is less than the potential evapotranspiration can be estimated when the average rainfall and evaporation are known. For a three month crop like maize, the probability of moisture deficit has been estimated and an interpretation in terms of crop yield is given in the following table 3 placing Matungulu in a comparatively better position than Mbiuni.

Table 3

Matungulu and Kabaa Probability of Expected Maize Yield

	Poor to Nil	Fair	Good
Kabaa	33%	32%	35%
Matungulu	8%	14%	78%

The first guide to the evaluation of the crop water requirement for a crop is the ratio of the mean annual rainfall to the mean annual potential evaporation (r/E_o). A good crop is obtained when the rainfall exceeds two-thirds or at least one half of the potential evaporation. Although this condition is met in Matungulu area, it should be realized that even if the estimates of evaporation and crop requirements are correct, the total seasonal amount of rainfall still might be insufficient for a crop because of the fact that part of the rainfall is not available due to surface run-off and deep percolation or sub-surface run-off (Braun 1977). This statement underscores the need to use several indices for estimatin crop-water requirements. For instance, rainfall probability data could be combined with soil moisture data to give a more reliable estimate of crop-water requirements.

In sum, there are comparatively more rainfall recording stations in the district than for other climatic parameters such as temperature, humidity, and soil radiation.

In the case of temperature recordings, the monthly mean values of temperatures for most of the stations do not vary much, however, there is a considerable variation of temperature with altitude. The latter relationship is known to cause slow growth of crops particularly at high altitudes of the highland zone of Machakos such as Mua-Mitaboni and Iveti Hills. The following tables 4, 5, 6, and 7 show the minimum mean, maximum mean and mean temperatures and humidity of Matungulu and Mbiuni

locations respectively.

Table 4

Minimum Mean Temperature (^{o}C) for Matungulu and Mbiuni

Year	1975	1976	1977	1978	1979	Total
Station						
Matungulu	13.2	14.7	14.8	15.0	14.8	14.4
Mbiuni	14.6	14.6	15.5	15.3	15.5	15.1
TOTAL	14.0	14.7	15.2	15.1	15.2	14.8

Table 5

Maximum Mean Temperature (^{o}C) for Matungulu and Mbiuni

Year	1975	1976	1977	1978	1979	Total
Station						
Matungulu	23.8	25.8	25.0	24.8	24.8	24.8
Mbiuni	25.2	25.0	25.7	24.9	25.3	25.3
TOTAL	24.7	25.6	25.4	24.8	25.1	25.1

Table 6

Mean Temperature (^{o}C) for Matungulu and Mbiuni

Matungulu	18.5	20.2	19.9	19.9	19.8	19.7
Mbiuni	19.9	20.1	20.6	20.1	20.4	20.2
TOTAL	19.3	20.1	20.3	20.0	20.2	20.0

Table 7

Minimum Mean Humidity (%) for Matungulu and Mbiuni

Matungulu	43	45	48	52	51	47.8
Mbiuni	42	44	50	53	52	48.0
TOTAL	42.2	44.0	49.3	52.0	52.0	47.9

Source: Medical Research Centre, Nairobi.

It is of paramount importance to establish a link between ecological factors and agriculture in any land-use study. Moss (1960: 231) states that "in planning on an ecological basis it is not sufficient to examine soil and vegetation as separate entities. They operate

as two separate but strongly dependent open systems. To neglect the soil is to eliminate the part of the plant-soil system which will remain when the vegetation has been removed for cultivation; to neglect the vegetation is to make it impossible to evaluate, or even recognize those soil properties which influence and are influenced by it." (Moss, 1960).

There seems to be a close association between soils and area under coffee cultivation as evidenced by most of the soil sampling sites falling under the 'coffee soils' - the red friable clays (see fig. 6). It is not however, easy to find a close link between the distribut of vegetation and the area under coffee in Matungulu Location. The object of the following pages is two-fold First, to give a brief overview of the vegetation distribution of Machakos District. No attempt is made here to relate the vegetation types to land-use patterns since this would be out of scope of the current study. Second, an attempt is made to show the interrelationship between ecological factors (mainly soils and vegetation) and landuse patterns of Matungulu Location.

On the distribution of vegetation in Machakos District, Owako (1971: 178) notes that the "variation in rainfall and soils are equally reflected in vegetatio patterns. Remnants of forests on Ithembo (sacrificial or worshipping) sites on the hill suggest that the more favourable parts of the hills once supported forests,

while the less favourable ones supported combretum and Acacia tortilis on the Eastern plains." The grassland and acacia savanna cover both the Kapiti and Athi plains to the west and north-west of central hill masses of the district.

The vegetation of Matungulu Location may be put under the following categories (see fig. 9): grassland- acacia savanna (I); combretum savanna (II); Mixed acacia-combretum (III) and forest (IV). "In this context the term savanna connotes simply the group of tropical vegetation types which consist physiognomically of more or less continuous layer of grasses and herbs, with a tree layer of variable density. As the trees become less denser, these savanna types merge into savanna woodland, which in some cases may be devoid of grasses, and structurally, strongly resembles closed secondary forest. With decreasing tree density the savanna types merge into open grasslands on steppes (Moss 1960: 216-217)". The natural vegetation of the area between Koma-Rock, Matuu Hill and Kisukioni and a part of Syanthi plains is predominantly grassland-acacia savanna. The common acacia species is Acacia drepanolobium (whistling thorn) or "iunga". The soils covering

this south-north stretching zone, range from black to dark-grey clays of Athi plains (fig. 6). The dominant land use is livestock farming - cattle, goats, and sheep being the major animals. (fig. 12). It is important to note that this zone and the western fringes of zones II and III are the main source of farm manure for intensive coffee farming sub-locations of Sengani, Kingoti and Kambusu.

The Combretum Savanna occupy the area stretching north and east of Chief Uku dam and extending through Nguluni market, Kisukioni, Kalandini, to the confluence of Kalala and Maindaindo rivers. The tree species in this open woodland savanna include combretum Molle R. Br. "iama". The grasses of this zone include "Hyparrhenia spp." and "Themeda triandra" occurring on shallow stony soils - red friable clays with laterite horizons being among the dominant soil groups. The landuse is varied and range from livestock farming (as in I) to maize, beans, pigeon peas and coffee farming. Quarrying based on trachytic tuffs used as building stones is found on scattered spots on both sides of Kalala river.

The southern half of Matungulu, part of Katheka sub-location, parts of Syanthi plains are covered by various high acacia species. Examples of this type

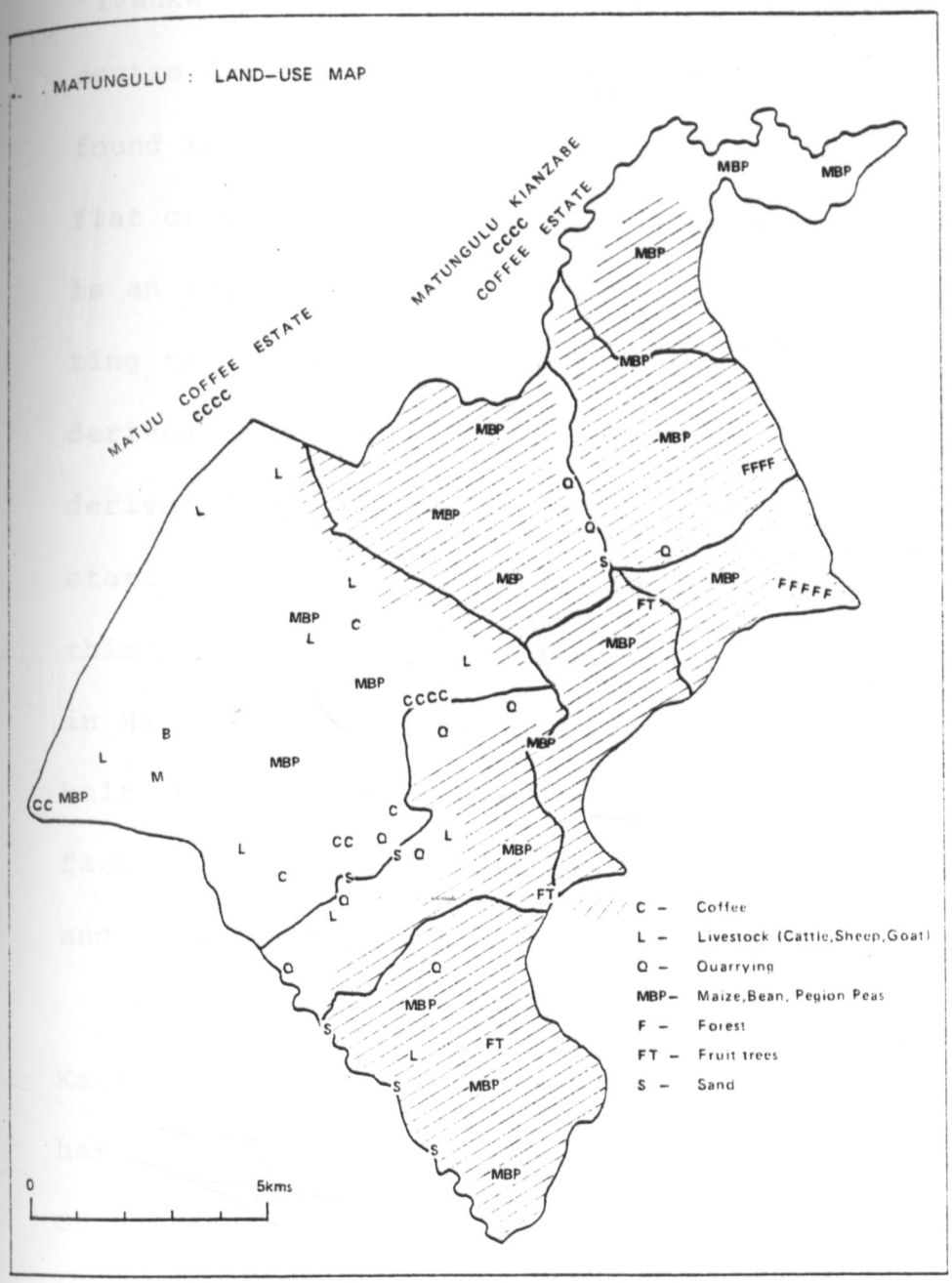


Fig. 12: Matungulu: Land use Map.

of vegetation is Acacia Xanthophloea (yellow bark) "ivauka" found around Tala township and Syanthi shopping centre (Plate 4). Acacia Xanthophloea "iea" is found in close association with Acacia kirkii (dense flat crowns) "ithi" along the river beds. The former is an indicator of high water table. The soils supporting this vegetation range from the dark compacted loams derived from volcanic ash to dark-red sandy clay loams derived from the Basement system. Landuse of this vegetation belt is the same as the previous two. However, this area has the most extensive and intensive quarrying in Matungulu Location. Quarries are found on a wide belt stretching from Syanthi shopping centre and Katine factory to the north-east and bounded roughly by Katine and Kithongoni rivers to Kathaana river in the south-west.

The original vegetation of the area to the west of Kanzalu Range is difficult to describe since much of it has been cleared to give way to intensive cultivation of coffee, bananas, maize, beans, pigeon peas, fruit trees; sugar-cane and vegetables on the valley bottoms. Mbuvi et al (1977: 49) observe that "the natural vegetation probably consisted of broad-leaf forest with a heavy undergrowth of bush." Today the upper slopes of Kanzalu Range are covered by small patches of exotic

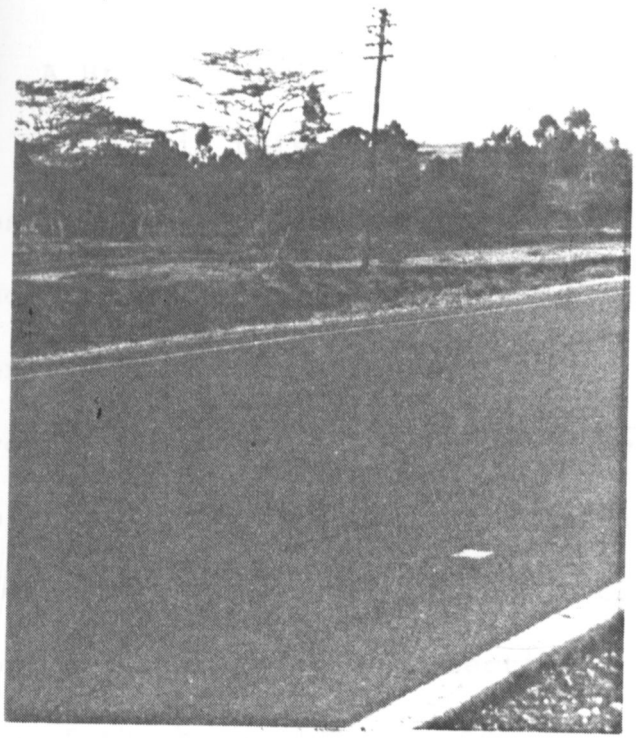


Plate 4: Acacia Xanthophloea
near Tala Township

forests consisting mainly ofcedar, wattle and eucalyptus trees. Kingoti forest is an example of this forest. High population pressure on land and areal expansion of coffee farming are the potential threat to the forest.

2.5 A Brief Overview of Human Resource Base

So far in this chapter an attempt has been made to present mainly a general survey of Matungulu physical resources in relation to coffee production. It is, however, necessary to note that the production of coffee involves the interaction between the ecological and socio-economic factors in which the vital link is the decision-maker, namely, the farmer. Consequently, an attempt will be made in this section to give a brief overview of the human resource base of the study area in relation to coffee production.

It was noted in chapter one that the population of Machakos district is 1 million people. High population concentration is to be found on the central hill masses whereas, the lowlands are still sparsely populated. The major factor influencing population distribution is the physical factors - the most important of which is rainfall.

It was said earlier in this chapter that the popu-

lation of Matungulu in 1979 was 76,326* people. It should be noted the 1979 Kenya population census took into account two more newly created Matungulu sub-locations - Kibogo and Kianzabe with populations of 12,307 and 6,940 respectively. Similarly, Sengani sub-location was split into two sub-locations viz, Sengani and Kalandini. To get a clear population distribution and density of Matungulu Location, these changes must be taken into account as they may lead to erroneous conclusions. Consequently, in the current study the population of Kibogo and Kianzabe were deducted from the total 1979 population figure. Likewise, the population of Sengani and Kalandini were combined to form the former Sengani sub-location. All this was done to ensure that the locational areas remained relatively constant and would so give a more reliable population density and distribution picture. Kyaume sub-location has lost some of her population to Tala township.

Therefore, 1979 population figures represent an increase of 28.8% over the 1969 figure of 40,524. Fig. 12 shows population change between 1969 and 1979. The greatest population increase were at Kingoti and

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* Source: Agricultural Office, Northern Division, Machakos.

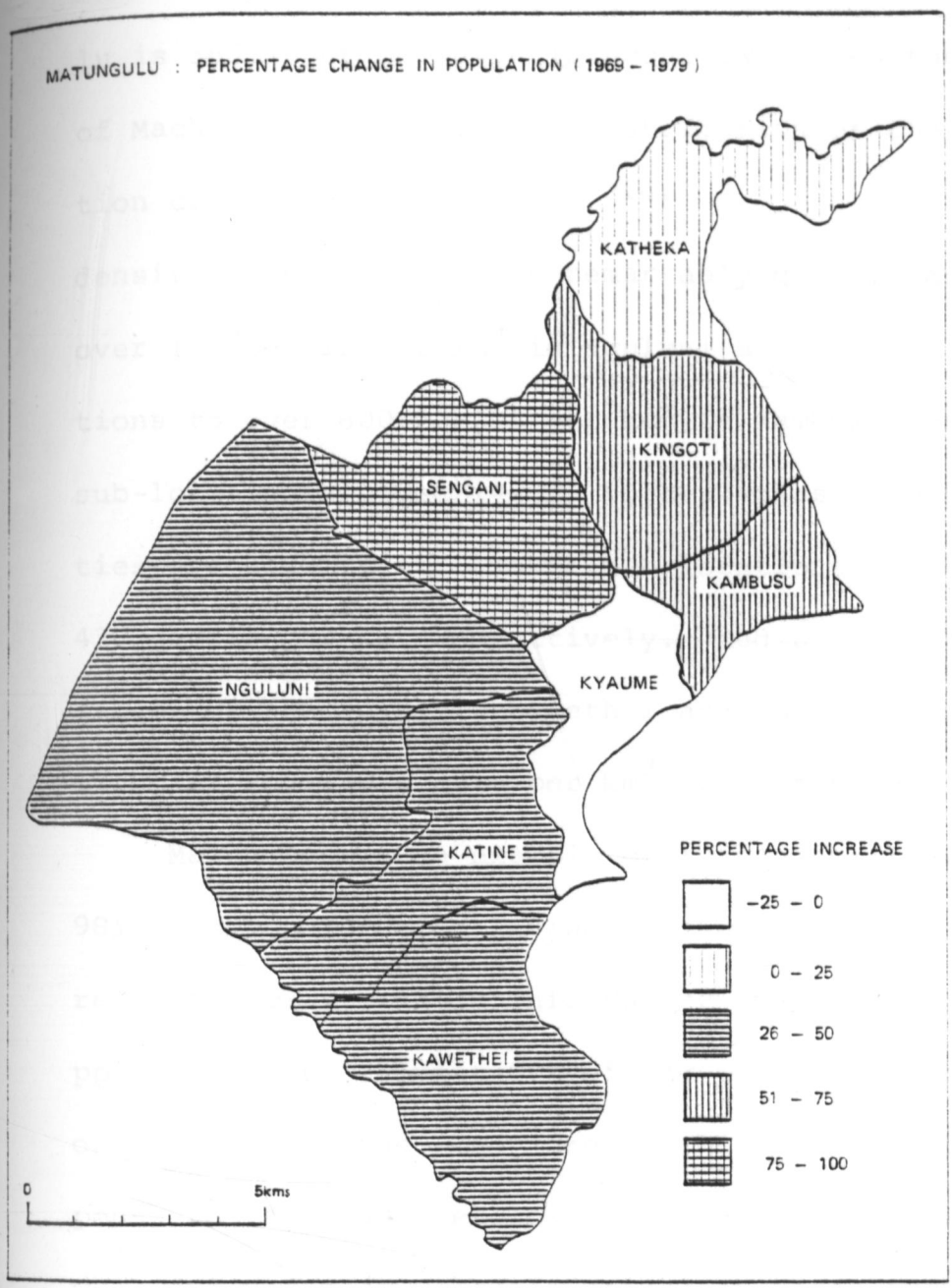


Fig.13:MATUNGULU: Percentage Change in Population
(1969 - 1979)

Kambusu. The mean density of the population of Matungulu is 385.7 per km^2 which is about two times the average of Machakos District. The distribution of the population can be seen in figure 14. The range of densities in Matungulu is remarkably great, ranging from over 100 people per km^2 in Nguluni and Katheka sub-locations to over 600 people per km^2 in Kambusu and Sengani sub-locations respectively. Other areas of high densities are Kingoti and Kyaume sub-locations with 545 and 438 people per km^2 respectively. Medium population densities are found in Kawethei and Katine sub-locations with 361 and 270 people per km^2 respectively.

Matungulu is an example of rural density with about 98% of the population living in the rural area and the remaining 2% living in Tala Market and other small shopping centres. Almost 60% of the population live in one-quarter of the study area. This is largely a response to favourable ecological conditions (rainfall and well-drained deep volcanic soils) in these areas. As will be seen later, this high concentration of population in a small area has a profound influence on the area under both coffee and food crops.

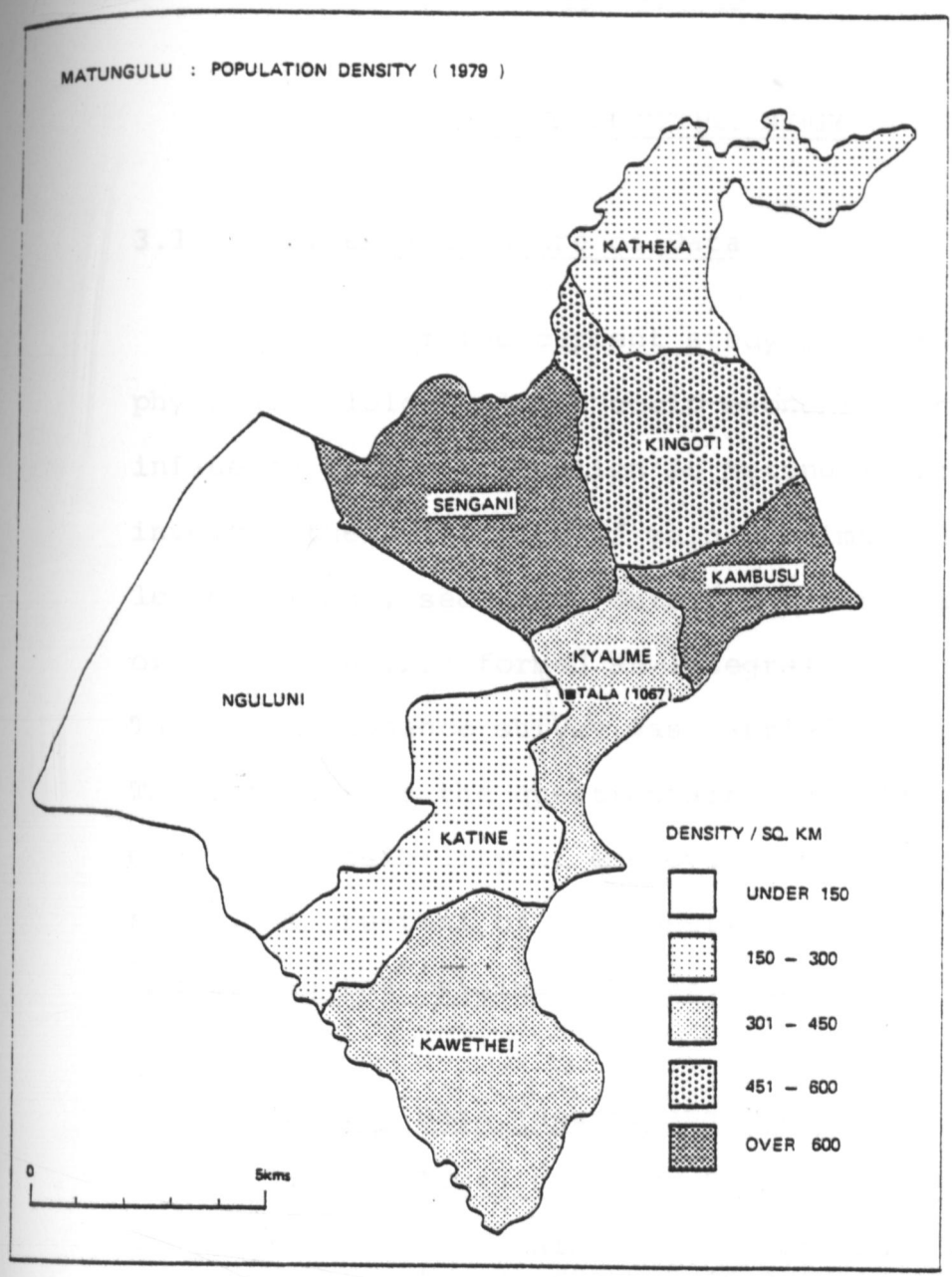


Fig. 14. MATUNGULU: Population Density (1979)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Sources and Nature of Data

The aim of the current study is to identify some physical, biological and socio-economic factors that influence coffee production in Matungulu Location. This involved the collection of mainly primary data, and to a lesser extent, secondary data. Hence the administration of questionnaires formed an integral part of the study. The reconnaissance survey was carried out in July 1979. The pre-test of the questionnaire was also made to examine the feasibility of employing this technique in the study. A pre-test of the questionnaire led to some changes in the original format.

3.1.1 Primary Data (Source and Type)

3.1.1.1 Administrative Questionnaire:

To obtain data on farm population characteristics such as age, family size, educational status of the farmstead members; role of extension service, and co-operative societies; land tenure; labour requirements for coffee production, environmental perception of the farmers, proportion of the total individual's farm under coffee in relationship to the one under food crops; reasons for planting coffee and so on.

3.1.1.2 Soil Sampling

Soil sampling was another component of the primary data source. This was carried out with a view to investigating

the nutrient status of the soils, and hence their potential for coffee production, and to find out whether there was any relationship between the "coffee soils" and the area under coffee. If there was, for example, close association between these two factors, this would then help find out if there was competition in landuse for coffee and food crops. After all, food crops also do well on the coffee soils.

3.1.2 Secondary Data (Source and Type)

A considerable amount of secondary data was collected from many and varied places. The following is the summary of the source and nature of this data.

3.1.2.1 Physical Data

From the Meteorological Department at Dagoretti, Nairobi, some climatic data for Machakos district and Matungulu Location in particular were obtained.

3.1.2.2 The Medical research centre offices at Nairobi, Tala and Kingoti were sources of climatic, data of the location. This was considered to be more accurate than the same data collected by the divisional agricultural office at Kangundo - a point to be clarified on the section of "probable research limitations."

3.1.2.3 Socio-economic Data

Ministry of Agriculture and Coffee Research Foundation (CRF), Ruiru, Kenya. The former provided the Machakos district annual reports on both cash and food crops of the district. The hectarage under coffee, annual production, quality and the money earned from the crop were collected. Similar data was also obtainable from the district's agricultural office at Machakos town, and also a wide range of data related to the physical, biological and socio-economic factors influencing coffee production.

Among this form of data were the Coffee Research Foundation's monthly bulletins - the "Kenya Coffee". Coffee Research Foundation Annual reports; its series of Technical Circulars and other publication were bought, and later on, together with the other forms of data, brought over to Canada by the author.

3.1.2.4 The Coffee co-operative societies of Matungulu Location and the District Unions provided the records on the actual number of coffee farmers (from Gross-Payment Journals); coffee yields; diseases and pests; coffee earnings; credits obtained by the farmers and other agricultural inputs. Personal interviews with the chairman, treasurer and secretary of Matungulu Co-operative Society together with several factory managers gave the author an insight into the problems facing co-operative societies.

3.1.2.5 The divisional agricultural office (Kangundo provided records on yields, agronomic practices in the location, climatic and, coffee production data of Matungulu Location. The divisional land adjudication office at Kangundo also supplied information on sub-locations already surveyed and where title deeds had (had not) been issued and those where surveying was still in progress such as Nguluni. The locational administrative boundaries were also confirmed in this office.

3.2 Sampling Design:

Random sampling was used to select 5 out of 8 sub-locations: Kingoti, Kambusu, Sengani, Nguluni, and Kawethei. There are about 1500 members of Matungulu Growers Co-operative Society, whose names are written in The Gross Payment Journals kept both by each of the eleven coffee factories of Matungulu Location and the Matungulu

Growers Co-operative Society's head office at Tala. A list of names of the members (farmers) in each factory was prepared.

Selection of names for each sub-location was difficult because members from several sub-locations would be found to be taking their cherry to one factory. For example, Kalala factory, the oldest and the largest of of the Matungulu factories had members from Kingoti, Kambusu, Kyaume, and Sengani.

Random sampling was not used because of several shortcomings of the technique. According to McCarthy (1965: 8) "the most obvious shortcomings are that lists of population elements with which to work are seldom available, and that the sheer mechanical labour of selecting a large random sample can become overwhelming. In addition, the following less obvious shortcomings can be cited: (1) If a population is spread over a large geographic area, the elements in random sample will also be widely scattered and interviewing costs will be much greater than if the sample elements could be "clustered" into compact geographic groups. (2) When special groups within a population are to be singled out for study, a random sample from the entire population may not provide a sufficient number of cases in each group for the purposes of the study. (3) The use of certain known

characteristics of the population may enable one to achieve the desired degree of accuracy with a smaller sample than would be required by simple random sampling." Systematic sampling was therefore preferred to simple random sampling (see McCarthy 1965: 21).

A systematic sample of 250 farmers was eventually selected from a total of 15000 farmers forming the Matungulu Growers Co-operative Society. On per sub-location basis, this sample was a direct representative of the proportion of coffee farmers in each sub-location. The highest number of farmers (100) was from Kingoti followed by Sengani and Kambusu with 50 each, then by Kawethei and Nguluni with 40 and 10 respectively.

The advantages of systematic sampling as recorded by McCarthy (1965: 21) are:

(1) "If a list is available, the mechanical details are simple than for random sampling, where tables of random numbers must be used.

(2) Systematic selection can be used by field workers to obtain sample elements as they pre-list, thus shortcutting one of the steps in the sub-sampling of clusters.

(3) Systematic selection spreads the sample elements out over the population. Point 3 has a particularly strong appeal when the ordering is a geographic one."

Farmers homes were located and the administrative questionnaire was used to obtain information on farm

characteristics. All 250 respondents were interviewed. From this number, 50 farm holdings were used for sampling of soils. As some of these farm holdings comprised of similar soils, it was decided that only 32 farm soils, top and sub-soils making a total of 64 were analysed. This was done with the advise of my supervisor Dr. P.V.X. D'Costa, a Soil Scientist and in accordance to the standard procedures as described by Black (1965); Peach (1965 : 914-925); Olsen (1962); Chapman (1965 : 891-904); Bremmer (1965 : 1149 - 1176); Prower and Wilcox (1965 : 933-951); Bouyoucos (1927 : 317-331) and Ahn (1973).

Similarly, soil sampling was done according to the procedures outlined by the Coffee Research Station (CRS), Ruiru and as described by its 1979 Technical Circular. This circular stated that soils should not be sampled when too wet, due to difficulty often encountered when using sampling tools, particularly in the lateritic clay soils in most of the coffee growing areas. Since most coffee plants in Kenya are grown in the fields of varying topography (slope), CRS states that information on this is necessary since soil fertility is often influenced by the slope of the land in which coffee is grown. Decision on where to sample, should therefore take into account the specific slope in the field. The diagram figure 16 is intended to give

the farmer the general classification of slopes which could be found in the coffee plantation. The symbols shown against the slopes should be used for defining soil samples sent to the CRS for analysis.

The following is a summary of the soil sampling technique used:

(1) soils were sampled equidistant from 4 coffee bushes (i.e approximately 2 m from each bush (see diagram fig. 15).

(2) samples were taken by auger from depths of 15-30 and 40-60 cm.

Additionally, one metre deep soil profile (Plate 5) was dug near a coffee farm to depict the vertical as well as the horizontal physical changes in the soil properties. This would give a clear picture of the nature of the soils.

3.3 Analysis of Data

It has already been briefly discussed how the soil samples were analysed to investigate the sufficiency or deficiency of soil nutrients in coffee plots in Matungulu location. The information was counter checked to ensure accuracy and reliability of the results. A case in point was the data regarding the number of kilograms of clean cherry, earnings credits

and other agricultural inputs for the farmers who were to be considered in the multiple regression model, where the Matungulu Growers Co-operative Society had to be approached to provide such data.

Other analyses included the evaluation of the cartographic materials such as maps and diagrams for accuracy and relevancy. Similarly, the process of data processing involving editing, coding and tabulations, and map construction were carried out both in Kenya and at McGill University, Canada. All the information collected in the questionnaires were transferred to coding sheets using appropriate numerical codes for the responses obtained from the respondents. Tables showing percentages of farmers for example, experiencing labour problems and so on were prepared. From these tables it was then possible to prepare one large input-data table whose data were used for the subsequent statistical analyses, eg. the step-wise-regression by use of computer.

Associations between variables were examined by bivariate and multivariate analyses. Correlation matrix was produced along with regression equation for predicting coffee yields from the physical, and socio-economic

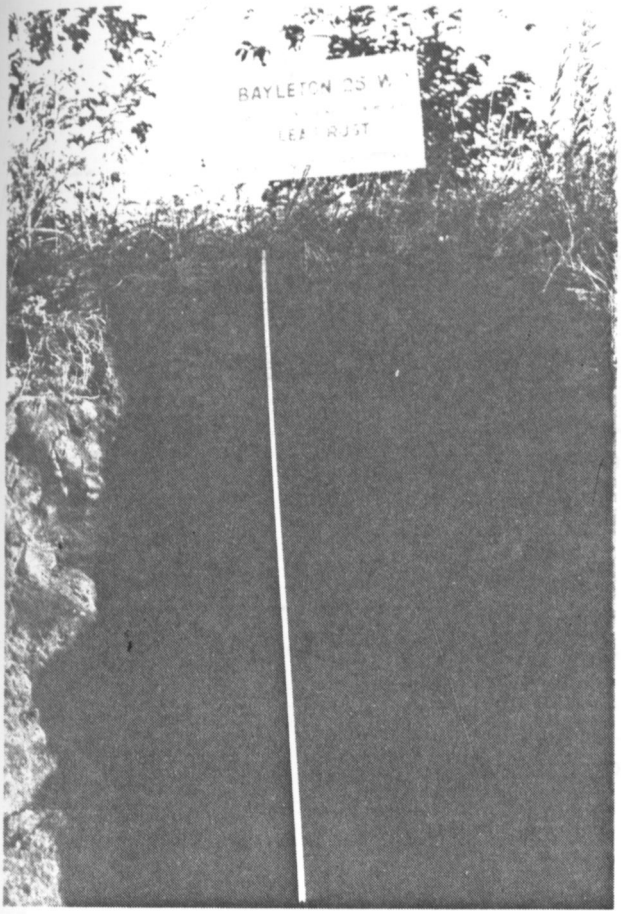


Plate 5: A Soil Profile from Ngonda, Tala

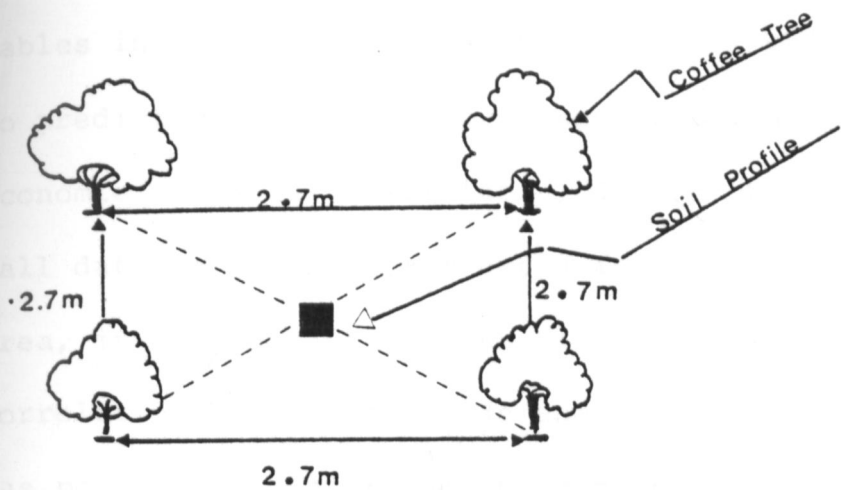
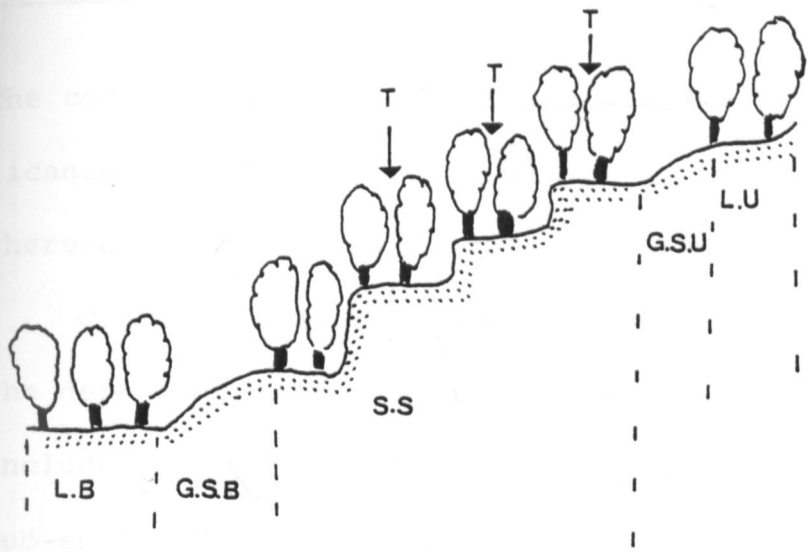


Fig. 15: Site of the Soil profile.

variables. Lack of quantitative data on the influence of the biological factors such as disease/pests and weeds on coffee yields led to the omission of these variables in the step-wise regression model which was used to predict coffee yields from some physical and socio-economic variables. Similarly, due to the lack of rainfall data on the per farm basis in the current study area, it was thought wise to find out if there was any correlation between altitude and rainfall. Since it was possible to determine the altitude of each farm (from topo-sheets and air-photographs), then establishment of a strong positive correlation between altitude and rainfall would lead to the former being used as a surrogate for the latter. To investigate the relationship between these two variables, the undermentioned nine rainfall stations of Machakos District, with a mean recording period of 29 years were used in the analysis. The mean rainfall and the altitudes for these stations were 820.1 mm and 1395.07 meters, respectively. The respective rainfall and altitudes are as follows:

Station	Rainfall (cm)	Altitudes (m)
Kangundo	94.4	1575
Matungulu	98.7	1576
Machakos Dam	78.07	1573



LEGEND

L B	Level Bottom		
G S B	Gentle Slope Bottom	LU	Level Upland
S S	Steep Slope	T	Terrace
G S U	Gentle Slope Upland		

Fig. 16: Topographical Defination of Coffee Land for Soil Sampling.

Station	Rainfall (cm)	Altitudes (m)
Kabaa	74.18	1227
Ngelani	99.31	1840
Makueni	79.22	1098
Mbooni	90.0	1767
Kibwezi	63.9	900
Makindu	61.3	9998

The correlation coefficient was 0.875 with T and F significance 0.000 (see figure 17), . Altitude was therefore used as a surrogate for rainfall.

Coffee yield (YD) in Kg/hectare were treated as the dependent variable and the independent variables included altitude (ALT); pH of top soil (pH_T); pH of sub-soil (pH_S); Potassium of top soil (K_T); Calcium of top soil (Ca_T); Carbon (C); Cation exchange capacity (CEC); number of coffee trees (TR); income of the farmer (INC); investment on coffee (INV); farm size (FS); distance from the factory (DF); topography (Tp) and the proportion of total farm under coffee (CF).

Inability on the part of the author to get analyses of either top or sub-soils (or both) from the department of soil science, University of Nairobi, led to the exclusion of some of these variables (eg. Phosphorus; clay content), in the final multivariate analysis. Topography which was measured at ordinal scale, unlike other variables which were measured at interval scale,

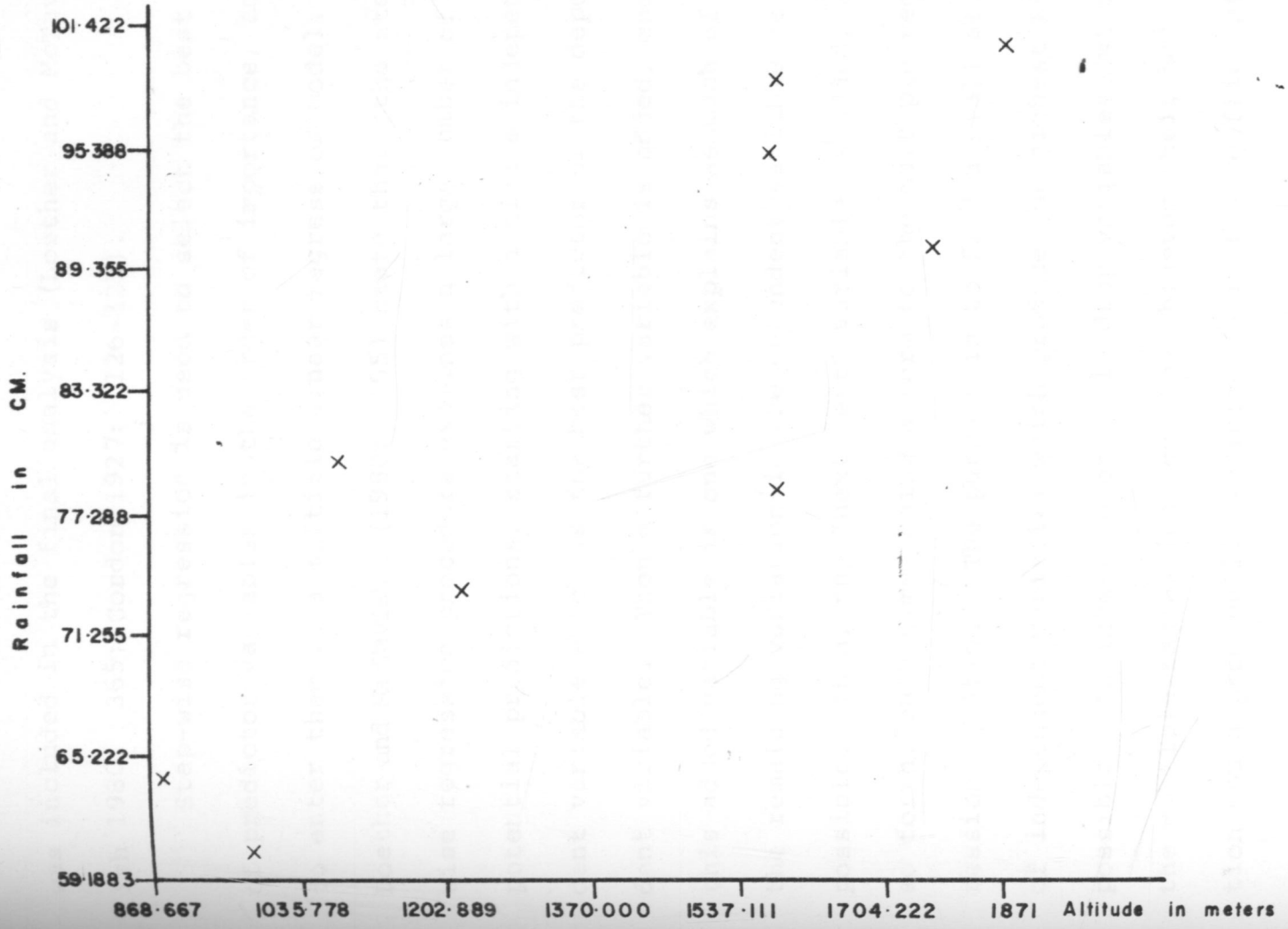


Fig.17 Scatter diagram showing the relationship between altitude and rainfall for nine stations in Machakos District

was included in the final analysis (Loether and McTavish 1980: 365; Gordon 1927: 126-129).

Step-wise regression is used to select the best set of predictor variables in the order of importance, and to enter them in a multiple linear regression model. Loether and MacTavish (1980: 365) state that "the step-wise regression procedure examines a large number of potential predictions, starting with a single independent variable which is the best predictor of the dependent variable. Then a further variable is added, and this added variable is one which explains as much of the remaining variation in the dependent variable as possible. Then, the "next best" variable is added, and so forth, each time adding a term to the multiple regression equation. The purpose is to find a small set of independent variables which produce the highest R^2 possible. An investigator could drop variables out of the multiple regression equation whenever their addition would produce little increase in the coefficient of multiple determination, R^2."

Gordon (1977: 126-129) elaborates on the criteria and working of this technique. He states that "the criteria of importance is based on the reduction of sum of squares, and the independent variable which reduces

the largest amount in a given step is entered in the regression. Estimated and observed value of y may be plotted on a line plot and/or scatter diagram."

So far we have discussed the various statistical techniques used in the data analysis. It is worthwhile at this stage to comment on these techniques. The basis of statistical testing is the probability theory which is used to make statistical inferences or predictions. Before this is done, some assumptions have to be made about the population from which the sample is to be drawn. This is important because the interpretations made out of our data is based upon a set of assumptions about the data being analysed. Loether and McTavish (1980: 255) observe that "in order to make intelligent use of these interpretations, it is necessary to be familiar with the assumptions being made". A detailed discussion of these assumptions of the linear regression model have been discussed elsewhere in an important paper by Poole and O'Farrel (1971). What follows is first a summary, mainly based on this paper and secondly a discussion on how the data of the current study relate to these assumptions.

1. Lack of measurement of error: Each value of X and Y is observed without measurement of error. If this condition is not met and also the magnitude

of the error is unknown, it follows that the coefficients of regression equation are biased and may not be accurately estimated.

2. Linearity: The relationships between Y and each of the independent variables X are linear in the parameters of the specific functions chosen; Generally, the regression model fits a straight line (regression line) through a scatter of data points. The goodness of the fit of this line is however tested by the correlation model.

3. Means of conditional distribution of the error terms (e); Each conditional distribution of the error terms or residual has a mean of zero. Norcliffe (1977: 178) states that "the conditional distribution, is normal when, for any value of X, Y is normally distributed, and for any value of Y, X is normally distributed."

4. Homoscedasticity: "The error term is homoscedastic ie. each conditional distribution has a constant variance." If these conditional distribution have unequal variance as is normally the case, then a situation known as heterocedasticity is said to exist and which can lead to highly biased estimates. In theory, the closer one gets closer to homoscedasticity, the greater one's faith is in regression coefficients.

5. The values of 'e' are serially independent; thus the values of e are independent of each other and their covariance is accordingly zero. It should be noted here that if this assumption is not met, autocorrelation is said to occur.

6. Autocorrelation, Norcliffe (1977: 218) states that, "the value of e (the residuals from the regression are pairwise uncorrelated.) Recent work by Martin (1974) indicates that if spatial autocorrelation is present in 'e' there is loss of efficiency in estimating the regression coefficients."

7. The independent variables, X are linearly independent of each other. This assumption unlike the previous ones which apply to both simple and multiple regression, must be satisfied specifically in the latter case. If it is violated, in any specific case, multicollinearity is said to exist.

8. "Each conditional distribution of 'e' (and therefore Y) is normally distributed. This is required for tests based on the t-distribution and as in other t-tests, as the sample size becomes large, so this assumption may be progressively relaxed (Norcliffe: 1977 : 218).

If the testing of these assumptions of the classical regression model reveal that a particular assumption of the classical regression model is not satisfied the data can be transformed. Either, the input data may be transformed, most frequently by applying logarithmic reciprocal power or arcasin transformation else a variation on the classical regression model may be applied. Geographers frequently use the first of these methods inorder to satisfy the normality and linearity assumptions.

No attempt was made to test the presence of measurement error, since as Poole and O'Farrel (1970: 152-153) put it "any test of the degree of measurement error is clearly made difficult by the fact that the amount of error is unknown". This problem could also be ignored if the sole objective of the regression analysis is to predict the value of Y corresponding to a given Set of X values". The aim of the current study was to predict coffee yields (Y) from a number of independent variables (X_i).

One of the simplest ways to test the linearity of a relationship is to construct a scatter digram of biva riate normal distribution (see fig.17). Such digrams serve as a useful tool for illustrating the meaning of linear relationship. In the case of the current study, these diagrams were drawn by the computer and some of them may be seen in the (fig.18). Visual outlook of these scatter diagrams indicate that the input data mee the linearity assumption. If this transformation is no satisfied, in any given instance, the input data are generally transformed to yield new raw data which satis fy this assumption more closely.

Fig. 18: Scatter diagram showing the relationship between coffee income and yields.

Fig.19: A histogram showing the distribution of Potassium in soil profiles.

In the case of the input data for the current study, common logarithm transformation was made simply to see if the r value could be improved. As the correlation matrix in Appendix C-2 shows, there was generally litt increase in the value of r. This indicates that it ma not have been necessary to transform the raw data. Sim larly, this applies to the normality assumption which was tested by means of distributions, and histograms (fig. 19).

It is impossible to test directly in any specific empirical example, the validity of the assumptions re- lating to the characteristics of the disturbance (erro terms) in assumptions 3,4, 5, and 6 in the current stu Poole and O'Farrel (1970 : 155) add that "if the assump tion of normality does appear to be seriously violated, the data may be transformed to derive more normal condi tional disturbance distributions. However, the robust- ness of regression analysis with respect to the assump- tion of normality and the fact that there is a great need to satisfy such other assumptions as homoscedasti- city and linearity, together have the result that trans formations specifically for the purpose of impossing no mality are infrequent".

The conclusive statements of Norcliffe (1977) and Poole and O'Farrel (1970) are very fitting. In the case of the assumptions we have discussed in the foregoing section that fortunately these assumptions tend in practice, not to be 'independent' in the sense that if one is violated, then several others are usuall violated. For example, if assumption 7 is not met, the it is quite likely that assumption 3,4,5 will also not be met. The converse is likely to be true, so that in normalizing their data, geographers have often, and per haps unwillingly, met several other assumptions.

Step-wise regression appears to be the most appro- priate statistical technique in diagnosing the main phy sical and socio-economic factors which influence small- holder coffee production in Matungulu Location. It was also used by Williams, Joynt and McCormick (1975) in th macroscale analysis of Canadian Prairie crop districts' cereal yields 1961-1972 in relation to weather, soil an trend. The limitations of linear-regression model are highly appreciated here and therefore discussed in the next sub-section.

3.4 Research Limitations

The success of a study like this depends on the availability of the relevant data and the analytical to

used. The nature of the problem required the use of bo primary and secondary data. In this case, a questionnaire formed an integral part of this study. Accuracy is vital in interviewing techniques. However it is not often possible to achieve such accuracy by interviewing techniques due to a number of reasons. Harring and Loansbury (1975) note that "first the respondent may not fully understand the question. Second the researcher may not fully comprehend the answer, or the respondent may either intensionally or unintensionally provide misleading information". In spite of the shortcomings, this method has been found to be the mos appropriate in many agricultural studies.

Most of the farmers do not know the exact area of their holdings, or the exact area under coffee. To so this problem, the standard spacing of coffee of 2.7 m 2.7. m, which gives 1329 trees per hectare, was used t calculate the exact area under coffee. The size of la under food-crops or any other landuse was calculated b counting 70x70 paces/strides as an acre which was late converted into hectares. Some farmers didn't keep pro records of receipts indicating the weight of their che delivered to the coffee factories.

In this case, and indeed for all farmers whose yields were used in the step-wise regression model, the coffee factories were approached to provide records on such farmers. The general lack of farm records on the part of the farmers led to estimation on input-output analysis. This is bound to introduce some errors. Nonethe less, it is believed that some reliable estimates were collected. Similarly, due to lack of data on physical yields, incomes, farm credits on the per farmer basis from either primary factories or Matungulu Co-operative Society's headquarters at Tala for the year before 1978 led to confining the current study to two years viz. 197 to 1979. For a very accurate prediction of the factors influencing coffee yields, a long period is necessary. The result of the current study should serve to remind both the farmers and Co-operative Societies of the need for keeping accurate farm and other related records if research is to be useful for improving both the physical and economic yields of coffee.

Little data is available on evapotranspiration, wat balance, radiation, soil temperatures, and hours of sun- shine. Even for the parameters for which data is availa ble, such as rainfall and temperature, gross extrapola- tions are inevitable, particularly in describing spatial variations, when there are only several recording statio and when even the climatic data are not themselves recor ed accurately. It has already been mentioned in this chapter that due to lack of adequate rainfall stations, altitude was used as a surrogate for rainfall. This was also logical particularly when it is realized that multi- variate techniques require data on the per farm basis.

Lack of input parameters for biological variables such as disease/pests and weeds led to these being omitted in the final step-wise regression analysis. Leaf analysis which is important in the determination of the general nutritional status of coffee trees (through the diagnosis of visual and latent deficiencies) was not carried out, too. It is, however, believed that the overall effect of these will be represented by other socio-economic variables such as Income and Investment.

The coffee production survey was carried out at a time when the locational boundaries had been changed. Lack of proper locational and sub-locational boundaries led to confining the current study to the pre-1979 boundaries.

The step-wise regression model assumes that the relationship between dependent and independent variables is linear and that the variates are normally distributed. We know that some relationships are non-linear and non-normal in distribution. Secondly, the relationship between the independent variables may not be easily identified because of high-order interaction. Difficulties associated with the use of computer in geographic study like the current one are highlighted by Kahimbaara (1975: 160). He states that "for a model to be oper-

ational, it is translated into a computer programme. It is therefore to be noted that two things are not necessarily the same thing. The computer programme may not faithfully represent the model because something is likely to get lost during the translation from the model to the programme. Such a loss may be due to limitations in the programming language and other practical considerations such as the cost of programming." Despite the likely shortcomings of the linear regression model, it has been used in many geographic studies with some promising results.

Due to lack of yield and income data on six of the 1978 observations, the sample size for multivariate analysis was reduced from 32 to 26. However, in the case of 1979, all the 32 observations were considered in the regression model. Similarly, some soil analysis such as percentage clay, and phosphorus could not be obtained from the department of soil science - Nairobi University. These variables were also omitted in the final analysis. Topography was measured at ordinal scale, unlike other variables. It is hoped that the presence of this variable in the regression model does not distort the results of the step-wise regression analysis very much.

Lastly, but not least, this study was carried out within a short time limit and within limited budget and manpower.

CHAPTER 4

PHYSICAL ENVIRONMENT AS A FACTOR IN COFFEE PRODUCTION

4.1. Introduction

An attempt was made in the section dealing with geology and soils to distinguish the coffee soils (mainly red friable clays) from other types of soils. Coffee requires a fertile, well drained, open textured soils. Such a soil is the key to increased coffee yields. In order for the coffee plant to do well, soil fertility has to be maintained by constant supply of fertilizers.

One of the ways by which the farmer can determine whether or not his soil needs fertilizer application is through the chemical analysis of his soils. Such analyse as Michori and Kimeu (1980: 81) put it "attempt to predict the probability of getting responses to the application of fertilizers, helps in evaluating the ability ofthe soil to guarantee good yields, and helps to determine the organic matter content, the soil reaction, pH and the level of nutrient supplying capacity. Hence, the results obtained from the above determination will supply reliable information concerning soil potentialities and specific conditions in the soil which can be improved by addition of correctives and by the introduction of other agricultural practices."

4.2. Physical and Chemical Properties of Matungulu Soils

Over most of the area under coffee, the soils are Nitosols whose particle size distribution is characterized by presence of high clay content relative to sand and silt. The clay percentages range from 16 on the relatively steep slopes to 56 percent on either relatively flat upland or bottom land (depressions). The mean is 40 percent. The silt fractions is very low ranging from 2 to 14 with a mean of 8 percent while the sand fractions are relatively higher ranging between 36 and 78 percent with a mean of 52 percent. The textural class of Matungulu coffee soils is therefore Sandy Clay (SC) as shown in Fig. 21 This diagram also shows the distribution of particle size of the top and sub-soils of the sampled farms. The second dominant texture class is sandy clay loam (SCL) and is followed by almost equally dominant clay (C) texture class. (See Fig. 20)

Sketchley et al (1978) notes that the surface soils in this coffee region are dominantly clayey. These soils are characterized by dark reddish brown colours (5YR 3/2). They are not sticky or slightly sticky and the surface layer is porous, very friable and retains water well. The sub-soil is a dark-reddish brown (2.5YR 3/4 to dusky red (2.5 YR 3/2) or (IOR 3/4 and also very friable. T

TRIANGULAR TEXTURE DIAGRAM

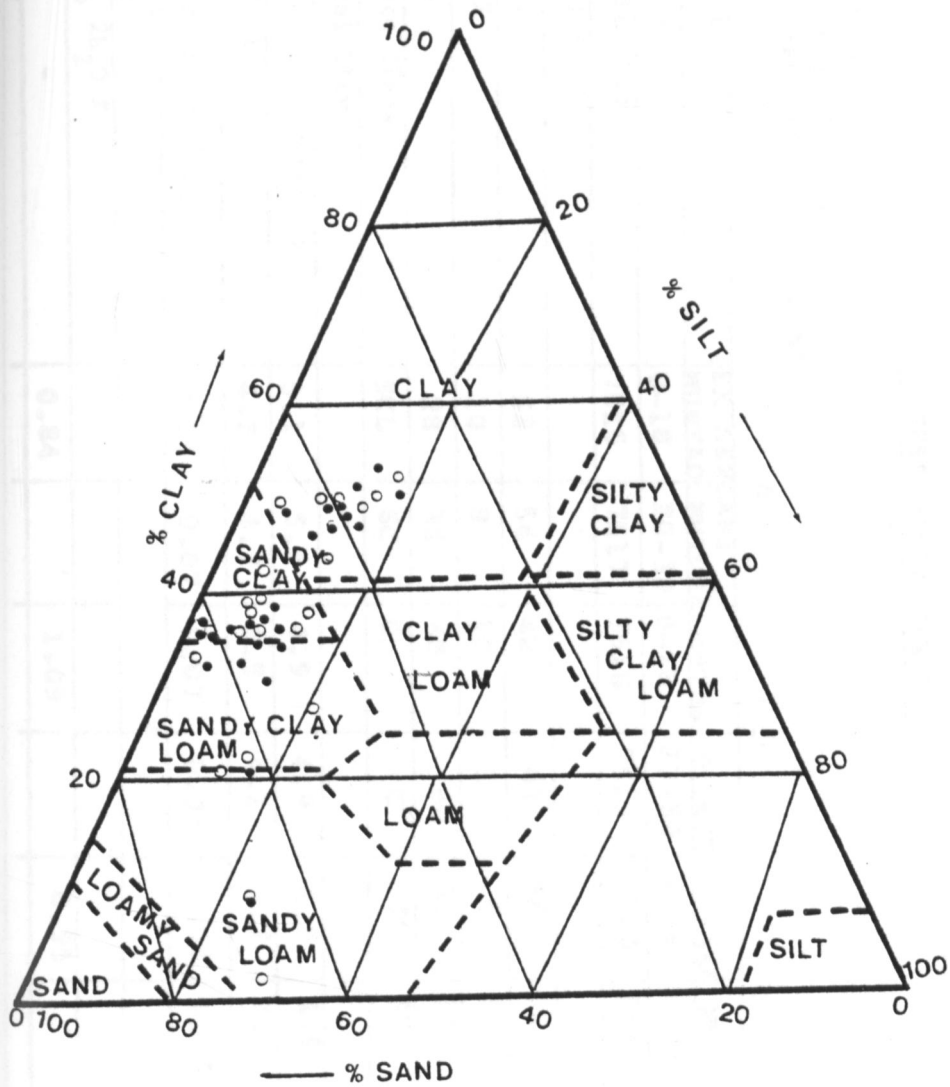


Fig.21 This diagram shows particle size distribution

SOIL TEST REPORT (SURVEY)

Inward Ref:
Date Sample Received:
Sample Sent by: as 7510/80

	4		5		6	
Field Ref.	EX SENGANI MUNYAO	MUTURA	MUTUA	MUINDE	THYAKA	MUSEMA
Depth in cm	0-18	20-30	0-18	20-30	0-18	20-30
Lab. No./80	7516	7517	7518	7519	7520	7521
Gravel %						
Sand %	62	56	42	42	58	56
Silt %	10	8	10	10	6	6
Clay%	28	36	48	48	36	38
Texture Class	SCL	SC	C	C	SC	SC
Natural Clay						
pH-H_2O 1:2½ Suspension	5.1	5.5	4.9	4.9	4.7	4.9
pH-KCl 1:2 "	4.3	4.7	3.9	4.1	3.7	4.0
EC (mmhos/cm) 1:2½	0.05	0.07	0.07	0.06	0.04	0.05
$CaCO_3$%						
$CaSO_4$ $2H_2O$ %						
C %	0.84		1.09		0.95	

Fig. 20: Table showing some physical and chemical properties of Matungulu coffee soils.

depth to the weathered bed-rock varies from 1 to 3 meters". Otherwise the soil profile is very uniform to a great depth and there is almost no horizon differentiation (Plate 5). Because of their good physical properties, these soils are well suited for cultivation of especially coffee.

Most of coffee soils range from very strongly acid pH 4.5-5.0, strongly acid 5.1-5.5. to very slightly acid 6.1-6.5. (Table 8 in Appendix D-2, respectively).

There is a widespread deficiency of Nitrogen in Matungulu coffee soils since most of them have less than 0.2% which is considered by the National Agricultural Laboratories (NAL) to be the critical level below which nitrogen deficiency is said to occur. One of the ways to correct Nitrogen deficiency is to ensure a constant supply or concervation of organic matter. In any given soil, the C/N ratio is interrelated if one of them falls the other will correspondingly fall. Eden (1979:9) states that "there is a tendency for soils of low pH value to have higher than average C/N ratios.

EX. SEMBANI

Field Designation..	DISH ON MULWA 149/2/8/396		PETER KILONZO 149/2/6/995		COSMUS NGEI 149/2/9/13273		MUNYAO MUTURA 149/2/10/1359	
Lab. No. ../80 ..	7510	7511	7512	7513	7514	7515	7516	7517
Depth .. cm ..	0-18	20-30	0-18	20-30	0-18	20-30	0-18	20-30
Colour								

Chemical Test Results

pH	5.9	6.2	3.9	4.4	4.3	4.3	5.2	5.7
Na m. e. % ..	0.15	0.11	0.11	0.08	0.12	0.16	0.12	0.12
K m. e. % ..	1.17	0.64	0.57	0.36	0.45	0.45	0.43	0.56
Ca m. e. % ..	7.6	5.0	1.0	1.0	0.8	1.4	2.1	2.6
Mg m. e. % ..	2.7	1.9	1.0	1.2	0.7	0.8	1.4	1.3
Mn m. e. % ..	0.88	0.74	1.12	0.94	0.63	0.53	0.48	0.39
P. p. p. m. ..	164	106	6	4	8	5	5	3
N %	0.18	-	0.16	-	0.03	-	0.08	-
C %	1.82	-	1.65	-	0.34	-	0.84	-
Hp m. e. % ..	-	-	1.9	0.6	1.5	1.4	0.2	-

Table 8. Soil Chemical Report

Over one half of Matungulu coffee soils have C levels of less than 1% which is considered low by the NAL. Though the mean is 1.1%, it should be realized that there are farms having as low as 0.01 and 0.34 percent respectively. The highest Carbon content in the study area is 2.35%. The general lack of Carbon in most of these soils can be attributed to lack of mulching - a factor to be discussed under the section dealing with agronomic practices in coffee production.

An attempt to relate C to physical factors such as altitude or topography is bound to bring some problems. For example, it is doubtful whether such high association (of 0.904 between C and topography respectively), is related to either organic matter movement, or the lower soils being more poorly drained, or having denser vegetation.

Cation exchange capacity (CEC) is the total number of exchangeable cations in the soil. The greater the number, the higher the CEC and vice-versa. In the case of the Matungulu coffee soils, the CEC varies from 5.4 to 22.8 m.e % with a mean of 12.4 m.e. %. CEC is dependent upon the total surface area of the soil. Hence sandy soils with small surface area have low CEC. Since clay has the largest surface area, it has also the highes CEC. CEC is again associated with other soil properties

such as C (0.908). Markham and Babbedge (1979: 230) state that "exchange capacity often depends on the organic matter content of the soil than on its clay content."

Low pH is associated with low exchangeable cations such as Ca, K, Mg, Fe. High pH is similarly associated with the high cations and hence fertile soils.

The coffee soils of the study area are well supplied with K and Ca. However, in the case of Calcium, there are several sites with as low as 1.0 m.e. % which is 50% lower than the recommended value of 2.0 m.e %. Although, the Magnesium levels are low in most coffee soils, it appears that the Matungulu coffee soils have a mean of 1.0 m.e %, the level below which deficiency in the mineral is said to occur.

Oruko (1975/76: 23) notes that "coffee soils in Kenya are generally supplied with potash; secondly, the main mulching material is usually Napier grass which is known to have a high K content and therefore helps to keep the level of K in these soils. Apart from the fact that the level of Ca is generally high in soils, the Kenya coffee soils also receive Ca from much fertilizers as C.A.N., superphosphates, lime and/or sisal wastes (in places where this is used as mulching material). Consequently, no responses have been obtained from potassium or

has observed where excessive levels of these nutrients, especially K, are present. Such cases are often associated with a fall in quality; excessive levels of K and Ca are believed to impair the quality of coffee beans, mainly as a result of imbalance with Mg. Mehlich (1967) indicated that proper balance between Ca, K, and Mg in both the soil and the plant is important if high quality coffee is to be obtained.

As in most coffee growing soils in Kenya, Matunqulu coffee soils are generally deficient in Phosphorus (i.e. with less than 20 ppm). The phosphorus content in these soils ranges from as low as trace and 3 ppm to as high as 164 ppm. In an effort to explain the low levels of phosphorus in the coffee growing soils of Kenya, Oruko (1975/76: 21) states that "these soils are very highly weathered and therefore have denuded with time of inorganic P. Secondly, as a result of the harsh weathering, the positively charged reactive surfaces of iron and aluminium oxides are continually exposed."

There is generally a very weak association between coffee yields and soil properties. A case in point are the Potassium and Carbon with a correlation coefficient (r) of 0.104 and 0.014 respectively. Altitude which was taken as a surrogate for rainfall seem to have very negligible association with coffee yields (r=0.170). This low association between rainfall and coffee yields should not be taken to suggest that rainfall is not critical in coffee production; the significance of rainfall could have been obscured by the high-order interaction of the variables in linear regression model. Another reason why there is a low association between soil properties and coffee yields is due to the fact that these factors are relatively uniform in the study area (e.g. similar coffee

4.3. Soil Properties and Fertilizer Application

The most important soil property in the determination of fertilizer application to coffee trees is the soil reaction (pH). In the case of Nitrogen, fertilizers such as Ammonium Sulphate Nitrate (A.S.N.), Calcium Ammonium Nitrate (C.A.N.), Ammonium Sulphate (A.S.) and Urea, CRS in Tech. Cir. No. (25: 1978) states that "the conditions of their use and the rates of application depend on the soil reaction (pH) and the amount of the crop estimated in the current season and also the balance of nutrients in the soil (see table 9),C.A.N is a neutral fertilizer and does not change the pH. Hence, in a soil with pH less than 4.4, C.A.N. is recommended as being nearer to neutral than the other forms of single nitrogen fertilizers. If the pH is above 5.8 A.S.N. or A.S. which are acid fertilizers are recommended and because this fertilizer is not expected to decrease the pH. An annual alternation between C.A.N. and A.S.N. is recommended."

A good example is Mr. Kilonzo's farm table 8, where a value of 3.9 was recorded. Since in this farm the (Hp) range from 1.9 to 0.6, addition of lime is considered necessary This amount can be worked out with the advice of soil scientist from the University of Nairobi or NAL. However, where the pH range from 5.2 to 5.7, as is the case in Munyao's farm (Table 8), application of **C.A.N.** would be necessary since this soil has Hp.(0.2).

Compound Fertilizers such as NPK are recommended in coffee growing areas of Matungulu. The advantages of these fertilizers over the straight N, P and K ones is that it may save labour by substantially reducing the man-hours required

Table 9

The Form of Nitrogen Fertilizers

Reaction (pH)	Acid Soil under 4.4	Moderately acid soil .4 - 5.4	Mildly acid soil over 5.4
Form of Nitrogen Fertilizers	For each three applications use C.A.N. twice, A.S.N. once or Urea* once.	Alternate between calcium ammonium nitrate and Ammonium Sulphate nitrate or Urea.*	Ammonium sulphate or Ammonium Sulphate Nitrate.

* If Urea is used it must be cultivated into the soil since the nitrogen may be lost into the air as ammonia if it is left on the dry soil surface.

Table 10

Rate of Application of Nitrogen Fertilizers

mount of crop stimated in he current eason	kg Nitrogen ha/per year	kg fertilizer ha/year			Gram fertilize year/per tree		
		21%N	23%N	26%N	21%N	23%N	26
ess than 1000 kg lean coffee per ectare (5kg of lean cherry per ree)	80	390	350	310	330	300	26
000 - 1500 kg lean coffee per ectare (5-7 kg of lean cherry/tree)	140	680	610	540	570	520	46
00 - 2000 kg ean coffee per ctare (7-10 kg of erry/tree)	140-200	680 to 575	610 to 875	540 to 775	570 to 850	520 to 700	46 t 62
er 2,000 kg ean coffee per ctare (over 10 kg cherry/tree	up to 300	1460	up to 1310	1160	1200	up to 1000	90

The rates per tree are calculated for tree spaced at 2.75 m x 2.75 m or 7.5 sq.m/tree. For other spacing coffee trees should (according to CRS) be given the same amount of fertilizer as coffee spaced 2.75 m x 2.75 m. For Urea (46%N) multiply by 0.55. The timing of fertilizer application is shown in Chapter 1, table 2.

In the case of the available phosphorus, it was mentioned that this mineral is generally lacking in most coffee soils. CRS Tech.* Cir. No. 38: 4-5 indicate that "an ample amount of phosphorus from any source is necessary for most growth and sufficient wood formation. It is particularly important to mature trees for a sound fruit formation and early maturity of berries. The best response to phosphate is obtained on young coffee trees."

Where the supply of both Ca and P are low and pH is below 5.4, CRS (1978): 5) recommend the application of single superphosphate; where acidic conditions are encountered below pH 4.4, (like the second farmer table 8) the application of the basic slag (see table 11) rather than the single superphosphate may be applied. In a situation where the ratio between Mg and K levels are adequate either double superphosphate or diammonium phosphate is recommended depending on whether the Ca level is in need of adjustment. For soils with pH values

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* Coffee Research Station, Technical Circular No. 38, 1978.

above 5.4 and provided that calcium is in good supply, while phosphorus is low in supply, the diammonium phosphate only would normally be recommended. Where soils are alkaline having pH values above 6 and both Ca and P are in low supply, CRS recommends then double superphosphate. The rates of application of these fertilizers can be seen in table 11.

Table 11

Rates of Application of Phosphate Fertilizers

Soil Reaction (pH)	Acid Soil under pH 4.4	Moderate acid soil pH 4.4 - 5.4	Mildly soil over pH 5.4
Forms of phosphate fertilizers	Basic Slag	Single superphosphate Double superphosphate	Diammonium phosphate Double superphosphate.

Types	Quantity gm/tree
Basic Slag	350g/tree
Single superphosphate (SSP)	350g/tree
Double superphosphate (DSP)	150g/tree
Diammonium phosphate (DAP)	150g/tree

Potassium Fertilizers

Potassium fertilizers include potassium sulphate (sulphate of potash) and Potassium chloride (Muriate of Potash). These fertilizers are applied when the soil is deficient of K ie. less than 0.4 m.e/100g and the pH is under 5.4. Before potassium fertilizers are applied

CRS Tech. Cir. No. 38 (1977: 5) advises that "the ratio of potassium to other cations (Calcium and Magnesium) should be taken into account. These elements should be in the ratio of 1:2-3:4-6; K:Ca:Mg; but the minimum required is about 0.5 m.e/100g of K. The level of Potassium in the soil could be raised by the use of organic manure like Napier grass mulch, coffee pulp and cattle manure (one debe of cattle manure on the average weighing 7kg/debe supplies about 0.7 m.e/100g K). The general rate of application recommended is usually 100-190 gm/tree (approximately 135-225 kg/ha depending on the amount of K required to put the K, Mg, and Ca into proper balance."

It should, however, be noted that while organic manures improve the physical properties of the soil such as structure, pore size, aeration, drainage and thereby encouraging good rootgrowth, indiscriminate use of these manures could be harmful and therefore must be avoided. Oruko (1975/76: 24) state that "these fertilizers are not only formed from different materials of varying chemical compositions, but also under different conditions. As a result, the nutrient constitution of organic manures is not consistent. And often one nutrient may be present in quantities which are out of propor-

tion with those of other nutrients, especially with regard to the nutrient cations of K, Ca, and Mg. Generous application of organic fertilizers may thus introduce nutrient imbalances in the soil, which as pointed out by Northmore (1965) may have adverse effects on quality."

Magnesium Fertilizers

The basic magnesium fertilizers are magnesite (super mag) Dolomitic limestone, magnesium green label, magnesium sulphate and magnesium nitrate like other fertilizers discussed above, Mg fertilizers are applied when the soils are low in Mg ie. 1.0 m.e/100g and the pH is below 5.4. When pH is below 5.4 CRS Tech Cir. No. 38 (1978: 6) state that "the application super mag or magmax red label is normally recommended. For soils with pH values above 5.4, the application of magnesium sulphate would be recommended. The rate of application for mg fertilizers are dependent on the K:Mg:Ca ratio. This ratio ideally should be in the order of 1:2-3:4-6; K:Mg:Ca, respectively. For magnesium, if the Ca or K levels are such that 0.5 m.e/100G or more magnesium is required to satisfy the optimum ratio, the general recommendation is normally 170 grams/tree (230 kg/ha) of super mag of 340 grams/tree (460/ha) of either magmax

of magnesium sulphate is recommended, depending on the soil reaction (pH)."

Foliar Feeds

Foliar feeds fertilizers are supplementary fertilizers applied to the foliar (leaves). In this type of plant nutrition, the nutrients instead of being taken by the roots, are taken by the leaves. Foliar feeds are particularly useful in areas where there are inadequate supply of plant moisture throughout the year as in the current study area. Since, they are readily taken by the plant they can also play a useful role where the coffee plant has been damaged by disease and pest infestation. The author found that these fertilizers (locally called 'vatalisa ya matu') were very popular, and verbal conversation with the farmers indicated that the fertilizers had good response to coffee yields. This is a factor which needs further investigation by the Coffee Research Station.

Soil Ameliorants

This group of fertilizers is used to improve the pH of too acid soils. Gatitu et al (1978: 11) state that "the lime recommendation gives the amount in kg/ha of liming material required to bring a 6 inches depth

of soil to be the desirable pH value (usually pH 5.4). This dressing is normally recommended when the soil reaction is too low, say below pH 4.4. Below this pH value, the exchangeable acidity (Hp m.e%) is high. This acidity is associated with permanent cation exchange capacity CECp and develops as a result of the removal of metal cation mainly through (a) acid forming fertilizers (b) uptake of nutrient elements by plants (c) high rainfall (high leaching rate of cations) (d) soil erosion under these conditions Calcium and Magnesium are normally in low supply and excess exchangeable acidity (Hp) is present. Then to ameliorate the soil, for every 1 m.e% Hp, 500 grams/tree of liming material is recommended."

The following table [12] shows some of the fertilizers commonly used in the study area.

Table 12

Machakos Fertilizer Prices for 50 kg Bags

Type	Price K SHS
DSP	163.70
DAP	183.50
20:10:10	127.40
SSP	80.20
11 x 52 x 10	206.55

Table 12

Machakos Fertilizer Prices for 50 kg Bags

Type	Price
DSP	163.70
DAP	183.50
20:10:10	127.40
SSP	80.20
11 x 52 x 10	206.55
Urea 46%	139.20
Sulphate of Ammonia	72.35
CAN 26%	100.75

Source: Northern Division Agriculture Office : MA/S8/4/6 Circulation of 15.7.80.

4.4 Influence of Diseases/Pests and Weeds in Coffee Production

4.4.1 Diseases/Pests

While it was impossible in this study to show the relationship between biological factors and coffee yields through the linear regression model, it is suggested that these factors are very critical in coffee production and may account for some of the residuals (or proportion unexplained by) of the linear regression model.

The table 13 based on the 250 sampled farms shows the diseases and pests detected by farmers in Matungulu Location.

Table 13

Disease and Pests Detected by Farmers

Disease/Pest	Number	%
Bacterial Blight of Coffee Elgon/Solai die-back	194	77.6
Coffee Berry Disease (Colletotrichum Coffeanum)	179	71.6
Leaf Miner (Leucoptera spp.)	171	68.4
Leaf Rust (Hembieta Vastatrix)	169	67.6
Green Scales (Coccus alpinus)	146	58.4
Others	20	8
Thrips (Diarthrothips coffeae)	12	4.8
Dusty Brown Beetle (Gonocephalum simplex)	6	2.4
Giant Looper (Ascotis selenaria reciprocaria)	4	1.6
Kenya Mealybug (Planococcus kenyae)	3	1.2

The low recurrence of certain pests such as Kenya Mealybug, 0.2; Dusty Brown Beetle, 2.4; Thrips, 4.8; Green Tortrix, 0.4; and Giant Looper, 1.6% respectively, should not be interpreted to mean that their distribution is not widespread; rather it should be understood that most farmers were unable to identify or recognize them. An extensive survey by the author revealed the existence of these pests. It is clear from this table that the Elgon/Solai die-back, 77.6%, Coffee Berry

Disease (CBD) 71.6%; Leaf Miner, 68.4%; Leaf Rust, 67.6% and Green Scales, 58.4% were the most serious and widespread diseases and pests at the time of the field survey. There was a serious infestation of coffee by Leaf Miner in the northern half of Matungulu Location. Other coffee pests identified by the author were Antestia Bug (Antestiopsis spp.), Leaf Skeletonizer (Leucoplema dohertyi), Berry Borer (Hypothenemus Hampei), Star Scale (Asterolecanium coffeae), Lace Bug (Habrochila sp.)

Leaf Skeletonizer was as widespread as Leaf Miner. Star Scales had its worst hit on the upper slopes of Kambusu and Kingoti sub-locations (see Plate 2). Lace Bug was found in several farms at Sengani and Nguluni sub-locations' coffee growing areas.

4.4.2 Weeds

Weeds are detrimental to coffee because they compete for water and plant nutrients. They can reduce yields by 25-35 percent. They can also be used to indicate soil fertility.

Weeds, like disease and pests have to be controlled if coffee productivity is to be increased. The role of weed in coffee production is clearly described by Kamau (1980: 111). He states that "in coffee, the adverse effec of weed competition may not be seen for many months. But in the dry season, coffee which had to grow with the weed will be seen to be deficient in phosphorus, liable to wi

and lose more leaves than coffee which grew during the rains without weed competition (Wallis, 1961). Weed growth during the wet season lowers the mean yield by about a quarter to one third, and the proportion of grade A beans by about 35% (Jones and Willis, 1963). Minimum weeding as opposed to clean weeding several times will reduce the yiel by as much as 54% (Raynolds, 1967)."

Another adverse effect of weeds on coffee production as noted by Hocombe and Yates (1963) is that "weeds can cause losses due to difficulties in harvesting a weedy crop the reduction in quality of the crop due to the presence of poisonous seeds or seeds which taint the crop products, and weeds can also act as alternative hosts for insect pests an diseases."

Table 14 below show the weeds that are considered by the farmers as a serious threat to coffee production and hence, constitute a major source of financial loss.

Table 14

Weeds Considered by Farmers as a Serious Threat to Coffee Production

Weeds	Number	%
Couch Grass (Digitaria scalarum)	226	90.4
Star Grass (Cynodon dactylon)	138	55.2
Wandering Jew (Commelina benghalensis)	132	52.8
Water Grass (Cyperus rotundus)	114	45.6
Black Jack (Bidens pilosa)	61	24.4
Bristly Foxtail, Love Grass (Setaria verticillata)	47	18.8
Mexican Marigold (Tagetes minuta)	46	18.4
Thorn Apple (Datura stramonium)	30	12
MacDonald (Galinsoga parviflora)	22	8.8
Pigweed (Amaranthus hybridus)	11	4.4
Oxalis (Oxalis latifolia)	7	2.8

From table 15, it may be concluded that the most dangerous weed in coffee production is Couch grass (Digitaria scalarum). Other dangerous weeds are Star grass (Cynodon dactylon), Wandering Jew (commelina benghalensis), and Water grass (Cyperus rotundus).

Wallace et al (1973 : p. 250) note that "the need for weed control has been better recognized by coffee growers than any other aspect of production. Its beneficial effects are more easily demonstrable and weeding of crops is also a traditional agricultural practice." Similarly, the tropical farmers have for many years used flora(including weeds) to predict the potential of local soils for crop growth. One example by Wrigley (1969: 29) will serve to illustrate this feature. Wrigley writes that "a varied flora is a good indication of soil depth, sometimes caused by a pan, or a limitation set by pH or nutrients. Certain grass species are indicative of poor or fertile soil. In southern Uganda a good stand of elephant grass "Pennisetum purpureum" is only found on a deep fertile soil suitable for coffee production and bananas. When the soil fertility has been reduced by over-cropping, neither elephant grass nor bananas will grow satisfactorily and the land is colonized by "cymbopogon afronardus" and other grasses

indicative of low fertility. If the land is allowed to rest, elephant grass will colonize the area when the fertility level has risen sufficiently." The following table 15 based on the sampled farms shows the weeds that are considered as indicators of soil fertility in coffee farms.

Table 15

Weeds Considered by Farmers as a Sign or Indicator of Soil Fertility

Weeds	Number out of 250	%
Pigweed (Amaranthus hybridus)	192	76.8
Wandering Jew (Commelina benghalensis)	170	68
Water Grass (Cyperus rotundus)	114	45.6
Thorn Apple (Datura stramonium)	89	35.6
Black Jack (Bidens pilosa)	74	29.4
Mexican Marigold (Tagetes minuta)	46	18.4
MacDonaldi (Galinsoga parviflora)	51	20.4
Oxalis (Oxalis latifolia)	30	12
Star Grass (Cynodon dactylon)	23	9.2
Couch Grass (Digitaria scalarum)	22	8.8
Bristly Foxtail (Setaria verticillata)	5	2

It can be seen from table 15 that Pigweed, Wandering Jew and Water grass are the best indicators of soil fertility.

Weeds may be controlled through cultural, mechanical, chemical and biological methods. The cultural method of weed control involves regular removal of weeds by hand or panga, whereas, the mechanical method involves the removal of weeds using farm machines. Chemical and biological methods involve removal of weeds by use of weed-killers (or herbicides) and application of a mulch or shading the ground by planting cover crops respectively. Whichever method is deemed suitable for controlling the weeds, Kamau (1980: 111) states that "one or more of the following factors should be considered: (a) labour availability, (b) cost of labour, (c) availability and cost of mulching material, (d) cost of herbicides and (e) the climatic conditions. Of the many experiments which have been conducted here at Ruiru and the sub-stations, in connection with weed control, no definite conclusions has been arrived at to date regarding the method which is best." Experiments carried out by CRS at Ruiru concerning various methods of weed control (Kamau 1980: 117) "indicate that the herbicide used on coffee to control weeds can help to all-

eviate labour problems. Not only is the labour problem alleviated, but there is also a saving in costs of controlling weeds. The initial costs of herbicide use may be high, as one has to buy a sprayer, but this should not be viewed as a constraint. This is because the sprayer can be used also in other enterprises, and this helps to spread the cost. It would be safe to say that herbicides have a future role to play in controlling weeds even in the small-scale farms. The advantages resulting from the use of herbicides outweigh the disadvantages in costs. Furthermore, combination of either hand-weeding and herbicide use or slashing and herbicide use is feasible."

In the case of the coffee growing area of Matungulu, the use of herbicides may be encouraged partly due to the labour shortage, partly due to the fact that this area falls on the East of the Rift Valley where, according to CRS (Michell 1977: 4) weeds do not grow throughout the year under conditions of well distributed rainfall and sunshine, and where clean weeding and mulching do not produce low increases in coffee yield. Otherwise, Mitchell (1977: 5) states that "in the drier areas East of the Rift weed growth is easier and cheaper to control, whilst clean weeding and mulch application both

produce highly economic increases in yield. In such areas a system of continuous chemical weed control without cultivation, combined with mulching, is effective and economical."

CHAPTER 5

THE HUMAN ENVIRONMENT AS A FACTOR IN COFFEE PRODUCTION

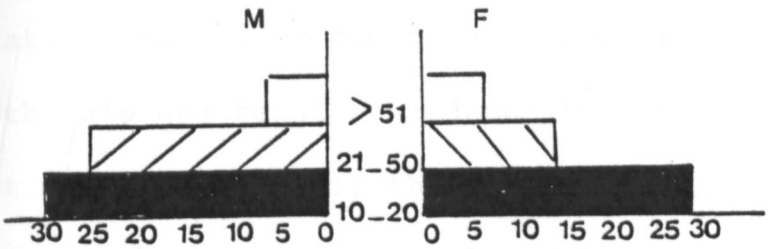
5.1 Farm Population Characteristics and Labour Availability

5.1.1 Socio-economic Characteristics of Farm Population

The question of the general population characteristics, such as population densities and distributions, was discussed at length in earlier chapters, particularly in chapter 2, hence it is not necessary to go over this ground again. The population pyramid (fig. 22,) is based on the sample of 250 farmsteads comprising of 1368 farmstead members, show their age/sex distribution. It is clear from this pyramid that male and female children between 10 and 20 years of age account for over 55% of the total farm population with adults between 21 and 50 accounting for a further 39%. In the 21 to 50 group, males outnumber females in a ratio of 2:1. The reason why there are more males than females might be due to the technique that was used which is different from the one used in the National Survey. The adults over 51 years account for only 6% of the population, with equal numbers of males and females.

Looking at table 16 which shows some important

MATUNGULU FARMSTEAD MEMBERS
AGE / SEX DISTRIBUTION



LEGEND

	Male	Female
Adult	>51	>51
Adult	21_50	21_50
Children	10_20	10_20

Fig. 22: This pyramid shows number of farmstead member age / sex distribution

population characteristics of the Northern division of Machakos, and which is based on the 1969* National population Census, it can be seen that the proportion of both male and female children (though their ages are not shown) is roughly the same as the sampled one. However, there were more female adults than males in 1969, contrary to the sampled data. This might be due to the fact that in the case of the sampled data, the children up to 10 years were excluded since they do not actively participate in the process of coffee production (eg. coffee picking and so on).

Table 16

Important Statistical Information About the Northern Division - Machakos District: a) Population (1969)

Location	Adults		Children		Total
	Male	Female	Male	Female	
Kangundo	7,960	9,838	11,289	10,911	39,998
Matungulu	7,865	10,069	11,488	11,102	40,524
Mwala	3,619	5,444	4,692	4,678	17,533
Mbiuni	3,287	4,273	4,450	4,377	16,387
TOTAL	22,731	28,724	31,919	31,068	111,442

Source: Divisional Agricultural Office - Kangundo.

* It was not possible to compare the age/sex distribution of farmstead members with the 1979 National population Census figures for Matungulu since the 1979 figures were provisional and without age/sex breakdown.

The elementary family of man, wife and unmarried children form the basic economic unit of Matungulu small-holder life. The average age of farmers is 49 years. In a rural area like this one where 60% and 32.4% of the farmers are full-time and part-time respectively, and where only 7.6% of the farmers can be classified as absentee farmers (source:field data) the implication of such age is that elder people are in full control of the coffee farming. Bearing in mind the fact that this group account for only 6% of the total farm population, their success in this occupation will depend largely on their ability to control the labour of the youth who form the bulk of the total farm population. The response of the latter will depend on the availability of alternative employment opportunities. This is critical in Kenya, as in many other third world countries, where farming has lost status among the youth. It is no wonder, therefore, to find that 77% of the farmers interviewed stated that they were helped in farm activities by children under 15, since most of these are in primary school (staying with their parents at home) and a few in the first two forms of the secondary school.

The statistical data from the questionnaires show

MATUNGULU _ FARMERS EXPERIENCING LABOUR SHORTAGE BY SUB-LOCATION

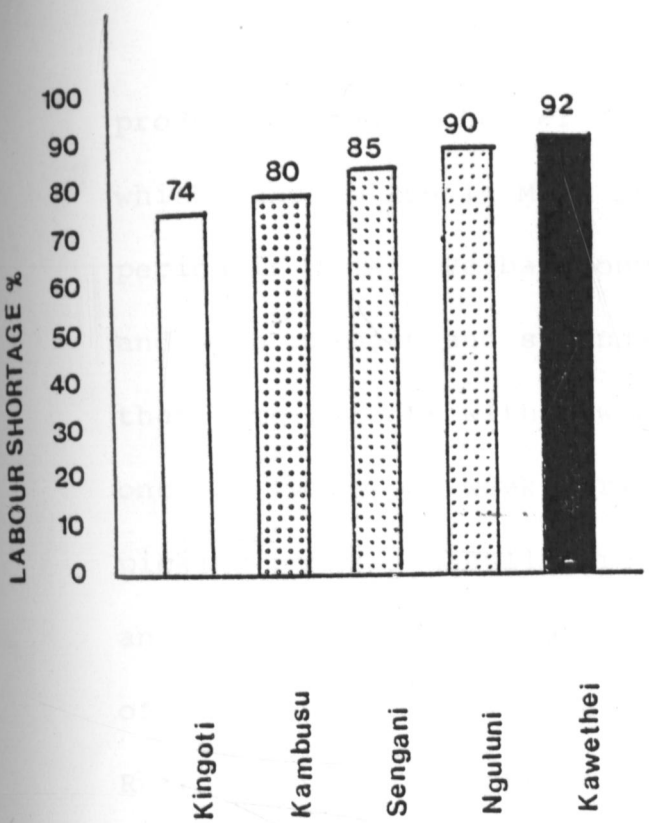


Fig. 23 : This histogram shows percentage of farmers experiencing labour shortage by sub-location

clearly that 52.9% of the farm activities are performed by children under 15. It is only spraying which is not done by the children under 15 because it involves handling dangerous chemicals. Spraying is done by either the factory staff or hired labour or parents. It can be seen that children under 15 form an important source of farm labour for coffee production.

The significance of school-going children in coffee production can be better be seen during the harvesting which takes place in May, June and July with its peak period in June. Verbal conversation between the author and some primary and secondary school teachers indicated that some parents withdrew their children from school once or twice per week during the peak of the coffee picking season, usually around the month of June. In another verbal conversation between the author and an official of the Coffee Research Foundation (CRF) at Ruiru, Kenya, the (CRF) official indicated that coffee picking in the Foundation's estates was done by hired labour. Some parents living or working in these estates had a tendency to withdraw their children from school in order to pick coffee in the Foundation's estates - additional hand means additional 'Uhga' (maize-meal) for the family.

In the case of Matungulu coffee growing area, children play a significant role in cherry picking, delivery to the local pulpery and separating the ripe berries from the un/semi-ripe; or healthy from disease damaged ones (Plate 6 and 7). An attempt to rectify the 'coffee picking school-going children issue' problem is like cutting the neck to save the head since the parents claim that the school fees come from the sale of coffee; if the child doesn't pick coffee, then he/she would not be in school the following term or year. Odingo (1979: 93) is therefore right when he points out that "one must first and foremost look at the family contribution before looking at the additional labour to supplement family sources."

Yet, despite the seemingly great contribution of family labour towards coffee production, 82.8% of the interviewed farmers indicated that they were experiencing labour shortage. The diagram figure 23 which is on a sub-locational basis show this clearly. Broadly speaking, it can be seen that all the five sub-locations of Matungulu are experiencing an acute shortage of labour, Kawethei being affected the most.

Labour shortage in coffee production arises out of

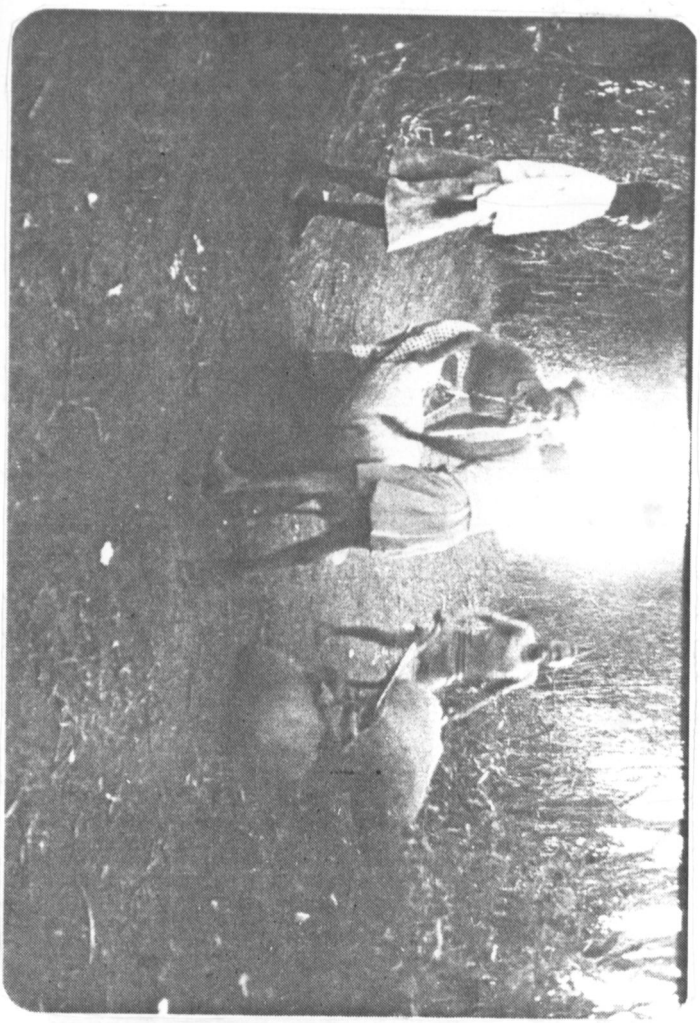


Plate 6: Farmstead members transport cherry to Kyamwole Coffee factory.

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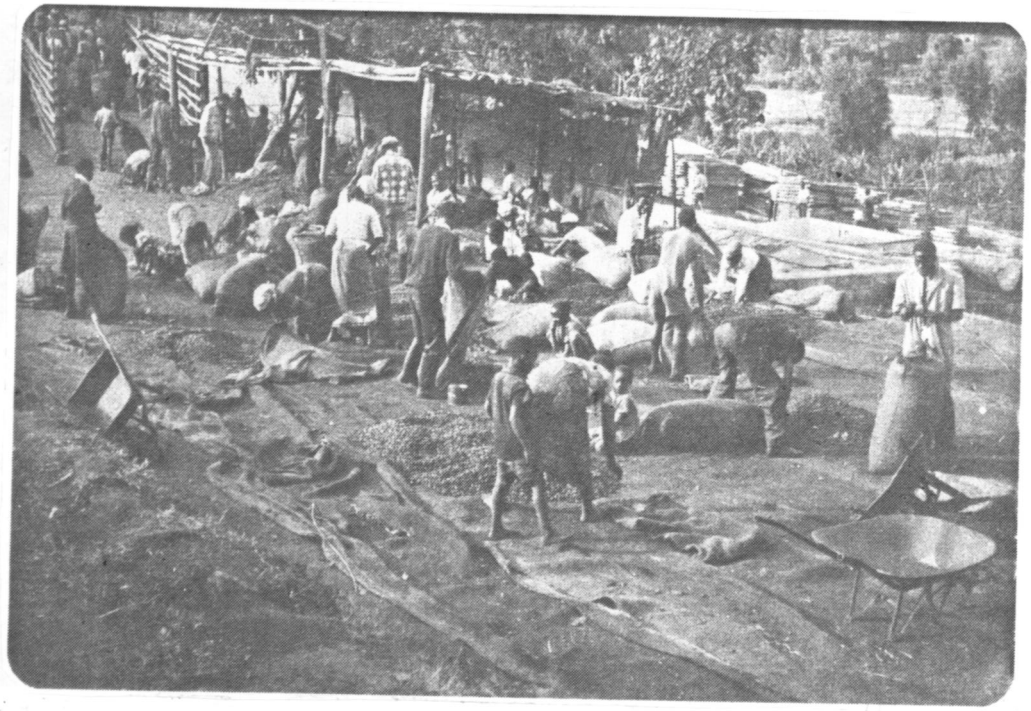


Plate 7: Sorting out of coffee berries at Kyamwole Coffee factory

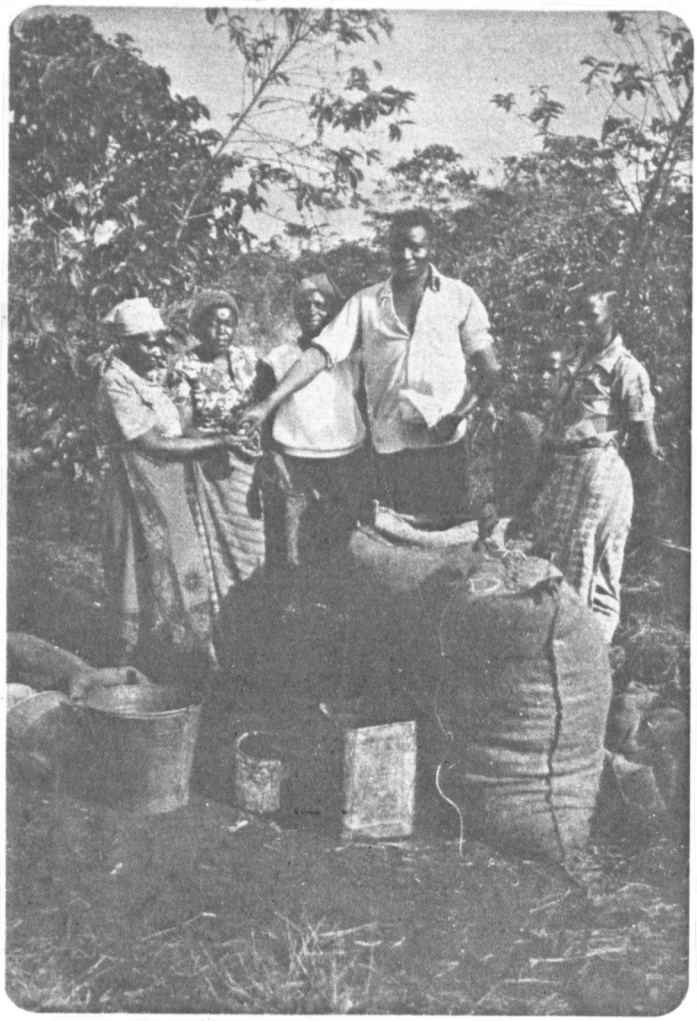


Plate 8: Progressive farmer pays women coffee pickers their dues.

several factors. First, labour is sometimes scarce and expensive in some periods in the year. Second, coffee is labour intensive requiring a lot of human labour input, almost throughout the year. Thirdly, labour shortage is partly due to a lack of money to pay for either the casual or hired labour and partly due to competition from the neighboring coffee estates such as Matungulu and other estates around Thika and Ruiru which transport labour from Matungulu back and forth free of charge thereby depriving Matungulu coffee region of the most needed manual labour. The estates also offer more lucrative wages than the small-scale farmers.

Within the setting of the small-scale farmers, there are progressive farmers (see Plate 8) who compete both with the estates and less progressive small-scale farmers. Since the former are able to pay higher prices for the labour, they stand a good chance of winning the remaining scarce labour. The poor farmer is sometimes left with only two alternatives; either to harvest as much as he can with the help of his family or to harvest and sell illegally his cherry to the progressive farmer at the farm gate or ask the progressive farmer to bring his labour, harvest the coffee, and buy it illegally at a depressingly low price. The second

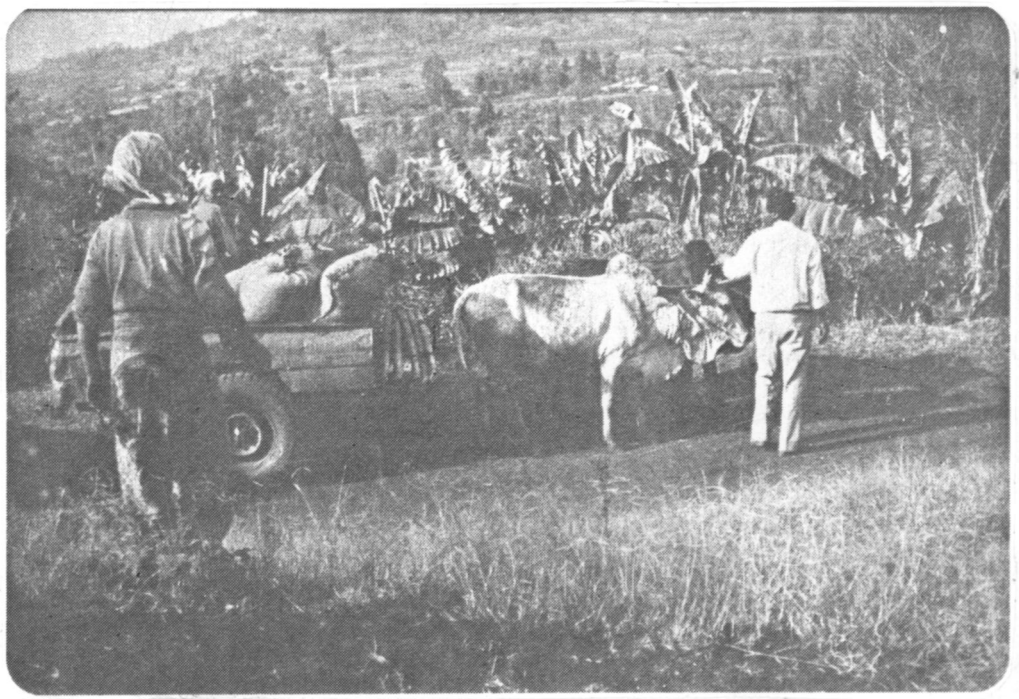


Plate 9: Transport of cherry to Kyamwole Coffee factory by ox-cart.

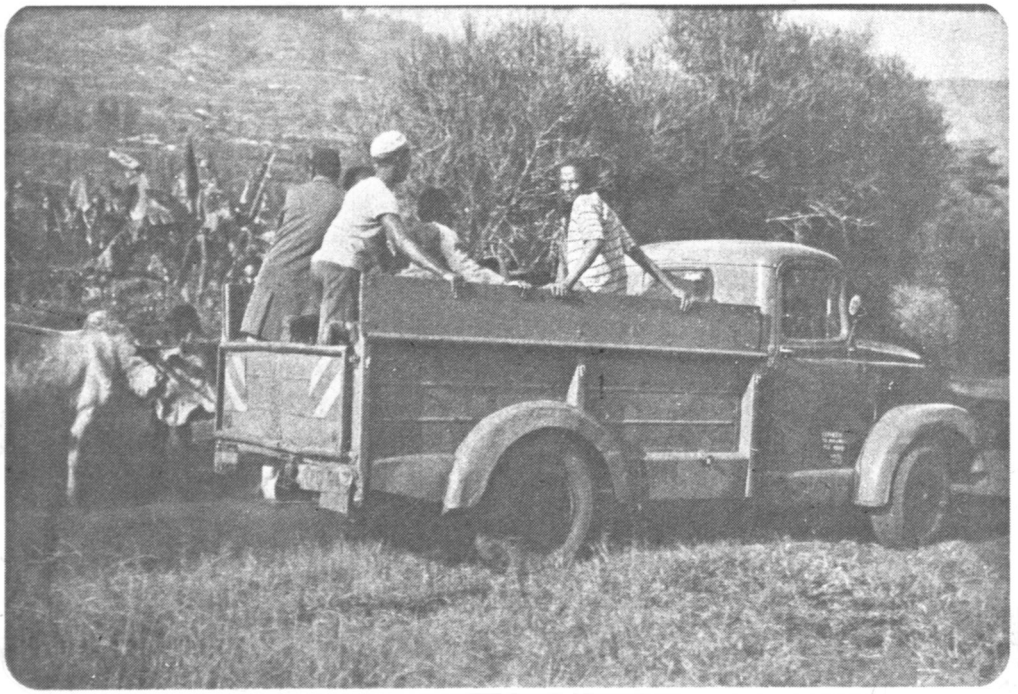


Plate 10: Transport of cherry to Kyamwole Coffee factory by a lorry.

alternative arises out of the fact that the transporting of the cherry to the factory is becoming increasingly expensive being a function of the distance the farmer is from the coffee factory. From the foregoing, it is clear that labour is a bottleneck in the production of coffee among the small-scale farmers of Matungulu Location.

The plates (6, 9, 10) show different modes of transport of coffee to the factory. It is important to note that ox-carts, and wheel-barrows form an important form of transport of cherry from the coffee plots to the factory. Because of poor transport facilities, some of the coffee berries harvested in some outlying farms may not reach the factory. Despite the poor transportation facilities from the farm to the coffee factory, analysis of coffee yields data, Appendix (C-1) shows that the distance from the factory does not have any significant effect on coffee yields ($r = -0.078$).

The farm labour problem is aggravated by out-migrations of some of the farmstead members (19.4%) working for wages in Nairobi or other townships, attending school or undergoing other forms of training. On the basis of the 250 farmers interviewed, 34% of the head of households were normally away. On a sublocational

base, the marginal sub-location of Nguluni led with 60%, followed by Kambusu with 44%, Kingoti with 32%, Kawethei with 28% and Sengani with 22%. When asked who managed the farm when the head of the household was away, 23.6% of the respondents stated that the farmer's wife/wives managed the coffee farms. Therefore, it may be concluded here that women's role in coffee production cannot be underestimated. Wallace et al (1973: 85) in reference to women's role in the Bugisu coffee industry point out that "it is clear, however, that women play a significant part in the cultivation of both coffee and food crops, even though we are not able to express their role in quantitative terms."

Casual labour is used to supplement family sources. The table number 17 show that the most important farm activities performed by casual/hired labour by percentage are coffee picking, pruning, weeding, delivery of cherry to the factory, land preparation, planting and spraying. The reason the percentage for spraying and planting are low is due to the fact that the former is done by factory staff and the latter is done by the farmer together with other farmstead members. Planting of young seedlings is sometimes not entrusted to casual labourers who are considered not careful enough in planting the young coffee seedlings. As all this data make

Table 17 : Matungulu : Source of Farm Labour

Farm	Family		Casual		Factory	
Activity	No.	%	No.	%	No.	%
Land Preparation	203	14.8	83	6.1	-	-
Planting	227	16.6	40	2.9	-	-
Weeding	218	15.9	96	7.0	-	-
Spraying	16	1.2	38	2.8	213	15.6
Picking	207	15.1	154	11.3	-	-
Delivery of Cherry to factory	203	14.8	93	6.8	-	-
Pruning	86	6.3	127	9.3	-	-
		84.7		46.4		15.6

plain, the family is by far the most important source of labour for coffee production.

It should also be noted that the labour operations include the use of both family and hired labour. The family labour was regarded as a chargeable item because of the alternatives foregone. The cost was calculated on the number of hours spent on each operation multiplied by the prevailing wage rate. Using this rationale together with a simple input-output analysis, it was possible to work out the total investment on the farm - the figure which was eventually used was the linear regression analysis. Investment = Agricultural Inputs x Cost/Unit Input (eg. labour x man-hour x cost/hr.; hence to calculate the amount of money spent on pruning or spraying, the total number of trees in the individual farm were multiplied by 80 cts. per tree in case of pruning and 20 cts. per tree in the case of spraying). It should, however, be noted that in many cases it was not possible to obtain precise information about 'input-output' analysis and hence approximations were resorted to.

Functional literacy plays a very important role

in coffee production. This is so when one realizes the fact that the use of fertilizers, pesticides, fungicides and herbicides involve the use of ratios, eg. so many kilograms of fertilizer to so many plants or so many litres of a chemical to so many litres of water. Similarly, the farmer has to keep simple farm records if he wants to operate economically. From this viewpoint education of the farmer and his family is an asset to coffee production.

Figure 24 represents the educational status of the farmstead members. It is clear from the diagram that the majority of farmstead reached upper and lower primary respectively. A small proportion attained the East Kenya Certificate of Education (KCE) and Kenya Advanced Certificate of Education (KACE). Very small proportions of the farmstead members have received other forms of training including University and Technical education. Similarly, the proportion of farmstead members who never went to school is less than 5 percent. Several observations can be made about the educational status of the farmstead members in Matungulu. Firstly, the degree of illiteracy is relatively low. It was not

MATUNGULU EDUCATIONAL STATUS
OF FARMSTEAD MEMBERS

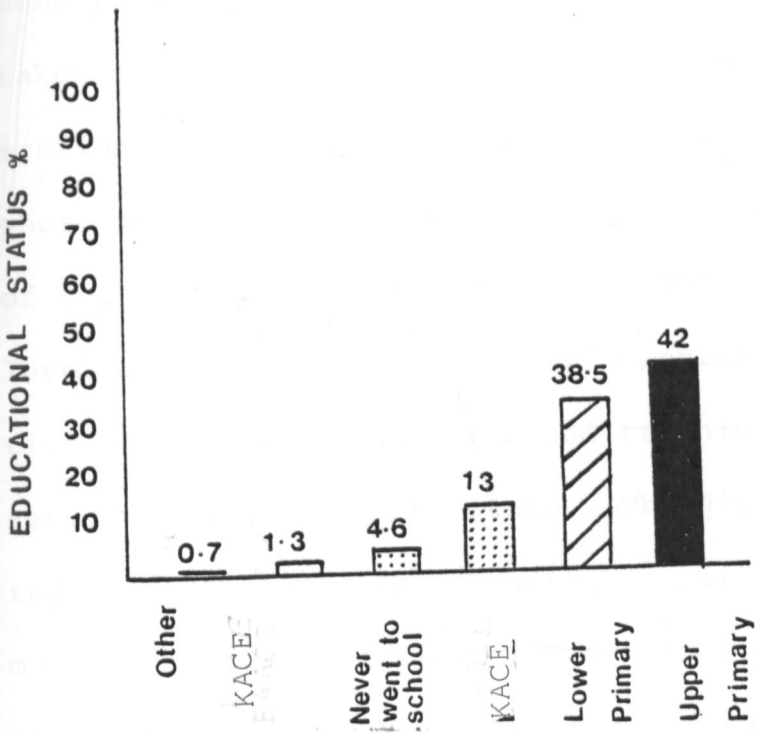


Fig. 24 : This histogram shows percentage of educational status of family

possible, however, to get information on the performance of the farmers under this category in coffee farming. Secondly, the fact that the majority of the farmstead members have attained primary education should not be taken to mean that they are able to carry out farm operations without difficulties. For a crop like coffee, whose success depends on the understanding and control of certain diseases and pests (as noted before), this level of education unless it is supplemented by effective agricultural education and training or extension service, is far from adequate. Thirdly, a proportion of the total farm population with K C E or KACE or above may not actively participate in farm operations. Some of the farmstead members in these educational levels are either involved in other non-agricultural activities or have migrated to the urban areas in search of wage employment. The saying that "farming has lost status among youth" particularly the school leavers still holds water in Matungulu like other parts of Kenya.

While functional literacy will help the farmer in day-to-day farm operations, his success in doing them will largely depend on knowledge obtained from agricultural schools or training and the effectiveness of the extension service. Table 18 shows the Matungulu farmers

who attended farmers' training centres by sub-locations. On the whole, only 15.2% of the farmers attended these agricultural training centres. The highest percentage

Table 18

Farmers who Attended Farmers' Training Centres by Sub-Location

Sub-Location	Sample Size	No.	%
Kingoti	100	13	13
Kambusu	50	9	18
Sengani	50	8	16
Nguluni	10	3	30
Kawethei	40	5	12.5
Total	250	38	15.2

of attendance (39%) was recorded at Nguluni. This is a relatively new coffee growing sub-location and the ecological conditions (eg. soils) are not as favourable as other sub-locations. The farmers appear eager to learn new agronomic practices. A similar trend can be seen in Kawethei sub-location. A comparative poor attendance is recorded in the older and more favourable sub-locations of Kingoti, Kambusu, and Sengani. While it may be argued that coffee farmers in these sub-locations are more experienced than those in Nguluni or Kawethei, the author strongly maintains that frequent attendance of

agricultural institutions, field days, co-operative societies and chiefs meetings (or barazas) are vital in gaining information on coffee farming. The diagram (fig. 25) show that the two most important farmers' source of information on coffee farming are co-operative societies and meetings (baraza). Other sources of information on coffee farming are from the radio (12%), extension staff (10.4%) and the press (9.2%). The small proportion of the farmers who obtain information on coffee farming through the local press may be explained by the fact that the farmers are unable to read and understand the CRS's publications, for example, the Kenya Coffee, Technical Circulars, and the local dailies, the 'Daily Nation' and 'The Standard' - written in English. The CRS has attempted to translate its publications in Kiswahili. However, the extent to which CRS's efforts are a success cannot be easily assessed.

5.1.2 Agrarian Characteristics

The diagram figure 26, shows that the dominant land tenure in Matungulu Location is individual ownership (freeholder) accounting for 97.2%. This is followed by communal ownership with only 1.6%. The disadvantage of the latter system of tenure as described by Jarrett (1977: 141-142) is that "it can allow several diff-

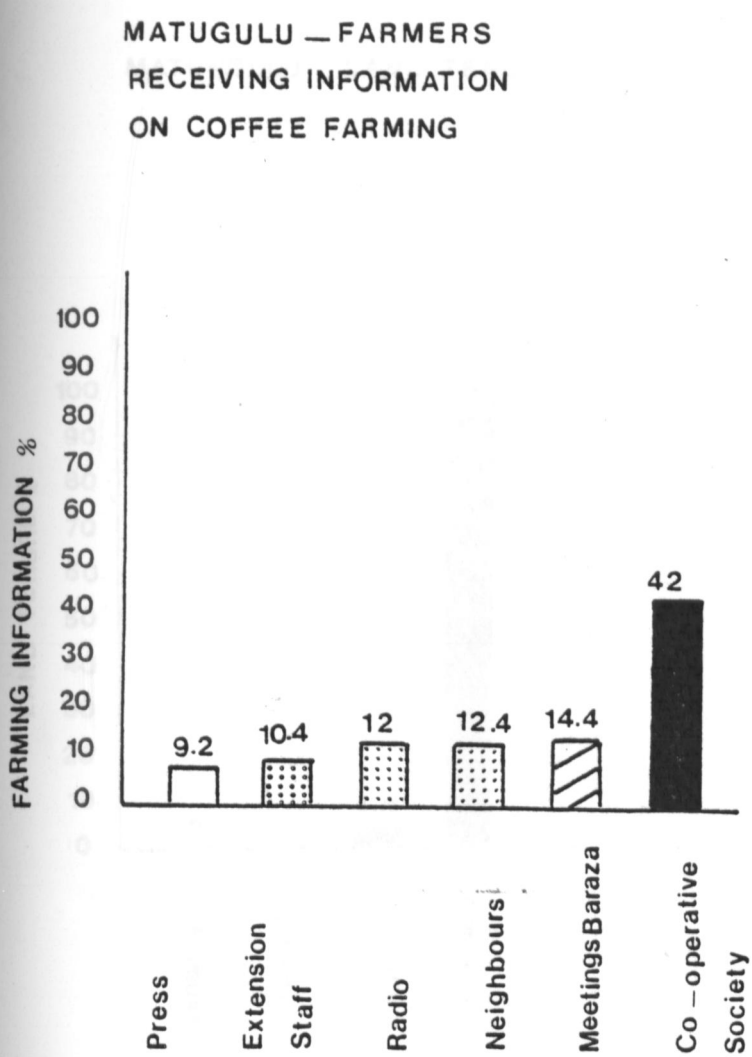


Fig 25 This histogram shows percentage of farmers receiving information on coffee

MATUNGULU : LAND TENURE

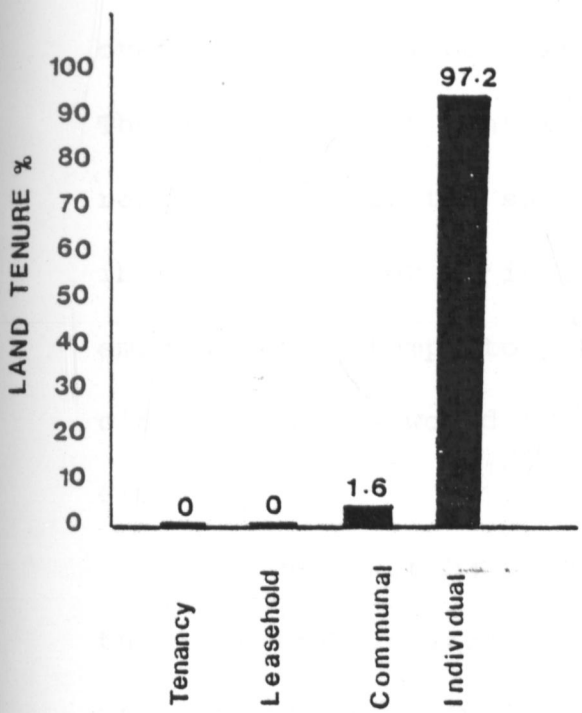


Fig 26 This histogram represents percentage of type of land tenure

erent kinds of right to co-exist over a single piece of land. The right to plant crops, for instance, may belong to one family but the right to pasture may be held by all the members of the extended family group; the right to any fruit from standing trees such as the oil-palm, may belong to one person, while the right to hunt over the land may be vested in the community as a whole. There is no doubt that the existence of several concurrent rights over the same area makes it almost impossible for a farmer to initiate any scheme of land-improvement. Any attempt to plant permanent crops or to enclose any plots would conflict with the rights of others."

On the other hand, however, the main advantages of the individual system as recorded by Makings (1967: 17) "are assumed to stem from the security it offers. Secure in his title, the freeholder may invest in and improve his land in the certain knowledge that he will reap the benefit either in his use of the land or through his powers of disposal (sale, sub-division, lease, gift or bequest). And the individual title may be said to offer not only incentive for improvement but also to provide security for loans to undertake the improvement."

Among the effects of introduction of the freehold

tenure at an early stage in developing an African country according to Makings (1967: 18) is that "it would lead to the emergence of fragmented farms built up by aggregation, in which the successful land holder expands by buying up the plots of others less successful." Incidently, this appears to be the general trend in the coffee growing area of Matungulu Location where the average farm size is 0.8 hectares.

Table 19

Matungulu: Fragmentation by Sub-Location

Sub-location	Sample Size	Number	Fragments per Farmstead
Kingoti	100	200	2.0
Kambusu	50	125	2.5
Sengani	50	100	2.0
Nguluni	10	16	1.6
Kawethei	40	144	3.6
Total	250	645	2.6

On an average it can be seen that each farmer from the sample has 2.58 fragments. The table 20 shows the number of fragments under coffee by sub-locations. Based on this table, it is evident that 36.4% of the fragments are under coffee. The number of fragments 1 km away from the farmsteads were 176 accounting for 27.28% of all fragments in the sample. Another factor

which gave rise to land fragmentation in Matungulu is inheritance.

Table 20

Matungulu: Fragments under Coffee by Sub-Location

Sub-location	Total number of fragments	Fragments under coffee	% of Total
Kingoti	260	100	38.46
Kambusu	125	50	40
Sengani	100	40	40
Nguluni	16	5	31.25
Kawethei	144	40	22.7
Total	645	235	36.4

From the foregoing, it can be seen that the socio-economic factors are the main cause of land fragmentation in the Matungulu area. This can be contrasted to the Caribbean where as reported by Hills et al (1972: 89), the physical factors seem to be the main cause of land fragmentation. They state that the physical factors that contribute to fragmentation include such natural features as escarpments, rivers, lakes, swamps, hills, extensive rock outcrops and the like, that create barriers to the surface continuity, and thus necessitate the fractioning of arable surfaces. Differences in soil, degree and direction of slope and micro-climatic features also introduce constraints or hazards sufficiently

great to prevent continuous cultivable surfaces. Cultural landscape features also in the form of highways, roads, dams, canals etc., may also fracture the existing surface available for crop production and contribute to farm fragmentation."

The disadvantages of land fragmentation have been discussed at length by Jarrett (1977: 143) and Hills et al (1972: 92). Jarrett warns that "the land must not be too heavily fragmented after any scheme of redistribution for even under conditions of personal ownership this is likely to lead to uneconomic working with a consequent depression of crop yields. The farming of dispersed fragments of land is usually uneconomic because time is wasted in movement between the plots; duplication of capital equipment may be necessary; the use of more efficient equipment may not be possible; control of weed, and pests is more difficult; and it is not easy to experiment with new crops and new farming methods." Hills et al add that "official surveys of any kind also have their difficulties multiplied by fragmentation. Officers of the agricultural extension service see fragmentation as a hindrance to the efficient dissemination of information on farming techniques and a break on the rate of demonstration, problem sol-

ving and essential field inspection." It is not easy to state clearly whether the 2.5 fragments per farmstead have adverse effects on coffee production.

More puzzling is the proportion of farms with registered titles which is very low indeed - 2.8% (see table 21 below). The implication of this in coffee production - the success of which depends also on the availability of farm credit is considerable, and will be discussed under the section dealing with the role of controlling institutions (eg. co-operative societies).

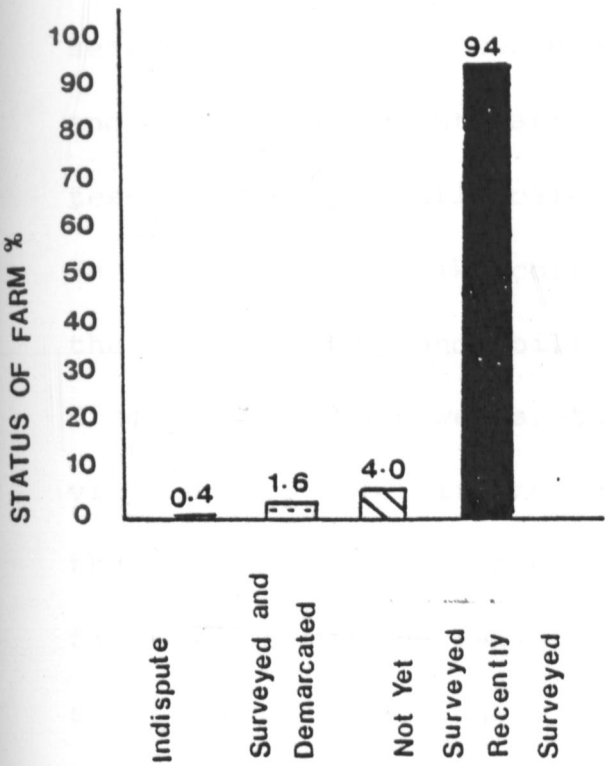
Table 21

Matungulu: Farms with Registered Title by Sub-Locations

Sub-Location	Sample Size	Number	%
Kingoti	100	0	0
Kambusu	50	7	14
Sengani	50	0	0
Nguluni	10	0	0
Kawethei	40	0	0
Total	250	7	2.8

The following diagram figure 27 shows the status of land without registered titles. 94% of this land was recently surveyed, 4.0% not yet surveyed, 1.6% surveyed and demarcated and 0.4% is in dispute. The diagram gives the reasons for widespread lack of registered

MATUNGULU STATUS OF FARMS
WITHOUT REGISTERED TITLE



27

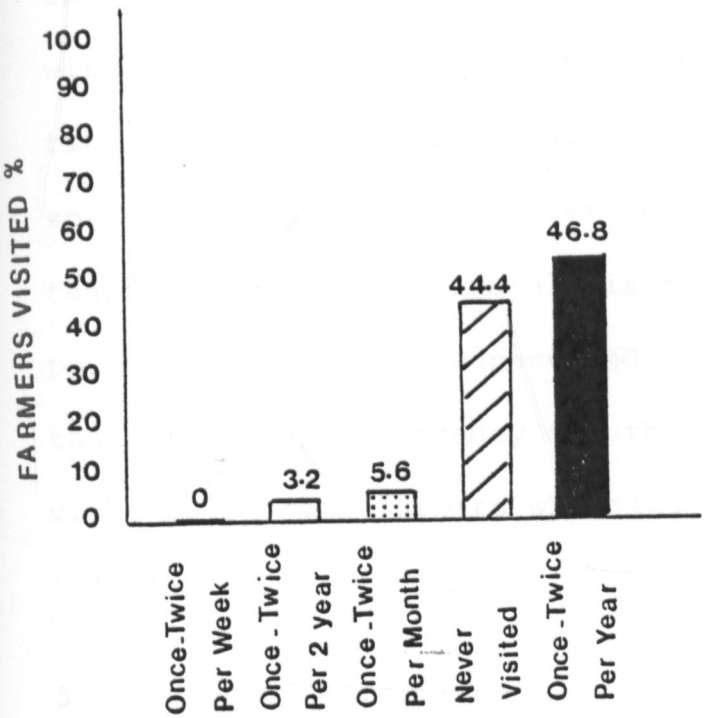
Fig27 This histogram shows percentage of farms without registered title

titles. In theory, it may be argued that Matungulu farmers are approaching a stage where they will be able to obtain farm credits to improve the coffee production.

5.2 Agricultural Extension Service

The extension service forms a link between the research institutions (where experiments on high yielding and disease resistant varieties of coffee, etc. are tested) and the small-scale farmer who is the producer. In case of a crop like coffee whose success depends on the understanding and ability to control some serious diseases/pests and weeds, the role of an extension service is very vital if the farmer is to increase both the physical and economic yield of coffee. The diagram figure 28 shows the farmers visited by the extension staff. From this diagram it is evident that the frequency of visitation by the extension staff is depressingly low - restricted to once or twice per year. About 45 percent of the farmers interviewed stated that they never visited by the extension staff; a correspondingly small number replied that they were visited once-twice per year and month respectively. No farmer was visited once or twice per week. Although the number of extension agents was not available, a crude estimate indicates that it might be as low as 15. A distinction has

MATUNGULU FARMERS VISITED
BY EXTENSION STAFF



28

Fig 28 :This histograms represents percentage of farmers visited by extension staff

to be made between the extension agents from the Ministry of Agriculture as represented by the divisional agricultural office at Kangundo and factory advisory staff. The latter category form the majority of the extension staff. The factory advisory team is charged with the responsibility of teaching the farmers essential agronomic practices such as pruning, mulching, and spraying. The main criticism levelled against the extension service in Matungulu is that it is not adequate, properly trained and supervised. The farmers complained that there was a tendency for the extension agents to visit prosperous farmers who gave them some inducement 'chai'.

5.3 Agronomic Practices

Successful coffee farming depends on many and varied cultural operations, such as soil conservation measures (mulching, fertility maintenance) disease/pests and weed control. Broadly speaking, the Matungulu coffee farmers are good conservers of soil. This is done through terracing, contour furrowing (see plate 2), mulching and gulley control. However, the cost of maintaining or constructing bench terraces is quite high (6/ = per 1 metre) and as a result 21% of the inter viewed farmers stated that they saw signs of soil ero-

sion on their coffee plots. 66% of the farmers stated that their soil was still fertile, 25.6% felt that soil fertility was declining while 8.4% agreed that their soils were infertile.

Soil fertility can be enhanced through manuring and mulching. Cattle manure is very expensive (800/= per 7 tons or 60/= for 1 ox-cart). Consequently most farmers in Kingoti, Kambusu and Sengani were finding it difficult to purchase cattle manure because of high cost brought about by the increased transport costs. The farmers in Nguluni and Kawethei - the suppliers of of the cattle manure were comparatively better off than those in the first three sub-locations. Fertilizers have also become expensive and the field survey revealed that some farmers used only 1 bag regardless of whether it was enough for the coffee plants - "something is better than nothing."

The importance of pruning in coffee farming cannot be underestimated. CRS (1977: 1) enumerate the main reasons for pruning as:

(i) "to maintain suitable crop/leaf ratio
(ii) to achieve regular uniform cropping yearly
(iii) to regulate cropping level
(iv) to assist in pest control

(v) to assist in disease control

(vi) to economize chemical use in spraying

(vii) to open trees to light and air

(viii) to avoid die-back of primaries and roots."

In short, there are two systems of pruning in Kenya viz. - 'single system' and multiple system. The latter system is thought more appropriate than the former. The latter system is thought more appropriate than the former. The plate 11 shows well pruned coffee in Matungulu. Like soil conservation measures, pruning has become very expensive sh. 1.00 per tree and is mainly done by hired skilled labour from the coffee factories. The factory workmen are also used in spraying pesticides and fungicides. There are also private sprayers who like the pruners, are expensive to engage, the rate being about 30 cts. per tree.

It has been said in chapters 1 and 4 in this thesis that mulching is a very essential agronomic practice in coffee production. However, 38.8% of farmers do not mulch their coffee nearly always because of a lack of mulching material; 3.6% did not mulch their coffee to avoid diseases and pest attack , whereas 5.7% did not mulch their coffee for fear of fire,set by a jealous neighbor. No evidence so far indicate coffee being set



Plate 11: Well Pruned coffee near Kyaume Primary School.

on fire in the Matungulu Location. Hence, the farmers' fear is unfounded.

There is a general tendency for most farmers to weed food crops first, leaving behind the coffee bushes unweeded (Plate 13). The argument here is that coffee trees are more resistant to weeds than such food crops as maize or beans. The point which the farmer should realize is that both coffee and weeds compete for soil nutrients, and as was seen in chapter 4, weeds can reduce yields drastically. Sometimes the weeds grew to a degree where the entire farm had to be abandoned. The Ministry of Agriculture officials at Kangundo issued a stern warning to those farmers or estates where sound agronomic practices were not followed. A case in point is the letter written to one farmer Ref. 3/coffee/1/vic/1630: 1980 where they found that weed control in one half of the coffee shamba was poor and needed improvement.

Interplanting is another agronomic practice common in Matungulu coffee farming (see Plate 12). This practice arises out of the shortage of food and insecurity associated with cash cropping. The farmers are not very sure as to whether the money earned from coffee



Plate 12: Interplanting coffee with maize at Mukalwa, Sengani.

will be enough to feed the resident farmstead members. The adverse effects of planting coffee with other crops is reflected by CRS Tech. Cir. No. 20, p. 3 which states "cultivation rules prohibit the planting of other crops within coffee. Where there is severe Fusarium Bark Disease (FBD), this is particularly important. Crops like beans will create a moist micro-climate round the bases of stems while 'greedy' crops like maize will deplete the soil nutrients and worsen the situation."

It is clear from the foregoing that despite the fact that agronomic practices in Matungulu Location are not generally bad, improvement on such agronomic practices as fertilization, pruning and other soil conservation measures must be stepped-up if the coffee yields are to improve.

5.4 Relationship between Price Changes and Area Under Coffee

Asked why they planted coffee, 98% of the Matungulu small-holders gave high income from coffee as the main reason for planting it. Other minor reasons included future security (1.2%) and persuasion by a neighbour (0.8%) (see figure 29).

The expansion of the hectarage under coffee took place after the boom period between 1976/77 and 1978

MATUNGULU—WHY FARMERS PLANTED COFFEE

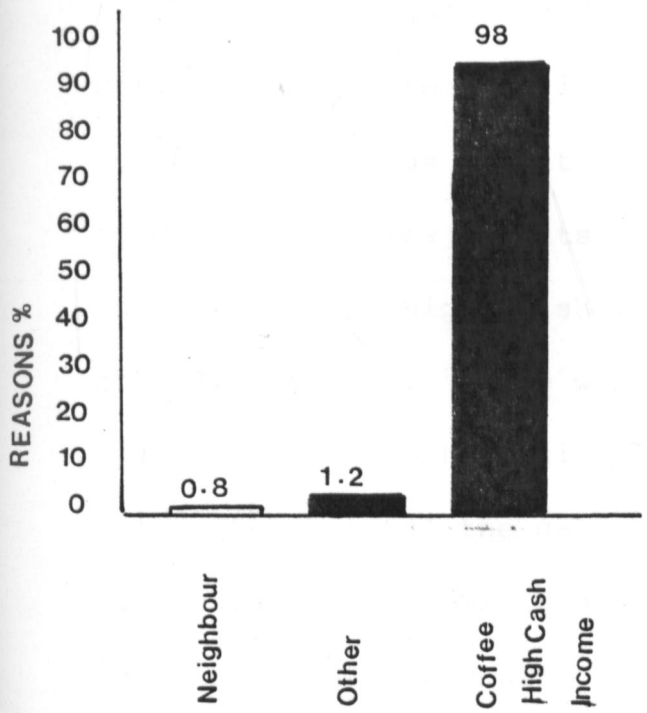


Fig 29 This histogram represents percentage of reasons why farmers planted coffee

during which time the coffee prices skyrocketted among the overseas consumer nations and fetching the all time price of £2000 per ton in countries such as Finland, West Germany and Japan. According to the Annual Divisional report No. 17, 1978: 15 "coffee dominated the talk of the year, very many farmers planted coffee on almost every suitable land available... seedlings were not enough. Coffee quality improved from last year, average class 6 as best to some societies getting as good as 3. Coffee payouts were still quite good. Payouts reached as high as shs. 6.55 per kg and as low as shs. 4.55 per kg. There was a problem of farmers because of the incentive given by the good prices, planting coffee outside the gazetted coffee zone. This was particularly so in Mwala and Mbiuni locations where a total of 15 hectares were planted under coffee."

Some small-scale farmers in Matungulu Location received as much shs. 7905.00 which was 2.5 times higher than the average for the 1979 figure (shs. 3211.00). Within this setting, some farmers received as much as shs. 80,000 whereas, others received as little as shs. 200,00.

The overall impact of the higher prices paid to the farmers was an areal expansion of coffee and a

corresponding decrease in hectarage under food crops. Plate 13 shows clearly that the wide area which was previously under food crops is now under one year old coffee. The number of plants and the corresponding hectarage as recorded by individual coffee factories in Matungulu is shown in diagram figure 30. The greatest hectarage was realized by Sengani, 1062 followed by Kakulutuini, 760, Kawethei , 700 and Kyamwole 660.

A real expansion of coffee has been at the expense of the proportion of individual farm under food crops. Diagram figure 30 shows that over 50% of the Matungulu farmland is under coffee. This trend can be seen by looking at the 9 year old air photograph Plate 2 which was taken in the pre-coffee boom period. The table 22 shows that 42.4% of the farmers have put less than one quarter of their farms under food crops. Consequently, 36% of the sampled farmers responded that they had adequate food supply to feed the resident members from April through October in 1979 (see Table 23).



Plate 13: Areal expansion of coffee plants near Tala.

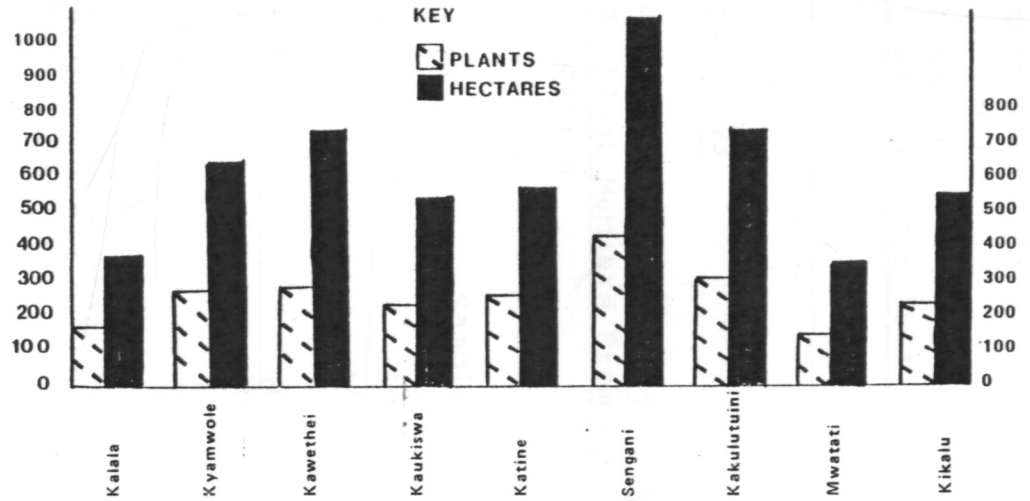


Fig. 30 MATUNGULU : NUMBER OF PLANTS & HECTARAGE UNDER COFFEE BY COFFEE FACTORY

Table 22

Matungulu: Proportion of Total Land Under Food Crops

Proportions of Farm	No.	%
Nothing (0%)	2	0.8
Very Small (0-5%)	49	19.6
Less than ¼ (6-20%)	55	22
Half (21-50%)	75	30
More than half (51-74%)	35	14
More than 3/4 (over 76%)	34	13.6
Total	250	100

Table 23

Matungulu: Farmstead with Sufficient Food For Their Resident Members From April - October 1979 by Sub-Location

Sub-Location	Sample Size	No.	%
Kingoti	100	27	27
Kambusu	50	10	20
Sengani	50	21	42
Nguluni	10	9	90
Kawethei	40	23	57.5
Total	250	90	36

Table 24

Matungulu: Factors Contributing to Food Deficiency by Sub-Locations

Factors	Kit	Kam	Sen	Ngu	Kawe	Ttl.	%
Comparatively small hectarage under food crops.	58	26	18	-	16	118	47.2

Table 24 continued

Factors	Kit	Kam	Sen*	Ngu	Kawe	Ttl.	%
Insufficient rainfall	15	3	8	1	1	28	11.2
Inadequate off-farm income	0	8	-	-	-	8	3.2
Other	0	3	3	-	-	6	2.4
Total	73	40	29	1	17	160	64

The worst hit sub-locations were Kingoti (27%), Kambusu (20%) and Sengani (42%). It should be noted that these sub-locations are also areas of high rural population density (see fig. 14) and also areas where there is almos no more room for food crops due to greater proportions of the individual farm being under coffee. The relativel new and sparsely populated sub-locations of Nguluni and Kawethei were not adversely affected by food shortage - they have relatively 'ample' land for food crops.

Asked to name the factors contributing to food shortage in Matungulu, 47.2% attributed food shortage to small hectarage under food crops (see table 24) above, while 11.2% and 3.2% attributed food shortage to inadequate rainfall and off-farm income respectively. Hence, it can be seen that increase in coffee production has led to direct decrease in hectarage under food crops.

* Abbreviations: Kit is Kingoti; Kam is Kambusu; Sen is Sengani; Ngu is Nguluni; Kawe is Kawethei; Ttl is total.

5.5 Role of Controlling Institutions:

5.5.1 Cooperative Societies:

Of the many controlling institutions in coffee production, co-operative societies play a very significant role and have therefore a special appeal to the farmers. The functions of the co-operative societies include among other things, processing of cherry, storage, marketing, provision of farm input and supplying of seasonal credits, hire service and advisory function.

At the beginning, the co-operative societies did the primary processing of coffee and bridged the gap between the farmers and various marketing organisations. Now the co-operative societies have evolved into multi-purpose co-operatives, handling many crops, investing in farms (such as Matungulu and Kayatta Coffee Estates) as well as buying houses and hotels in Nairobi and other places - a point to be discussed under the problems of co-operative societies. In 1977 the small-holder coffee co-operative society handled 50% of the coffee (Current Development Plan, 1979-1983: 39).

When the cherries (ripe berries) are picked, they

have to be pulped to remove the outer skin, graded, fermented and dried. The final product is known as the perchment which is later transported from the coffee factories to Kenya Planters Co-operative Union (Ltd.) Mills at Nairobi and Dandora. K.P.C.U. is a farmers organisation representing some 600 coffee estates owned by individuals, partnerships, companies and about 150 coffee societies representing over 300,000 small-scale farmers. K.P.C.U. does not buy coffee from members but provides services to the farmers when they deliver their crop. These services include storage facilities, coffee processing, financial assistance, merchandise and field advisory services (D.N. April 9, 1980: 22).

For one reason or another, some coffee co-operative societies have not been able to provide their members with certain essential services such as provision of farm credits, farm inputs such as fertilizers, and advisory function. The diagram figure 31 shows the percentage of farmers experiencing problems in obtaining agricultural inputs. It is clear from this diagram that over 60% of the farmers had difficulties in obtaining credit, labour, fertilizers, farm manure and transporting their cherry to the factory. Fungicides were not a very serious problem as the cost of these chem-

MATUNGULU FARMERS EXPERIENCING PROBLEMS
IN OBTAINING AGRICULTURAL INPUTS

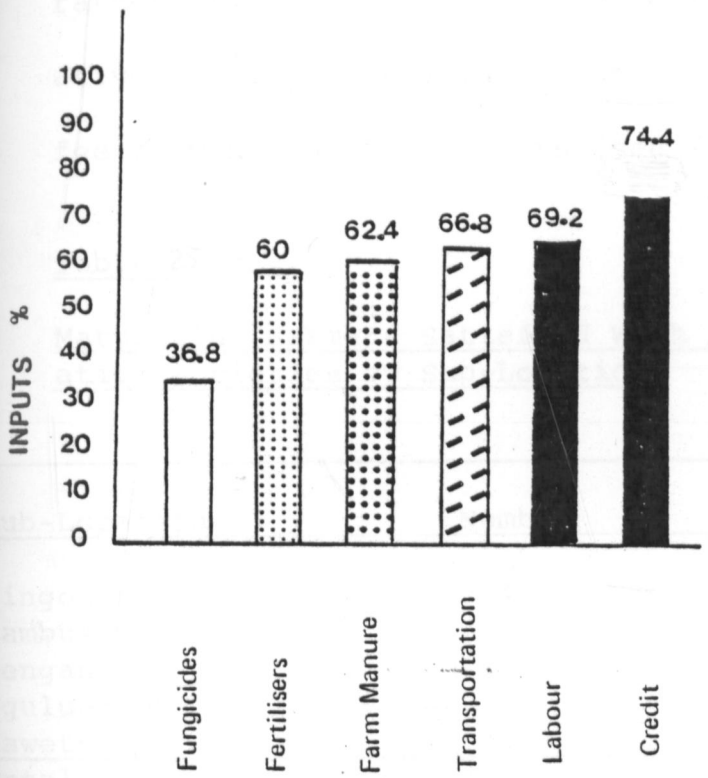


Fig. 31: This histogram represents percentage of farmers experiencing difficulties in obtaining agricultural inputs

icals were deducted from the farmers' gross earnings during the next pay-out. The table 25 shows that 54% of Matungulu farmers are not satisfied with the current services rendered by the co-operative society. This is rather disappointing when one realizes that the co-operative society is the main source of information on coffee farming for the farmers (see fig. 25, p. 173).

Table 25

Matungulu: Farmers Satisfied With Services of Co-operative Societies by Sub-Location

Sub-Location	Number	%
Kingoti	44	44
Kambusu	30	60
Sengani	19	38
Nguluni	9	90
Kawethei	33	82.5
Total	135	54

The variation in the degree of satisfaction among the farmers from Nguluni, Kawethei and Kambusu may be indicative of efficient management in these factories. Kingoti and Sengani farmers don't appear to be very dissatisfied with the services rendered to them by their co-operative societies.

Other problems facing co-operative societies include shortage of qualified and experienced personnel to

supply the general management, corruption, financial, social and political. Co-operative societies have come under severe criticism by many people of varied quarters of our society. Mungai (1980: 8) states that "members of co-operatives have pointed out how they get cheated by those who weigh and process their products such as milk and coffee." This feeling is probably reflected in case of the Matungulu small-scale coffee growers by the election poster (fig. 32) representing annual election for committee members of Kyamwole coffee factory.

The author attended the election portrayed by the poster in figure 32. The election system was not by secret ballot, but an open one where the members had to queue behind the candidate they supported. The shortcomings of such an election system tends to bring the same committee members annually. While such a trend ensures a continuity of policy, it has tended to make most of them firmly entrenched in their positions and thus become proud of themselves. Once these committee members are firmly established, they tend to 'socialize' the newly elected members into the dishonest ways of embezzlement of co-operative dues. An attempt to offer solutions to co-operative society's problems will be made in chapter 6.

MEN and WOMEN



Some farmers have 200 coffee plants and remain wealthy.



While some have as many as 3200 and ironically remain permanently impoverished.

WHY? WHY?

Fig. 32: SOURCE: Kyamwole Coffee Factory Committee Annual Election poster portrays corruption in management in favour of the Wealthy.

5.5.2 The National and International Coffee Institution

It has already been said that once the coffee has been ground by the Kenya Planters Co-operative Union (K.P.C.U) mills, it is then auctioned by the Coffee Board of Kenya (CBK) which is the sole organisation that markets coffee and subsequently hands over the money to the planter's agents, viz K.P.C.U., L.W. Mitchell, Estate Services, James Warren & Co., East Africa (E.A) Acceptances (Kuria 1979: 25).

Coffee is sold by a 'pool system'. Under this system, coffee is sold on behalf of the grower rather than outright purchasing of the crop from them. This is an important aspect of the system as it means that farmers are able to receive most of their proceeds from the crop without the industry retaining or making profits for itself. The aim of the system is to even out payment so that a given quality and standard of coffee receives the same payment regardless of the period of the year it was delivered for sale (D.N. 1979: VII). In other words, the farmers are sheltered from fluctuations in the coffee prices in the "International Market. The price of coffee here is regulated by the International Coffee Organisation (I.C.O) by introduction of quotas in an effect to arrest the possibility of price decline.

The farmers' motivation and subsequent investment on coffee will depend on how much the Co-operative societies, district co-operative unions, K.P.C.U., and finally co-operative societies are able to pay the farmer for his labour. The farmers are always out to maximize profits and will not invest in an agricultural undertaking, however good it may be (eg. fertilization) so long as they are sure that they will undergo loss. It can now be seen that in coffee production, the economic variables override the physical, biological ones.

A similar trend was seen towards the end of the section dealing with "analysis of data", where the use of step-wise regression model diagnosing the main physical and socio-economic factors influencing coffee production revealed that 73.1 percent and 76.1 percent of the variation of the coffee yields for 1978 and 1979 respectively, could be explained by two variables viz, Income and Investment.

Using all 14 explanatory variables, 85.5 percent and 91.9 percent of the variation of the coffee yields could be explained. However, it should be noted here that the contribution of the last 12 variables introduced were very negligible (see table 26)

Table 26

Predictor Variables introduced, and the resulting Accumulated Reduction in Residual Variance, during Step-Wise Regression Analyses of Coffee Yields for 26 and 32 Farms for 1978 and 1979

1978			1979		
STEP	Variable Introduced	Percentage Reduction in sum of squares	STEP	Variable Introduced	Percentage Reduction in sum of squares
1	10 INCOME (INC)	59.8	1	10 (INC)	76.0
2	11 INVESTMENT (INV)	13.3	2	11 (INV)	0.096
3	14 TOPOGRAPHY (Tp)	0.016	3	5 (K)	0.021
4	9 NUMBER OF TREES (TR)	0.034	4	2 (ALT)	0.025
5	7 CARBON (C)	0.003	5	14 (Tp)	0.003
6	6 CALCIUM TOP SOIL (Ca_T)	0.007	6	13 (DF)	0.004
7	12 FARM SIZE (FS)	0.009	7	15 (CF)	0.002
8	13 DISTANCE TO FACTORY (DF)	0.008	8	8 (CEC)	0.001
9	2 ALTITUDE (ALT)	0.002	9	4 (pH_T)	0.000
10	3 TOPSOIL pH (pH_T)	0.012	10	7 (C)	0.001
11	4 SUB-SOIL pH(pH_S)	0.012	11	9 (TR)	0.001
12	5 POTASSIUM (K)	0.004	12	12 (FS)	0.004
13	15 PROPORTION UNDER COFFEE (CF)	0.001	13	6 (Ca_T)	0.001
14	8 CATION EXCHANGE CAPACITY (CEC)	0.016	14	3 (pH_T)	0.000

It was mentioned in chapter four that Williams, Joynt and McCormick (1975) used step-wise regression in the macro-scale analyses of Canadian Prairie crop districts' cereal yields 1961-1972 in relation to weather, soil and trend. They found that 57 to 86 percent of the yield variation was explained by precipitation, potential evaporation, soil texture, topography and trend terms. Using all 16 explanatory variables, 62.0 percent of the yield variation for wheat, 73.3 percent of that for oats and 71.3 percent of that for barley could be explained (27). The contribution of the last five or six terms introduced were negligible, however.

It is therefore concluded that Income and Investment are the most important factors which influence small-holder coffee production in the Matungulu location - Machakos District. These two variables would consequently be the best predictors of the small-holder coffee yields of Matungulu location. Hence the Hypothesis 1.6.3 which states that "some physical, chemical and biological factors have a potential in influencing coffee production in Matungulu location" is disproved. It appears that these physical variables do not play a very significant role in coffee produc-

tion and that, instead, the economic variables viz Income and Investment are the dominant factors influencing small-holder coffee production in Matungulu. Physical factors appear insignificant in coffee production because we are dealing with an area where these factors such as soil, rainfall have little variation.

The dominance of the economic variables in coffee production is thought to be due to the fact that there is a great variation in socio-economic factors (eg. income); also these factors tend to lessen the adverse effects of the physical and biological factors. For example, the farmer who has higher income will most likely be the one who will successfully control diseases/pests and weeds; afford to buy farm inputs such as fertilizers, farm manure, hire labour for farm operations such as weeding, picking, pruning; has an ox-cart or lorry or can hire existing forms of transport to take his cherry to the factory. He is also capable of attracting farm credit and has probably a good command on extension staff and factory staff.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The central theme of this study has been the investigation of the physical, biological and socio-economic factor which influence small-scale coffee production in the densely populated Matungulu location of Machakos District. Kenya Coffee was chosen because of its dominant position in foreign earning capacity for Kenya and because it is the major source of cash income to the small-scale farmers living in Matungulu location and indeed the highland zone of Machakos District.

Producing more than 50 percent of the Kenya coffee for the export market, the small-scale sector has evidently outstripped the estate sector. However, the productivity per hectare is, on average, lower than the estate sector implying that there are some inefficiencies or constraints which consistently keep the yield low. If the slightly higher productivity per hectare of the small-scale sector of Machakos District than that of its estate sector is anything to go by, (or representative of Matungulu) it can be assumed that there is a potential for the small-scale farmers to produce even more with increased capital, effort and efficiency.

Since coffee is the main source of farm income and has no other competing cash-crop, in Matungulu and indeed, the highland zone of Machakos, it is also assumed that the farmers take the factors which influence its productivity seriously. A background knowledge underlying the operations of these factors is therefore, an asset to the farmers if they have to increase their productivity per hectare and quality of coffee. Improved production might lead to increase in both national income and rural farm income thereby raising the standard of living for the farmers and their families.

Considering the role of the physical environment in coffee production, such physical attributes as climate, geology, soils were discussed fairly broadly. It was established that Matungulu has the good climatic and soil requirements for coffee production. The most critical climatic factor influencing coffee production in the study area is rainfall, its amount, distribution and intensity. The mean annual rainfall for Matungulu coffee growing area is 1086 mm and is characterized by strong seasonal concentration around short-rains (Nthwa) October to December and long-rains (Uua) March to May. Most of the rain falls in the first month and with high intensity. Generally low infiltration rates usually

lead to great surface run-off and to severe soil erosion particularly on coffee farms whose erosion control measures are absent or have not been properly maintained.

No data are available on evapotranspiration, water-balance, radiation and soil temperature and hours of sunshine. Occasional droughts may occur and coffee has to be irrigated, particularly when the soil moisture regime drops down below 55 percent field capacity (F.C.) which in terms of soil moisture deficit, may be 150mm (6 inches).

The problem of irrigating coffee during the dry season in an area like Matungulu is that the exercise is expensive and laborious. There is inadequate surface and ground water supply in Nguluni, Kawethei and some parts of Sengani sub-locations. In some parts of Kingoti sub-location, the ground water level is sometimes 15 metres in the deep trachytic tuff. Water in these deep wells which are found in many farmsteads of Matungulu and Kangundo coffee growing areas is not easily utilized due to inappropriate equipment to remove or pump out the water and transport it to nearby coffee plots or distant fragments under coffee. Research should be done on the feasibility of utilizing water from the farmstead wells and available sources such as dams, ponds and streams for irrigation of coffee during the dry months of the

year.

The problem of coffee stress in the dry months due to the lack of moisture supply could be eased by the use of Foliar feed fertilizers. The importance of Foliar feed fertilizers is that they are readily taken by the coffee leaves rather than by the roots.

Geology per se does not directly influence coffee production. However, the soils upon which coffee grows are the product of the geological structures underlying the soils. The geology of the coffee growing area of Matungulu is mainly volcanic in origin - trachytic tuff. Soils derived from these rocks are known as Nitosols. They are well-drained, red friable clays, whose surface and sub-surface colours are dark-reddish brown to dusky red sandy clays with crumb or sub-angular structure. They range from very strongly acid (pH 4.5-5.0); to very slightly acid (pH 6.1-6.5). Extremely acid condition of pH 3.4 was also encountered in one coffee farm. In such a case, use of ameliorants such as liming is necessary to bring the pH to a desirable level.

The analysis of the soil samples indicated that the the coffee soils of Matungulu are generally low in nitrogen, carbon and phosphorus. The low nitrogen, and carbon content in these soils may be attributed to a

lack of mulching. The low phosphorus in the soils may be due to the fact that they are highly weathered and consequently denuded with time of inorganic phosphorus. Secondly, due to intensive weathering, the positively charged reactive surfaces of iron and aluminium oxides absorb phosphates.

There is a widespread lack of mulching material. Both the short and long term solution to this problem is compounded by the stiff competition between coffee and other forms of landuse. Coffee now occupies over one half of individual farms. The remaining portion is devoted to food crops and settlement. The close association between land under coffee and coffee soils as represented by soil sampling sites in fig. 6 is indicative of stiff competition between land under coffee and that under food crops. The question is should the farmer put the remaining portion of his farm under Napier grass or should he put it under food crops which can readily feed his resident farmstead members? However, an addition of farm manure could raise the C content of the coffee soils. The low P and Mg contents can be corrected by the addition of P and Mg fertilizers.

On the other hand, however, Matungulu coffee soils are generally well supplied with potassium and calcium

with means of 0.7 and 3.6 m.e% respectively. There were several sites where Ca values as low as 1.0 m.e% (- a value under 2.0 m.e% is regarded as being deficient). The source of high K content may be due to those farmers who use Napier grass mulch which has a high K content.

Excess levels of K and Ca are said to impair the quality of coffee beans mainly as a result of imbalance between Mg. Although, use of organic manures can improve the physical properties of the soil such as structure, pore size, aeration, drainage, thereby encouraging root growth; Oruko (1975/79: 24) warns that indiscriminate use of these manures could be harmful and should be avoided.

In conclusion of this section dealing with the soil properties and coffee production yield, it is observed that there was a very weak association between soil properties and coffee yields. This might be due to the fact that the role of physical factors are made to bear on coffee yields on the basis of their ability to interact with other biological and socio-economic factors, such as disease/pest and weed control, agronomic management and economic factors.

Although it was not possible in the current study

to gather the quantitative data showing the effect of such biological factors as disease/pests, it is strongly emphasized here that such dangerous bacterial blight, coffee diseases and pests as Coffee Berry Disease (CBD), Leaf Rust and Leaf miner to mention but a few, can reduce the coffee yield drastically and might be represented in the current study by the residuals of the stepwise regression model in the study. Similarly, the effect of weeds cannot be underestimated. It was remarked in chapter 4 that Kamau (1980: 111) notes "weed growth during the wet season lowers the mean yield by about a quarter to one third, and the proportion of grade A beans by about 35 percent." In the same chapter, reference was made to the source of fungicides, pesticides and herbicides that can be used to control coffee diseases/pests and weeds. Use of herbicides can help solve problems of labour shortage in the study area. The only problem would be increase in the cost of herbicides. In such a case, then the farmer has to work out simple cost-benefit analysis to find out whether it is still economical to use either labour or herbicides.

The elementary family of man, wife and unmarried children form the basic economic unit of Matungulu small-holder's life. The mean age of the farmers is 49 years

and 60% of the farmers are full-time while 32.4% and 7.6% of them can be classified as part-time and absentee farmers, respectively. About 80 percent of the farmstead members have attained primary education, 13% with Kenya Certificate of Education (KCE); and only 1.3% and 0.7% have reached Kenya Advanced Certificate of Education (KACE) and above respectively. The illiteracy among the farmerstead members is very low - 4.6%. Such a degree of functional literacy is important to the farmer and his family. As Wilson (1970: 148) puts it, "modern agriculture, even in its simplest aspects requires the imparting of some technical knowledge for which the printed word serves a most useful purpose. The planting of new varieties of seed and the associated use of fertilizers or spray for diseases and pests control may well require simple printed instructions to supplement advice of extension workers. Simple records become essential when sales and purchases, and possibly credit, are involved in an increasingly sophisticated agriculture. The local co-operative will issue receipts for produce delivered. It becomes necessary to be able to understand weights and measures if the farmer is not to run the risk of being continually cheated." To this end, the mass adult literacy campaign now underway in

Kenya should be given every bit of encouragement.

Farmers' agricultural education has been tailored in favour of only the head of the household - mainly the man and leaving his wife(ves) with little or no education. In an area like Matungulu where 34% of the heads of households are normally away, leaving farm operations in the hands of their wives; it is very important that these women are equiped with the necessary coffee farming skills. Women can effectively exchange farming ideas when they meet in the periodic markets.

Additionally, farmers should be advised to attend Farmers Training Centres, attend co-operative and Chief's meetings (barazas) where agricultural information on coffee farming is disseminated. Research findings by the author reveal very poor attendance at these agricultural institutions by the farmers and their family.

Equally important in the dissemination of information on coffee farming is the extension service. Some coffee farmers stated that they had never seen an extension agent for more than a year. The extension agents were accused of visiting only the 'progressive farmers.' It should be noted that "in order to achieve anything, the extension agents must win the confidence of the farmer and be able to demonstrate convincingly that adop-

tion of the new practices is worthwhile. It is clear that to undertake these responsible duties, the extension worker requires good training and strong support. He needs to have sufficient education and training to understand the reasons underlying the improvements he advocates and to explain and demonstrate them to the farmer (Wilson 1970: 143)."

It is true that the number and qualification of extension agents is very low. However, the existing number can be better trained through attending courses offered by the Coffee Research Station at Ruiru and its sub-stations. Standard qualifications need to be established to ensure only qualified agents are selected. The government through the Ministry of Agriculture would ensure the necessary supportive services such as supply of agricultural inputs (fertilizers, fungicides, pesticides, herbicides, loans and subsidies) are available. Likewise, the extension agents need to be given offices preferably in the coffee factories where the needy farmers could on specified office hours seek the advice of the extension staff. A well outlined work schedule and proper supervision is necessary, if the extension agents have to visit as many farmers as possible. These agents should be supplied with bicycles which will enable them

to reach the farmers without wasting precious time waiting for irregular 'matatus' (taxi).

Yet, the extension service cannot be effective without strong backing and continuous feedback from research institutions. The latter should evaluate the extension service finding out whether the research findings reach the farmer and whether the farmer's problems are brought back to the research institution. In other words, there should be good co-ordination among the various research institutions, extension services and the farmers. In this connection, the farmers should be allowed to air his views in decisions made for him. It is high time that planning started from the bottom rather than the top.

It was clear in chapter six that labour is a bottleneck in the coffee growing area of Matungulu. Over 80 percent of the interviewed farmers stated that they were experiencing labour shortage. The seasonal nature of its availability leads to underemployment at certain times of the year and acute shortage and high costs, particularly at planting, weeding and coffee picking seasons. The competition for labour between the small-scale sector and estates, and between the 'progressive' farmers and other ordinary farmers; and the lack of

money are the main causes of labour shortage in Matungulu. Other reasons causing labour shortage are migrations of young people to Nairobi and other urban centres in search of wage employment, and the negative attitude of these people towards farming. Farm credits, particularly during the weeding and harvesting period, can partly solve the problem. Although farm credit can be obtained from the local co-operative society, the complaint among most farmers was that it was small and at times it came too late when the labour problem had reached its peak. There were complaints among the co-operative societies about some of the money being used for other purposes for which it was not intended. Admittedly, it is difficult to supervise the use of the farm credits and the farmers should act responsibly on this issue.

Farming has lost its status among the youth. The educational system and attitudes of the youth and some parents towards manual work has literally chased the youth from rural areas leaving their aging parents with the heavy burden of coffee farming. This kind of youth underemployment is a common feature in many urban centres of Kenya where these youths can be seen acting as procuring agents for 'matatus' and buses. These enter-

prising 'travel agents' perform a marginal service in preference to manual labour. A need for a complete review of the curriculum to instill positive attitudes towards farming is urgently needed. This should be accompanied by subsidized farm incomes which will attract the youth to return to the rural areas.

The success and failures of small-scale farming, can in a way, be reflected by the operations of the co-operative societies. These societies have a significant role to play in processing, marketing, supply of agricultural inputs and credits, advisory and hire services. For one reason or other some co-operative societies have not been able to provide efficiently, their members with some of the essential services already mentioned. For example, 60% of the interviewed farmers replied that they had difficulties in obtaining the agricultural inputs (fig. 31) and consequently 54% of the farmers were not satisfied by the services rendered by the co-operative societies. This is very disappointing since the co-operative society is the main source of information on coffee farming (fig. 25). This tended to destroy the farming morale of the farmers.

The problems facing co-operatives range from administrative, financial, social and political. Some

of the administrative problems as noted by Okereke (1970: 153) include "(a) unsatisfactory recruitment policy whereby mediocre local personnel is preferred to outsider expertise, (b) insufficient locally trained and experienced managerial staff to run the unions and societies, (c) limited training facilities for co-operative personnel and (d) growing size of the unions as business units being out of proportion to the available calibre of management." Sound management is necessary to put the movement on sound footing. In this respect, the government in the Current Development Plan 1979-1983 has pointed out that it will strengthen the control, supervision and guidance activities of the Ministry of Co-operative Development. Secondly, there will be a substantial expansion of training facilities for co-operative leadership at the Co-operative College of Kenya.

In the recent past, co-operative societies have expanded the scope of their operations. Some have bought plots to erect multi-storeyed buildings for renting and so on. With the current crisis that have plagued these unions, one wonders if these projects being planned can sufficiently be supervised and economically runned, particularly when it is realized that one of the basic problems of the unions is a lack of qualified per-

sonnel at the managerial level. The farmer is always the victim. This point was admitted by the retiring Commissioner of Co-operative Development, who stated that "Co-operative unions were handling too much financial, marketing and operational responsibilities for which they are ill-equipped (Daily Nation, June 17, 1980)." A case in point is the criticism which appeared in the editorial of Daily Nation, May 31, 1980 labelled against Kenya National Federation of Co-operatives (KNFC) and Co-operative Bank of Kenya. The Bank was said to have no branches in rural Kenya where its clients are. Plans were underway to open such branches in Kisumu and Meru. However, they decided to create another company to build a Co-operative House when they could not build branches. The priority was wrong. Sh. 20 million of the total cost of 65 million of the building was borrowed. This meant that the Bank was not playing its role of providing the agricultural credit efficiently, since it was required by law to invest only in lending to co-operators.

The election of the management committee in the

local co-operatives which is not by secret ballot, but where the members have to queue behind the candidate they support, is unfair and should be corrected immediately. First, it denies the members their right to vote for the candidate they want. Secondly, the members are not free to vote because of fear of intimidation. Consequently, some inefficient and corrupt committee members are continually returned to office. While this ensures continuation of policy, these members become proud of themselves and tend to offer the members inefficient, unfair and non-dedicated service.

One of the main functions of the controlling institutions such as the co-operative society is the supplier of agricultural inputs to the farmers. In 1980, the farmers were taken for a ride by the distributors of agro-chemicals who supplied the farmers with 'fake' chemicals. A lot of small-scale farmer's money went into the drain. His yields correspondingly fell and so was his income and morale. The government should provide stricter supervision, in order to ensure that ineffective chemicals are no longer imported.

The co-operative society should ensure that the farmers get such agricultural inputs as fertilizers, sprays, credit on time. Where farmers are likely to

spend the farm credit on other things for which it was not intended, the co-operative society should give a form of credit in kind. A case in point is credit for farm manure, where the farmer can have his manure delivered through the arrangement with the co-operative society.

Having received the agricultural inputs from the co-operative society, the farmer should use all the recommended agronomic practices, such as pruning, mulching, manuring, soil erosion and weed - disease/pest control. The idea of weeding food crops first, leaving coffee plants for a longer period (since they are 'tougher') to compete for soil nutrients, should be abandoned if coffee yields are to be raised. Similarly, interplanting of coffee with food crops increases competition between coffee plants and the food crops for the nutrients.

The type of land tenure can foster or hinder coffee production. In general, individual ownership tends to encourage the farmers to invest on his farm since the benefits accrued from his farm go to him directly. In principle, the farmer stands a better chance in attracting farm credit from the bank. However, individual land tenure may lead to excessive land fragmentation built up by the aggregation in which the progressive

farmers expand by buying up the plots of other needy farmers. This may influence coffee production capacity in Matungulu where the mean farm size is 0.8 ha and where each farmer has an average of 2.6 fragments. One of the main advantages of land fragmentation is that it helps to spread the environmental risk over the number of fragments and seen in this context, the farmers' eggs are not in one basket. On the other hand, the scattered plots belonging to one farmer may pose problems of effective management of the farm, loss of time and energy spent in getting to the scattered units. There is no immediate solution to this problem since the less successful farmers have to sub-divide the land among their sons or sell parts of it to obtain school fees or food for the school-going family members or resident ones respectively. However, if farm productivity is to be increased in Matungulu, it is suggested here that land policies should be introduced to reduce the degree of fragmentation in the area.

Almost a hundred percent of the small-scale coffee farmers stated that they planted their coffee due to its high cash income earning capacity. High prices were paid to the farmers particularly during the coffee boom in 1976/1977-1978 were responsible for the areal expansion of coffee plants, which has triggered another

chain of events along the line. In essence, pasture has lost land to food crops and food crops are now rapidly losing land to coffee. These changes in landuse might lead to dietary deficiencies commonly found in areas where high value cash crops have been introduced. With more and more individual farms under coffee, the farmer is left at the mercy of international forces of supply and demand beyond which he has no control.

"Admittedly, we have gone far from the starting point, but this does sharply remind us that when producers venture into the hurly-burly of cash cropping and all that this entails, they may well find that they have left behind them any life of comparatively placid self-sufficiency which they may previously have enjoyed. The path of economic development is tortuous and rocky and no one who treads along it can tell whither it will lead (Jarrett 1977: 113)". Hence, the farmers should be advised to spare part of their farm for food crops for 'you never know what may come.' This statement is very true when one considers the fact that there have been fluctuations in the international price for coffee. The price has fluctuated from about £1400 per ton before 1976 to £2000 during the coffee boom in 1976/77-1978 and afterwards fell to about £1700 per ton.

Paradoxically, it is in these areas where cash crop farming has been firmly established, that the farmers have improved their lot economically much more than their counterparts in non-cash crop growing areas. This becomes more apparent when one compares the socio-economic lifestyles of the people living in wetter, richer volcanic soils of the highland zone of Meru, and Machakos with those living in comparatively drier and poorer sandy loams of Tharaka, Mwala, Mbiuni, and Makueni respectively. Matungulu is a region of economic growth. New shopping centres, schools, churches and health centres have been built throughout; the road network has been improved greatly and more than 11 small factories for processing coffee have been constructed now employing several hundred workers.

The sale of coffee is regulated by the International Coffee Agreement (ICA). It does this by establishment of quotas which are determined by historical and, to some extent, political factors. The quota system means that the poorest quality and cheapest coffees will not find their way to the market. Hence, the only chance for the Kenyan coffee and Matungulu at that, is to ensure high quality is produced. This is done with increased effort, efficiency and capital.

The problem of restricting production as noted by Clark (1967: 171-172) is "how to get coffee growers from increasing their production beyond those quantities which can be sold in quota, non-quota and small domestic markets, and indeed how to get growers to cut back their production to the level of prospective sales. From the point of view of the National economy, one obviously wishes to prevent growers from going into production or to put those growers out of production who are likely to make little money out of coffee growing anyway, either because their costs are high or because they are producing coffee which has a low sales value."

In an effort to arrive at a predictive model for small-scale coffee production, a step-wise regression model using physical, and socio-economic variables was tested. The analysis revealed low association between physical parameters and coffee yields on the one hand, and high association between socio-economic factors and coffee yields on the other hand. 73.1 percent and 76.1 percent of the variation on small-holder coffee yields for 1978 and 1979 respectively, could be explained by two variables viz Income and Investment.

This could be contrasted with a study carried out by Williams, Joynt and McCormick (1975) using the same

model for the macro-scale analyses of Canadian Prairie crop district cereal yields in relation to weather, soil, and trend. They found that between 57 to 86 percent of the yield variation could be explained by physical parameters such as precipitation, potential evaporation, topography and trend terms.

Two observations can be made in relation to the above mentioned studies. Firstly, the low association between physical and coffee yields in the current study may be due to the fact that this area has relatively uniform factors such as coffee soils and rainfall. The much greater variation in socio-economic factors such as the farm income, investment and educational status of the farmer and his family may be the contributory factor to the close association between these socio-economic variables and coffee yields. Secondly, there is a great variation in physical factors but little variation in farmers education, income and investment. In short, Matungulu is an example of physically homogeneous and socio-economic diverse environment, whereas, the Canadian Prairie is the opposite.

In conclusion, then, this study has shown that, the Matungulu area of Machakos has good physical potential for coffee production; and that most of the variation in

coffee yields can be related to socio-economic, rather than physical,variables. The major restrictions on coffee yields are inadequate agronomic practices and extension advice; lack of credit and investment; labour shortages at critical times and a poor transportation network. Although benefits from the cash crop are obvious to the area, the widespread displacement of food crops by coffee has led to food shortages in the area, and policies should be introduced to ensure that a significant part of each farm (1/3) remains under food crops. This will improve the self-sufficiency of Matungulu and reduce its dependence on the fluctuations in the international coffee prices.

A-1: QUESTIONNAIRE

COFFEE PRODUCTION SURVEY 1979/80
MATUNGULU LOCATION

FARMSTEAD MEMBERS:

Enumerate members of this farmstead as follows (note): exclude married daughters, but include son's wives if living on the farmstead).

01 NAME OF RESPONDENT _____

02 Relationship to head of household:-

0 head of household	
1 wife	
2 brother/sister	
3 uncle/aunt	
4 father/mother	
5 child	
6 grandchild	
03 Head of Household age	
sex (1male;2female)	
occupation _____	
04 Wives aged 16-25 (number	
26-45 (")	
over 46 (")	
05 Male children aged 10-20	
Female " " 10-20	
06 Male adults aged 21-50	
Female " aged 21-50	
All adults over 50	

C EDUCATIONAL STATUS OF FAMILY:

State the educational level of the members of this family and the total number at each level:-

	Head of Household	Other Members	Total
Never went to school			
Lower Primary			
Upper Primary			
K.C.E.			
K.A.C.E.			
Other (specify)			

D EXTENSION SERVICE :

08 Have you ever attended Farmers' training centre? (1 YES:2 NO) [ ] YES [ ] NO

b. Do you think the course(s) offered there were useful in the improvement of your coffee? (1 YES; 2 NO)

[ ] YES [ ] NO

09 How do you get information on Coffee farming?

0 radio [ ]
1 press [ ]
2 co-operative society [ ]
3 meetings(Barazas of chief etc. [ ]
4 neighbours [ ]
5 extension staff [ ]

b. How often does the extension officer pay a visit to your farm? (insert number of times in the box provided below)

[ ] never visited
[ ] times per week
[ ] times per month
[ ] times per year

c. Are you satisfied with the services rendered to you by the extension officers? (1 YES; 2 NO)

[ ] YES skip to 10

[ ] NO proceed to 09 (d)

d. Why are you not satisfied with the services rendered to you by the extension officers? (state the reason)

e. In which way can the extension service be imroved? (suggest)_____

_____

10 Have you ever received information from the extension officers on the following (1 YES; 0 NO)

	YES	NO
1. plant density		
2. spacing		
3. prunning		
4. mulching		
5. weed control		
6. diseases/pest control		
7. spraying times		
8. manure/fertilizer application		
9. planting time		
10. irrigation		

11 If so, do you follow these recommendations? (1 YES; 0 NO)

[ ] YES skip to Part E [ ] NO proceed to 12

12 Why didn't you follow the recommendations given to you by the extension officers? (state the reason)_____

E ENVIRONMENTAL PERCEPTION OF FARMER

13 Which of the following physical, biotic and socio-economic factors do you consider critical for coffee production? (2 for Very Important; 1 for Important; 0 for Less Important)

	VERY IMPORTANT	IMPORTANT	LESS IMPORTANT
1. rainfall (mbua)			
2. temperature (uvyuvu)			
3. soil quality (muthemba wa muthanga)			
4. sunshine (syua)			
5. weeds control (iia)			
6. diseas/pest control (mowau ma kaawa)			
7. mulching (kwikia kaawa mavuti)			
8. pruning (kusea-mukasi/ kutila na musumeno)			
9. shading (muunyi)			
10. fertilizer/manure (mbolea)			
11. irrigation (kunyithya kaawa)			
12. labour force (atethya ma wia)			
13. working capital mbesa sya ukunithya wia)			
14. distance from coffee plot to factory			
15. distance from home to coffee plot(s)			
16. access to extension staff			
17. farm size (unene wa muunda)			
18. land tenure (kwithiwa na watho iulu wa muunda/kitheka)			
19. co-operative societies			
20. other (specify)			

14 Have you detected any of the following pests/ diseases in your coffee? (1 YES; 0 NO)

	YES	NO
1. Coffee Berry Disease (CBD) (uwau wa mbindi)		
2. leaf rust (nganga)		
3. leaf skeletonizer/leaf miner (itu kwikala kisingi itina wa langi ila ya ngilini yauma)		
4. elgon die back (kuma kwa mbonge kuma mithyani)		
5. thrips (mbangule)		
6. green scales (nyua)		
7. other (specify) _____		

15 Are any of the following weeds in your farm? (1 YES; 0 NO)

	YES	NO
1. oxalis		
2. macdonald weed (kang'ei)		
3. black jack (munzee)		
4. cough grass (kithangai)		
5. stargrass (ikoka)		
6. mexican marigold (muvangi)		
7. watergrass (mbiu)		
8. datura stramonium (muvongolo)		
9. wandering jew (mukengesya)		
10. pigweed (w'oa)		
11. seteria verticillata (kiamata)		
12. other (specify) _____		

b. Which of the above weed(s) do you consider a serious threat to your coffee plants? Insert the number of the weed in the box provided here):

[ ] [ ] [ ] [ ] [ ]

c. Which of the weed(s) in number 15(a) is an indication or sign of fertile soil (insert the number(s) against the weed(s) in the box(es) provided here:-

[ ] [ ] [ ] [ ]

16a. Do you mulch your coffee? (1 YES; 0 NO)

[ ] YES [ ] NO

skip to 17 proceed to 16(b)

b. State the reason(s) for not mulching your coffee_____

_____

17. Do you have difficulties in obtaining the following agricultural inputs? (1 YES; 0 NO)

	YES	NO
fertilizers		
farm manure		
credit (mikovo)		
labour		
transport of cherry to factory		
fungicide/pestcides		
other (specify) _____		

18a. Are you satisfied by the services rendered to you by the Co-operative Society? (1 YES; 0 NO)

[ ] YES [ ] NO

skip to Part F proceed to 18(b)

b. Why are you not satisfied by the services rendered to you by the Co-operative Society? (state the reason)_____

_____

c. How can the services of the Co-operative Society be improved? (describe)_____

F LAND TENURE

19a. What is the size of this farm? (Ha./ac.) _____

b. What is the size of your coffee farm?_____

c. State the type of landtenure (1 YES; 0 NO)

	YES	NO
individual (kitheka/ muunda wa mwene)		
communal (muunda/ kitheka kya kumeanisya; kya Utui; kana mbai)		
freehold		
leasehold (kukomboa)		
tenancy (kutuw'a)		
other (specify)_____		

20a. Does this farm have registered title?
(1 YES; 0 NO)

[ ] YES [ ] NO

skip to 20(c) proceed to 20(b)

b. If the farm title is missing, what is the status of your farm? (1 YES; 0 NO)

	YES	NO
not yet surveyed		
recently surveyed		
in dispute		
surveyed and demarcated		
other (specify)_____		

c. If the farm is fragmented, state the number of fragments [ ]

d. How far is the farthest fragment from the farmstead?

[ ] km.

e. Is any of the fragments under coffee?
(1 YES; 0 NO)

[ ] YES [ ] NO

N.B. In numbers 21-25, place a tick ( ) against the correct answer.

21. Why did you plant coffee? Because:-

- coffee is the highest cash-income earner [ ]

my neighbour/friend/relative etc.told me to plant coffee

other (specify) _____

22. What proportion of the total land is under coffee?

less than a quarter (1-25%)

half 50%

more than three-quarters (over 76%)

23. What proportion of the total land is devoted to foodcrops?

very small (0-5%)

less than a quarter (6-20%)

half (50%)

more than a half (51-74%)

More than three quarters (76%)

24. How old are your coffee trees?

under 1 year

3-5 years

6-10 years

11-20 years

Over 21 years

G LABOUR REQUIREMENTS

25a. What is the status of this farmer? (1 YES; 0 NO)

	YES	NO
full time farmer		
part-time farmer		
absentee-farmer		

b. Other occupation (place a tick against the correct answer)

	YES	NO
business		
teaching		
other (specify) _____		

In number 26 give 1 point for YES; 0 point for NO)

26a. Is the head of the household normally away?

☐ YES ☐ NO

proceed to 26(b) skip to 26(c) and (d)

b. If the head of household is normally away who manages the farm?

farmer's wife/husband ☐
other wife/wives ☐
relative ☐
other (specify) _____ ☐

c. Are any members of this farmstead apart from the head of household normally away?

☐ YES ☐ NO

proceed to 27

d. Enumerate farmstead members normally away as follows (note: exclude married daughters)

A	B	C	D	E
number	sex	relation to head	location of residence (name of place)	reason for absence
	1 M 2 F	(A)		(B)

M= male F= Female

(1) relation to head of household

0 head of household
1 wife
2 brother/sister
3 uncle/aunt
4 father/mother
5 child

A	B	C	D	E

(11) reasons for absence

1 formal education
2 other training
3 wage employment
4 job seeking (urban-centre)
5 military

	A	B	C	D	E	
6 niece/nephew						6 other(specify)
7 grandchild						
Total						

27. What is the source of labour for the following farm activities? (place a tick ( ) against the appropriate answer)

	family	casual	other (specify)	month of operation
1. land preparation				
2. planting				
3. weeding				
4. spraying				
5. picking				
6. delivery of cherry to the factory				

In number 28, where possible 1 point for YES; 0 point for NO).

28. Do you experience labour shortage in your coffee farm?

[ ] YES [ ] NO

b. What is the cause of this shortage? (state)

c. Do school children under 15 assist you in farm activities?

[ ] YES [ ] NO

skip to Part H

d. Which of the farm activities mentioned in number 27 do school children perform? (insert the number of activity in the boxes below:-

[ ] [ ] [ ] [ ]

H SOIL STATUS OF THE FARM

29a. Are there signs of soil erosion in your farm?

[ ] YES [ ] NO

skip to 30

b. Estimate the degree of severity: (place a tick ( ) against the correct answer)

Section of farm	absent	minor	moderate	severe
coffee plot(s)				
foodcrops				
pastures				
other(specify)				

30. Are the following measures of soil conservation present in your coffee plot? (1 YES; 0 NO)

	YES	NO
terracing		
contour furrowing		
gulley control		
manuring		
mulching		
trash lines		

31a. What is the nutrient status of your soil? (muthanga wa muunda waku wiona uilyi ata? (1 YES; 0 NO)

	YES	NO
fertile (munou)		
fertility slowly declining (unou nuendee na uthela)		
infertile (mumosu)		

b. What do you consider to be the cause of the change in fertility of your soil?

(state)_____

32. What proportion of the total farm is under forest/woodland?

nothing (0%)	
less than a quarter (5-24%)	
half (50%)	
more than a half (over 50%)	

I FOOD STATUS HOUSEHOLD

33a. Was the food from this farmstead sufficient to feed all resident members in the last season?

☐ YES ☐ NO

skip to Part J — proceed to 33 b. and c.

b. Which of the following statements explain the cause of the deficiency in food?

acreage under foodcrop is comperatively small	
lack of sufficient rainfall	
inadequate off-farm income	

c. If the food was not sufficient, what are the sources of additional supplies? (1 YES; 0 NO)

	YES	NO
purchased at the market using off-farm income		
purchased at the market using money from coffee earnings		
gift from relative/friend		
other (specify)		

J FARM INCOME AND EXPENDITURE

34a. Was any off-farm income earned by the members of this farmstead last season (i.e."long rains" April through October 1979)?

☐ YES ☐ NO

skip to 35

b. What was the source of this off-farm income? (place a tick ( ) against the correct response)

business
urban employment
rural employment
other (specify) _____

c. How often is this off-farm income earned? (place a tick ( ) against the correct response)

monthly
every season
irregularly
almost never

d. How much was this off-farm income in Kenya shillings? [ ]

35. How was the coffee income spent?

	Item	Amount in KSh.
1.	seed	
2.	fertilizer/chemicals	
3.	food	
4.	labourers working in the farm	
5.	school fees	
6.	clothing	
7.	household items	
8.	building	
9.	purchase of car/matatu etc.	
10.	other (specify)	

In numbers 36 and 37 put a tick ( ) against the appropriate answer:-

36. How many coffee trees do you have in your farm?_____

37. How many kilograms of cherry did you harvest in 1979?_____kg.

38. How much money did you earn from coffee in the years 1978 and 1979 respectively?
In 1978-------Shs. and in 1979 -------Shs.

39. Did you apply manure on your coffee farm?

[ ] YES [ ] NO

Go to 42(b).

b. What was the cost of manure plus the transportation cost? Shs.----------

40. Did you apply fertilizer on your coffee farm?

[ ] YES [ ] NO

Go to 43(b) and 43(c)

b. What type of fertilizer did you apply _____

c. How many bags of fertilizer did you use _____bags and what was the cost of each bag?_____Shs.

41. Did you apply any pesticides, fungicides or herbicides on your coffee farm?

[ ] YES [ ] NO

Go to 44(b)

b. What was the total cost for the items mentioned in 44(b) used in plant protection?
_____Shs. (i.e. in 1979).

42. How many days did it take either your family or hired (casual) labour to complete each of the following farm operations?

	PERIOD AND COST		
	Family labour(F)	Hired labour(H)	
	Days	Days	Cost in Shs.
1. Land preparation			
2. Planting			
3. Weeding and decoughing			
4. Prunning			
5. Mulching and erosion control			
6. Spraying			
7. Harvesting			
8. Other			

43. How much did it cost you to transport your coffee to the factory? _____Shs.

44. If you took a loan from your co-operative society; how much money was deducted from your Gross earning of 1979 towards recovery of the loan?

45. What is your opinion of this respondent?

1. very cooperative
2. cooperative
3. somewhat cooperative
4. uncooperative

46. On understanding of the questions?

1. excellent
2. good
3. fair
4. poor

Introduction To Appendices:

The aim of this section is to provide guideline information for easy understanding of the correlation matrices and raw data matrix which follow in the next page. Inorder to understand the correlation matrices the following table B-1, which shows the 15 variables considered to influence smallholder coffee production in the study area, is provided.

Variable Number	Variable's Full Name	Variable's Abbreviated Name
1	Coffee Yield	YD
2	Altitude (m)	ALT
3	Top Soil pH	pHT
4	Sub-Soil pH	pHS
5	Potassium	K
6	Top Soil Calcium	CaT
7	Carbon	C
8	Cation Exchange Capacity	CEC
9	Tree Number	TR
10	Income	INC
11	Investment	INV
12	Farm Size	FS
13	Distance From Factory	DF
14	Topography	Tp
15	% Total Farm Under Coffee	CF

B-1 Table showing the variables considered to influe
coffee production.

In the case of the raw data matrix C-3 the first figure 212.00 is the yield of the first farmer (F1). By reading across the page, the yield figure is followed by altitude of the farm above the sea level; pH of both top and sub soils; Potassium, Calcium and Carbon contents of the soil; Cation Exchange Capacity of the soil; number of coffee trees in the farm; Income; investment; farm size; distance of the farm from the coffee factory; nature of topography and the proportion of the farm under coffee. In short, these three lines of F 1 contain the information of the first farmer. The same procedure is followed in the case of the second farmer (F 2) and, indeed all other farmers, where the three lines in each case, contain the information of the farmer in question.

C-1: CORRELATION MATRIX OF 15 VARIABLES BASED ON RAW DATA:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	0.170	0.141	0.069	0.104	0.034	0.014	-0.015	0.616	0.774	0.391	-0.122	-0.078	0.001
2		1.000	0.895	0.829	0.376	0.392	0.196	0.057	0.168	0.143	0.391	0.037	0.396	0.123
3			1.000	0.947	0.593	0.453	0.384	0.252	0.089	-0.007	0.303	0.108	0.383	0.310
4				1.000	0.664	0.522	0.325	0.197	-0.063	-0.127	0.330	0.191	0.435	0.258
5					1.000	0.639	0.462	0.386	0.086	-0.037	0.068	0.120	0.610	0.399
6						1.000	0.053	-0.182	-0.170	-0.067	0.091	0.340	0.321	-0.168
7							1.000	0.908	0.391	0.001	-0.222	0.308	0.067	0.904
8								1.000	0.367	-0.071	-0.226	-0.054	0.133	0.994
9									1.000	0.878	-0.198	-0.103	0.005	0.350
10										1.000	0.034	-0.077	-0.069	-0.082
11											1.000	-0.152	-0.077	-0.168
12												1.000	-0.246	-0.071
13													1.000	0.153
14														1.000
15														

*Any correlation coefficient > 0.306 is significant at 0.05 level.

C-2: CORRELATION MATRIX OF 15 VARIABLES BASED ON TRANSFORMED DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.000	0.726	0.568	0.573	0.081	0.386	-0.417	-0.541	-0.198	0.133	0.643	-0.007	0.167	-0.293	-0.536
2		1.000	0.911	0.842	0.368	0.369	0.189	0.58	0.115	0.072	0.313	0.038	0.379	0.186	0.055
3			1.000	0.950	0.585	0.508	0.403	0.267	0.076	-0.052	0.309	0.119	0.367	0.305	0.255
4				1.000	0.648	0.577	0.339	0.204	-0.054	-0.136	0.331	0.196	0.434	0.288	0.204
5					1.000	0.685	0.476	0.392	0.158	0.034	0.096	0.128	0.606	0.202	0.354
6						1.000	0.046	-0.180	-0.247	-0.128	0.126	0.341	0.362	-0.100	-0.188
7							1.000	0.910	0.429	-0.013	-0.207	0.310	0.070	0.662	0.896
8								1.000	0.437	-0.057	-0.216	-0.054	0.139	0.745	0.989
9									1.000	0.840	-0.184	-0.095	-0.041	0.267	0.419
10										1.000	0.094	-0.063	-0.139	-0.100	-0.067
11											1.000	-0.143	-0.059	-0.053	-0.197
12												1.000	-0.240	-0.082	-0.047
13													1.000	-0.024	0.093
14														1.000	0.831
15															1.000

*Any correlation coefficient > 0.306 is significant at 0.05 level.

	21.200	600.000	219.120	764.119	0.500	1.200	3.000
	45.500						
F2	15000.000	1480.000	3.900	3.400	0.590	3.000	1.650
	33.600	10500.000	35000.000	938.629	7.500	0.500	1.000
	41.700						
F3	152.000	1490.000	4.300	4.400	0.450	0.800	0.340
	11.400	300.000	495.629	1982.829	0.300	0.200	2.000
	42.900						
F4	476.000	1486.000	5.200	5.700	0.430	2.100	0.840
	8.700	270.000	1547.000	2485.000	0.200	1.000	2.000
	40.000						
F5	233.000	1450.000	5.000	5.100	0.520	3.200	1.050
	14.800	300.000	757.269	1300.000	0.200	1.000	3.000
	33.300						
F6	1092.500	1485.000	4.400	4.600	0.380	0.800	0.950
	11.800	630.000	2040.500	1554.000	0.500	1.100	3.000
	41.700						
F7	153.500	1487.000	4.700	5.700	0.500	1.400	0.400
	11.800	300.000	478.879	997.500	0.200	1.800	3.000
	33.300						
F8	1039.000	1520.000	5.000	4.700	0.630	2.600	1.050
	13.700	3002.000	2701.399	119.560	2.300	2.000	2.000
	41.000						
F9	447.500	1720.000	4.400	4.500	0.340	0.800	1.590
	10.300	300.000	1418.569	1880.299	0.200	1.500	3.000
	33.300						
F10	402.000	1700.000	5.300	6.100	0.300	4.200	0.820
	10.100	304.000	105.000	1637.749	0.200	0.250	3.000
	33.300						
F11	356.000	1600.000	5.000	4.700	0.430	1.400	2.350
	17.600	500.000	1128.519	1246.249	0.400	2.000	3.000
	33.300						
F12	574.500	1740.000	5.700	5.200	0.740	6.700	2.350
	22.800	740.000	1825.879	1514.899	0.500	1.500	3.000
	35.700						
F13	856.500	1520.000	5.000	4.500	0.340	2.100	0.950
	5.400	260.000	3034.370	2945.250	0.200	1.200	2.000
	40.000						
F14	1567.500	1480.000	6.500	6.600	0.890	0.690	0.890
	11.400	700.000	4232.242	1134.000	0.500	2.000	2.000
	38.500						
F15	34.000	1540.000	4.600	4.600	0.530	2.000	0.780
	11.500	480.000	88.400	655.000	0.400	3.000	1.000
	44.400						
F16	141.500	1500.000	4.900	5.100	0.960	4.600	1.370
	16.500	600.000	4610.131	513.739	0.500	1.500	3.000
	54.500						
F17	6309.000	1700.000	5.200	4.800	0.540	4.600	1.940
	14.700	7000.000	16087.941	952.729	5.300	1.800	3.000
	40.800						
F18	308.000	1620.000	4.900	4.900	0.360	0.500	1.060
	10.000	1000.000	1001.000	174.370	0.800	1.000	3.000
	42.100						
F19	84.280	1520.000	6.100	6.000	1.400	8.100	1.200
	14.800	900.000	388.369	267.139	0.700	1.500	2.000
	41.200						
F20	61.000	1480.000	5.200	5.800	0.530	4.200	1.090
	15.200	200.000	155.550	1425.000	0.200	2.000	3.000
	50.000						
F21	184.000	1510.000	4.800	4.800	0.360	2.000	0.920
	9.000	400.000	598.000	623.329	0.300	3.000	2.000
	42.900						
F22	184.000	1510.000	4.800	4.800	0.360	2.000	0.920
	9.000	400.000	598.000	623.330	0.300	1.300	2.000
	42.900						
F23	119.500	1520.000	5.400	5.200	0.890	6.300	1.310
	19.000	550.000	388.369	586.249	0.400	1.200	2.000
	40.000						
F24	14089.695	1440.000	5.900	6.800	1.640	7.100	1.400
	9.800	900.000	10776.293	4180.000	0.300	1.500	3.000
	42.900						
F25	4438.293	1522.000	5.100	5.200	0.570	1.800	0.400
	6.000	400.000	4327.000	3400.000	0.300	1.750	2.000
	42.900						
F26	2139.299	1510.000	5.400	6.400	1.560	7.300	1.020
	11.400	900.000	4668.867	902.200	0.700	2.000	3.000
	41.200						
F27	1133.000	1560.000	4.800	5.700	0.720	5.600	1.100
	13.600	700.000	1444.579	1160.000	0.500	2.250	2.000
	38.500						
F28	1542.500	1520.000	5.300	6.400	1.120	4.600	1.000
	14.400	200.000	1002.619	1612.000	0.200	3.500	3.000
	50.000						
F29	1085.000	1490.000	5.600	6.700	1.080	4.900	1.100
	14.800	295.000	711.549	1960.239	0.200	1.000	2.000
	33.300						
F30	113.300	1500.000	4.500	5.400	1.560	7.100	0.700
	9.600	400.000	88.400	1350.000	0.300	4.500	1.000

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DO YOU WISH TO PRINT THE TABLE OF RESIDUALS
?
yes

CASE NO	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD.RESID.
1	212.000	591.283	-379.283	-0.272
2	15000.000	15301.816	-301.816	-0.217
3	152.000	251.538	-99.538	-0.072
4	476.000	1759.203	-1283.203	-0.922
5	233.000	245.667	-12.667	-0.009
6	1092.500	1312.973	-220.473	-0.158
7	153.500	-125.369	278.869	0.200
8	1039.000	-731.023	1770.023	1.272
9	447.500	614.666	-167.166	-0.120
10	402.000	416.359	-14.359	-0.010
11	356.000	732.410	-376.410	-0.270
12	574.500	348.999	225.501	0.162
13	856.500	2895.907	-2039.407	-1.465
14	1567.500	2153.447	-585.947	-0.421
15	34.000	-1056.391	1090.391	0.783
16	141.500	1540.805	-1399.305	-1.005
17	6309.000	6584.652	-275.652	-0.198
18	308.000	-969.942	1277.942	0.918
19	84.280	300.127	-215.847	-0.155
20	61.000	110.851	-49.851	-0.036
21	184.000	193.576	-9.576	-0.007
22	184.000	-1334.385	1518.385	1.091
23	119.500	-438.070	557.570	0.401
24	14089.695	10921.715	3167.980	2.276
25	4438.293	4437.703	0.590	0.000
26	2139.299	3988.964	-1849.665	-1.329
27	1133.000	404.353	728.647	0.524
28	1542.500	1518.110	24.390	0.018
29	1085.000	2041.754	-956.754	-0.687
30	113.300	703.693	-590.393	-0.424
~~31~~	~~10.000~~	~~-158.780~~	~~168.780~~	~~0.121~~
32	808.000	791.804	16.196	0.012

D-1 : Table showing residuals

D-2 Table showing elementary statistics

VARIABLE	MEAN	STD.DEV.	STD. ERROR	MAXIMUM	MINIMUM	RANGE
1	3392.925	4735.379	928.684	17673.000	122.000	17551.000
2	1415.308	424.917	83.333	1740.000	0.0	1740.000
3	4.788	1.533	0.301	6.500	0.0	6.500
4	5.085	1.724	0.338	6.800	0.0	6.800
5	0.721	0.474	0.093	1.640	0.0	1.640
6	3.511	2.685	0.527	8.000	0.0	8.000
7	1.582	2.209	0.433	11.400	0.0	11.400
8	37.704	135.202	26.515	700.000	0.0	700.000
9	1320.624	2440.452	478.612	10000.000	0.0	10000.000
10	7905.000	10675.125	3662.493	80000.000	0.0	80000.000
11	1022.675	925.796	181.563	4000.000	0.0	4000.000
12	54.810	274.371	53.809	1400.000	0.0	1400.000
13	1.415	1.011	0.198	4.500	0.0	4.500
14	3.519	7.192	1.411	38.500	0.0	38.500
15	713.744	3459.046	678.375	17673.000	0.0	17673.000

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