ENVIRONMENTAL PROBLEMS OF SMALLHOLDER SUGARCANE PRODUCTION IN THE NYANZA SUGAR BELT

BY

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A thesis submitted in part fulfilment for the Degree of Master of Science in the University of Nairobi

1976

DECLARATION

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

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This thesis has been submitted for examination with my approval as the University supervisor

PROF. R.S. ODINGO
(University Supervisor)

CONVERSIONS

1 Hectare (Ha)	=	2.471 acres
1 Metre	=	3.281 feet
1 Kilometre	=	0.62 miles
1 Inch	=	25.4 millimetres
1 Long ton	=	1.016 metric tons
1^{o} Centigrade	=	1.8^{o} Fahrenheit
K£1	=	K.Shs. 20/-

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ABSTRACT

Due to a variety of favourable environmental factors, Commercial Sugarcane development projects are centred in the Coastal, Western and Nyanza Provinces of Kenya. However, previous plans for sugarcane production expansion based on opening virgin lands have not materialised because imports of sugar are still running high, more than 80,000 metric tons in 1975. Like most other commodities, world market prices have undergone marked swings in 1973/74, resulting in a difficulty to project sugar production and consumption patterns within a reasonable degree of error. In view of this problem, the current Kenya Development Plan focuses on self-sufficiency with an export rather than an import overlap. To achieve this goal, agrarian reform, to tackle the stumbling block of land holding and tenure patterns, is suggested to be the sine qua non of economic development, the precondition for increasing sugar production, improving income distribution, facilitating employment opportunities and reversing rural to urban migration in the Nyanza Sugar Belt. The area has a total of over 32.44 thousand hectares of cane. Kenya relies more on the Sugar Belt which supplied 97,747 metric tons (59.5% of the total production in Kenya) of sugar in 1974. But the present expansion of sugarcane well into marginal lands in the belt is doomed to failure unless solutions are found to alleviate environmental problems limiting sugarcane growing and production. This thesis is an account of the environmental problems affecting smallholder sugarcane production. It indicates that a gap exists in the literature between cane growing in Kenya and other Countries. Needless to say, the increase of sugarcane production in the future will largely depend on contribution

from the "traditional farmers" in the Sugar Belt.

The survey revealed that sugar production in the area is being hampered by the vagaries of weather, diseases, pests and weeds alike, although the actual spatial distribution and yield of the crop will depend on a farmer's willingness and ability to ameliorate environmental limitations. Rainfall is a limiting factor in sugar production, but the availability of moisture to cane depends on its amount and timing as well as on texture, structure and organic matter content of the soil. A positive relationship ($r=0.670$) has been observed between cane growth rate and monthly rainfall. The probability of obtaining a rainfall of 1500mm or more per annum is 27% at Miwani and 17% at Kibos. Rainfall unreliability in the area calls for timeliness in land preparation, planting, weeding, top-dressing and harvesting cane, while irrigation is a prerequisite in areas where optimum rainfall required for cane growth cannot be obtained. Temperature and radiation are not limiting factors in cane growth and production, but sometimes the losses caused by biotic agents in afflicted areas lead to abandonment of cane fields. Environmental problems such as these will inevitably lead to a decline in sugar yield unless technological innovations are used by peasants. In reality the Sugar Belt is not an area of "milk and honey" where an easy livelihood can be derived without real effort. Analysis of soil samples revealed that 90% of the sugar plots are particularly deficient in nitrogen which is indispensable to sugarcane. Phosphorus and sugar yield are insignificantly correlated ($r = -0.1240$), while there is little relationship (r =0.2418) between cane yield and potassium. Simple correlation between sugar and nitrogen shows a positively high significant linear relationship (r=0.9642) at 99% level of probability. Similarly, partial correlation between sugar and nigrogen holding phosphorus and potassium constant reveals a higher significant relationship (r=0.9648) at 99% level of probability. The principal determinant influencing the spatial variation in sugarcane productivity is nitrogen. It is clear from this thesis that substantial nitrogenous fertilizer in the form of Ammonia Sulphate Nitrate would be needed to boost sugar yields in the absence of intercropping with leguminous crops and animal manure, which has become a scarce commodity with the decline of cattle population in the area.

One of the greatest problems is cane fire which has become a widespread human ecological factor in the Sugar Belt. Malicious burning of cane in the area resulted into a loss of 9,000 metric tons of cane in 1973. A significant correlation (r=8273) exists between increasing illegal cane burning and increasing cane prices. Furthermore, a test was run to depict the relationship between net payment and amount of cane sold. The correlation coefficient (r=0.8539) between these two variables was significant at 99% level of probability. Hence, net payment to the farmer is a limiting factor in cane production. Another cause of cane shortage is attributed to the diversion of cane from the white sugar zones to jaggery factories. Although the Sugar Belt is accessible to "islands" of heavy population concentration, labour is a limiting factor, partly because peasants face acute competition from large-scale farmers in terms of labour. Farmers are further confronted with a host of socio-economic problems arising from the farmers' perception of environmental limitations to sugar production, illiteracy, religious taboos, absenteeism, lack of title deeds and inadequate credit schemes. In addition, demographic characteristics of the farmers, incomplete migration of family to the sugar farm in the settlement schemes, land use competition inexperience of the farmer in sugar industry and lack of extension services present further problems. The thesis has examined and established the impact of the environmental limitations on peasant sugar production as well as giving recommendations for policy planners and suggestions for further research lines. There is urgent need for more direction and encouragement of sugar production by the government because there can be no progress or expansion without financial incentives. In the absence of government intervention there are likely to be shortfalls in sugarcane production.

PREFACE

Recent studies conducted in the Nyanza Sugar Belt area by scholars from various disciplines sparked my interest in the problems of smallholder sugarcane production. Naturally the core of this interest was based on the limitations imposed by the physical environment on sugarcane production. Thus pedological, climatic, and biotic factors determine the adaption and yield of sugarcane as well as setting the ecological limitations to its distribution. To these factors we must add the human resources, because agriculture is essentially a human activity involving human effort, judgement and ingenuity.

A detailed study was a prerequisite, if the relevant questions on the problems of smallholder sugarcane production were to be answered and this was carried out by the author from August 1975 to January 1976. During this period detailed fieldwork was carried out, which include interviewing 300 sugarcane growers who were members of cooperative societies in the area. Secondly, samples of soils drilled to a depth of 0-30 cms. were collected from 60 different sites of sugarcane cultivated plots. The location of the societies, rainfall, lack of communications, finance and time presented a problem. There is now a general incentive to grow sugarcane because of the recent increase in the price paid to growers of cane. In spite of this new demand condition the physical, economic and cultural factors will still remain an obstacle to sugarcane production. This research should be regarded as a case study, partly limited in scope because of the time and financial considerations but providing an opportunity for the assessment of the environmental problems that are affecting smallholder sugarcane

production with recommendations for appropriate policy-planners and decision-makers.

The field investigations upon which this thesis is based was made possible by a University of Nairobi Scholarship for Post-Graduate study leading to M.Sc. degree in the Faculty of Science in the Department of Geography at the University of Nairobi. Much information was obtained from the University Library, the Institute for Development Studies and the Ministry of Agriculture libraries, while the Department of Geography provided facilities for soil sampling, processing and analysis of data.

As is typical of any field survey, numerous people rendered assistance at one stage or another. My special thanks go to Mr. S.B. Obura, Senior Sugar Research Officer and Mr. G.J.A. Okullo, agronomist, who were useful in providing invaluable information on the technical aspects of sugarcane production. I gratefully acknowledge the cooperation accorded me by the Senior Soil Chemist, Mr. G. Hinga and Mr. J. Mbogo, entomologist at the National Agricultural Laboratories, Kabete, who were instrumental in getting the soil sample analysis underway.

Both Dr. P. Mbuvi of the Ministry of Agriculture and Dr. A.G. Ferguson, Department of Geography, ignited my interest in composite soil sampling and quantitative analysis in studies involving sugarcane respectively. Mr. D.I. Drayton, Agricultural Manager and Mr. T. Oyieke, a cooperative farm trainee with Friedrich Ebert Stiftung at Sugar Belt Cooperative Union provided useful information on problems of sugarcane extension in the area. Several persons, especially Mr. E. Kabongo, cane harvesting officer at Chemelil, and Mr. W.G. Obadha, agronomist at Kibos, gave freely of their scarce time to provide background information.

I gratefully acknowledge all the assistance I have received from the University of Nairobi. Mrs. J.W. Harmsworth of the Institute for Development Studies and Miss E.W. Muiruri, lecturer in the Department of Geography, through personal conversations, assisted me to clarify some of my own thoughts about this thesis. My deepest gratitude goes to many members of the Department of Geography, particularly Prof. S.H. Ominde who followed the progress of this study very closely with his encouragement and suggestions. I owe great debt of gratitude to my supervisor, Professor R.S. Odingo whose generosity, unfailing confidence in me, dedication and determination provided greatly appreciated stimulation, advice and guidance on this thesis. The author wishes to express his thanks to Miss J.A. Miduda, Mr. de Souza and Mr. S. Mbugua for their assistance in cartography, while Mrs. M. Nyawande and Mrs. C.M. Mumo helped in typing the manuscript. I acknowledge with greatest concern the assistance and encouragement by my brother, Mr. Danish Obara.

This preface would be incomplete without thanking the 300 smallholders who kindly provided part of the raw data on which this thesis was based. The information they provided will assist in some way in furthering our understanding of the problems of sugarcane production in the study area as well as in Kenya as a whole.

I am very thankful to my wife and two daughters who provided me with a sound, stable and harmonious atmosphere. I wish to express my gratitude to many colleagues who painstakingly read and criticized my manuscript. Any errors that escaped their notice or I failed to correct are my own responsibility. Despite my fairly sanguine point of view, I am wholly responsible for any discrepancies and shortcomings in this thesis.

CHAPTER I

INTRODUCTION

INTRODUCTION

THE STUDY AREA

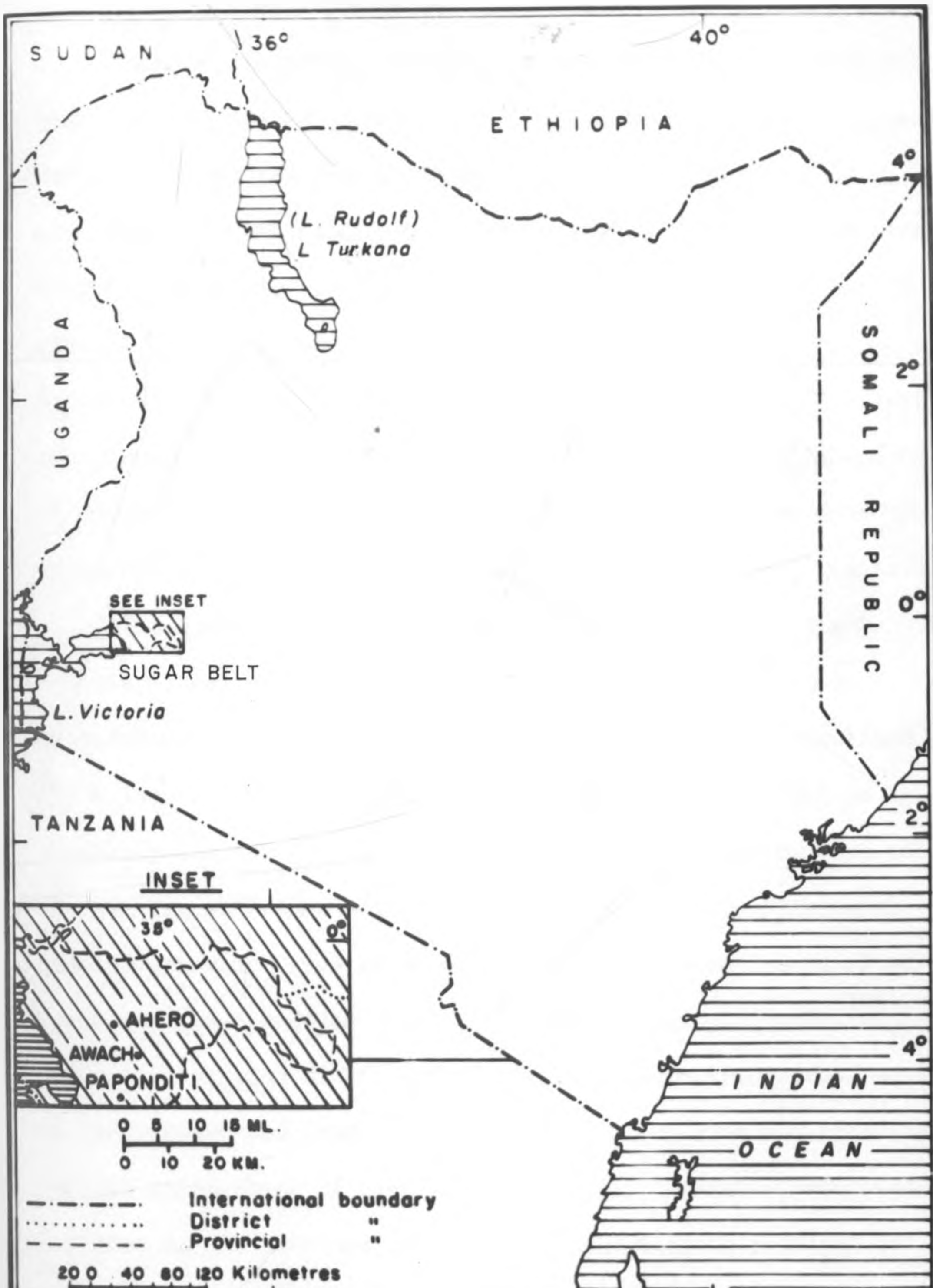
Location and extent of the study area

The Nyanza Sugar Belt falls in the Lake Victoria ecological zone of Kenya (Fig. 1). The belt constitutes the major part of Kano plains and the contiguous foothills and valleys of Nyando escarpment in the north. From the escarpment sugarcane plantations are superseded by the tea estates, indicating that ecological elements are unfavourable for the former crop.

The Southern part which occupies the largest proportion of the area is in Kisumu district of Nyanza Province, while the northern as well as the eastern portions fall within the domain of the Nandi and Kericho districts of the Rift Valley Province.

Suitability of the study area

The significance of the Nyanza Sugar Belt for the study of agricultural geography is seen in the context of the diversified environment which is a product of tectonic and ecological processes. It has natural endowments evident in the soil conditions, temperature and rainfall distribution unknown in other sugarcane growing areas of Kenya. This latter statement is partly supported by the failure of sugarcane trials in Donyo-Sabuk and Kiambu districts, whereas the Sugar Belt was admirably adapted to this crop due to its rich soil, high temperature and relatively high rainfall. However, it may be hypothesized that the varied structural features and



Source: Soil and land-use survey

FIG.I LOCATION OF THE SUGAR-BELT IN KENYA pattern has given the area a diverse landscape, which provides both opportunities and problems for sugarcane growth and production.

Despite its potentialities, the Sugar Belt constitutes an area where floods and drought have become almost annual phenomena during the past few years. Since the intensity of these environmental constraints varies from year to year and from place to place, there is likely to be wide variation in the output of sugarcane per unit area. Consequently, the entrepreneur's perception of the environmental limitations may result into spatial organization of agricultural enterprises and subsequent abandonment of sugarcane as well as other crops. Allan (1965) warned of the danger of disregarding or underestimating environmental limitations.[2]

The Sugar Belt fulfilled the requirement of this study because it had an earlier contact with commercial sugarcane production which for several decades was absolutely monopolized by the Asians and Europeans. But the Swynnerton plan (1954) to intensify the development of African small-scale agriculture paved the way for the first major effort at coordinated agricultural development which greatly benefited the high potential areas of Kenya such as the Sugar Belt.[3] The area is now characterized by peasant-plantation dichotomy and there are some traditional attitudes to land tenure and inheritance practised along-side new opportunities for the improvement of farming experiences. Moreover, the recent settlers in the area are likely to be experiencing problems of adjustment to agricultural innovation or a new environment.

The area has one of the highest population concentrations in the country, which should serve as a labour reservoir for sugar industry at critical periods, especially during planting, weeding and harvesting sugarcane. Nevertheless, increased population growth tends to outstrip the advantage accruing from the present economic growth of the area. Thus, rapid population growth and increasing land scarcity as well as other environmental problems constitute a great challenge for the belt's agriculture in the near future.

One of the reasons for choosing the Sugar Belt was that the author was conversant with the area, hence it was easier to obtain leaders with good reputation who enjoy the confidence of the sugarcane growers on the basis of giving advice. In normal circumstances, farmers in the rural areas are suspicious of strangers and hesitate to give information on their own private business and financial transactions.

Origin and diffusion of sugarcane in the area

Sugarcane was first grown as a plantation crop in Kenya in 1902 when Jagat Singh purchased about 42.5 hectares (ha.) freehold farm near Kibos at Shs. 2.00 per 0.4 ha. and planted sugarcane, maize and Indian pulse. In 1914 the Department of Agriculture carried out its first research trial which consisted of 0.81 ha. of observational block of "ribbon stripped" variety commonly known in Luoland as "Kampala", a name suggesting that it originated from Uganda. The exact site of the observational trial was in Kisumu Township area, just behind the Town Hall. From this period on, sugarcane started diffusing to other parts of Nyanza as a backyard crop in homesteads mainly for "chewing". Consequently, other softer varieties for chewing were brought into the area from Uganda which was well ahead of Kenya in sugarcane development.

But Forrester (1962) noted that sugarcane is indigenous to Kenya.[4] This statement cannot be supported in the present study because the type of sugarcane which is cultivated throughout East Africa is almost exclusively the "noble" cane, which geneticists have proved to have originated from the South Pacific Ocean.

The excessive sweetness and "gummy" nature of sugarcane led the Luo to call it "niang" to distinguish it from "tiang", the commonly chewed stalk of maize, or sorghum in the area. Similarly, this sweetness was recognized by early historians to India who termed sugarcane a crop that produced "honey without the help of bees".[5]

Miwani White Sugar Factory was erected in 1922, and in 1952, 60.7 ha. of sugarcane had been established by African smallholders whose lands adjoins the Miwani factory. By 1953 the first actual sales from Kano plains to Miwani factory started. In 1963, eight African cooperative societies had some 404.7 ha. under cane, and by the following year, the Muhoroni Sugar Settlement Schemes was established, while the number of societies had grown to eleven, with others in the process of formation. Furthermore, the incorporation of Chemilil Sugar Company in 1965 initiated a new organized agrarian development both in the Luo and Nandi Land Units. Communally-owned sugarcane blocks in these areas were grouped into primary societies according to clan and area. At the time of the survey, there were 39 active societies with about 11,736.3 ha. of sugarcane. The information on the origin and diffusion of sugarcane indicates that sugarcane is a new enterprise to many African small-holders, thus they may lack the appropriate sugarcane husbandry.

THE STUDY PROBLEM

Statement of the problem

The Nyanza Sugar Belt has historically been divided into two sectors - large-scale farms which were at one time called Scheduled Areas and from which Africans were prohibited and small-scale farms which were located in Non-scheduled Areas, or areas reserved solely for Africans. While many African farmers have long grown a little sugarcane for sale in local markets, primarily for "chewing", the commercial production of sugar in the area was confined until the late 1950's to aliens.[6]

In 1961, a working party on sugar production recommended that in future a proportion of sugar production would come from smallholder settlements, pilot irrigation schemes on the Kano plains and smallholder production of rain-grown cane in adjacent areas of Kano plains, Nandi and Kipsigis districts.[7] The establishment of small-scale sugarcane development calls for a greater understanding of environmental problems associated with the new industry.

Despite the gloomy forecasts on the recent years of a looming shortage of sugarcane, there is considerable optimism about the future of the sugar industry in the Nyanza Sugar Belt. However, following the 1975 and 1976 increase in sugarcane price from Shs. 92/= to Shs. 105/= per ton respectively, there is a strong feeling that both small and large-scale farmers now have the incentive to work even harder and produce more. With the current inflationary trends which have adversely affected agriculture, it is generally the small-scale farmer who has been most seriously hit, with the result that his capacity to produce more diminishes. Although the large-scale farmers are equally hit, many of them have "shock-absorbers" and still afford proper husbandry.[8]

Notwithstanding the present large number of smallholders involved and the contribution they make towards the production of sugarcane, very little information on the system exists. The system is important because it is estimated that approximately 75% of future sugarcane production from Nyanza will depend on this sector. Moreover, sugarcane is the lifeblood in the area, providing the majority with employment and their major cash income.

Potentiality of increased sugar production per unit area by smallholders is enormous in the belt, if these farmers could practise modern sugarcane husbandry techniques. Consequently, the small-scale farmer still requires, despite technological advances, reasonable weather and a few soil limitations to implement sugarcane production programme successfully. It must be stressed that while sugar production is bound to rise because of Government encouragement and emphasis on self-sufficiency by early 1980's,[9] and other reasons already mentioned, the physical and human environment certainly provide a strong deterrent to small-scale sugarcane production in the area. Though some of these factors are "invisible" and hardly lend themselves to quantification, the point is that they reduce attainable sugarcane production just the same. Moreover, accelerated growth of population and the opportunity of commercial sugarcane development in the study area has resulted in soil deterioration and the destruction of vegetation cover has augmented to the difficulties of soil conservation.[10] Natural micro-variations are multiplied by the effects of human activities with the result that even the smallest peasant farm will have many categories of land. Thus soil fertilization policy and sugarcane production decisions can be formulated precisely by taking a series of soil samples from every plot of sugarcane on the farm. Although the extensive sampling of soils which are not usually cultivated has facilitated the mapping of broad "natural" soil types, this has not really contributed much to the store of agricultural planning information. Sugarcane has been grown on suitable soils in the study area mainly through a process of trial and error.

Many researches have been conducted in the area by scholars from various disciplines and institutions, but there has been no systematic study highlighting problems of smallholder sugarcane production in the context of the environmental limitations. These problems constitute the main theme of this thesis. The sugar industry furnishes a classic example of an agricultural enterprise operating under a high degree of environmental influence. Sugarcane is a tropical crop, demanding for its best performance a high level of soil fertility, a relatively warm temperature throughout the year, and large amounts of moisture and sunshine. The relationships between sugarcane and environment implies studies of:

(a) Climatic factors - moisture, temperature, light, and wind;

(b) Edaphic factors - parent material and soil; and

(c) Biotic factors - pests, diseases and weeds, as all these relate to sugarcane adaptation, distribution, and production.

But the patterns of sugarcane production have been greatly influenced by historical, political, economic and sociological considerations. This has resulted in situations in which sugar is not always grown where it is best adapted nor where it can be grown most economically.

Specific objectives

The detailed objectives of the research are:

(1) A systematic evaluation of the potentiality of the physical and human environment in the Sugar Belt area for the purposes of sugarcane production.

(2) To examine the mechanical and chemical contents of the soil from sugarcane plots on the farms.

(3) An attempt to analyze pedological, climatic and biotic factors of significance to sugarcane production.

(4) To determine demographic characteristics of the farmers and socio-economic problems limiting sugarcane production by interviewing a sample of small-scale farmers.

Research hypothesis

The study is based on the assumption that sugarcane production is a function of the physical environment as well as human environment. Several null hypotheses may be formulated in view of this assumption.

(1) No significant linear relationship exists between sugarcane yields and pedological elements: nitrogen, phosphorus and potassium.

(2) Rainfall, weeds, diseases and pests do not limit sugarcane production.

(3) The human environmental factors do not limit sugarcane production.

If these environmental conditions necessary for cultivation of sugarcane are known, circumstances can be manipulated to a certain extent. Thus a full study of the environmental parameters limiting sugarcane production is hoped to provide a guide for policy-planners and execution by decision-makers.

Conceptual definitions

The environment is widely used within so many disciplines. To some it loosely means the sum of all that is found within the surrounding of some objects, living or non-living. Others have attempted to differentiate between that part which is functionally related to the object, and that part which is not functionally related. Because of vagueness, indecision, and lack of understanding regarding the exact nature of environment, many studies have been a quantitatively expressed quasi-average of few selected external conditions and influences which are affecting the object, but have failed to tie these functionally with the object itself.[11]

Mason and Langenheim (1957) pointed out that in ecological investigations, all we have to work with empirically is:

(1) organism

(2) physical phenomena that enter a significant relation with the organism, and

(3) the empirical relations between the phenomena and the organism either singly or in various combinations.[12]

The environment has been used in this thesis to embrace both the physical and human environments. The primary concern was not the environment per se, but rather it was sugarcane and its environmental interrelationships.

LITERATURE REVIEW

General Remarks

Although no similar studies on smallholder sugarcane production have been made in the Nyanza Sugar Belt, one would turn to abundance studies on ecological limitations to sugarcane growth and production in other parts of tropical as well as subtropical countries. A review of these studies is not without practical value to the present study. Despite an almost complete paucity of information about this sector of farming which is readily available for planning and execution, there are some researches which have been done in the study area by individuals and institutions that may also be of interest in this thesis.

Available Literature

In the lower altitudes of the Sugar Belt, "black cotton" soils which are often poorly drained and susceptible to weed growth predominate, but in the higher altitudes with generally high rainfall and low temperatures, the night time temperatures are low enough to inhibit cane growth, although the soils are sandy loams, well-drained and relatively weed free.[13] However, temperature and radiation are not limiting factors to sugarcane production.[14] Ochung (1969) stated that sugar economy was actually determined to a large extent by the prevailing physical conditions.[15] He also mentioned socio-economic problems like the inexperience of the farmer in the new enterprise, lack of capital, the inability of the cooperative societies to serve the farmer effectively and the inadequacy of the means of transport, as factors limiting sugarcane development in the area. Similarly, Ogungo (1971) found that the sugar development in the area was hard-hit by labour shortage.[16]

The unevenly distributed and inadequate rainfall experienced throughout the area not only adversely affect the establishment of new crops but also greatly interfere with the growth and yield performance of plant crops and ratoons alike.[17] It seems that the frequent moisture stress experienced in the Sugar Belt may largely account for the poor and stunted growth in sugarcane.

Gibb and Partners (1961) said that the most unfavourable environmental conditions affecting cane in the area were water-logging, ratoon stunting disease, mosaic disease, smut disease, stoloniferous grass weeds, and the parasitic plants of striga species were troublesome.[18] They also noted that cane yields of 30-40 tons per about 0.4 ha. were achieved under dryland conditions when the rainfall was adequate and well-distributed, but yields fell to 20 tons or less if the rains were poor. In addition, reduced yields caused by poor rainfall occurred in two seasons out of five.

Sugarcane requires soils that are reasonably well-drained and do not contain excessive salinity of high clay fractions.[19] Clays, loams, marls and calcareous soils are more or less suitable for cane cultivation, but rich, porous clays and alluvial soils on lowland are the most favourable.

On the heavy "black cotton" soil of the Kano plains, cambered beds, ditches or furrows must be formed in order to lead off surplus water. Sugarcane can give good yields on sandy soils provided that nutrient deficiencies are rectified by the application of fertilizers or manures and provided there is sufficient water supply. But nematodes sometimes prevent healthy growth on sandy soil.[20] However, fertilization alone is not conducive to high cane yields because other cultural practices are paramount. Fertilizers like nitrogen may only help to minimize on yield potential of any crop variety. Proper land preparation, good cane establishment, correct plant population, good weed control and finally good mechanical cane cultivation should be put right for cane crop to benefit from fertilization.

Weihe (1956) laid emphasis on fundamental questions of suitability of soils and climate in the expansion of sugar industry.[21] Despite these questions, Hill (1963) gave three reasons for the cultivation of sugarcane on the less ideal heavy soils in the Sugar Belt.[22]

(1) Heavy soils cover the greater part of the Sugar Belt.

(2) The soils cover the flatter segments where extremely large blocks of even slope can be obtained and these are of course most suitable to mechanized cultivation.

(3) Ultimately, the lighter soils were developed first, with cereal and subsistence crops as they were easier to cultivate. Sugarcane had to be planted on the vacant heavy land, where it would grow and other crops would not.

In spite of the foregoing argument, the history of the Asian

Settlement beneath the escarpment shows that the land was most suitable for the growth of sugarcane.[23] Moreover, the inauguration of the Ahero Rice Scheme (1967) and the recent extension of the sugar plantation indicated a further realization of the agricultural potentiality of the area.[24]

Rainfall is a limiting factor in the area where the average lies between 1275-1500 mm. per annum, but it is also subject to considerable variation.[25] Barnes (1957) included the following considerations in his summary of conditions affecting sugarcane in the Sugar Belt area:[26]

(1) Fertile soils, responsible to good cultivation and able to support sugarcane with or without the use of fertilizers.

(2) Rainfall and temperature range must suit the crop. The rainfall should be 1250 mm. or more per annum, well-distributed; short periods of a few weeks without rain unobjectionable, provided the capacity of the soil for retaining and releasing water is satisfactory, but the climate should be warm to hot.

(3) Land suitable for sugarcane should be located within a maximum distance of about 16 kilometres of a suitable factory site.

(4) Communications within the cane growing areas should be good.

(5) Good labour in adequate numbers must be readily obtainable.

(6) The area should be reasonably healthy.

These conditions were not fully understood at the initial stages of the sugar industry in the present study area and their impact must be felt by small-scale farmers who are in most cases located in marginal land because the best soils had been occupied by nucleus sugar-estates. Little or no response has been noted from phosphate, potash, or sulphur in Nyanza soils, although exceptions to this rule do occur, but nitrogen is the most important fertilizer.[27] The red soils of the elephant grassland of the Lake Victoria districts are very suitable for the crop which grows most luxuriantly.[28] However, the Sugar Belt red soils are patchy, and in the Combretum-hyparrhenia patches of gravelly soil termed laterite, or "murram" occur on fairly steep slopes of foothills.

For good yields temperatures should rarely fall much below 21°C., and there should be a rainfall of more than 1000 mm. spread over at least 9 months in the year unless irrigation is to be employed.[29] These conditions are partly satisfied over an extensive part of the Sugar Belt. The uneven rainfall regime of the area is a great disadvantage, for both planting and harvesting may not occur throughout the year, and the factories may not be kept in almost continuous operation.

Beneficial effects of an adequate water supply at the outset of or during tillering have also been reported.[30,31,32] Rawson (1874) made a study of the effect of rainfall on yield of sugarcane and found that annual rainfall greatly influenced the crop of the following year, but had only a slight effect on that of the current year.[33] Without irrigation, sugarcane requires approximately 1500 mm. of precipitation evenly distributed throughout the growing period.[34] Barnes (1952) said that the location of small sugarcane cultivations on the fringes of swampy land, or in places where the water table is quite near the surface is related to the alternating periods of rain and drought.[35] This practice has given rise to the fallacy that sugarcane is a swamp loving crop. In actual truth the indigenous farmers know by long experience that the cane needs water and that although it may survive in dry places, it grows very slowly.

Similarly, the heavy deposition of dew supplements the water supplied by rainfall and the high humidity checks transpiration.[36]

Ellis (1963) noted that cane yields vary greatly with rainfall,[37] and similar dependence of cane production on rainfall has been reported elsewhere.[38,39] In view of the foregoing discussion, rain not only reduces soil moisture tension by replenishment of the soil water reserves, but it directly reduces very considerably, the plant water deficit. But the incorporation of sugarcane into the new irrigation schemes in the Kano plains necessitates a basic layout for fields due to the nature of the terrain.[40]

Tasselling or flowering reduces sugar production considerably, and Vijayasaradhy and Narasimhan (1953) reported that frequent irrigation had an accelerating effect on flowering.[41] This effect may, however, have been due to nitrogen leaching, because if adequate nitrogen is available to a crop in its early stages of development, tasselling may be largely suppressed.[42] It may also explain reports to the effect that withholding water at appropriate times may effectively control tassel formation.[43]

Clement et al (1952) indicated that the relationship between radiation and the growth of sugarcane was positive and linear, and a similar relationship was found to exist between moisture content of leaf sheaths and growth.[44] Legendre (1975) found that ripening of sugarcane was associated with incident sunlight and temperature, but not with rainfall.[45] It seems from the various literature cited that the decisive factor in sugarcane cultivation is the climate, for this determines the duration of the growing period and also the yield of sugar. A short dry season is necessary during the later stages of growth when the sugar is being stored.

Natural and climatic factors are regarded as a crucial element in the decision of the producers.[46] Nevertheless, sugarcane will grow upon almost any soil, that is, it does not demand any particular soil so long as there is a good depth as well as good drainage.[47] The depth and fertility of the soil may be reflected in the yields of sugarcane. Purseglove (1972) stated that sugarcane can grow on a wide variety of soil types, but heavy soils are usually preferred.[48] In the Sugar Belt it grows in clay loam, sandy clay loam and clay soils. Although sugarcane tolerates a wide range of soils, it has been found to be a gross feeder. Thus soils should possess high natural fertility, or be given adequate manuring.

Bischoff (1975) said that sugarcane does not make very great demands on the mineral contents of the soil, provided that there is plentiful supply of nitrogen.[49] Nitrogen is a basic essential for the growth of plants. Because of the high prices of nitrogen fertilizers and possible scarcity of the required inputs and the problems of moving fertilizer to many of the world's farmers, alternative methods of bringing nitrogen to sugarcane could have a considerable importance for the increase of agricultural output. Increasing the rate of biological nitrogen fixation, a process of transformation of nitrogen from the form (N_2) in which it is found in abundance in the atmosphere and elsewhere into a combined form which can be used by sugarcanes for growth, is a method which deserves wider recognition in the Sugar Belt. Recent estimates suggest that biological nitrogen fixation contributed at least four times as much nitrogen to the soil throughout the world.[50] Studies in some countries show that sugarcane's demand on the soil is comparatively frugal and that the crop will thrive on sandy as well as on heavy clay soils, but marshy and impervious grounds are unsuitable.[51] The generality of some of these statements must be stressed when dealing with the present study area where environmental conditions are in some ways different.

Barnes (1953) categorized sugar soils into six main types to which he added a seventh:[52]

(1) Red lands which become sticky and plastic when wet, but they are porous. Their fertility is initially high, but declines with cropping and heavy manuring becomes necessary, however, lime and organic matter are low and must be supplied by suitable dressings, or in the latter case by cover crops which are ploughed in.

(2) Black lands having a clay subsoil. These are clay loams with an impervious subsoil and are often shallow and difficult to manage.

(3) Black lands with calcareous subsoil, consisting of a light coloured rather soft marl, have a top soil of loam or clay loam easily worked and are highly productive when of sufficient depth.

(4) Brown clay loams usually derived from shale, have a stiff top-soil which is very difficult to work, but which responds to artificial and organic manures.

(5) Alluvial lands deposited by streams. They are loams of high and enduring fertility, and easily worked.

(6) Sandy loams which need liberal application of fertilizers to enable them to support good crops, but are free draining and easy to work.

(7) Soils of organic origin, such as the muck soils. Also

everglades formed by decomposing vegetation and water-borne silt, which are in effect reclaimed marshland.

Some of these soils are unknown in the study area where soils are generally clays of slight to moderate slope, but on the foot-hills, or escarpment, sandy and gravelly loams occur on fairly steep slopes. According to Kipps (1970), sugarcane needs loam, clay loam, or muck including clacareous soils derived from volcanic ash, but sandy loams require more moisture and fertilizers, whereas the pH should be 5-8 and the depth should range from 0.46-1.50 metres.[53]

Amongst various factors which influence sugarcane production, nitrogen and water are of paramount importance, but no factor acts singly in limiting cane growth.[54] Leak (1950) reported beneficial effect of large dressings of nitrogenous fertilizers on plant and ratoon crops.[55] However, Das (1936) recorded positive response of nitrogen on tillering, height and leaf width of sugarcane.[56] But Borden et al (1944-45) reported that nitrogen application increased the reducing sugars in juice resulting in low quality of juice.[57] Lander and Narain (1935) did not observe any ill-effect of nitrogen fertilization on juice quality.[58] Consequently, Rege and Samabhadti (1941) reported definite fall in juice quality with a progressive increase in level of nitrogen fertilization.[59]

Rao and Narasinham (1956) recorded that an increase in uptake of nitrogen by plants under high level of nitrogen, especially 91 kilogrammes per about 0.4 ha. depressed the sucrose content in juice.[60] In view of these discrepancies, the author may only suggest that intricate chemical processes which are vital for sugarcane are not yet fully understood and some experiments are probably based on trials and errors. On the other hand, fertilizer requirements may vary markedly according to soil type and cane variety, although generally cane's main requirements are nitrogen, phosphate and potash, but calcium and sulphur may also be essential. In the Nyanza Sugar Belt, economic responses to nitrogen fertilizers on well-drained sandy soils have been obtained, but there is yet to be established a significant nitrogen response on heavy black clays of impeded drainage. The negative response of nitrogen application in the latter soils is perhaps due to leaching, which is common in these waterlogged soils.

Despite the physical factors, sugarcane requires a large amount of unskilled labour and a substantial amount of capital, but the size of the sugar industry has probably been limited more by social and political considerations than by shortage of capital.[61] Cane is an extremely bulky commodity and one which must be processed within 48 hours of harvesting, but burnt cane must reach the factory within 24 hours. This has not been possible in the study area because cane cannot be moved to a mill from widely scattered peasant farms without exceptionally good organization and transport facilities. From the point of view of both space and time a high degree of integration must be achieved between the cultivation and processing of cane. Smith (1970) also noted that the main problems facing outgrowers were a shortage of labour and the high cost of transporting cane to the factory.[62] These socio-economic variables are likely to exert far-reaching influences on sugarcane production in the Sugar Belt.

SUMMARY AND SCOPE OF THE STUDY

Summary of Chapters

Chapter I contains a preamble of the research objectives, literature review, significance and limitations. Chapter II presents a comprehensive treatment of methods used in this thesis. Emphasis is placed upon the problems of data collection and their solutions; techniques and tools of data collection; methods of data analysis, presentation, interpretation; and a critical examination of statistical approach, with special reference to this thesis.

In Chapter III the author endeavours to review extensively and critically the potentiality of the environment. From this appraisal, diversification possibilities for agriculture appear to be numerous at first sight, because of the favourable physical and human parameters of the belt.

Chapter IV deals with physical environmental limitations on sugarcane production. It contains analysis of pedological factors of significance to cane production based on mainly primary data. The climatic factors influencing the crop are also analysed using data collected from meteorological stations and from other published sources. In addition, biological limitations are analysed with emphasis on major sugarcane diseases, pests and weeds.

The fifth Chapter attempts to analyze the limitations imposed by the human environment on sugarcane production. It comprises discussion on social, economic and cultural factors based on mainly primary data collected by interviewing farmers using recording schedule (Appendix B).

Chapter VI contains conclusions and recommendations of the results for planning exercises and their policy implications for research, extension and sugarcane development planning as well as suggestions for further research lines.

Scope and limitations of the study

This research is both quantitative and descriptive. Although developments in the analysis and interpretation of data from simple statistical procedures to computer programming permit the simultaneous evaluation of many variables, computer was not used by the author due to its high costs.

Secondary data obtained from published and unpublished sources as well as those obtained from the interview have their own limitations. Most of the smallholders did not maintain any farm records. Reliance, therefore, had to be placed on the memories of the respondents. There was difficulty in collecting data in respect of items like owned and cultivated land, farm inputs or outputs, income, labour requirements and non-farm expenditure.

Data collected by personal field observations also were inevitable to limitations. The soils were drilled to a depth of 0-30 cm., because about 75-80% of the sugarcane roots are found within this limit where nutrients, pH, soil moisture and texture should be ideal. Any departures from the chemical composition of the soil samples are partly associated with leaching during the rainy days when soils were withdrawn from cane plots.

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CHAPTER II

METHODS OF DATA COLLECTION AND ANALYSIS

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METHODS OF DATA COLLECTION

Problems of data collection and their possible solutions

In view of anticipated problems of interpreting the recording schedule, the author was assisted by two vernacular speaking undergraduates who translated the questions from English to Nandi and Kipsigis. Similarly, they translated the answers from vernacular version in their own words into English. However, this was a minor problem as only a few Nandi and Kipsigis farmers could not understand and speak Luo, the language in which the questions were often asked by the author and answers noted in English. There were a few cases where 3 farmers were Luhyia and 1 a Kikuyu. These farmers were questioned in English because they were able to speak this language quite well. Interviewing farmers in some areas proved a problem at the initial stages of field survey because there was still the looming scare of cholera, particularly, in Kisumu District.

Sometimes it was a problem to find farmers at their holdings except during September when it was raining in the area. This problem was partly solved by visiting the farmers very early in the morning or late in the evening. Moreover, roads and bridges in the smallholder areas became impassable during the wet days, thereby making it practically impossible to use bicycles and cars offered by friends. Furthermore, some areas were seriously flooded (fig. 2) and could not be visited until the end of rains when floods slowly receded.

Fig. 2. Both photographs illustrate flooded areas along Kisumu—Ahero road depicting pedestrians going to Ahero market

The heavy clay soils were not easy to drill even after the end of rains. Carrying soil auger, polythene bags containing soil samples and other tools became cumbersome regardless of employing two men to help in handling tools and drilling the soil. Before finishing the survey, the auger got broken, but it was immediately sent to Kisumu for welding.

A few respondents almost refused to be interviewed, but this problem was solved after the author attended "baraza" of chiefs and assistant chiefs, and the leaders of cooperative societies were instrumental in introducing the author to the farmers. To overcome these problems, the author had to exercise great patience and tact. The enumerator need not be discouraged by the unfriendly attitude of farmers in the beginning, nor become overoptimistic when his first relations are friendly with the farmers.[1] A common observation is that the taciturn farmer who at first is barely civil, eventually becomes more helpful and accurate in supplying information, while those who receive us with open arms often quickly tire and are far from accurate in either physical or financial data. To ensure that all the necessary information was being collected and correctly recorded, cross-examination of the farmers was done by introducing some questions which were more closely tied.

Limitation of funds for transport and accommodation created a serious setback in the field survey by the author. This problem was partly solved by taking a sample of the farmers. Consequently, the single interview was conducted by the author because it has the merit of minimizing both time requirements and costs of the field investigation.

TECHNIQUES AND TOOLS OF THE FIELD SURVEY

Multi-stage Sampling

Multi-stage sampling means sampling in stages.[2] Due to the large size of the area, a modification of a random sampling design was vital to reduce the costs of creating reliable sampling frames and to save time. Birch (1960) used this technique in farm survey.[3] Although random sampling ensures that the members of a population have equal probabilities of being selected and that the selection of a unit in no way influences the selection of other one, for practical purposes, the procedure does not always ensure an adequate areal coverage.[4] Some clustering of the sample points is inevitable and, as a consequence, important spatial properties may be overlooked. To overcome this problem a stratified random sampling technique[5] was devised by the author according to the three sugar factories (table 1 and fig. 3). This zoning was based on the Kapila Report (1972)[6], which was devised to ensure that each white sugar factory had adequate number of small-scale "outgrowers" to supply it with sugarcane.

There were 39 active and 2 inactive cooperative societies in the area dealing with sugarcane production, marketing, and farm purchase. After obtaining lists of all societies, a purposive selection of 20 out of 39 active societies was made. This gave 7 societies from Muhoroni, 7 from Chemilil and 6 from Miwani zones selected by designing a numerical number to each cooperative society using a table of random sampling numbers[7], thereby giving 51.3% of the total number of active societies.

Table 1

SUGAR-BELT COOPERATIVE SOCIETIES IN EACH SUGAR FACTORY ZONE, 1975

Muhoroni Zone	Chemilil Zone	Miwani Zone
Songhor	Nyatao	Chemursoi
Koru	Simbi	Nyakoko
Tamu	Ngeny	Olikoliero
God-Abuoro	Kibisem	Chiga
Oduwo**	Nyakunguru	Magare
Kunyak**	Mikiria	Kabonyo
Muhoroni	Amilo	Onyisa
Fort-Ternan	Jaber	Keyo
Makindu	Nyang'	Kajulu
Pala	Harambee	
Mariwa	Chemase	
Mombwo	Owiro	
Urafiki	Mbidhi**	
Koisagat	Masaka*	
Chill-Chilla	Orago*	
Kipsitet		
Kaitui		

* Dormant or inactive society and not shown on fig. 3

** Not shown on fig. 3

Source: Sugar Belt and Muhoroni Cooperative Union's Offices.

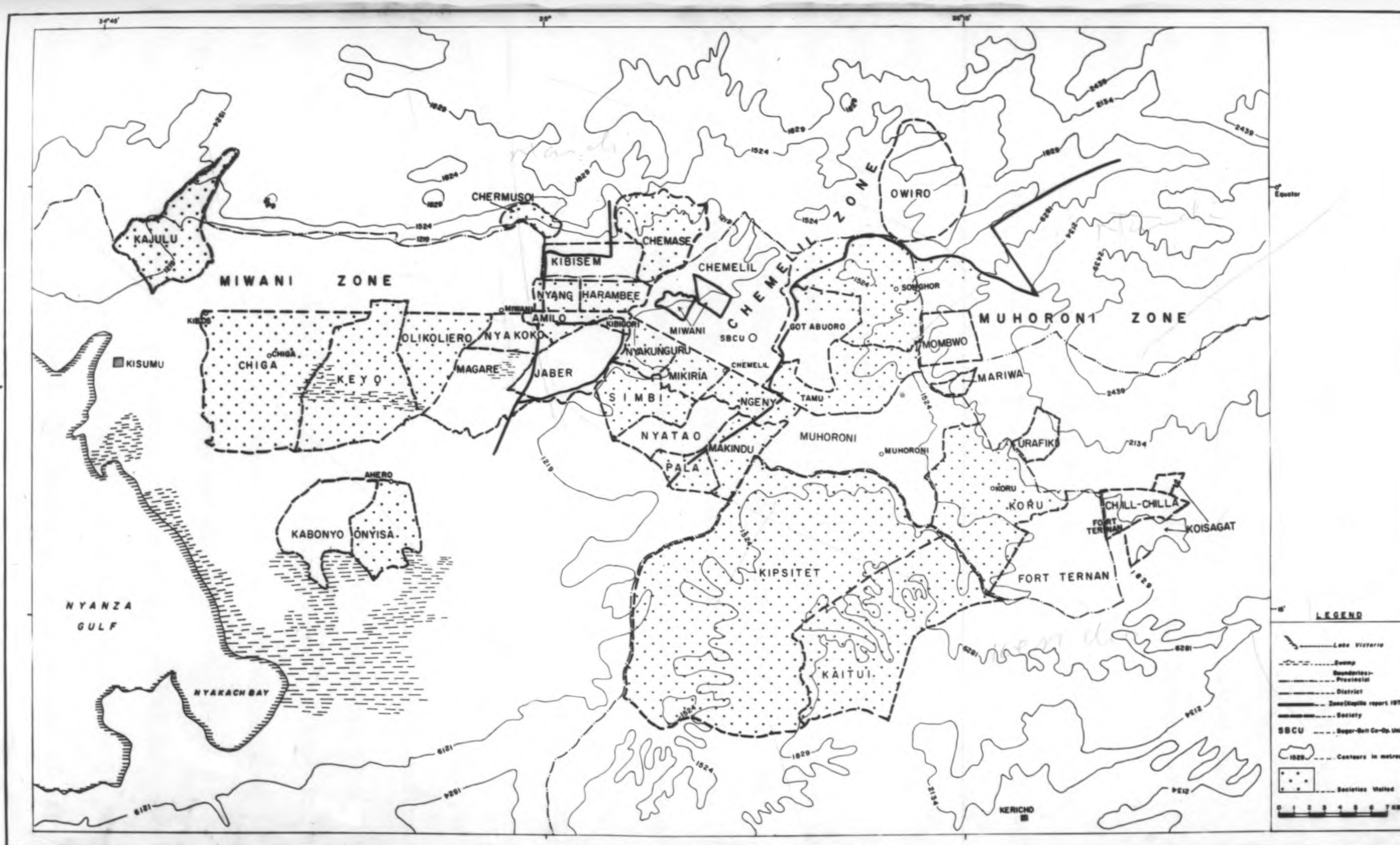

FIG.3 NYANZA SUGAR-BELT ZONES

Sugarcane growers' membership lists were obtained from selected cooperative societies. Table 2 shows the three factory zones, estimated number of societies, number of recorded sugarcane growers and the proportional distribution of farmers per society in the sample.

Membership lists obtained from selected societies were copied and those who had ceased being members were noted. It was found that people who had moved out from the societies were not properly indicated and some lists included those who were not growing sugarcane. A revision of these lists was of paramount importance before drawing any sample. The 20 societies chosen had a membership of about 6000 sugarcane producers out of roughly 10,000 members from the 39 active societies in the study area. This was about 60% of the total sugarcane growers under all cooperative societies.

However, ultimate sample design called for a proportional random sample of 300 farmers. This was done by serially numbering all the members in each society using a table of random numbers.[8] Data forming part of the background of this thesis are therefore derived from 5% of the total population of 6000 farmers, or about 3% of the 10,000 estimated smallholders in the Sugar Belt. The selection of a large number of farmers by the author conforms to the laws of statistical regulation and inertia. The former law emphasizes that a reasonably large number of farmers at random will, on the average, be representative of the whole population of farmers, while the latter law requires the choice of large groups of aggregates of data because these are likely to change more gradually and regularly.

Table 2

DETAILS OF PLANNED AND ACTUAL SAMPLE BY ZONE AND COOPERATIVE SOCIETY

Zone	Cooperative Society	Membership	Sample Size	
			No	%
Miwani	Onyisa	521	26	8.7
Muhoroni	Kipsitet	502	25	8.3
Chemilil	Chemase	491	25	8.3
Muhoroni	Songhor	483	24	8.0
Muhoroni	Koru	416	21	7.0
Muhoroni	Tamu	412	21	7.0
Miwani	Olikoliero	392	20	6.7
Miwani	Keyo	322	16	5.3
Chemilil	Amilo	308	15	5.0
Miwani	Kajulu	265	13	4.3
Miwani	Chiga	260	13	4.3
Chemilil	Simbi	245	12	4.0
Muhoroni	Pala	229	11	3.7
Chemilil	Harambee	189	9	3.0
Muhoroni	Kaitui	181	9	3.0
Miwani	Chemursoi	172	9	3.0
Chemilil	Ngeny	160	8	2.7
Muhoroni	Makindu	157	8	2.7
Chemilil	Nyakunguru	153	8	2.7
Chemilil	Mikiria	142	7	2.3
TOTAL		6000	300	100.0

Source: Membership Lists of Nyanza Sugar Belt Cooperative Societies, 1975

Stratified Random Composite Soil Sampling

The Sugar Belt was stratified as has been mentioned. 60 stratified random soil samples drilled to a depth of 0-30 cm. were drawn from smallholder sugarcane cultivated plots (Fig. 4). Choosing the 60 soil samples was done by serially numbering all the 300 interviewees using a table of random numbers. The different drilling sites were based on the variations in relief elements at each sugarcane cultivated plot. This is similar to a catena concept, a sequence of soil profiles which appear in regular succession on topographical features of uniform lithology. Moreover, the soil associations in the Sugar Belt area are catena-like in character although there is more or less variation in parent material in each association.[9] At least 3 samples taken from different parts of about 0.4 ha. were mixed to form a "composite" sample. This gave a more reliable representative sample because soils vary greatly even within a few metres due to differences in moisture regime, gradient, shapes of slopes, rocks, mineral deposits, biological environment (plants and animals) and time. Furthermore, sugarcane yield estimates were obtained from each plot of sugarcane to enable the author to attempt a quantitative analysis.

Soil auger was used to draw soil samples and a small pointed iron-bar was used to facilitate the removal of soil from the auger. The soils were stored individually in carefully labelled polythene bags then tied tightly with strong cords. Nutrient deficiency, sufficiency and richness were identified by laboratory examination of the soil samples. Mechanical analysis was similarly done in the laboratory. The author carried no soil examination from virgin land

Fig. 4. Composite Soil Sampling in sugarcane cultivated plot on farm by the author. The White mark on the auger indicates 0–30 cms. drilling limitation

but for comparative purposes, the existing soil surveys in the area were quoted where necessary.

Recording Schedule and Interviewing

The data for the study was collected mainly from August 1975 to January 1976 by personally interviewing the members of cooperative societies or the actual decision-makers. Questions were asked by the author instead of allowing respondents to fill the recording schedules by themselves in order to ascertain that questions were uniformly understood by informants who in most cases were illiterate or semi-illiterate.

Interviews were each carried out in a private place so that each farmer would speak without inhibition or outside influence. The recording schedules were open ended and the related probing questions were asked during the informal discussions prompted by the main question. Consequently, comments and statements were noted verbatim during the interviews.

The recording schedule contained information on environmental perception, agricultural enterprises, economic factors related to the internal organization of the farm, land tenure, labour problems, extension services, sugarcane fires, nutrition, household composition, literacy and numerous miscellaneous problems of sugarcane production (Appendix B). The idea was to get a detailed knowledge of some of these aspects and to acquire a general understanding of the farmers as well as to secure some statistical data useful in analyzing problems of small-scale sugarcane production. Moreover, it was necessary to identify problems which need more intensive investigation. Due to lack of farm records in nearly all cases, the author depended entirely on the memory of the respondent.

Much additional information was obtained from local data sources, especially annual factory records, district agricultural annual records and the like. Although these were the only sources where statistics could be kept in the same format from year to year, the author found that this was not always the case in the present study area. Files of various societies and unions provided extra information, while some data were obtained via conversation with managers of unions, societies' secretaries, and sugar technical officers. Last but not least, the names of plant indicators given by the respondents were identified by Luo-English Botanical Dictionary.[10]

METHODS OF DATA ANALYSIS, PRESENTATION AND INTERPRETATION

Processing, Editing, Classification, Coding, and Tabulation

Editing, coding, and tabulating data for processing were manipulated by slide rules, and desk calculators. Although the use of these instruments never reduced computational burden, the application of computers was avoided due to high costs, which the author could not afford.

Data editing was devised for examining the completed recording schedules. This ensured that data to be tabulated were as accurate and reliable as possible, consistent with other facts secured and uniformly entered. The author also classified all assembled facts, for example, size of holdings before tabulating the data.

Coding constituted an important stage, first in the designing of recording schedules and secondly, in data tabulation. It consisted of assigning numerical numbers, or symbols to each category of answer. However, coding is a highly technical procedure that requires expert knowledge and skill.[11]

Tabulation may be defined as the summarization of the results in the form of statistical tables.[12] The tables consisted basically of rectangular array of elements arranged in a set of rows and columns. These tables saved space by reducing explanatory and descriptive statements to a minimum, facilitated the processes of comparison, and facilitated final data analysis. Psychologically, data presented higgledy-piggledy are more complicated to comprehend than data presented in a clear and orderly manner.[13]

Chemical and Mechanical Soil Analysis

The soils were initially air-dried in the laboratory at the National Agricultural Laboratories, Kabete. Mechanical analysis for texture determination was performed by the Hydrometer method of Bouyoucos (1927).[14] The soil pH was measured by the use of glass electrodes on an EEL electronic pH metre. pH is the logarithm of reciprocal of concentration of hydrogen ion.

Available nutrients in the samples were estimated by methods based on those of Mehlich et al (1962)[15]. These nutrients were calcium, magnesium, potassium, sodium, phosphorus, carbon, manganese and nitrogen.

The different textural classes were expressed in percentages and the corresponding soil types were named accordingly. However, triangular diagram was used by the author to convey the visual impression of the spatial variations in the proportion of sand, silt and clay. In practice, there seemed to be a remarkable accuracy and precision in this technique of soil nomenclature, systematic naming. Ultimately, it was possible to interpret nutrient deficiency, sufficiency and richness according to the standards at the National Agricultural Laboratories, Kabete.

GENERAL SUMMARY AND LIMITATIONS OF STATISTICAL APPROACH

A scientist's urge to be strictly objective spurs him onto devising techniques of arranging his observations on a reproducible manner. These techniques include setting up representative samples for which comparisons may be done within samples, between samples, or between samples and other significant conditions.

Scientific analysis is basically a conversion of data into a simplified form, but statistical approach to a geographical study must be cautiously applied. The author had to be extremely careful with the type of data collected as well as the methods used to collect them. Both common sense and judicious judgement were vital in all phases of this thesis.

Quantitative approach permitted the author to test the null hypotheses by using mainly "F" test for statistical significance at 99% level of probability. The "t" test was also used in this thesis to calculate rainfall probability and the like. Although correlation coefficient, r, whose value lies between 1 and -1 provides a valuable indication of the degree of the interdependence of two varying correlated elements, the information which it supplies is liable to be very misleading unless the problem is correctly stated. Cases of "spurious correlation" may be inevitable and high correlation may be found to exist between two elements which are not related as cause and effect, but are collateral effects of some unknown or unsuspected cause. Moreover, an independent variable cannot be simply a surrogate measure of the dependent variable or an erroneously high correlation will be the result.[16]

Partial correlation coefficient is the correlation between two random variables with one or more of the other random variables held constant.[17] This technique was used in Mauritius to analyze the association between sugarcane yields and meteorological data.[18] In the present study it is used to determine the correlation between sugarcane yields and the soil elements: nitrogen, phosphorus and potassium. The technique is useful in situations where ordinary correlation may be misleading, but it becomes difficult to interpret if several independent variables are involved. Moreover, the application of this method to the case of a large number of variables although perfectly straightforward, is troublesome on account of introducing many signs.

It is often difficult to select independent variables, especially in bioenvironmental studies. Only the extra-bioenvironmental variables may be actually considered as independent, for example, sunshine, rainfall, in some cases - ambient temperature and wind. This is the case in the Sugar Belt where there is interaction of animate and inanimate systems.

Another problem is that of non-linear relationship, where the correlation coefficient may give an altogether wrong value of the extent of the interdependence of two varying quantities, and data transformation may have to be resorted to. It was essential for the author to have a thorough acquaintance with the nature of the elements correlated, otherwise there was great danger of being led astray by statistical coincidences: a danger which was not infrequently underestimated.

The author also used standard deviation, and coefficient of variation in the analysis of rainfall variation in the Sugar Belt. Rainfall probabilities were analyzed for only two stations which had long term and continuous records. Such analysis is useful for the purposes of predicting the chances of crop failures or success. In order to avoid erroneous conclusions it is important to give the proper interpretation to precipitation data, which often cannot be accepted at face value. For example, a mean annual precipitation value for a station may have little significance in sugarcane growth and production if the gauge site has been changed significantly during the period for which the average is computed. Also, there are several ways of computing average precipitation over an area, each of which may give a different answer. But the most accurate method of averaging precipitation over an area is the "isohyetal method" that is, station locations and amounts are plotted on a suitable map, and contours of equal precipitation[19] (isohyets) are then drawn. The isohyetal method permits the use and interpretation of all available data and is well adapted to display and discussion.

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CHAPTER III

THE PHYSICAL AND HUMAN ENVIRONMENT IN THE SUGAR BELT

THE PHYSICAL AND HUMAN ENVIRONMENT IN THE SUGAR BELT AREA

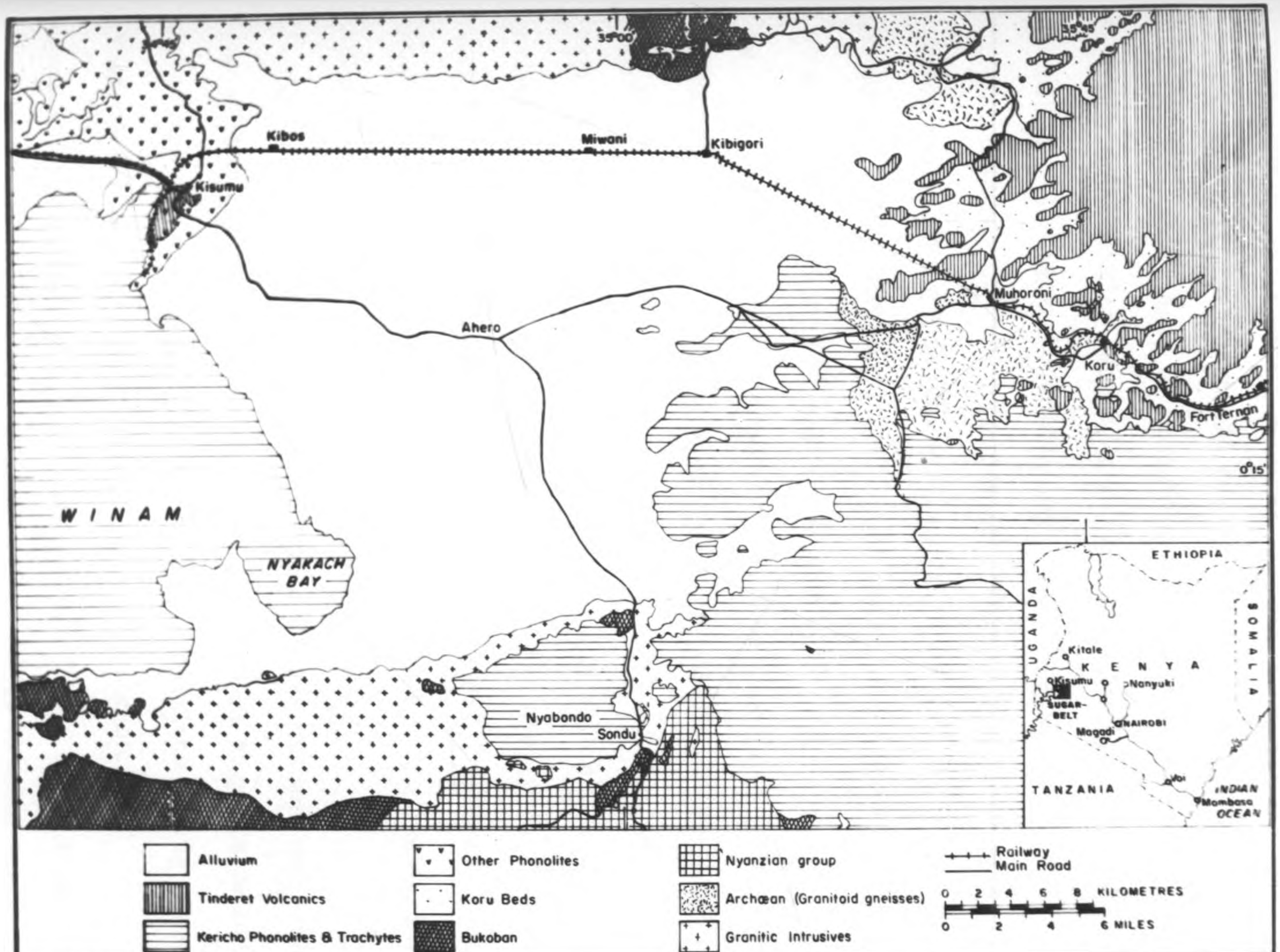
Introduction

Man's environment is the product of all external conditions affecting him: food, clothing, shelter, air, land and transportation. However, since human purpose involves concern for the future, the supply of resources like food for the rapidly increasing population of the world has gained the attention of many writers.

A more complete understanding of the specific environmental requirements of sugarcane is basic to a sound ecological approach. Moreover, the difficulties that confront the small-scale farmers in the area in making wise decisions on future sugarcane production largely stem from the physical and human environments. Hence the author endeavours to comment on the various components of the environment in this chapter. This is useful in assessing the suitability of the environment as well as establishing its potentialities and restrictions which influence agricultural production.

Geomorphology

Geomorphological consideration is based on the examination of geology, topography, drainage, floods and pedology of the area. The area consists of an alluvium peneplain of quaternary sediments, (50,000 - 1,000,000 years ago) resting on the floor of rift valley that resulted from down-faulting between two parallel faults: Nyando and Nyabondo (Fig. 5). An extensive zone of



SOURCE: African scientist 1969

FIG.5 MAIN ROCK OUTCROPS IN THE SUGAR-BELT AREA granite development is part of the large batholith, which stretches to the north of the plain, forming the prominent Nyando Fault-scarp.[1] Geological structures of the rift and highlands to the north and south are as old as pre-cambrian granites (over 2200 million years ago) or granitoid in many parts characterized by numerous foothills capped by sequences of lava flows, both from Kericho and Tinderet volcanics, that erupted during Tertiary to recent periods. To the west lies the Kenya type of phonolite, capped generally by laterite with variable reddish soil cover. Saggerson (1952) confirmed that these rocks comprise phonolites, basalts, agglomerates and light coloured tuff.[2]

During the Pleistocene period, about 1,000,000 years ago, the plain was part and parcel of the Nyanza Gulf. Large parts of its floor were covered with lacustrine deposits. With the gradual fall of the Lake at various base levels,[3] the silt and clay sediments were deposited in swamps and marshes that persisted and left behind as series of beaches, later superseded by erosion and fluvial process that brought in new materials and the lacustrine sediments were reworked by alluvial deposits.

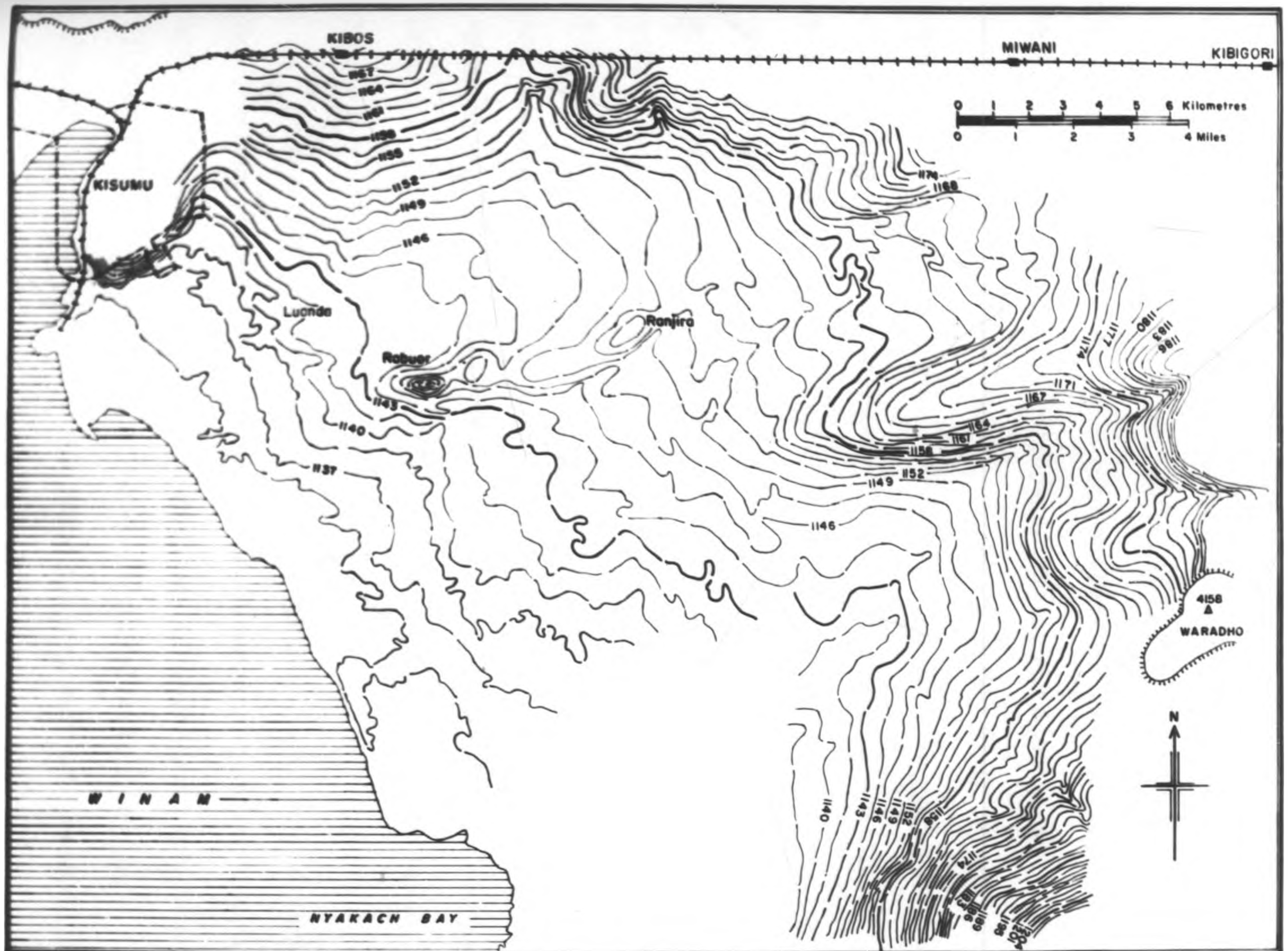
The "Koru Beds", sedimentary rocks, are miocene sediments (25 million years ago). Presence of these rocks suggests deposition by rivers and currents in lagoon or gulf conditions during a period when occasional eruption of tuffs was quite common.[4]

Examination of the geological formations, which range from basement complex to volcanic rocks is necessary because important morphological differences in soils of the Sugar Belt area are fairly related to the kinds of rocks. The acid igneous rocks like granite have formed predominantly sandy soil commonly noticed in Kibos area. Basic igneous rocks such as basalt have produced a residue which is predominantly clay in large parts of the Sugar Belt. Consequently, the sedimentary rocks known as the "Koru Beds" have weathered to form a much more homogeneous soil because they are composed of material which has, to a greater or lesser extent, been sorted during a previous cycle of erosion and deposition. Geological complexes have also produced various topographical features, which influence soil formation in the belt.

Eastward the area rises and merges with alluvial fans and valley terraces of the hills and mountains to the north, east and west. The area has been cut into rugged forms by the various rivers.[5]

Fringing the broad central plain to the north is the spectacular Nyando escarpment and the Tinderet highlands to the east. To the south of the Nyando River is a lower rocky tableland extending from west of Muhoroni to Awasi market. This tableland is a lava bed that lies at about 1370 metres above sea level and 30-90 metres above the plain. A large section of the Sugar Belt is about 1300 metres so that the average temperature in the area is well over 21^{o}C, the temperature above which abundant sugarcane growth occurs.[6]

There are three zones of the plain.[7] Firstly, the plain proper, which is very flat with gentle relief broken in places by minor ridges (Fig. 6), intersecting water courses and their levees. It extends from the lakeshore at about 1140-1160 metres, and covers roughly 70,000 ha. including all the swampland and nearly all irrigable land of the Sugar Belt area. Secondly, the higher belt stretching north, east, and south from the plain proper with a



SOURCE : African scientist 1969

FIG.6 DETAILED RELIEF SKETCH OF PART OF THE SUGAR-BELT gradient 1:150. A segment of this belt, that is, Kibos, Miwani and Chemilil has irrigation potential. Thirdly, a zone represented by foothills to the escarpment with steep slopes and elevation roughly 1200 metres without irrigation potential.

Figure 7 depicts that on the steep escarpment, hilltops and hillslopes, the soils are much more shallow and stony, with occasional rock outcrop interspersed. These unsuitable soils for sugarcane production are commonly observed on the Nandi escarpment, Songhor inselbergs and Awasi tableland. According to Bunting (1969),[8] natural slopes with a continuous soil cover occurs at all slopes below 40° and the angle of 30°–32° is considered critical for stability, while slopes of 32°–37° are characterized by thin soils and they form the limiting angle of coherent and are undisturbed by mass movement unless they are excessively wetted. But slopes of 37°–40° usually have lithosolic, that is, rocky or stony soils. These are the undeveloped soils which D'Hoore (1964)[9] referred to as the "Non-soils". Nyanza Sugar Belt is not exceptional to these "rules of thumb" and soils in areas like Songhor hills consist of large boulders as well as shallow stony soils.

Both geological structures and topographical features determine the drainage pattern of the study area. A general trend of drainage system is east to west, although tectonic processes with the onset of Pleistocene times produced consequent modifications of the drainage system. Apart from the major rivers, most of the smaller rivers are ephemeral, existing only during the rains. Some of the rivers meander in mature courses, debouching into a swamp near the lake.

Drainage of the whole area eventually flows into Lake Victoria

(Fig. 8), although the gradual rise of the water level of Lake Victoria, heavy silting of the Nyando and Miriu rivers coupled with the absence of any strong currents in the gulf has resulted in the formation of extensive lakeside swamps. An interesting feature of these rivers is that they rise in the highlands having heavy precipitation. When they get to the lowlands, they cause serious flooding and eventual loss of vast tracts of potential agricultural land. One of the worst floods occurred in 1906, while the whole of Kenya was subjected to grave flooding in 1961, and early months of 1962, and the study area was a victim of this environmental hazard. Serious flooding also occurred in 1968 when the Ahero-Kisumu and Ahero-Sondu roads were destroyed and again in 1970/71, 1971/72 and 1974/75. The author observed that presently, flooding has become an annual phenomenon in the area, and the danger of flooding calls for proper flood control techniques in the irrigated areas (figures 9 and 10). The near-annual flooding invariably causes loss of property and damage to cash crops as well as subsistence crops, and is responsible for periodic peaks in the incidence of water-borne diseases.[10] In view of this hazard, any period of severe flooding is likely to bring an increase in ailment from such causes as pneumonia, dysentery, cholera and typhoid. Consequently, thousands of hectares of good cultivatable lands have been permanently submerged and this phenomenon has stimulated population migration from the Kano plains to the Resettlement Schemes.[11]

Soils of the area have been mapped (Fig. 11) and described by several authorities.[12,13,14] These soils are characterized by soils predominantly of alluvial or lake origin (basal plains); soils of colluvial apron and fan base areas having profile incorporated with recent sand and gravel accretion; and rock out-crops or shallow soils (0-120 cms.). Below is a detailed summary of the information contained in the soil map according to agricultural suitability (Fig. 12).

1. Swamps: These are mainly very dark greyish or black heavy cracking clays characterized by seasonal swamps, suited to rice through reclamation, and permanent swamps unsuitable for crops without extensive reclamation.
2. Poorly drained soils: Soils dominated by very dark grey, poorly or very poorly drained impermeable cracking, medium or heavy clays suited to rice, but fair for sugar and cotton. Furthermore, pockets of soils ranging from purely clay to loams of sloping colluvial fans developed from and underlain by clay and ash are suitable for sugar and cotton.
3. Somewhat poorly drained soils: These soils comprise dark brownish sandy clays, light clays moderately permeable and poorly permeable clays suitable for sugar and cotton. However, areas of very dark brown lighter clays overlying below very dark pooorly drained medium or heavy clays are fairly suitable to sugar, cotton and rice. Areas of infilled deltaic deposits of swamp fringes, and very brown friable textured clays are suited to sugar and cotton. Similarly, brown gravelly loam to sandy loam and hill wash overlying gravelly clay can be used for these cash crop. Areas with dark brown coarse sandy loam to clays overlying massive mudstone below (90-120 cms. are unsuitable for sugar but suited to grazing and subsistence crops. Some of these soils are associated with severe erosion hazard, especially in steep areas.

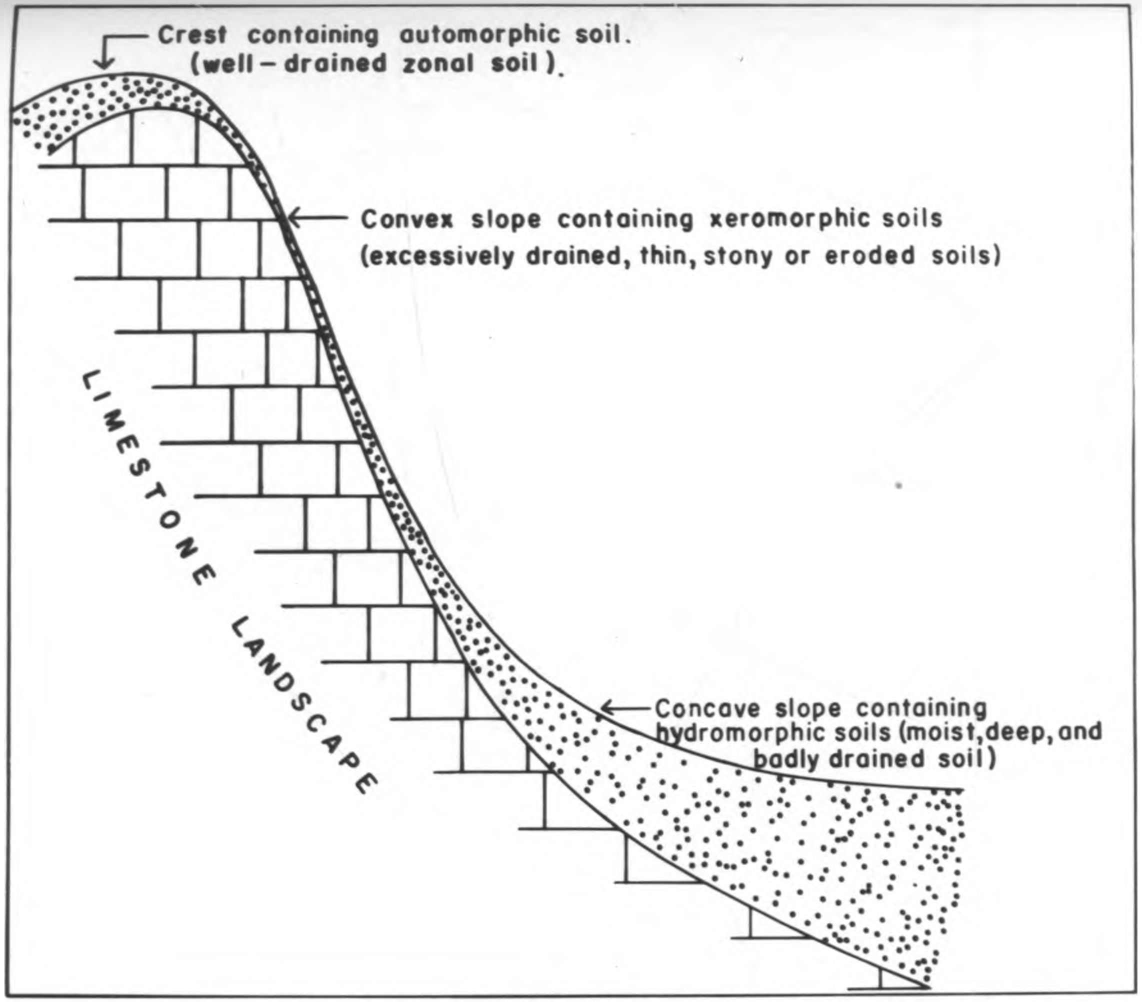
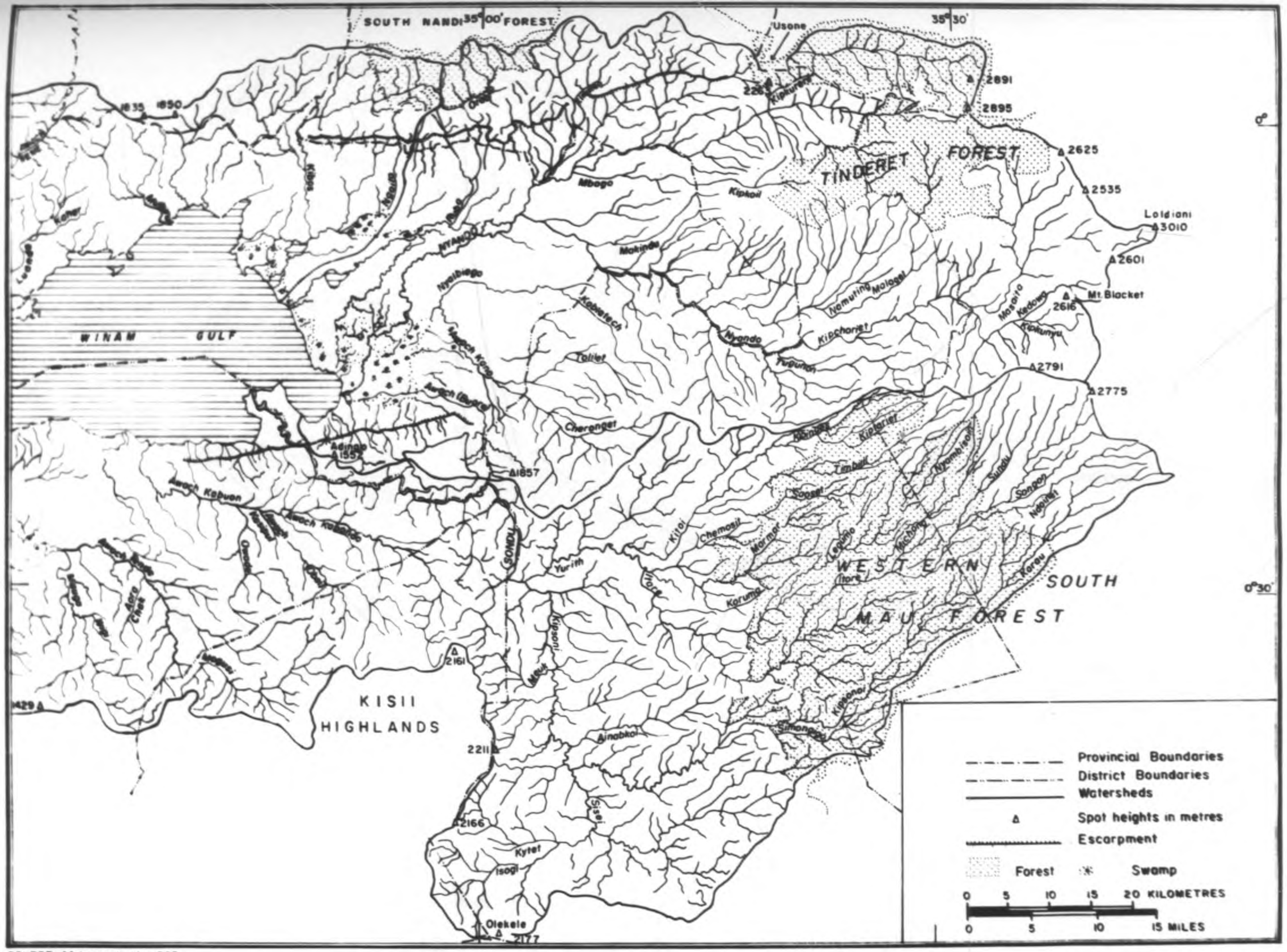


FIG. 7 IDEAL PROFILE ON A LIMESTONE LANDSCAPE LIKE KORU LIMESTONE AREA



SOURCE= African scientist 1969

FIG.8 DRAINAGE SYSTEM IN THE SUGAR-BELT AREA

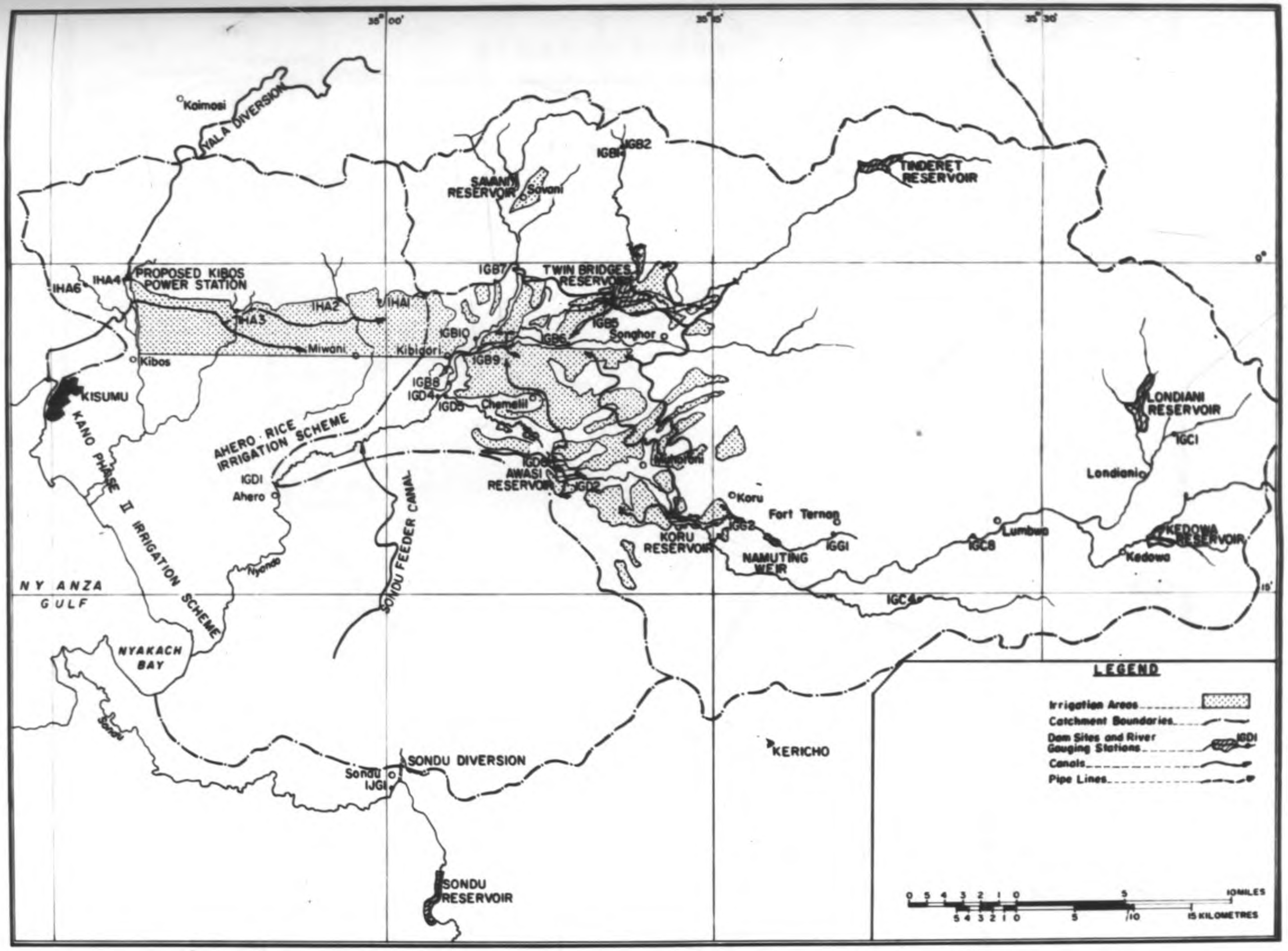
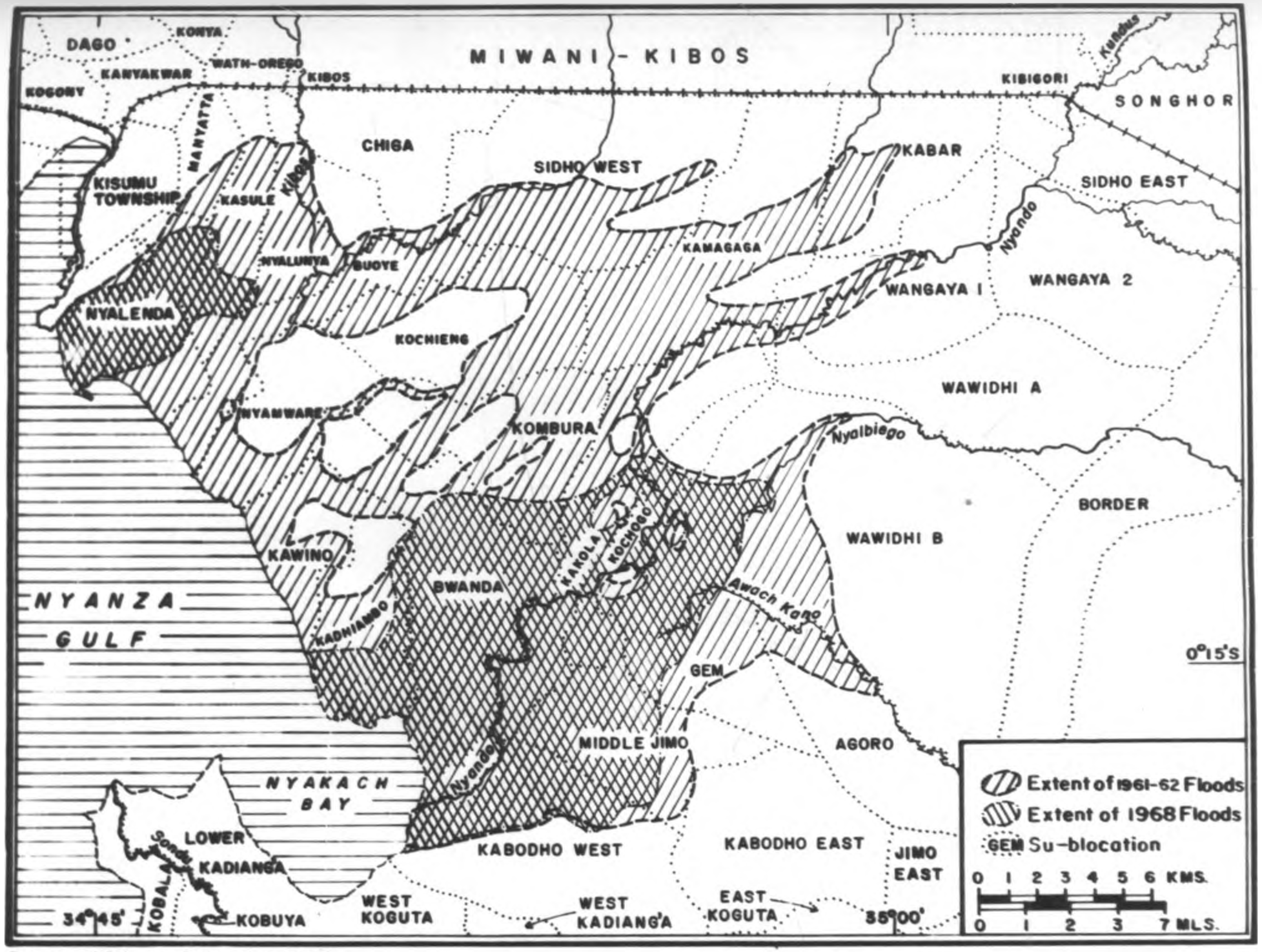


FIG. 9 NYANZA SUGAR-BELT IRRIGATION AREAS



Source: African Scientist 1969

FIG. 10 EXTENT OF THE 1961-62 AND 68 FLOODS IN THE LOWER SUGAR-BELT AREA (KANO PLAINS)

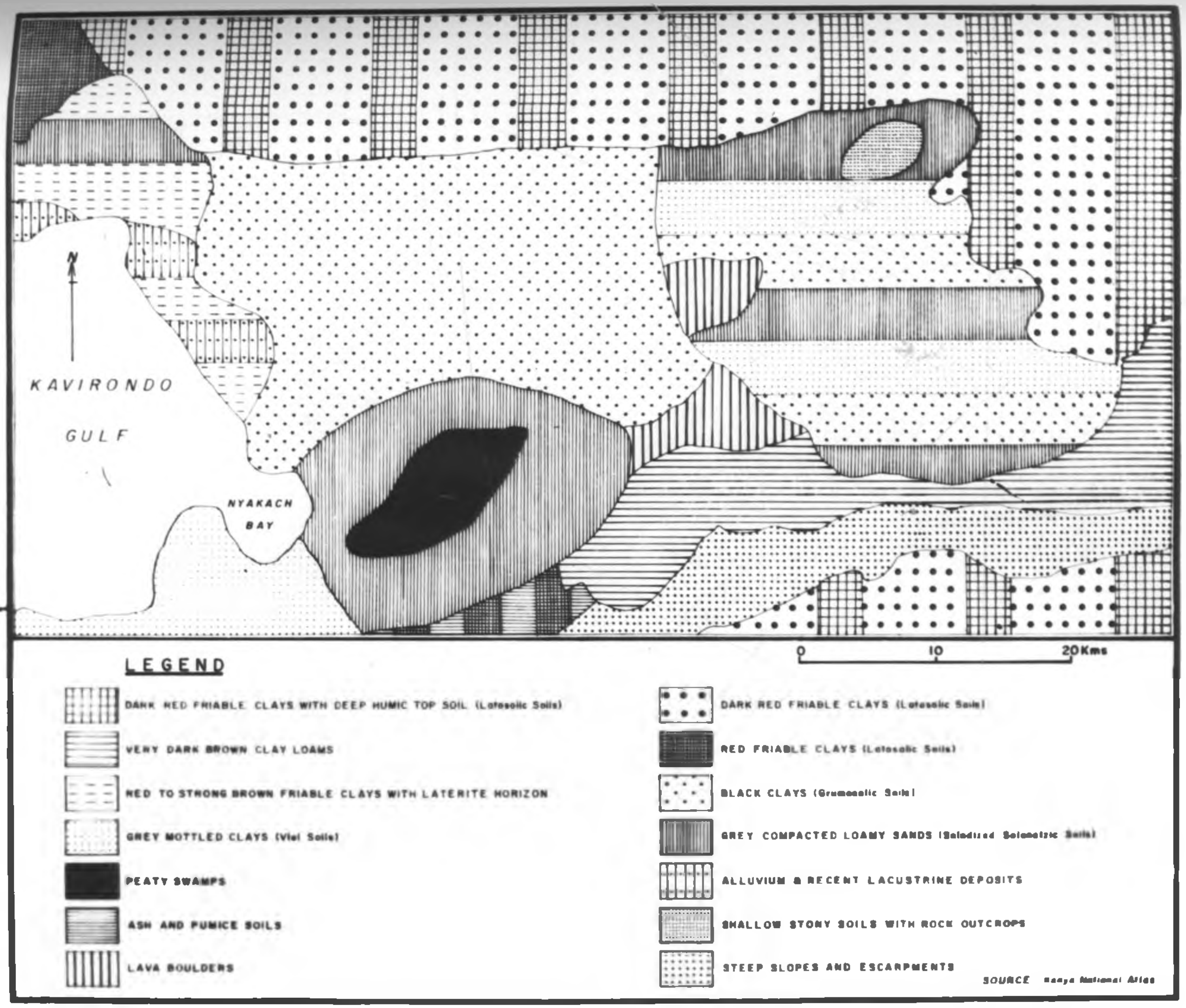


FIG.11 GENERALISED SOIL MAP OF THE SUGAR-BELT

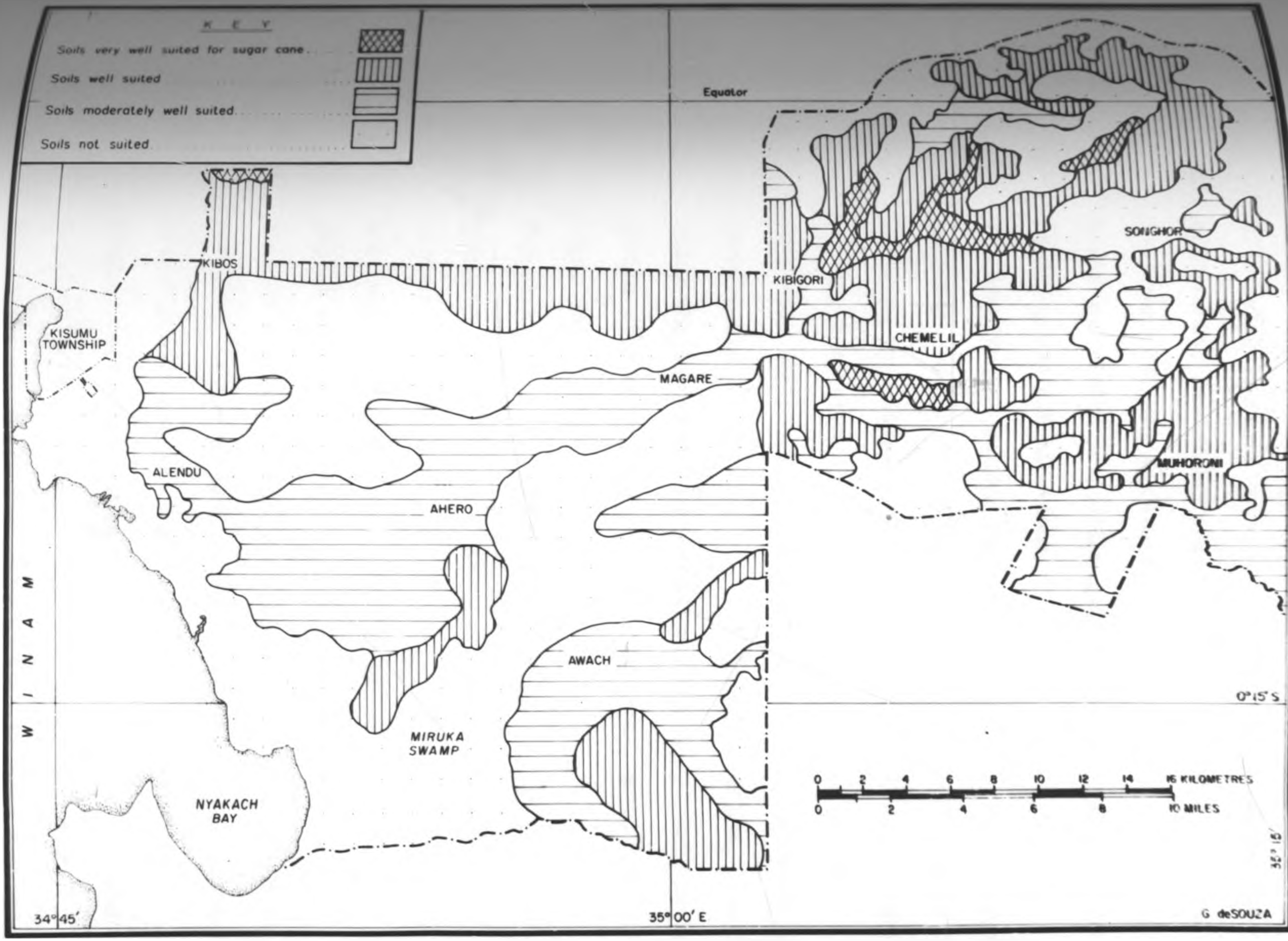


FIG. 12 NYANZA SUGAR BELT: SOIL SUITABILITY FOR SUGAR CANE

4. Better drained soils: These soils are dark brown and are of varying texture: sandy clay loam, coarse sandy loam, sandy loam, sandy clay and clay loam. They have medium to low humus and are exposed to erosion hazards in some areas. Sugar and cotton production can be practised except in areas of topographic limitations.

5. Saline-Alkaline soils: Mainly dark brownish and moderately permeable soils of varying tecture. They are slightly alkaline to saline-alkaline soils fairly suited to sugar and cotton, but better for grazing as well as settlement.

6. Latosolic soils: The soils consist of dark yellowish to dark reddish brown coarse hill wash accumulation, localized below the escarpment of granitized material. Soil tecture varies from sandy loam to sandy clay loam, suitable for sugar and/or cotton.

7. Phonolite rock or shallow lateritic soils: Rock or laterite outcrops or very shallow (0-25 cms.) soils belonging to Kenya or Kericho type phonolite material, and granitized material are unsuitable for sugar, save for grazing and shallow rooted subsistence crops.

8. Shallow over mudstone: These are very shallow (5-25 cms.) gravelly, silty, or sandy clays overlying massive, sometimes gravelly mudstone and shallow (30-85 cms.) dark brown grey clay to loam overlying massive, sometimes gravelly mudstone unsuitable for sugar except grazing and settlement.

The clay contents in "black cotton" soils vary from 35-60% in the topsoil and 40-70% in the subsoil, but the silt content is about 20% in the topsoil.[15] Such soils are suitable for irrigation in places of undulating relief, 2-6% slope. In order to obtain maximum benefit from irrigation, there is need for flood measures to prevent flooding from the uncontrolled rivers and from the lake by building dams and dyke systems to confine the lake water transgression. Moreover, application of chemical fertilizers and organic manures would be necessary in improving structure of most soils. The rate at which water infiltrates into the soils should be considered before irrigation and the rate and method of application should be commensurate with the rate of intake in order to avoid wastage.

Climate

The principal climatic features of interest to the agriculturist are the rainfall and the temperature because variations in these two parameters are undoubtedly linked, but not so closely as to forbid their consideration separately.[16] The Nyanza Sugar Belt experiences sub-humid Tropical Climate,[17] which is classified as humid in terms of rainfall.

Temperatures in the Sugar Belt are modified by the altitude and the proximity of Lake Victoria. As with humidity and wind, seasonal variations in temperature are small. The mean monthly maximum and minimum temperatures experienced throughout the period 1968-1974 at Chemelil are provided in table 3. Highest temperatures occur from December to March. The minimum temperatures seem to be low enough to inhibit sugarcane growth and reduce cane yield, although temperature variations in the area means that a wide range of crops can be grown. Other important factors shown in table 3 are relative

TABLE 3: SUMMARY OF MEAN MONTHLY METEOROLOGICAL DATA FOR CHEMILIL, 1968-1974

Month	Rainfall in mm.	Pan evaporation in mm./day	Evapotranspiration in mm/day	Radiation in GmCal/ cm^2/day	Sunshine Hours/ Day	Temperatures Max. °C	Temperatures Min. °C	Wind Km. p.h.	% Relative Humidity 0900	% Relative Humidity 1500
Jan.	118.3	6.0	5.9	574.2	8.5	30.6	14.4	5.7	64.1	44.1
Feb.	102.5	6.6	5.3	584.9	8.7	30.7	14.7	5.9	62.9	40.5
Mar.	129.9	6.5	3.1	582.4	8.5	31.0	15.1	5.7	61.8	40.5
Apr.	221.8	5.8	5.0	540.3	7.7	29.3	16.0	5.3	74.0	52.7
May	171.1	4.8	6.5	517.7	7.1	27.9	15.8	4.5	75.3	59.0
Jun.	146.2	4.5	4.0	493.7	7.3	27.5	14.2	4.5	74.7	53.7
Jul.	103.2	4.3	3.6	472.6	6.7	27.4	14.2	4.3	71.5	52.1
Aug.	97.8	4.3	5.0	486.7	6.7	28.0	14.2	4.8	73.5	52.2
Sep.	97.3	4.9	4.7	510.6	7.2	29.3	14.1	5.0	68.2	57.7
Oct.	109.0	5.1	3.6	430.4	7.7	30.0	14.2	5.1	64.3	51.3
Nov.	114.4	5.3	4.3	421.1	7.1	29.1	14.7	5.1	65.2	50.4
Dec.	101.6	5.9	3.8	457.9	8.5	30.4	14.1	5.4	61.3	41.0

Source: Chemilil Sugar Company Ltd., Agronomic Annual Report, 1974 humidity, sunshine hours, rainfall regime, wind speed, radiation, mean evapotranspiration data and mean pan evaporation data. These parameters emphasize the suitability of the environment for agricultural development and the success of sugarcane production to more or less extent is proof of this.

Nyanza Sugar Belt is regarded as part of the High Potential land areas of Kenya, which reliably receive about 1250 mm. per annum (Fig. 13). Much of the rainfall occurs as torrential thunderstorms, which is not beneficial but produces rapid erosion, rapid run-off and large gullies in the thick soil cover of cultivated fields, especially in Awasi, Nyando escarpment, Kipsitet and steep hillslope areas of the Sugar Belt. The distribution of precipitation within the area corresponds very roughly with the occurrence of the highest elevation (table 4), that is, actual amounts received over the entire area increase from the gulf shore eastward apparently accompanying the rising relief; the plain being comparatively less wet corridor of rainfall (fig. 13).

Physiography of the area remarkably influences the rainfall, the amount of precipitation decreases from north to south, being highest over the highlands where precipitation reaches over 1500 mm. per annum. But the lower grounds at the foot of the scarps are rainshadow areas receiving about 1200 mm. annually. Sugarcane is not grown on the Nyando escarpment due to low temperatures of about 15°C, instead sugar is superseded by tea which prefers cooler climate and more acid soils.

Although there is a positively moderate relationship between rise in altitude and mean annual rainfall in the area, the computed correlation coefficient, r = 0.50, is not significant at 95% level

Table 4

CORRELATION BETWEEN ALTITUDE AND MEAN ANNUAL RAINFALL IN THE SUGAR BELT AREA

Station	Years of mean	Altitude in metres (X)	Mean annual Rainfall in mm. (Y)
Kisumu	71	1149	1208
Kibos Cotton	20	1174	1240
Miwani	45	1207	1404
Ahero	22	1220	1183
Chemelil	35	1229	1297
Muhoroni	63	1300	1502
Koru Coffee	8	1585	1715
Songhor M'lale	20	1768	1284
Savani Tea Estate	30	1860	1475
Nandi Siret	15	2161	1499
	Mean	1466	1381
Correlation Coefficient (r) between altitude and rainfall = 0.50			

$$r = \frac{\sum xy}{(\sum x^2 \sum y^2)^{\frac{1}{2}}}$$

Where $x = X - \bar{X}$

$y = Y - \bar{Y}$

$$r = \frac{268084}{539340}$$

$$= 0.50$$

of probability using "t" test. About 25% of the spatial variation in precipitation in the Sugar Belt is accounted for by the variation in altitude. The remaining 75% is perhaps explained by proximity to the lake, seasonal movements of the equatorial low-pressure trough and humid westerly airstream from the Congo basin.

The predominant influence on the seasonal distribution of rainfall in the Sugar Belt area are two main air mass systems: the north-east and the south-east airstreams. Passage of the inter-tropical front over the area coincides with wet seasons, namely: March to May, usually known as the "Long Rains" and October to November, usually referred to as the "Short Rains". Furthermore, prevailing wind from the south-west has the opportunity of picking up moisture from the lake and this moisture is subsequently received by the hinterland, the Sugar Belt. Fearn (1961) noticed that the area under study derived its geographical unity from the structural history of the Lake plateau and from the climatic pattern due to the distribution of rainfall.[19]

Table 5 indicates the mean monthly and annual rainfall computed from data over 20-71 years of six stations in the area. The area enjoys a bimodally distributed rainfall pattern (figs. 14, 15, 16, 17, 18 and 19) with a mean annual rainfall of at least 1000-1500 mm. An examination of the rainfall histograms for various locations presented in these figures indicates, however, that there is no protracted dry season. Even during the dry spells of December-February, several thunder showers are likely to occur. Long term records indicate erratic variations in rainfall distributions occurring over long periods as well as seasonally over monthly periods. Such erratic variations in rainfall have serious reper-

Table 5

MEAN MONTHLY AND ANNUAL RAINFALL AT SELECTED STATIONS IN THE NYANZA SUGAR BELT AREA (Rainfall in millimetres)

Station	Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Kisumu	71	53.33	73.82	147.67	196.40	166.01	93.61	63.86	87.37	70.86	58.74	95.90	100.06	1207.63
Ahero	22	62.12	74.18	152.62	179.80	152.72	71.55	69.49	74.77	68.01	82.93	108.35	86.88	1183.44
Kibos	20	54.00	94.68	168.13	180.52	140.72	87.98	55.35	71.14	77.20	83.93	121.92	104.50	1240.07
Miwani	45	70.77	81.79	152.15	220.47	170.43	100.33	82.30	109.98	98.81	94.74	119.89	102.36	1404.02
Chemilil	35	62.30	81.30	131.80	198.30	164.30	99.80	74.20	100.00	90.20	94.00	117.90	85.60	1296.70
Muhoroni	63	62.00	109.00	161.00	247.00	186.00	115.00	102.00	126.00	99.00	78.00	113.00	104.00	1502.00

Source: 1. D'Costa, V. and Ominde, S.H. (1973). Soil and Land-Use Survey of the Kano Plain-Nyanza Province-Kenya. Occasional Memoir No. 2, Department of Geography.

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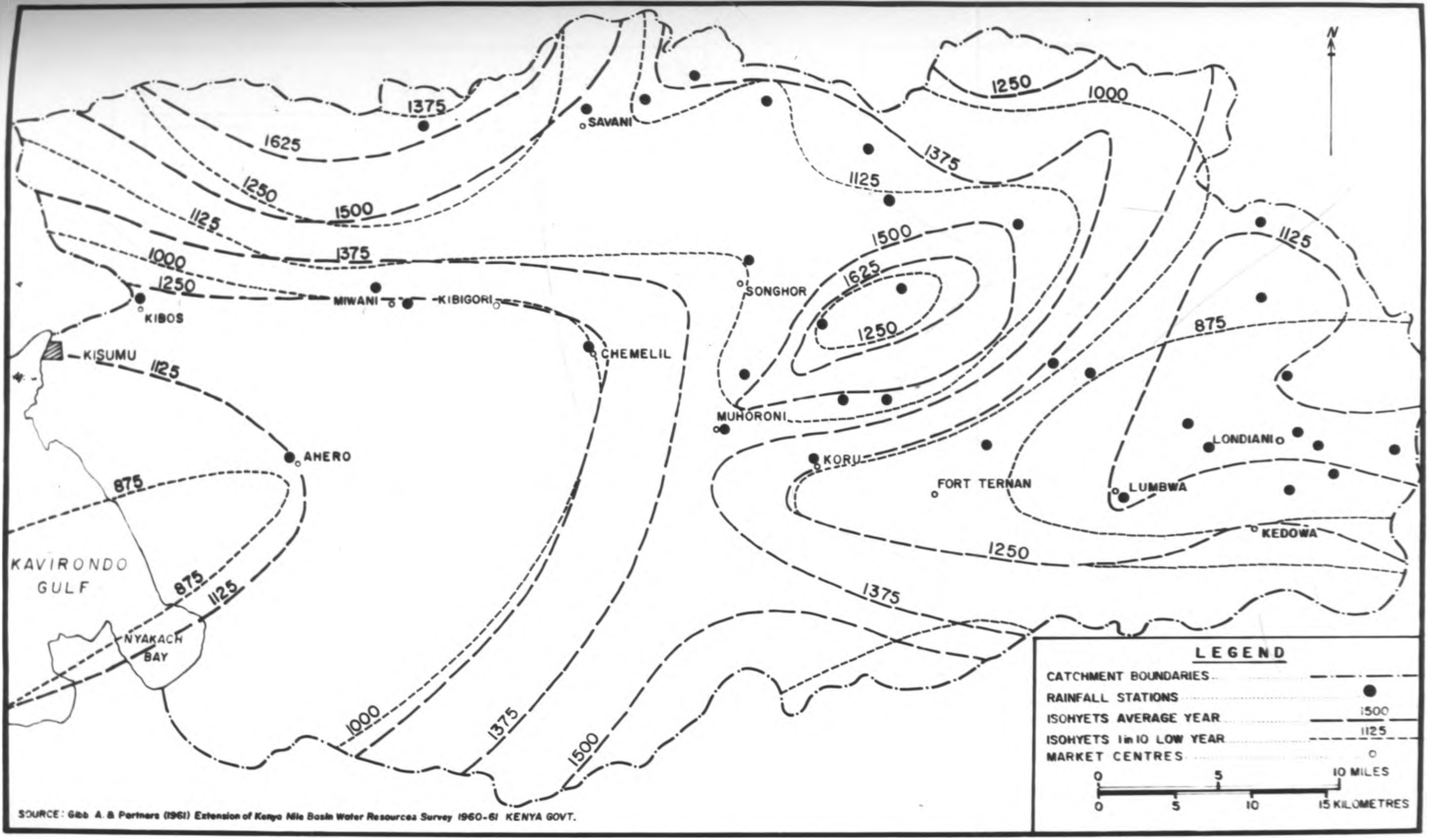

FIG.13 RAINFALL DISTRIBUTION (mm) IN THE SUGAR-BELT AREA

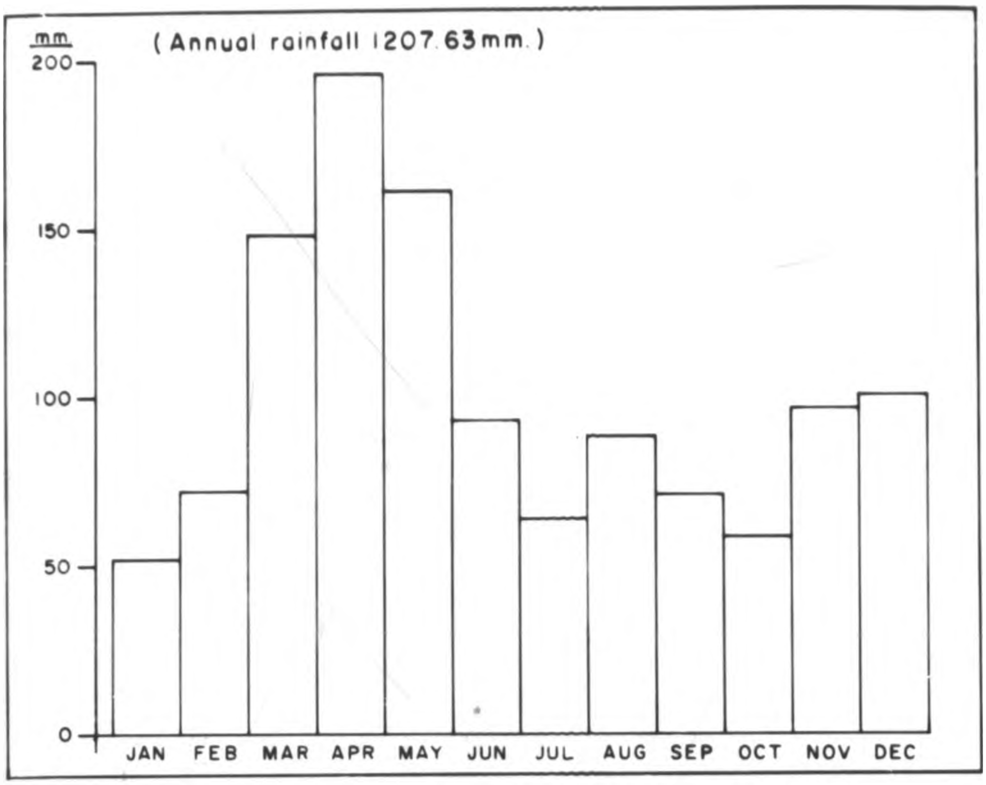

FIG.14 ANNUAL PRECIPITATION AT KISUMU

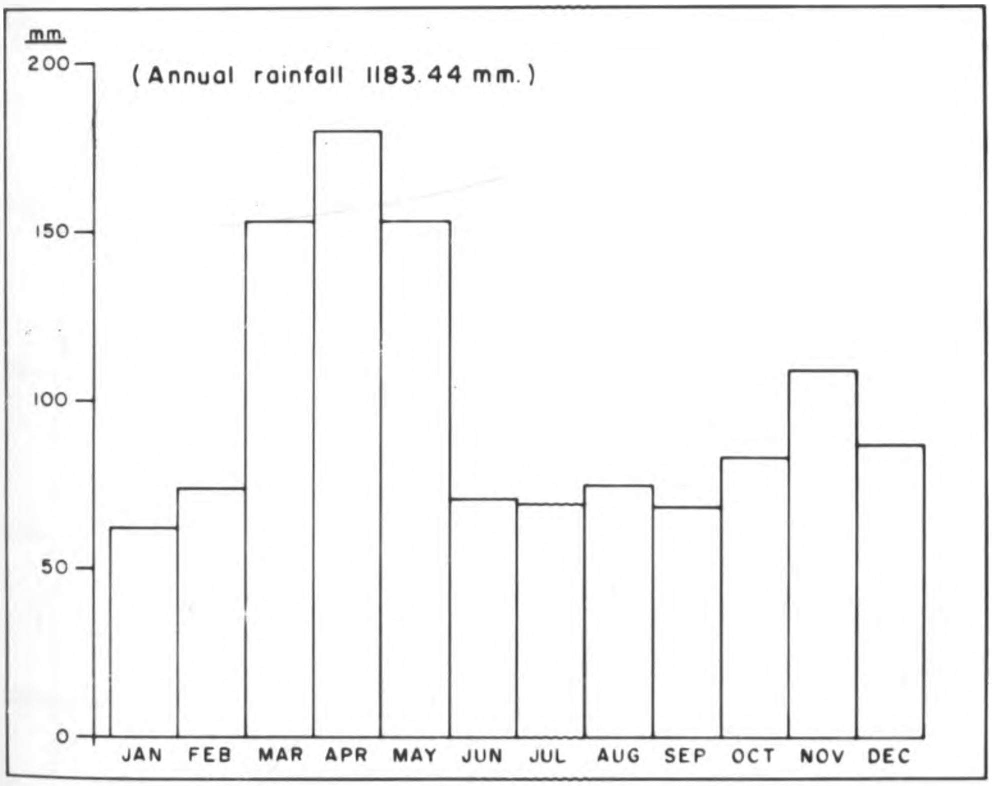

FIG.15 ANNUAL PRECIPITATION AT AHERO

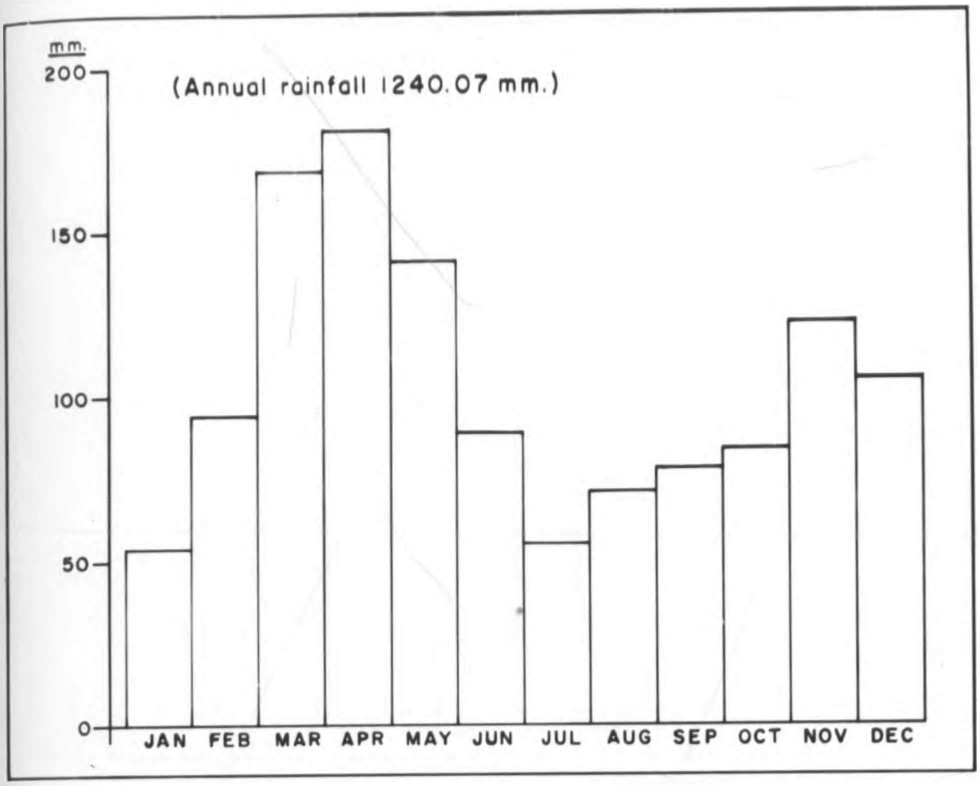

FIG.16 ANNUAL PRECIPITATION AT KIBOS

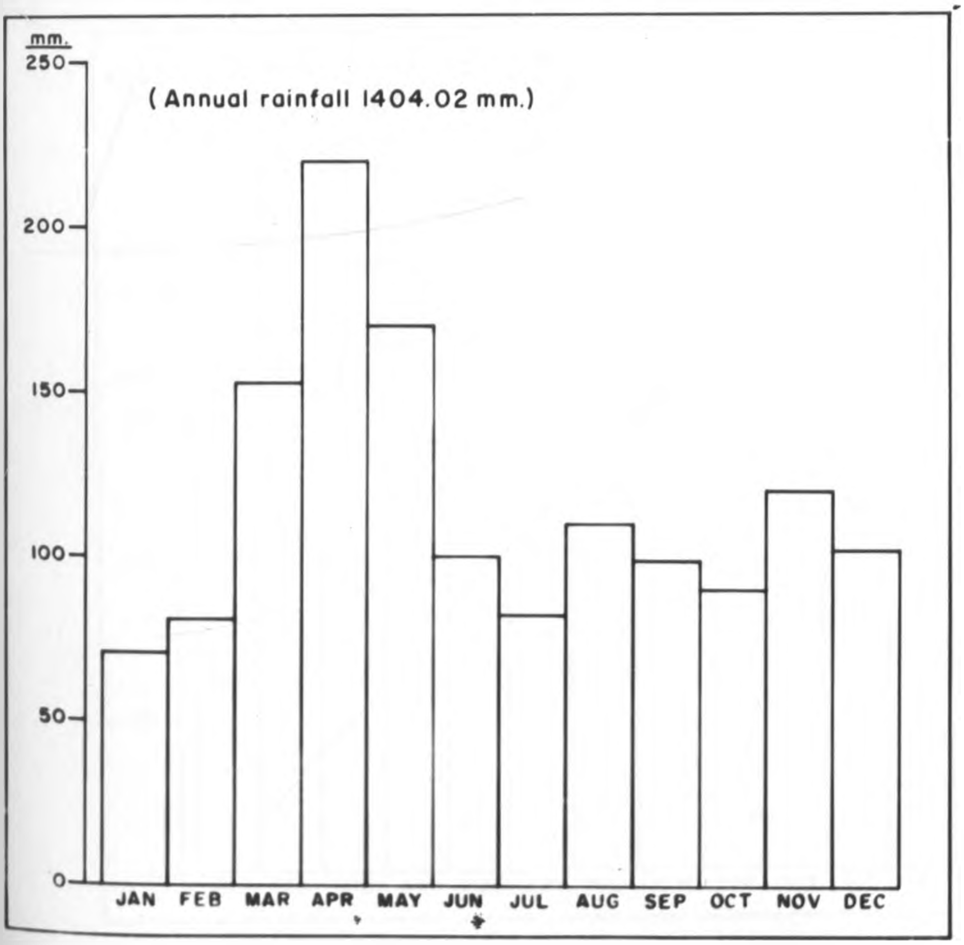

FIG 17 ANNUAL PRECIPITATION AT MIWANI

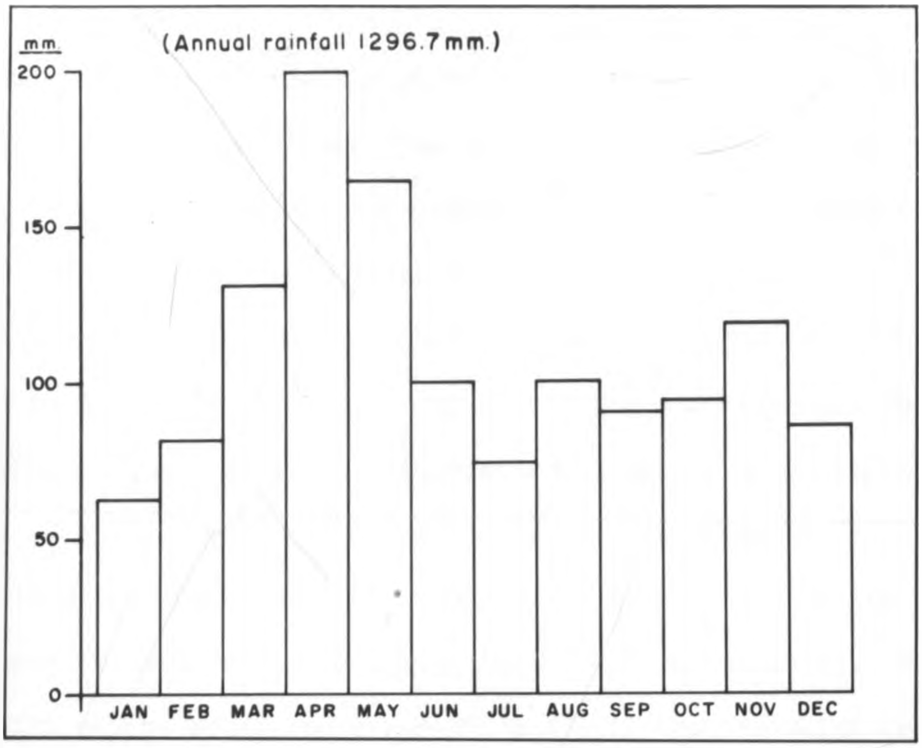

FIG.18 ANNUAL PRECIPITATION AT CHEMELIL

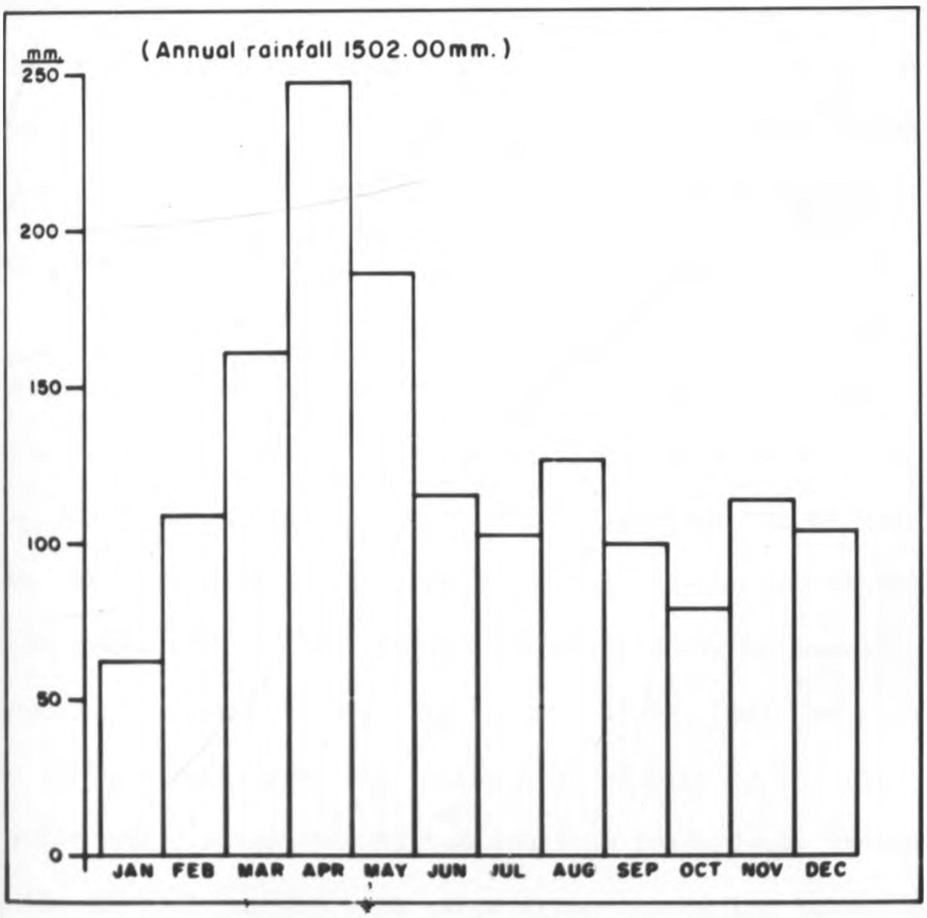

FIG.19 ANNUAL PRECIPITATION AT MUHORONI

cussions that result in alteration of drought and flood in the area. But variations in the time of onset and the amount of precipitation received from one season to the next are reflected in crop yield fluctuations which may at times be disastrous.[20] The rainfall received in the Sugar Belt is further subjected to other environmental parameters which may reduce its effectiveness for sugar cane production. Radiation, temperature, lengh of day, atmospheric humidity, and air movement determine the effectiveness of rainfall from the agricultural point of view, since they determine the rate and amount of evaporation and evapotranspiration (table 3). To this list may be added rapid run-off and soil erosion which are equally vital in agriculture. Studies by Woodhead (1968)[21] show that annual evaporation of 2200-2400 mm. in the area greatly exceeds the total annual rainfall of the stations given in table 5. It is clear from this discussion that the decline in sugarcane yields in the Sugar Belt can be ascribed to the short supply of available soil moisture in the relatively dry months.

In summary, the varied range of altitude, together with the associated variations in temperature and rainfall has helped determine the range of crop enterprises of the area as well as limiting the area of the Sugar Belt where sugarcane can be grown with success. The rainfall regime varies not only in the amount which different areas receive, but in the reliability of the annual distribution at each station. But no area of the belt can, however, be said to be marginal, as the rainfall is nowhere so low that cultivation under reasonable system would be precarious, though of course the Kano plains and some other areas around the lakeshore would benefit from irrigation. The rainfall regime of the area can be summarized as one in which rainfall comes throughout the year, but in which two peaks of rainfall occur soon after the equinoxes.[22]

Vegetation and Ecology

Vegetation is determined by the interaction of physical factors such as the various components of climate, the soil types, and the catenary effects referred to in the previous chapter. The catenary effects are the result of interacting edaphic and biological environment. Other factors influencing vegetation in the study area are burning and different types of land-use: agriculture, grazing and human settlements. As the vegetation in the Sugar Belt is largely the result of the interaction of climate, soil and human activities, it follows that the mapping of vegetation types gives similar agricultural planning indications to any of the causal variables considered in isolation

Ecologically the Sugar Belt falls under scattered-Tree Grassland, Low Tree-High Grass or Combretum-hyparrhenia,[23,24,25] which is further divided into three ecological zones.[26,27] Firstly, is the lakeshore savanna zone, which rises from the lakeshore to 1200 metres. This is the hottest zone with rainfall ranging from 750-1000 mm. per annum. The principal agricultural enterprises are maize, groundnuts, kenaf, cotton, and root crops. Rice is also grown under irrigation (fig. 20), while livestock is the main source of agricultural income. Despite the low rainfall in this zone, sugarcane has extended into this area. Secondly, the star Grass (Cynodon dactylon) zone occupies 1350-1800 metres. It has more than 1500 mm. of rainfall per annum, but it is warmer than the Kikuyu Grass (Pennisetum Clandestinum) zone. This zone is well suited to live-

Fig. 20. Both photographs indicate people cultivating rice at Ahero Irrigation Settlement in November, 1975. At the background is the Nandi Escarpment

stock. Thirdly, is the "Intermediate" or "Higher Rainfall" savanna which falls as its name suggests between the zones mentioned above with respect both to altitude and rainfall. Although rainfall is more reliable than in the lakeshore savanna, its soils, consisting primarily of red or brown friable clays, tend to be less fertile. Portions of the area are suitable for robusta coffee, but the whole area is suited to cotton, sugarcane, groundnuts, oil seeds, maize, beans, millets, sorghum and root crops. Consequently, animal husbandry is possible in the whole area.

Shallow soils, with strongly developed lateritic horizons on gneiss, and on basaltic and phonolitic rocks have savanna vegetation dominated by combretum trees and grasses of Hyparrhenia spp. Acacia Seyal dominate outcrops of phonolitic lavas in Awasi area where extensive communities of Acacia spp. have isolated stands of Balanite aegyptiaca and Euphorbia candelabra. The two latter vegetation species are indicators of poor soils for agricultural purposes. Ridges in the Sugar Belt are generally occupied by Acacia spp. associated with Red Oats grass botanically referred to as Themeda triandra. Themeda triandra indicates vegetation which is often burnt by pastoralists. The heavily grazed areas are dominated by Hyparrhenia filipendula, but the lower parts of the plain have been reduced to turfs of Hyparrhenia by grazing. Stony gneissic mountains west and north of Songhor are dominated by scattered Combretum Bauhinia, interspersed with tall grasses. Bauhinia is the most important tree of the savannas, with heavy dark-grey and black clay soils and it thrives on clay soils which occur on slopes with good surface drainage, even where subsoils may be very seepy and wet during rainy seasons.

On the waterlogged plains with alkaline black clays, Pennisetum mezenum is often dominant grass. The non-alkaline grey clays, in flat bottoms of valleys contain dense stands of Hyparrhenia rufa. However, Acacia-Campylacantha grows luxuriantly along the river banks where soils are fertile and moderately well-drained, nevertheless, it can also be found around the rims of the clay plains where it seems to be dispersed from the flood plains.

Studies conducted in other countries indicate that there is very close correlation between soil and vegetation, hence soils can readily be recognized by the nature of the bush upon them.[28] But most of the Sugar Belt has been influenced by human activity so that there is little or no natural vegetation left. Consequently, it is more important to understand the dynamics of the vegetation pattern than details of its morphology; and the importance of recognizing the equation of the ecosystem in which solar energy, climate, soil, plants, animals and man are all involved is more fascinating to planners and geographers.[29]

In spite of any limitations, a vegetation survey is instrumental in assessing agricultural potential and possibilities, particularly in peasant areas where soil surveys are frequently unavailable and meteorological data may be meagre or completely lacking. The paucity of vegetation coupled with other ecological factors: drought, floods, diseases and soil differences determine the degree of variations of the farmers' environmental perception, and differences in agricultural systems of land-use.

Disease Problems

The discussion on the physical environment would be incomplete without a mention in passing of disease problems in the study area. Presently malaria is the most prevalent disease because of the suitable aquatic habitats favouring multiplicity of malarial vectors. The presence of large bodies of stagnant water in areas of swamps and irrigation stands out as a threat to human health and agricultural development. Malarial studies in other countries indicate that areas infested by mosquitoes may be unusable, or can only be used at certain seasons of the year perhaps for the dry season grazing of cattle. According to Farmer (1957) endemic malaria had a tremendous effect in retarding the agricultural development of the 'dry zone' of Ceylon until it became possible to control mosquitoes.[30]

Another water-borne disease is Schistosomiasis (Bilharzia) whose vector are water-snails, Bulinus Africanus (Physopsis group). The disease is transmitted into human beings when bathing, or cultivating rice in pools of standing water, although the "black cotton" soils are not very conducive to the Bilharzia vectors mentioned above. Other water-borne diseases commonly found in the area are cholera, amoebic dysentery, typhoid fever and the like. Cholera recently claimed many lives in the area.

Disease carrying insects like the tsetse-fly find a diversity of environment within which to prosper and in turn they become a serious impediment to agricultural development. Areas infested by tsetse-fly have relatively few people and their development lag behind tsetse-eradication. Onyango (1971) states that about 1901 epidemic of sleeping sickness was ravaging the north-eastern shores and the islands of Lake Victoria.[31] By 1953, about 10% of the Republic of Kenya was subjected to infestation with the fly,[32] and this included the Sugar Belt.

Several Glossina spp., vectors of cattle and human forms of trypanosimiasis commonly called "nagana" and sleeping sickness respectively, occupied the lakeshore belt by the turn of the century because the original vegetation cover, rainfall, and altitude, provide favourable conditions for them. Oral traditions of the lacustrine population suggest that the fly entered a well-populated area settled by a people practising fishing and pastoral activities.[33] Tsetse clearance in the Nyando valley occurred in the early 1950's. But Morris (1960) recorded three epidemics of sleeping sickness which caused tolls on human life and livestock.[34] Hence the Sugar Belt area has not fully recovered demographically and economically from the early invasion of tsetse-fly. Moreover the prolonged prevalence of tsetse-flies in certain portions of the area until recently is likely to have prevented cross-fertilization of ideas, trade and development.[35]

Despite these problems, the widespread occurrence of many debilitating diseases in the area naturally reduces the energy, initiative and mental capabilities of the indigenous people and a developing country like Kenya has to spend large capital resources on research and eradication programmes in order to alleviate the disease threats in an agricultural environment. Similarly, the impact of some of these diseases is to-day reflected in labour shortage in some areas of the Sugar Belt.

Demographic Factor

The Sugar Belt is an economic development area which knows no administrative boundaries because it comprises three districts:

Kisumu, Nandi and Kericho. By far the most striking characteristic of these districts considered as one universe is the number of people residing there. Oucho (1974) noted that overpopulation in the area is intensified; inter alia, by fragmentation of land, a commodity which has become more increasingly scarce for the teeming population.[36] However, it is not simple to give the estimate of population growth rates of Sugar Belt, but it may be taken to be more than 3.3%, which is the present national growth rate. Nevertheless, growth rates alone do not present the while picture, but growth rates as predicted by demographers will cause the population in the area to double by the year 2000.

A second facet of the demographic mosaic is age structure. In this aspect two major factors emerge, namely: the size of the dependent population, and the other is an indication of future growth. Table 6 gives a breakdown of the percentage of the population in each age-group. Approximately 48.2% of the people are aged 14 or under. The dependent population, that is, the percentage of the population under 15 years and above 60 years old is about 53.1% showing that the 46.9% in the productive years must support the remainder of the population. Moreover, not all of the people in the so-called productive years are contributing to agricultural output. Another explanation is that the size of the population under age 15 indicates a possible increase in the overall growth rate in the near future as these children reach reproductive age.

Wide variations in the population distribution exists in the Sugar Belt (fig. 21). The mean population density in 1969 for the three districts considered together was roughly 121 per square

Table 6

CUMULATIVE PERCENTAGE FREQUENCIES FOR POPULATION IN THE SUGAR BELT AREA BY AGE GROUP

Age Group	Male	Female	Total	Cumulative (Male and Female
0-4	18.5	18.6	18.6	18.6
5-9	16.2	16.8	16.5	35.1
10-14	13.0	13.1	13.1	48.2
15-19	10.4	10.7	10.6	58.8
20-24	8.5	8.2	8.4	67.2
25-29	7.0	7.2	7.1	74.3
30-39	10.2	9.6	9.9	84.2
40-49	6.8	6.3	6.6	90.8
50-59	4.5	4.1	4.3	95.1
60+	5.0	4.7	4.9	100.0

Source: Calculation from Kenya Population Census, 1969, Volume I. Statistical Division, Ministry of Finance and Economic Planning, November, 1970. pp. 121-122.

kilometre, but there are islands of population concentration (fig. 21). Population settlement in the area is restricted to the slopes and hilltops, the remaining low undulating plateau is extensively cultivated, while drier slopes unsuited to sugar production are extensively grazed. In some areas, there is no definite pattern of settlement, but villages tend to lie along the major communication

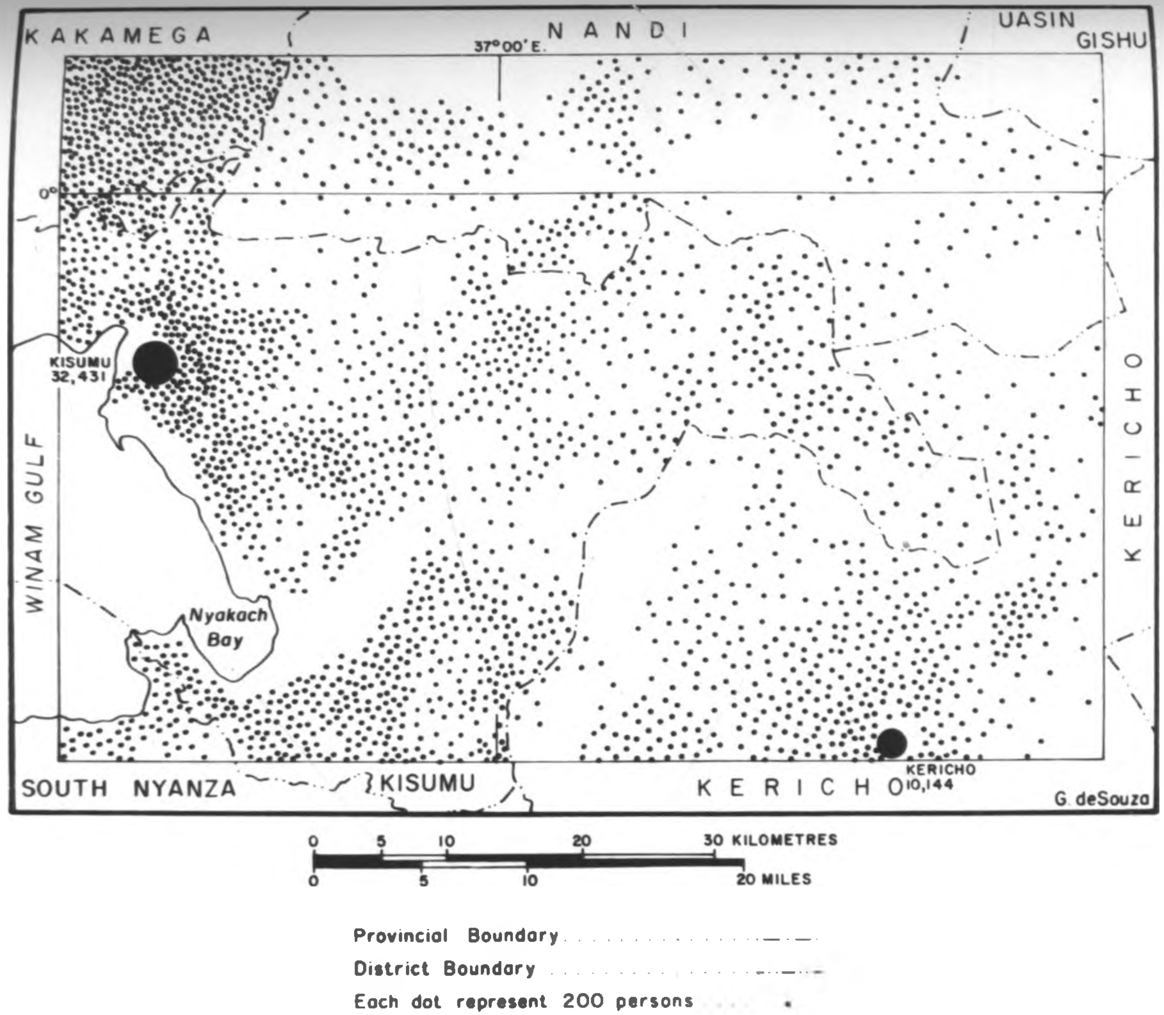

FIG 21 NYANZA SUGAR BELT AREA: POPULATION DISTRIBUTION, 1969 CENSUS

lines. Villages are scattered here and there in the lower parts of the plains.

The boundaries between the various ethnic groups are sparsely populated. These were known as the buffer zones separating warring tribes; Luo, Kipsigis and Nandi, but one should not lose sight of the tsetse-fly which occupied some of these belts until recently, thereby decimating human population and precluding human settlement.

The Nyanza Sugar Belt has a more recent history and settlement within the area was initiated by the colonialists who gazetted the area as a scheduled land for European and Asian farmers, although after independence the Africans were encouraged by the Government to settle in the former scheduled area.

Garst (1972) noted that the abrupt change in the ethnic composition of the population at the borders of the Kisii district is a remarkable feature of the cultural geography of Western Kenya.[37] The Nyanza Sugar Belt is remarkably heterogeneous ethnically, although the major ethnic groups are Nilotes, and Nilo-Hamites. Hence, the area is inhabited by different ethnic groups which have different cultural behaviour. This affects the system of land tenure, inheritance, and vulnerability to social changes. It partly accounts for the great diversification within the spatial diffusion of agricultural innovations. Moreover, with a relatively high population growth rate among the ethnic groups we notice population pressure acting as a stimulant to spatial population mobility.

In summary, the geographic and demographic background of the area indicates environmental problems of far-reaching influence on agricultural development.

Infrastructural Development

Transport has been one of the principal problems in the process of modernization of rural areas with post-independence break-up of former large-scale European and Asian farms, for example, in the Sugar Belt. Some remote areas are inaccessible and the cost of transport over extremely poor roads becomes excessively high. Figure 22 shows infrastructure in the Sugar Belt. Currently the major roads are tarmac surface. A few feeder roads are murram (gravel); they are passable in all weather, but most of the feeder and access roads are unimproved and very difficult, and therefore expensive to travel over. Obviously these roads make the marketing of all cash crops more economic.

Other transportation improvements are in the "pipe-line", although new road constructions in the escarpment and hilly areas is costly because of the steep and rocky nature of the terrain. Extensive gravelling is of paramount importance in the belt due to the nature of the predominantly clay soils and the risk of regular flooding in the Kano plains augment the cost of new road constructions as well as their maintenance, especially south of Ahero.

Extension of the railway system in the Sugar Belt has been instrumental in the economic development of the Sugar industry. The main railway line runs almost parallel to the major roads. Roads and railways are the most important infrastructural development influencing the profitability of sugarcane production, but there are numerous other developments aimed at upgrading the rural standard of living that are vital in alleviating population

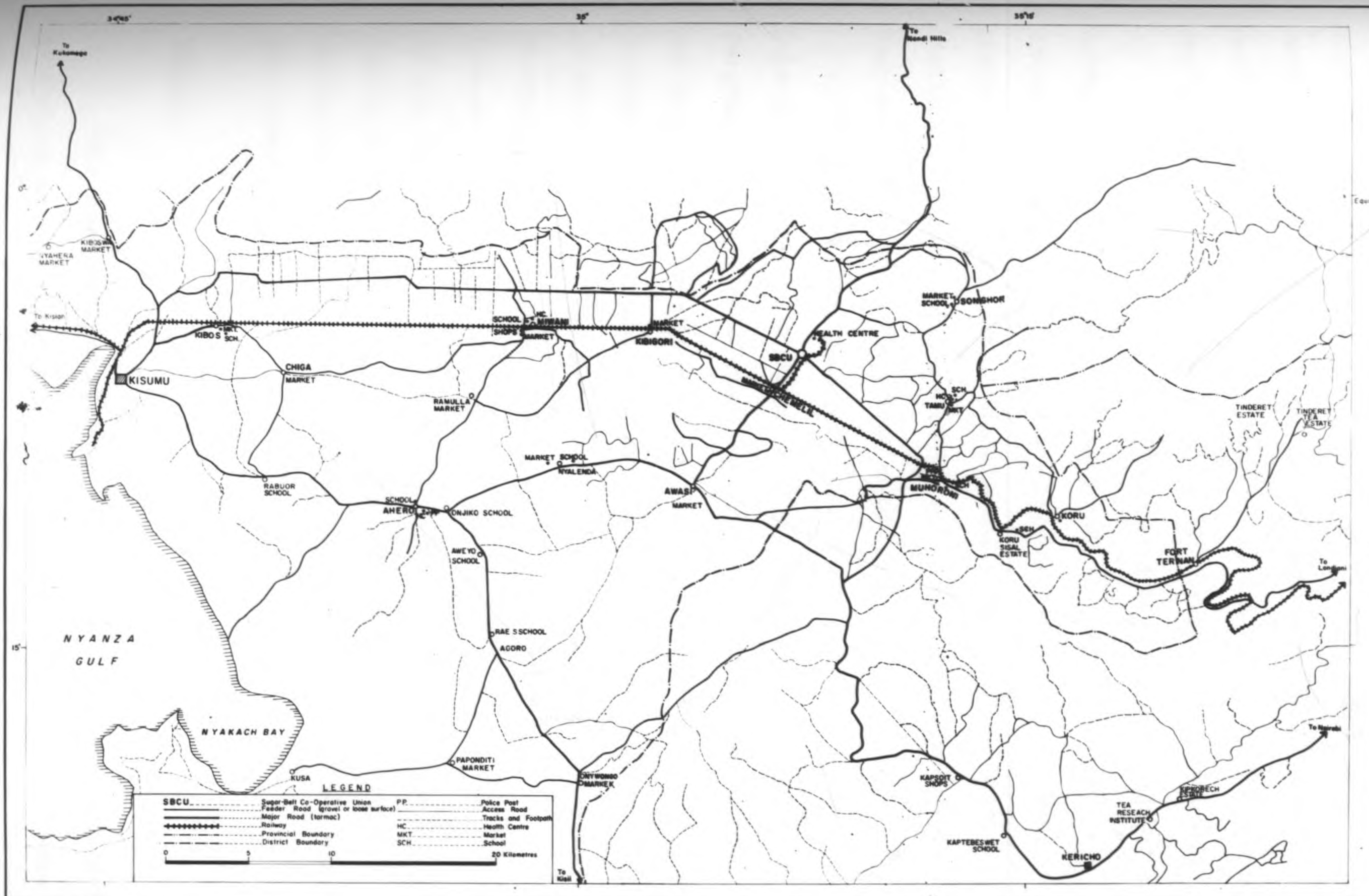

FIG 22 NYANZA SUGAR-BELT INFRASTRUCTURE

migration to major urban growth centres. In this regard the municipality of Kisumu faces an onerous task in providing the needed infrastructure and services for the old "peri-urban" areas included in the municipal area in the 1972 revision of boundaries.

Recently telephone lines and electricity have been widely extended in the Sugar Belt, especially in the areas of sugar factories. Plans are also underway for the construction of more health centres in the area. Other considerations include police stations and posts, which are at the moment located in areas where they are most critical for public security.

In summary, the Sugar Belt simultaneously represents the hope and likelihood of disappointment unless something is done. If programmes of rural development can convert sufficient numbers of the Sugar Belt farmers into highly productive cash producers without sacrificing food production the future is hopeful indeed. Ultimately, if these programmes fail to be implemented at the same rate as in recent past decades, it will certainly experience the manifold horrors of overpopulation. Despite these problems the varied natural endowments of the Sugar Belt have on the whole provided the farmers with a favourable opportunity for developing a diversified economy based on cotton, sugarcane, rice, maize, livestock and other subsistence crops.

Summary

This discussion has revealed that recent failures in sugarcane production can be largely attributed to certain environmental parameters which were overlooked at the initial stages of the sugar industry and are now causing problems in the area. Environmental appraisal has been focused on the geomorphology, climate, vegetation and ecology, disease problems, demographic factor and infrastructural development. It depicts the need for planned sugarcane development in the present study area. Furthermore, mushrooming agrometeorological stations giving a good coverage of the Sugar Belt according to the standards of the rest of Kenya do not rectify several deficiencies in the system of weather recording. A current programme to standardize and improve agrômeteorological recording techniques will result in better statistical series, although it cannot remedy previous omissions in the time series and it will take many decades to improve estimates of rainfall probability and other climatic parameters. Moreover, much ecological research is not amenable to "crash" programmes; long-term studies are essential to observe the effects of varying climatic, biotic and pedological factors on sugarcane production, which constitute the central theme of the next chapter.

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CHAPTER IV

PHYSICAL ENVIRONMENTAL LIMITATIONS TO SUGARCANE PRODUCTION

PHYSICAL ENVIRONMENTAL LIMITATIONS TO SUGARCANE PRODUCTION

Introduction

It is evident from the literature cited in this thesis that there has been intensive studies in other sugarcane growing countries for establishing ideal agro-climatological conditions for obtaining optimum sugarcane yield. These researches have brought out that soil, rainfall and temperature largely influence sugarcane growth and yield. Apart from these well-known factors diseases, pests and weeds are likely to account for considerable losses of sugarcane yield. This chapter attempts to analyze the impact of the pedological, climatic and biotic factors on sugarcane growth and yield in the Nyanza Sugar Belt.

PEDOLOGICAL FACTORS OF SIGNIFICANCE TO SUGARCANE PRODUCTION

Soil Texture

Soil texture is a physical property depending on grain size. It varies according to the proportion of sand, clay and silt. Appendix A.1 shows mechanical analysis of soil samples and indicates different texture grades, dominated by clay.

The textural classes are further presented diagrammatically (fig. 23) according to one American system of soil nomenclature.[1] It is evident from figure 23 that soil texture in the Sugar Belt tends to fall into three distinct groups: A, which is divided into A_1 and A_2, B, and C. Clay is predominant at the core, A_1, but

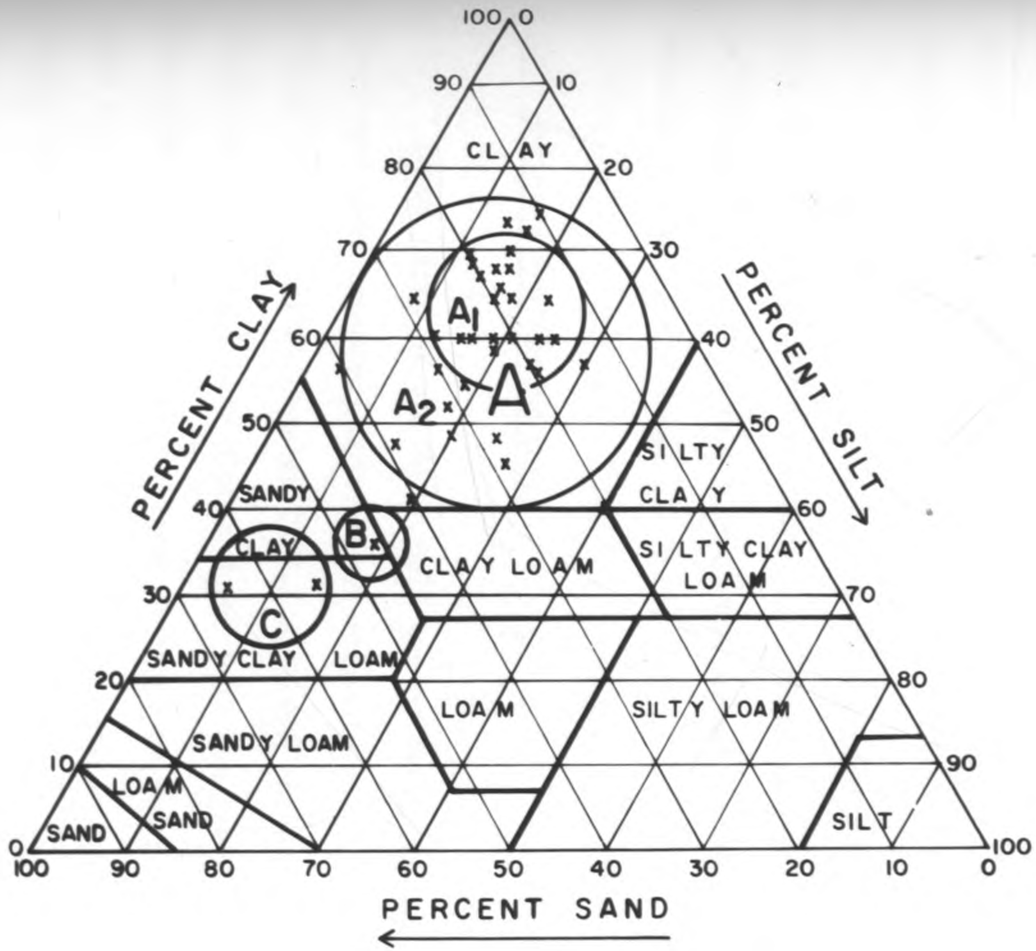


FIG.23 GRAPHICAL REPRESENTATION OF SOIL TEXTURE SAMPLES FROM SUGAR-BELT USING TRIANGULAR SOIL-TEXTURE

diminishes towards A_2. It has been pointed out in the preceding chapter that in the Sugar Belt, the Kano plains proper is dominated by clay, which diminishes until it exists in pockets at the peripheries of the Plain, for example, around Awasi, slopes of escarpments and foothills.

Point X lying between zones A and B nearly marks the tansition from clay to sandy clay. Zone B shows sandy clay, whereas zone C indicates sandy clay loam. These types of soil occur in pockets in the study area.

Variations in soil texture influence critical soil properties. Clay soils limit sugarcane yields and extension because they become waterlogged and impermeable during wet periods, thereby causing serious floods in the area.

Soil Drainage and Permeability

Large parts of the Sugar Belt are on heavy and invariably black and grey montmorillonite clays commonly referred to as "black cotton" soils (Chapter III). Although the soils on which sugarcane is grown in the Nyanza Sugar Belt are frequently adequate for growing a wide variety of sugarcanes given sufficient rainfall, some societies have large areas of "black cotton" soils which may easily become waterlogged because of their impermeable nature. Apart from their characteristic swelling and churning when wet, and shrinking and cracking when dry, these soils possess high plasticity and cohesion which make them cumbersome to drain and manage. Recent agronomic researches in the area shows that sugarcane requires fairly deep and well-drained soils.

Drainage on fields of 0–5% slope is very sluggish and therefore requires surface drains. Waterlogging inhibits atmospheric oxygen, which is indispensable for the life of the sugarcane, and hinders rooting by causing some roots to rot. Consequently, impeded drainage may reduce root respiration and hence retard nutrient uptake, besides rendering some nutrients physiologically unavailable to cane and converting other elements into a toxic state. For these reasons in poorly drained areas and after long spells of uninterrupted rainfall, the author observed that the canes turned yellow and the freshly planted fields had a squalid and impoverished appearance.

Good drainage stimulates beneficial microbial activity and promotes the development of large root system. The northern part of the Sugar Belt is well drained but the steep nature of the terrain there requires contour drains to reduce seepage and runoff. Poor drainage in smallholder areas can be minimized by planting cane over ridges (fig. 24).

Soil Depth and Cane Rooting

80% of cane roots are found within 0–20 cms., and maximum rooting density rarely exceeds 30 cms., depth often quoted as necessary to prevent a set-back to growth during droughts. Since most soils of the Sugar Belt are known to resettle fast, any deep cane cultivation is beneficial to ratoon crops because it helps in aeration and water percolation. Subsoiling operation of

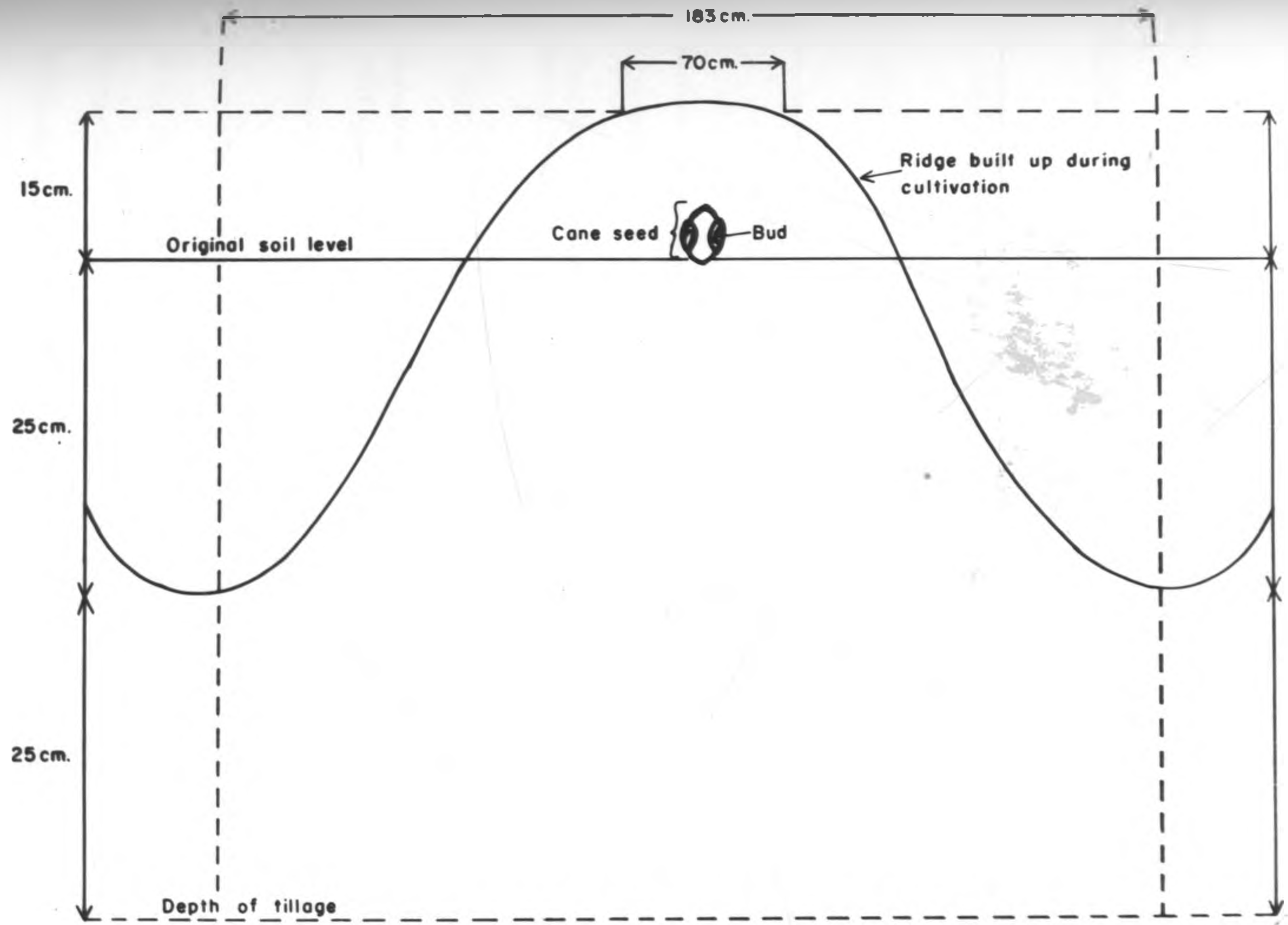


FIG.24 METHOD OF PLANTING SUGARCANE FOR IRRIGATION AND DRAINAGE ON CLAY SOIL OF SUGAR-BELT

both compacted soils immediately after harvesting significantly increases ratoon growth and yields (table 7). Observations from

Table 7

SUMMARY OF EFFECTS OF SUBSOILING TO A DEPTH OF 30-35 CMS. IN THE SUGAR BELT

Treatment	Mean Cane Growth in Cm. After 12 Months Subsoiling	Mean Cane Yield in Metric Tons Per 0.4047 ha.
Compacted areas subsoiled	220	49.8
Compacted areas not subsoiled	156	32.7
Non-compacted areas subsoiled	230	50.1
Non-compacted areas not subsoiled	184	36.9

Mean cane growth at 5% level of probability is 25.3

Mean cane growth at 1% level of probability is 41.5

Mean cane yield at 5% level of probability is 8.7

Mean cane yield at 5% level of probability is 13.9

Source: Chemelil Sugar Company Ltd. Agronomic Annual Report 1974.

pit and root studies show that some roots extend beyond these limits depending on the degree of soil compaction (figs. 25, 26, 27 and 28). Rooting varies from 0–46 cm. and 0–56 cm. meaning that soil is friable and uncompacted, but below 76 cm. one hardly notices cane roots. In compact soil cane becomes shallow-rooted and roots tend to grow horizontally (fig. 27). Gravelly soil around Kibos, Awasi and other areas inhibits deep cane-rooting, although it seems to aid permeability and, furthermore, supplies nutrients on breaking up.

Workability of the Soils

Sandy clay soils can be worked nearly at any time, that is, when wet and saturated with water. This type of soil is relatively easy to manage with simple implements like "jembes" and plough with draught animals. The easily impeded montmorillonite clay soil is difficult to work and on cracking during drought causes breaking of cane roots apart from increasing evaporation.

Due to these limitations in clay soils, it becomes paramount to employ a tractor so as not to harm working animals by putting them under an excessive strain, but these sticky and plastic soils tend to adhere to machinery and are puddled, resulting in delayed tractor operations and high costs, which small-scale farmers cannot afford. Planting sugarcane at the wrong time because of these limitations is likely to result in low cane yield.

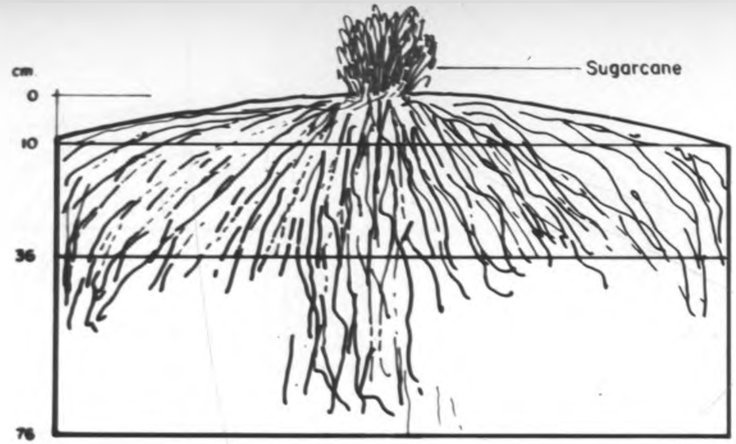
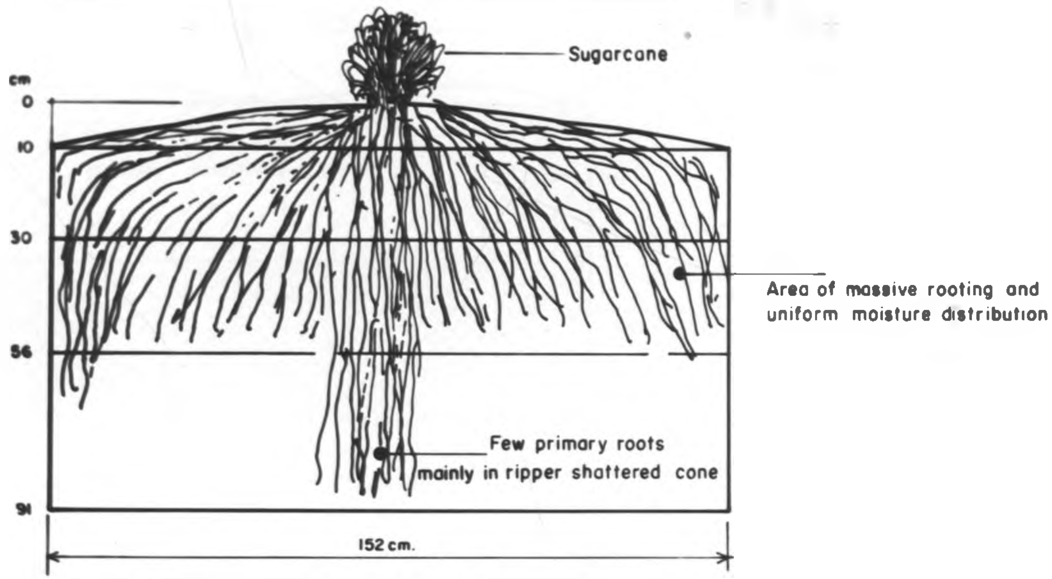


FIG 25 MAXIMUM CANE ROOTING EXTENDS TO 36CM



Source : Chemelil Sugar Company Ltd. Agronomic Annual Report 1974

FIG26 LESS COMPACT SOIL ALLOWING MORE VERTICAL ROOTING OF CANE

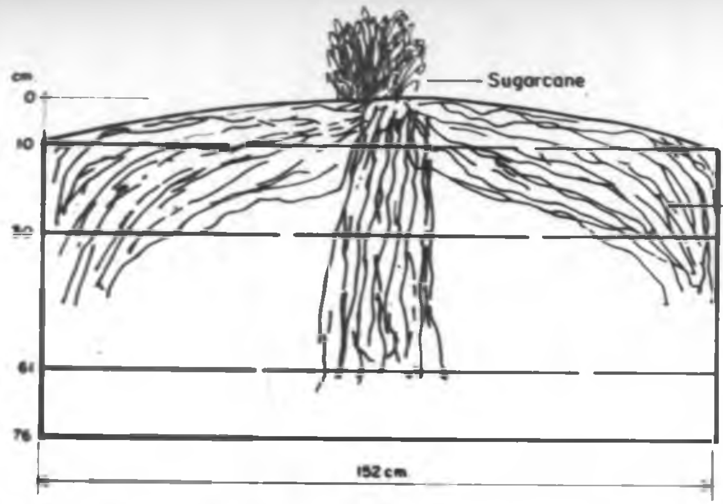
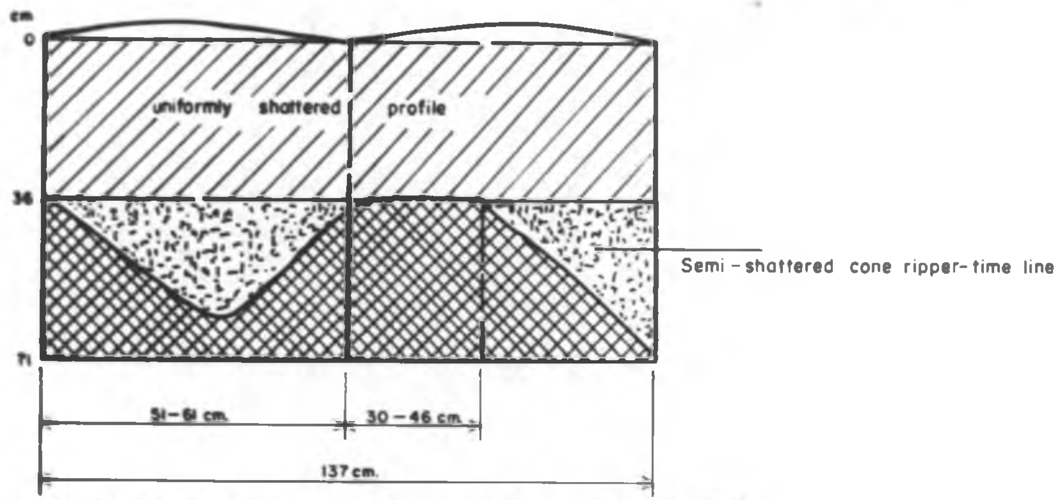


FIG.27 MOST OF SUGARCANE ROOTS GROW HORIZONTALLY DUE TO COMPACT SOIL



Source : Chemelil Sugar Company Ltd. Agronomic Annual Report 1974

FIG.28 CROSS-SECTION OF 25, 26, and 27

Availability of soil moisture

Due to long hours of sunshine per day, high maximum temperatures, abundant radiation, high evaporation and other meteorological factors, evapotranspiration, which is the sum of transpiration from plants and evaporation from the soil is high, varying from about 3.5–7.3 mm. per day and this grossly affects available soil water for crop utilization (Appendix A.2).

Figure 29 shows rainfall, evapotranspiration, and soil moisture determinations averaged after 8–11 days. These short period records are more meaningful for agricultural purposes than mean monthly, or annual figures which do not explain seasonal distribution of rainfall. As has been shown in chapter I, sugarcane needs 1500 mm. of rainfall but this should be well-spread throughout the year so that 125 mm. occur every month in order to have optimum cane growth and yield. On this basis alone, the seasonal rainfall distribution fails to satisfy the requirement of 125 mm. except between March and May (fig. 29). For most parts of the year, cane suffers from moisture stress. There seems to be very strong relationship between rainfall, evapotranspiration and available soil moisture because the higher the rainfall the lower the evapotranspiration and the higher the soil moisture regime. High soil moisture is associated with high rainfall, particularly, between March and May, but the peaks and valleys of the two do not coincide exactly because there is a time lag in the infiltration, percolation and accumulation of rain-water to a depth of 50 cm.

There is no moisture in the soil from late September to December and after 10 days in January to the end of February due to less rainfall and high evapotranspiration rate than rainfall. The author observed that prolonged drought such as this leads to soil desiccation and wilting of sugarcane, especially, in Awasi where annual rainfall is sometimes lower than 900 mm., the minimum rainfall required by most crops. It was noticed in the preceding chapter that nearly all small-scale sugarcane growers are located in areas of marginal rainfall, hence their cane yield is relatively low. This problem may be solved, partly by irrigation, although this may prove to be uneconomical. Furthermore, there is need for improvement of soil structure through careful soil management practices like applying farm-yard manure, green manure, and sulphate of Ammonia, which helps to prevent soil deflocculation and impeded drainage.

Soils derived from volcanic rocks possess great moisture retaining capacity and are ideal for sugarcane cultivation, and whereas these are common in Mumias and South Nyanza, they only occur in pockets in Nyanza Sugar Belt, while the coastal corals soils are poor in nutrients and have low moisture retaining capacity because of their sandy nature. The fact that sugarcane grows on heavy clay soils does not mean that it produces its best there, because the best yields in the study area have been obtained on the moderately steeply sloping (6-13% slope) areas of sandy soils, where good drainage explains the superior growth.

It is known that when moisture drops to 8% of the weight of pure clay, it no longer yields water to support crop growth, while pure sand yields up to 1.5%[2]. Furthermore, when the potential available soil moisture to a depth of 50cm. is less than 40% (fig. 29), sugarcane wilts. These conditions are common in the

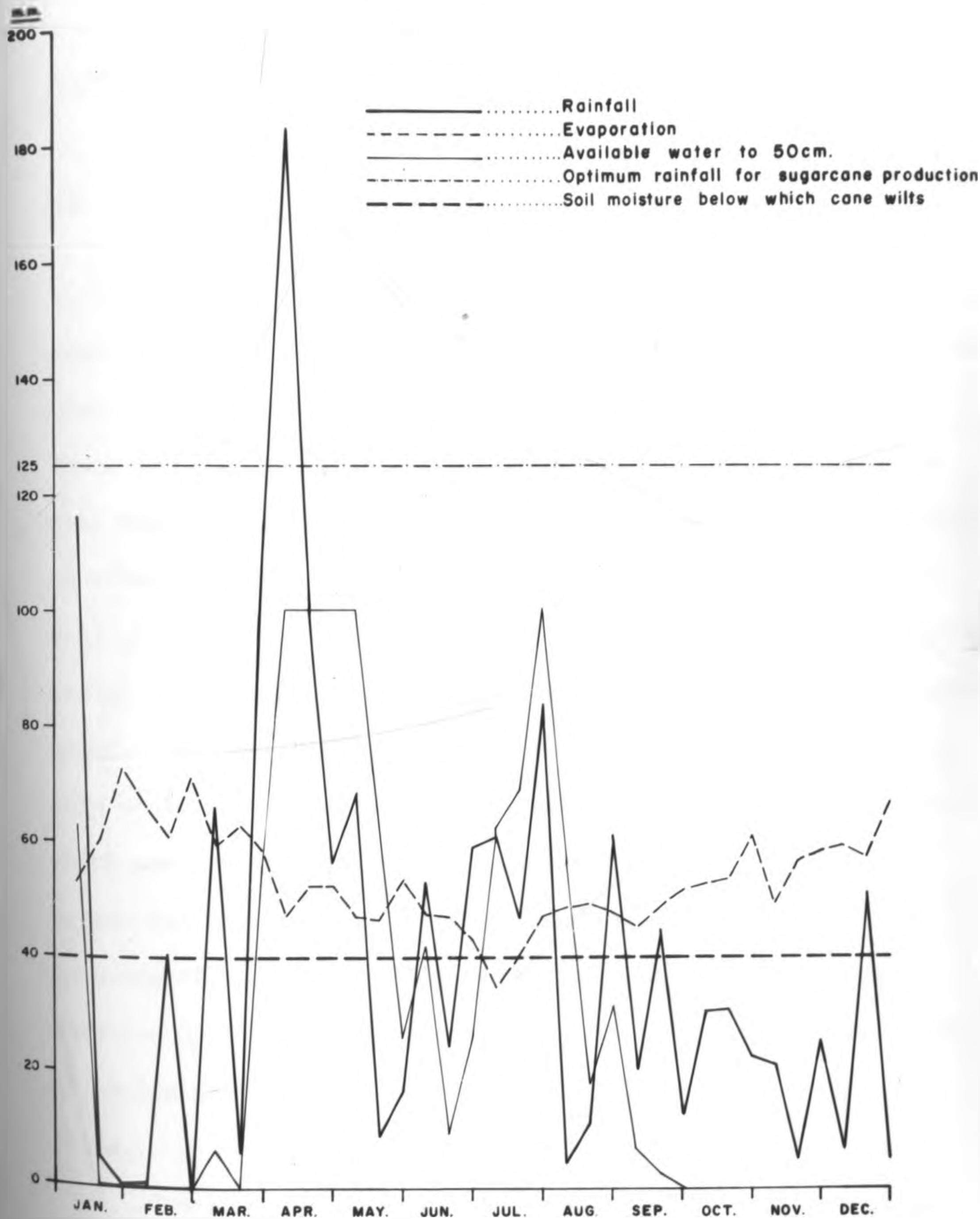


FIG.29 ESTIMATION OF AVAILABLE SOIL MOISTURE

Sugar Belt where in some areas, soil moisture may drop to zero as has been seen in the foregoing discussion. Hence soil moisture is a limiting factor in sugarcane production.

Problems of soil fertility

pH:

Sugarcane tolerates a wide range of soil types, that is, growing on acid to alkaline soils with a range of pH 4-8, although ideal soils for its optimum growth correspond to a pH of 6-7. These are fairly comparable to the pH 5.2-8.1 obtained from the soil sample analysis (Appendix A.3). In Western Kenya the optimum pH values are obtainable in Mumias and South Nyanza red volcanic soils, whereas in Nyanza Sugar Belt, they are randomized, particularly, in the "Combretum Hyparrhenia" woodland of Koru and Songhor areas. However, the results obtained from soil analysis such as this must be cautiously treated because problems of soil salinity which are now uncommon may be encountered in the long run if proper cultural practices are not devised by farmers. Already leaching of cations from the sandy soils, which are invariably situated up the hills is resulting in an embarrassing deposition of sodium in clay soils which are located on the lower parts of hills.

The pH value of a soil determines soil fertility and one can be fairly confident that, if the pH of a particular soil falls, this is due to an increased exchangeable hydrogen with a concurrent decreased exchangeable bases. Hence pH determination is a vital measure of the degree of base saturation, salinity, alkalinity, acidity and neutrality, all of which are essential soil properties in sugarcane production. The pH of the cultivated sugarcane plots indicates that the soils are generally fertile.

Soil Erosion

The phenomena resulting in removal of topsoil and loss of fertility is called soil erosion. Wholesale destruction of natural vegetation for extensive and intensive cultivation in the Sugar Belt has resulted into increased exposure to the erosive effects of rain, wind and drought. But persistent rainfall in some areas, for example, the highlands gives rise to leaching of soil minerals (fig. 30), while the sheer mechanical force of raindrops, especially, in heavy downpours, as well as that of strong winds directly carries away soil particles. The drier the soil, the more is lost to the wind, a common phenomenon in the Kano plains during drought. It was observed that erosion by water is serious on the Nyando escarpment, steel hill-slopes and Awasi area.

Eroded materials, or colluvial soils are toxic in areas where they are deposited, a situation which is likely to occur around Kibos area where materials removed from the Nyando escarpment accumulate. But the degree of erosion is also a function of fertility, soil type and the type of rock.

Soil degradation calls for maintaining a plant cover because vegetation plays a significant role in protecting the soil moisture by breaking winds as well as intercepting precipitation. Disregarding the value of the forest as a source of charcoal, timber, food

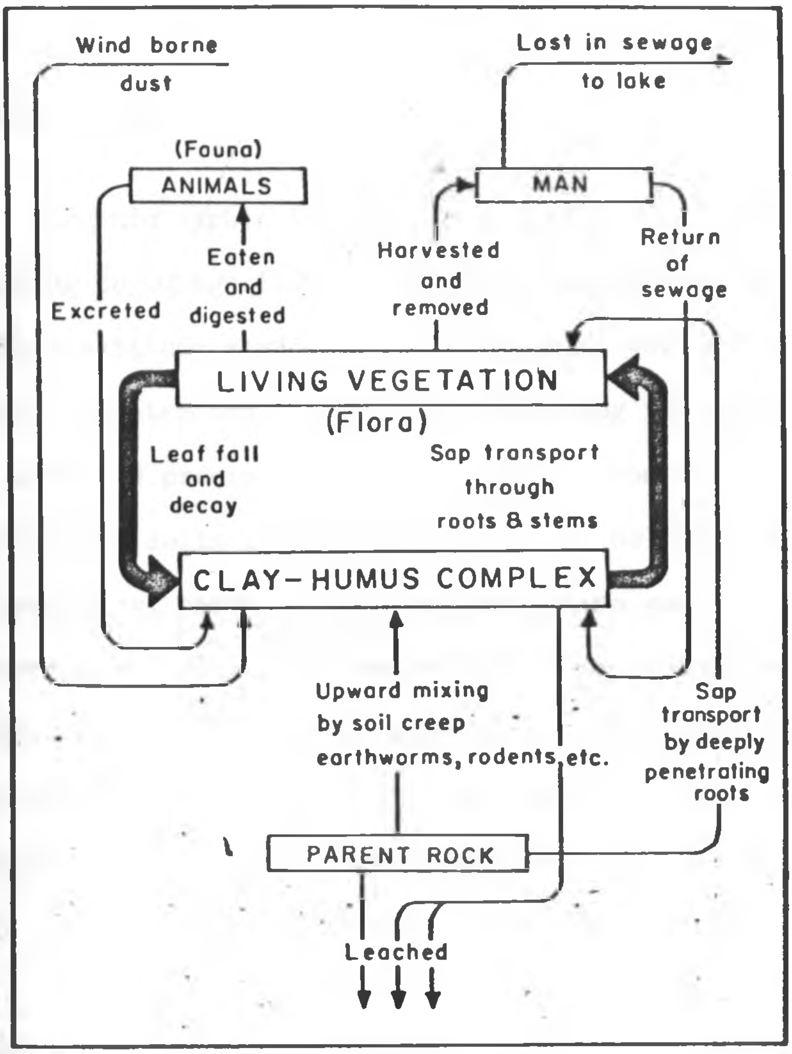


FIG.30 THE NUTRIENT-CYCLE

and lumber for paper products man has thus through forest devastation lost his best ally in the battle against soil erosion. This statement is true of the Sugar Belt which was originally, perhaps, forested and now most of the land surface is exposed to the vagaries of the weather. The variations in soil erosion can cause variations in sugarcane production in the study area.

Nutrient Status

Organic carbon is very low in most soil samples (Appendix A-3). According to Odingo (1974),[4] detailed information from soils of the high altitude savannalands of Kenya as well as much of East Africa indicates that these soils including the so-called volcanic red loams are problem soils and a look at some of the leading agricultural soils in Kenya leaves one in no doubt as to their lack of permanence, however, with few exceptions most of the soils are low in humic content, the range being from 0-5.3%, and are often deficient in many essential minerals. Analysis of soil samples from the Sugar Belt supports these findings and the small-scale cane producers are in a worse position due to the relatively low humic content ranging from 0.60-2.86% (Appendix A-3).

It cannot be denied that, without a cover of nutrient demanding vegetation, no soil can maintain indefinitely a high base status in a humid climate, no matter how rich in bases the underlying parent-material and without such a vegetation cover to abstract bases from the soil and to return them in a base-rich humus, leaching quickly removes all the bases as they are released from decomposing minerals in the subsoil (fig. 30). What we expect to be going and lumber for paper products man has thus through forest devastation lost his best ally in the battle against soil erosion.[3] This statement is true of the Sugar Belt which was originally, perhaps, forested and now most of the land surface is exposed to the vagaries of the weather. The variations in soil erosion can cause variations in sugarcane production in the study area.

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Although most of the soils are well-supplied with K, Na, Ca, Mg and Mn, the N deficiency (table 8) is exerting serious

Table 8

KEY TO CHEMICAL TESTS TOGETHER WITH NUMBER OF SOIL SAMPLES RECORDED AS DEFICIENT, SUFFICIENT AND RICH IN NUTRIENTS

Nutrient	KEY TO CHEMICAL TESTS ACCORDING TO NATIONAL AGRICULTURAL LABORATORIES, KABETE					
	Deficient		Sufficient		Rich	
	Standard	Sample No.	Standard	Sample No.	Standard	Sample No.
Na	Seldom applies	0	0-1.99 m.e.	56	2 m.e.	4
K	0-1.99 m.e.	0	0.2-1.5 m.e.	59	1.5^+ m.e.	1
Ca	0-1.99 m.e.	0	2.0-10 m.e.	9	10.0^+ m.e.	51
Mg	0-.99 m.e.	0	1.0-3.0 m.e.	5	3.0^+ m.e.	55
Mn	0-0.09 m.e.	11	0.1-2.0 m.e.	59	2.0^+ m.e.	0
P_{ppm}	0-19.99 ppm	11	20-80 ppm	41	80^+ ppm	8
N	0-0.19 m.e.	54	0.2-1.0 m.e.	6	1.0^+ m.e.	0

Interpretation

Na	=	Sodium	Ca	=	Calcium	P_{ppm}	=	Phosphorus parts per million
Mn	=	Manganese	Mg	=	Magnesium	m.e.	=	Milli equivalents
K	=	Potassium	N	=	Nitrogen	+	=	over or above

limitation on smallholder sugarcane yield. The deficiency is partly attributed to the fact that cane being a heavy user of nitrogen greatly exhausts the soil, and partly attributed to low levels of organic matter.

Figures 31, 32, and 33 show scatter diagrams together with regression lines of sugarcane yields against N, P and K. In figure 31 there is a direct strong positive linear relationship because increasing N contents seem to favour increasing sugarcane yields, while in figure 32 there appears to be no direct linear relationship since high P contents do not necessarily correspond to high cane yield, neither do low P necessarily influence low cane yield, although there seems to be some minor relationship in that some vertical cluster is noticed almost parallel to Y-coordinate. Thus, the regression is almost horizontal indicating almost zero correlation. The pattern in figure 32 is dubious because the points show indefinite orientations. Similarly, figure 33 shows weak positive linear relationship because the points are randomized and widely separated from each other. The residuals, or error terms, that is, the differences between estimated and actual values of the dependent variable are large as can be seen in figure 33 because the individual points are at greater distances from the line of best-fit.

Table 9 shows comparison of simple correlation between cane yield and three fixed variates (N, P, and K), while table 10 indicates simple correlation between the independent variables themselves. The impression emerging from table 9 is that sugarcane and Nitrogen show a statistically significant linear relationship at 99% level of probability, tested by "F"-test. The correlation Coefficient, $r = 0.9642$, while the coefficient of determination,

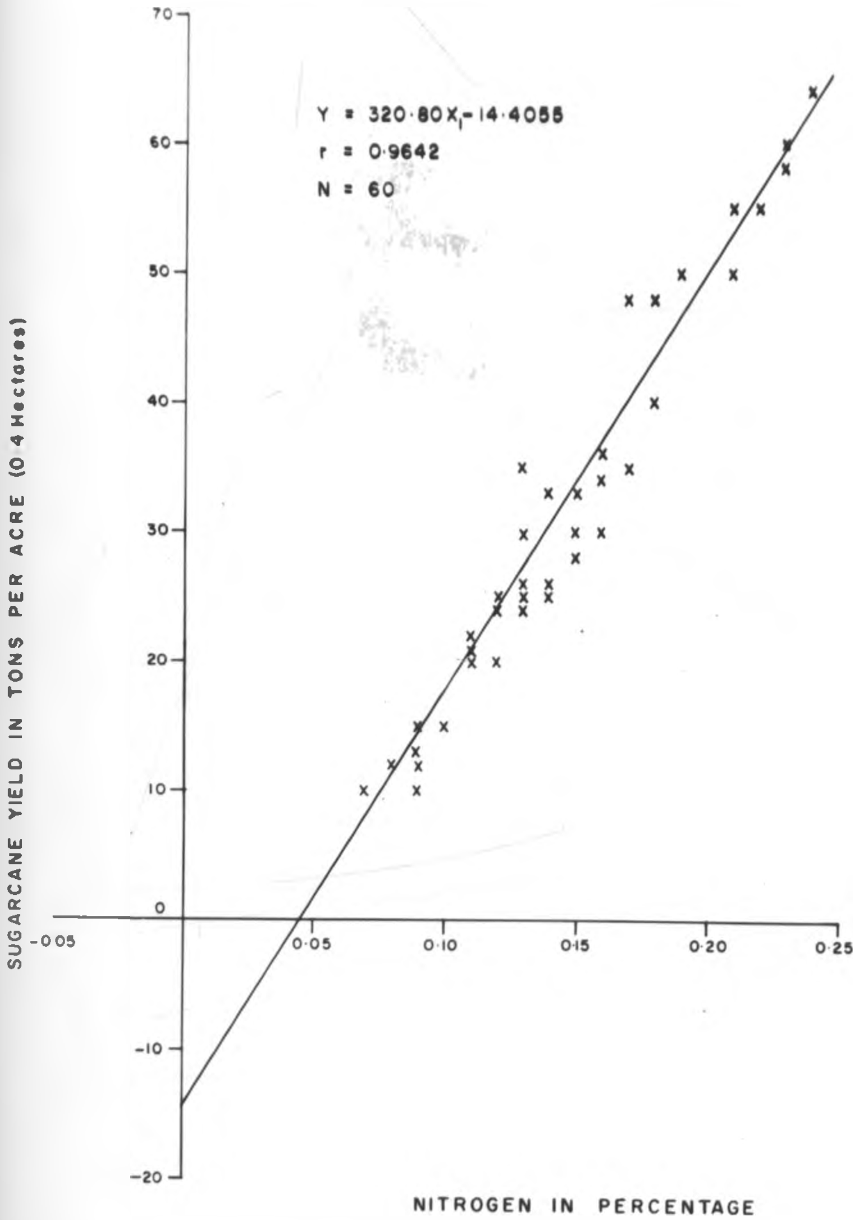


FIG.31 RELATIONSHIP BETWEEN SUGARCANE YIELD AND NITROGEN CONTENT IN THE SOIL

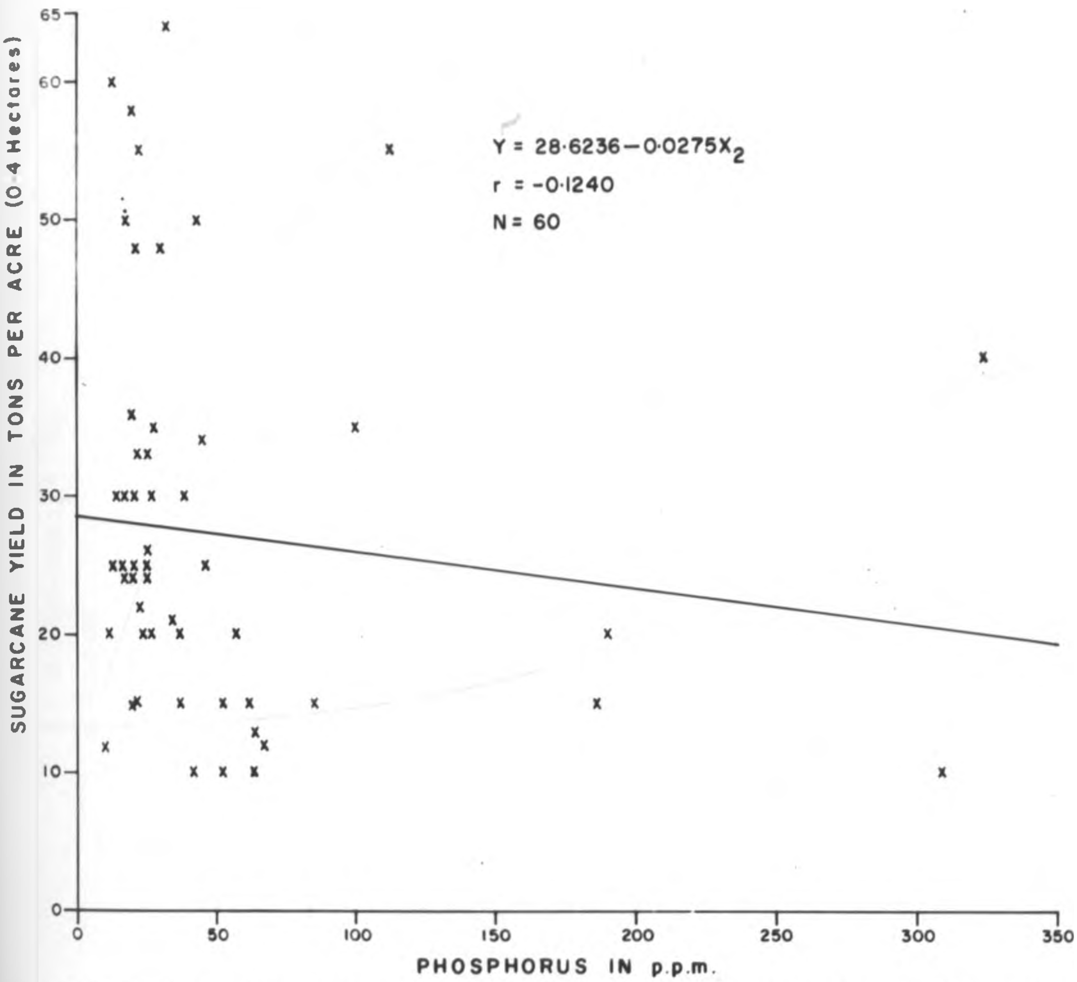


FIG.32 RELATIONSHIP BETWEEN SUGARCANE YIELD AND PHOSPHORUS

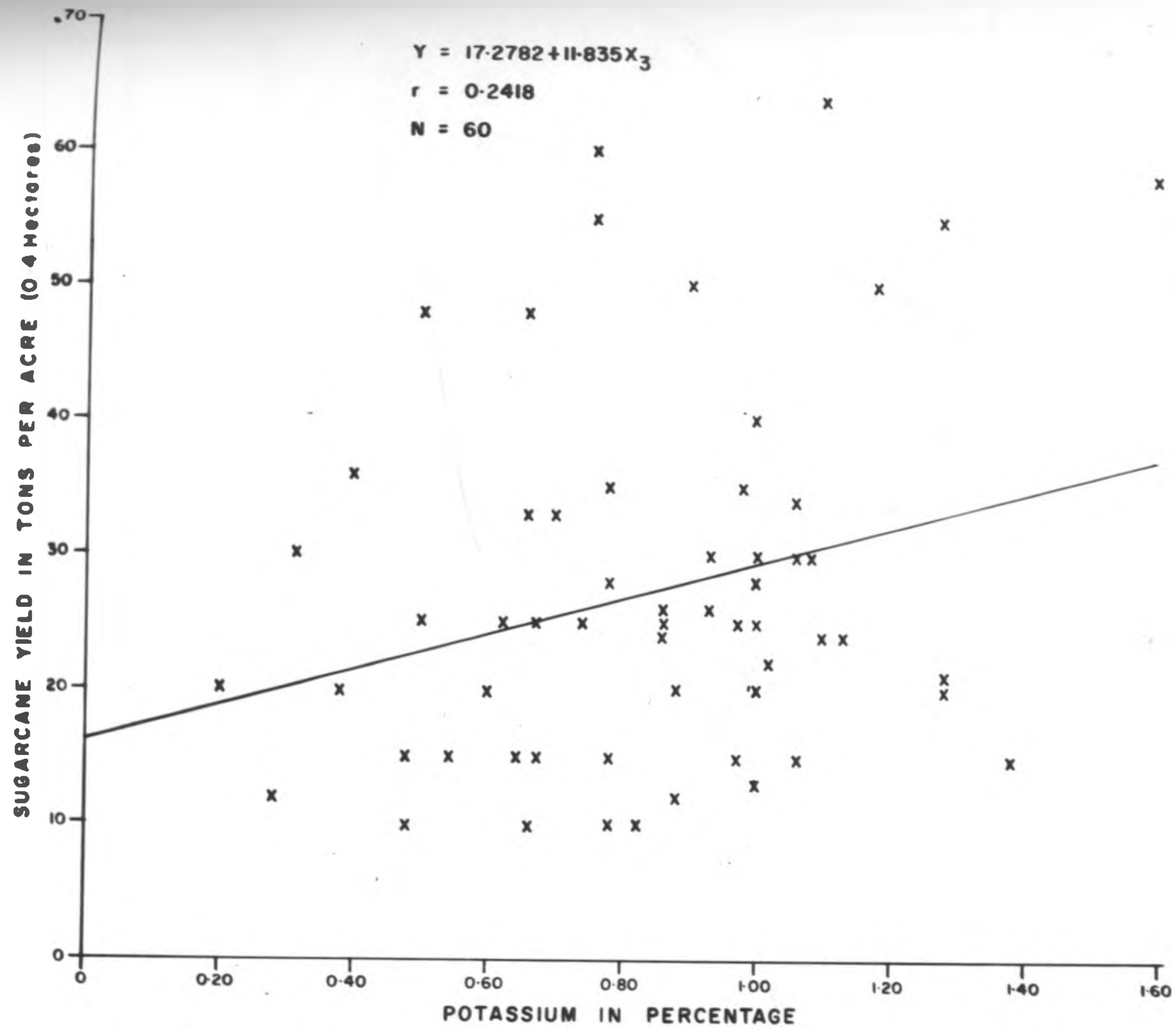


FIG.33 RELATIONSHIP BETWEEN SUGARCANE YIELD AND POTASSIUM

Table 9

COMPARISON OF SIMPLE CORRELATION COEFFICIENTS BETWEEN CANE YIELD AND THREE INDEPENDENT VARIABLES (N, P AND K)

INDEPENDENT VARIABLES (SOIL NUTRIENTS)	r BETWEEN CANE YIELD AND VARIABLES N,P,K	STATISTICAL SIGNIFICANCE
		"F" TEST
N	0.9642*	Yes
P	-0.1240	No
K	0.2418	No

* Significant at the 99% level of probability

Source: Analysis from sample survey

Table 10

COMPARISON OF SIMPLE CORRELATIONS BETWEEN FIXED VARIABLES (N,P,AND K)

VARIABLES	r BETWEEN FIXED VARIABLES	STATISTICAL SIGNIFICANCE
		"F" TEST
r_{23}	-0.1466	No
r_{24}	0.3212	No
r_{43}	-0.0959	No

Source: Soil Sample Survey

r^2 = 0.9297, indicating that a proportion of 92.97% of the variation in sugarcane yield is attributable to, or "explained by" covariation with the Nitrogen. Apparently, the correlation between cane yield and either P or K indicates no significant relationship at 99% level of probability.

All the fixed variables show positively or negatively weak correlation and using "F" test, all are insignificatn at 99% level of probability (table 10). Correlation between Nitrogen and Phosphorus is represented by r_{23}, but r_{24} is correlation between N and K, while r_{43} is K and P. Partial correlation coefficient between sugarcane and Nitrogen holding P constant, r = 0.9641 is statistically significant at 99% level of probability using "F" test. Moreover, when P and K are held constant, Partial Coefficient, r = 0.9648 and this is significant at 99% level of probability using "F" test (table 11).

From these analyses, the overall value due to the use of the regression and correlation between cane and Nitrogen is significantly high and the added value due to the two fixed variables (P, K) other than N is decidedly non-significant. Hence I am led to conclude that N is a very important predictor and that the other predictors add nothing to the reliability of the spatial variations in sugarcane yield in the Sugar Belt. This result here is in the direction which would tend to give an advantage to the use of Sulphate of Ammonia, but an overdose of N may have deleterious effect on sugarcane yields.

Partial correlation coefficient between cane yield and N holding P and K constant is high, r = 0.9648, which indicates a strong dependence on N content in the soil for cane. This strongly

Table 11

COMPARISON OF PARTIAL CORRELATIONS

VARIABLES	r BETWEEN SUGARCANE YIELD AND N HOLDING P AND K CONSTANT	STATISTICAL SIGNIFICANCE
		"F" TEST
$r_{12.3}$	0.9641*	Yes
$r_{14.3}$	0.2328	No
$r_{24.3}$	0.3119	No
$r_{12.34}$	0.9648*	Yes

* Significant at 99% level of probability

Explanations

$r_{12.3}$ = r between cane yield and N holding P constant

$r_{14.3}$ = r between cane yield and K holding P constant

$r_{24.3}$ = r between N and K holding P constant

$r_{12.34}$ = r between cane and N holding P and K constant

Source: Sample Survey

suggests that given a suitable environment, such as maintaining soil temperature, precipitation, soil erosion, cultural practices, the canes may be able to put on fast vigorous growth, which can be reflected on yield at a later stage. Moreover, the correlation between cane and N is less than 1, showing that the other environmental factors mentioned in the last sentence contribute to the variations in cane yield. In conclusion, N limits sugarcane production while P and K do not limit sugarcane production. This conclusion is confirmed by experiments in the Sugar Belt and elsewhere which indicate no significant responses to P and K fertilizer application, except Sulphate of Ammonia.

THE CLIMATIC FACTORS WHICH INFLUENCE THE CANE CROP

Rainfall and Temperature

Rainfall is basic factor in the growing of sugarcane in Western Kenya where cane is mostly grown under natural rain-fed conditions. The minimum rainfall required for optimum growth of cane is 1500 mm. per annum and this should be well distributed with 75% coming during the growing season, and available irrigation water to supplement the rainfall is required, but under favourable conditions it is agreed that 1375 mm. per year would be the lowest limit to sustain economic sugarcane production. Distribution of rainfall is an important aspect because cane has a long "gestation period", growing period of at least 10 months of active growth in Nyanza Sugar Belt or 8 months at the Kenya Coast (table 12).

(a) Phase I

Germination has the least length of time depending mainly on rainfall and temperature of a particular place. In Western Kenya it takes 1-3 months which is longer than at the Kenya Coast where it takes 1-2 months because of high temperatures at the Coast.

Table 12

DIFFERENT PHASES OF SUGARCANE GROWTH

Location	PHASE I	PHASE II	PHASE III
	Germination (months)	Very active Growth (months)	Sugar accumulation (months)
Western Kenya	1-3	10^+	3-4
Kenya Coast	1-2	8^+	2

Source: Author's Conversation with Senior Sugarcane Research Officer, Kibos.

Although at the Coast cane is in its proper environment, unfortunately the Coral type of sandy soils are slightly inferior due to relatively poor moisture content in the soil and heavy leaching of nutrients.

(b) Phase II

This is known as very active growth period lasting roughly 10 months at least in Western Kenya and at least 8 months at the Kenya Coast. But these findings are tentative, provisional because they are also a function of sugarcane variety and modifications of the environment by growers, for example, use of irrigation. During the second phase, there should be plenty of rainfall, well-drained soils and mean temperatures of 20^oC-30^oC with an optimum around 25^oC and soils should be free from excessive salinity or high clay fractions. Temperature and radiation are not limiting factors to sugarcane growth in the Sugar Belt, hence high rainfall or supplementary water supply by irrigation may help to boost sugarcane production.

(c) Phase III

Phase III lasts 3-4 months in the Western Kenya and 2 months at the Kenya Coast. It is the period of sugar accumulation. During this phase most of the plant activities slow down, while most products of photosynthesis are transformed and stored as sucrose. This stage requires low temperatures for reduced cane growth, but more accumulation of sucrose. However, this kind of climate does not prevail at the Coast, resulting in relatively low cane and sucrose yields than in Western Kenya.

During rainy season, particularly April and May, the Sugar Belt experiences lower temperatures and light intensity is somewhat lower, giving rise to relatively low evaporation (fig. 34). Conditions for cane growth are favourable during these periods (table 13) provided that rains are not so heavy as to cause incipient waterlogging of the soils. During the seasons of low rainfall (fig. 34), the growth of sugarcane is substantially reduced, especially January to February (table 13), but the periods are used for land preparation, cane transport with least damage to fields (fig. 35), mechanical cane cultivation for loosening of soils for water percolation, aeration and weed control. The value of coefficient of correlation between sugarcane growth rates and rainfall is 0.67. It is not signficant at 95% level of probability using "t" or "F" test. However, about 45% of the variations in the growth rates of sugarcane may be accounted for by the variations in rainfall. In some areas of the Sugar Belt, rainfall is a limiting factor as has been seen in Chapter III.

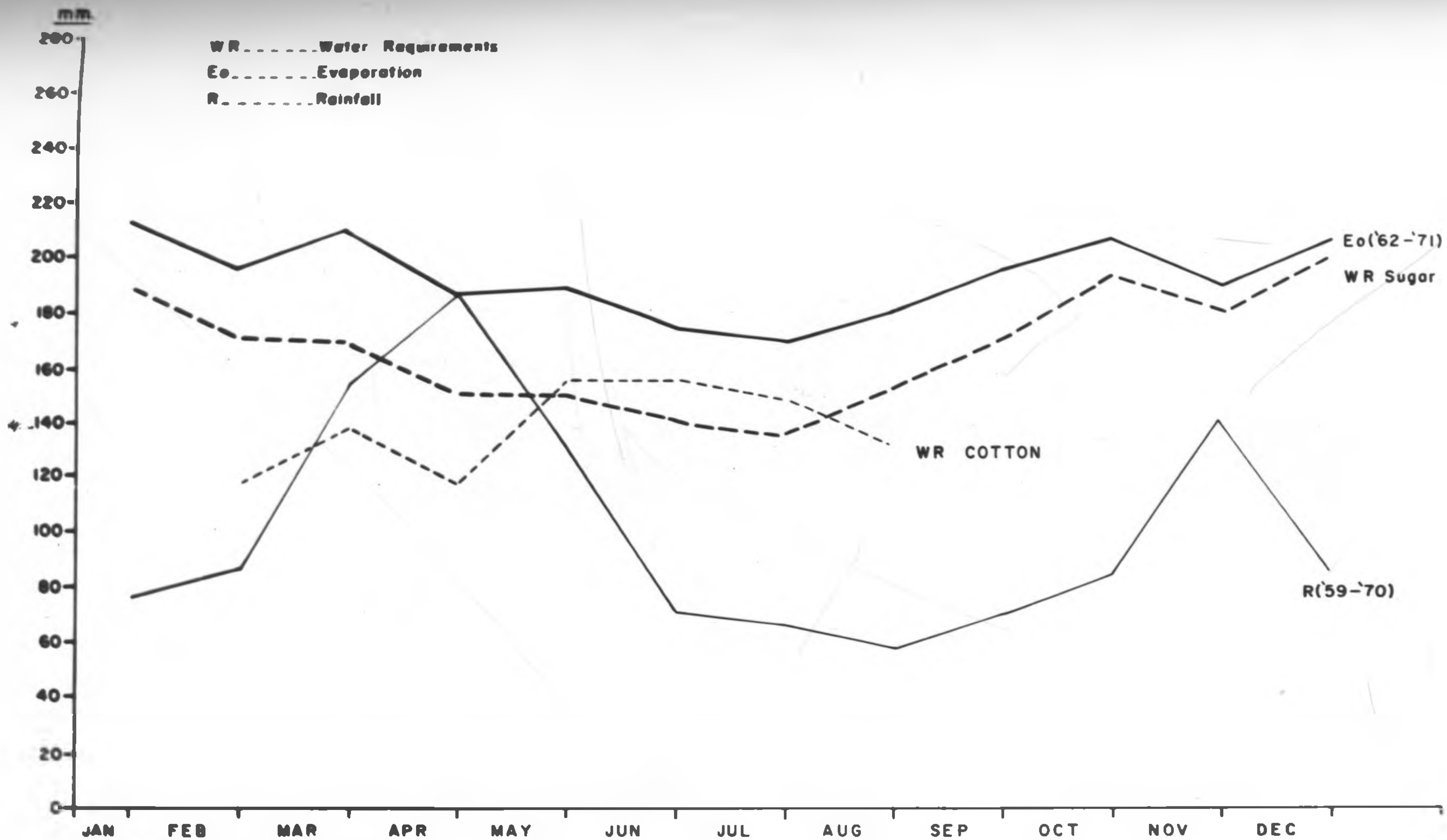
Table 13

SUMMARY OF MONTHLY SUGARCANE GROWTH RATES IN RELATIONSHIP TO MONTHLY RAINFALL

Months	Mean Growth in Field 9 (cm)	Rainfall in (cms)
January	5.0	121.7
February	4.1	41.0
March	10.5	187.2
April	40.0	340.4
May	31.0	94.4
June	16.4	117.1
Mean ($\bar{x}$)	17.8	150.3

Source: Chemelil Company Ltd., Agronomic Annual Report, 1974

Sugarcane is perennial crop requiring longer growing period than cotton (fig. 34), which needs less water than sugarcane. Water required by cotton exceeds that of cane only between March and May, giving the impression that it may be less risky to grow cotton rather than cane, however, cane is generally more tolerant to fluctuating weather conditions than cotton which is more delicate to these abnormal factors like floods, drought, hailstone and the like.



Source : Ahero Research Station

FIG.34 RAINFALL, EVAPORATION AND WATER REQUIREMENTS (For cane & cotton) AT AHERO

Fig. 35. Land preparation and sugarcane transportation during dry spells of weather by tractor and lorry respectively. In the foreground is maize garden

Rainfall Distribution and Variation

Reference has already been made to the lack of sufficient rainfall in most smallholder cane growing areas. Perhaps more significant than the low absolute level of annual rainfall is the distribution of whatever little rain there is throughout the year and the great unreliability of the weather.

Table 14 gives the mean monthly rainfall on ten stations in the Sugar Belt. It shows how unevenly the rainfall is distributed throughout the area, although some stations have longer records than others. Though this may only retard the rate of growth of sugarcane, it may also lead to the wilting of many other field crops. Rainfall is so unreliable that the risk of "freak" downpours is great. One big storm, waterlogging the soils for only a few days could deprive the sugarcane of oxygen and leads to a complete loss of the year's output.

The calculation of coefficient of variation is of value in many geographical studies, especially climatology because it offers a better means of comparison between different areas, and it is usually expressed in percentage as shown in table 14. The variations in rainfall in different locations are shown by standard deviations as well as by coefficient of variations, but the variations range from 36.69 mm. to 58.45 mm. and from 27% to 49% respectively. Long term records do not show significant departures from short term records. From these data, it is certain that the spatial variations in cane yields can be associated with rainfall differences in the Sugar Belt.

Rainfall Probability

The probability of obtaining less than 750 mm. of rainfall a

Table 14

RAINFALL ON TEN SUGAR-BELT STATIONS (MONTHLY MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION)

Station	Altitude	No. of Years	$\bar{X}$	S	V	V%
Kisumu	1149	71	100.64	43.78	0.44	44
Kibos Cotton	1174	20	103.34	39.84	0.39	39
Miwani	1207	45	117.01	41.59	0.36	36
Ahero	1220	22	98.62	38.66	0.40	40
Chemelil	1229	35	108.31	37.73	0.35	35
Muhoroni	1300	63	125.17	48.50	0.39	39
Koru Coffee	1585	8	142.92	37.73	0.27	27
Songhor M'lale	1768	20	107.01	52.06	0.49	49
Savani Tea Estate	1860	30	122.88	36.69	0.30	30
Nandi Siret	2161	15	124.91	58.45	0.47	47

Interpretation

$\bar{X}$ = Mean monthly Rainfall in Millimetres

S = Standard Deviation in Millimetres

V = Coefficient of Variation

or $V = \frac{S}{\bar{X}}$

year is 0-10%, that is, 0-10 years in 100 the rainfall is likely to be less than 750 mm. in the Sugar Belt. Even more striking than variation between stations is the unreliability of annual rainfall at Miwani and Kibos Cotton Research Station each having a record of 50 and 23 years respectively. It was desirable to make some assessment of the sufficiency of rainfall for sugarcane production by considering the possibility of receiving 1500 mm. of rainfall per annum at both stations. Since the frequency of distribution of rainfall is roughly normal, the probability is calcuated by the formula:[5]

$$t = \frac{\text{Difference of 1500 mm. from the mean}}{\text{Standard Deviation}}$$

From this formula, the value of t = 0.6168 for Miwani and 0.9871 for Kibos (tables 15 and 16). By referring to Fisher's table "t" (Fisher and Yates 1975)[6] these two values correspond to a probability of about 54% and 34% respectively. In 54% of the years a deviation from the mean as low or lower than 132 mm. may be expected but in only 27% of the years, or about one year out of four would a deviation of 132 mm. above the mean or a rainfall more than 1500 mm. be expected at Miwani. Similarly, the same argument may be developed for conditions at Kibos Cotton Research and the situation is worse than at Miwani because of a relatively low expectation, 17%. This latter trend is confirmed by table 16 which shows that the coefficient of variation is 39% at Kibos and 36% at Miwani. Judged solely on the expectation of annual rainfall, therefore, one might expect to grow sugarcane successfully once in four years at Miwani and about once in six years at Kibos. This indicates that those areas of the Sugar Belt receiving annual rainfall totals less than

Table 15

PROBABILITY OF OBTAINING 1500 mm. OR MORE RAINFALL PER ANNUM AT MIWANI IN 50 YEARS

Year	Rainfall (mm)	Year	Rainfall (mm)	Year	Rainfall (mm)
1925	1485	1942	1266	1959	1503
1926	1387	1943	1083	1960	1562
1927	1087	1944	1238	1961	1578
1928	1396	1945	1036	1962	1753
1929	1315	1946	1271	1963	1661
1930	1843	1947	1488	1964	1530
1931	1487	1948	1069	1965	1212
1932	1134	1949	1226	1966	1330
1933	1109	1950	1111	1967	1308
1934	1182	1951	1639	1968	1266
1935	1167	1952	1438	1969	1257
1936	1598	1953	1377	1970	1418
1937	1568	1954	1348	1971	1372
1938	1270	1955	1666	1972	1547
1939	1036	1956	1188	1973	1104
1940	1724	1957	1510	1974	1098
1941	1801	1958	1344		

Table 17 cont.........

$\bar{X}$ = 1368 ; P = 54%

S.D. = 214

t = 0.6168

Source: Miwani Sugar Mill Weather Station

Table 16

PROBABILITY OF OBTAINING 1500 mm. OR MORE RAINFALL PER ANNUM AT KIBOS COTTON STATION IN 23 YEARS

Year	Rainfall (mm)	Year	Rainfall (mm)
1952	1111	1964	1454
1953	732	1965	1166
1954	1372	1966	1404
1955	1304	1967	1203
1956	1239	1968	1413
1957	1327	1969	932
1958	1022	1970	1357
1959	1122	1971	1109
1960	1206	1972	1568
1961	1803	1973	1055
1962	1638	1974	1258
1963	1447		

$\overline{X}$ = 1271

S.D. = 232

t = 0.9871

P = 34%

Source: Kibos Cotton Research Station

those of Kibos and Miwani have poor expectation in obtaining optimum cane yields, except after a long time. In conclusion rainfall is a limiting factor in sugarcane growth and production.

in the study area.

BIOTIC LIMITATIONS TO SUGARCANE PRODUCTION

Biological limitations include pests, diseases and weeds. These biotic elements may exert their influence on the character of agricultural production directly or indirectly, and may account for considerable losses in sugarcane yields in the study area.

Pests

Peasts are some of the biotic factors limiting smallholder sugarcane production. There are many kinds of pests, but only those of economic importance in the study area are discussed below.

Red Stem Borers, Sesamia calamistic are very serious in drier parts of the Sugar Belt like Awasi and Ahero. Dead main shoot indicates the presence of this pest, while stems cut show holes through which caterpillar has bored its way. Older cane may not show signs of attack, although sugar content and growth will be affected.

Stem borers are widespread during drought when their other hosts like rice, maize, and sorghum are absent except sugarcane. Proximity of these cereals to adjacent cane fields poses great danger to cane because these pests if present, say, in maize field, will find their ways to sugarcane plots. The seriousness of "Nyanginja", Sesamia calamistic is well-known to small-scale farmers in the Sugar Belt, who are often confronted with low cane yields. Moreover, cane infested with this pest is hard to crush, and may spoil the machine. Good control measures include prohibition of sale of infested canes to smallholders, destruction of infested canes, spraying with 0.75% gamma Benzene Hexa-Chloride (BHC) applied over the seed canes or setts at the planting time before covering the soil. However, spraying is usually inefficient and expensive. Burning and crop rotation are good control measures.

Termites, Pseudocanthotermes militaris, usually attack cane setts, although they rarely cause considerable losses in the Sugar Belt. Occasionally, they attack mature cane during drought and there is no easy remedy, except to improve the moisture status of the soil, but smallholders have no means of replenishing the soil through irrigation, hence the occurrence of termites in some cane fields reduce cane yields. Symptoms of termites consist of mounds or white ants in the fields. These mounds should be destroyed and cane setts should be treated with a solution of dieldrin prior to planting.

Nematodes are present in sandy soils in the Sugar Belt. They cause leaf to curl longitudinally giving rise to poor growth, short joints and short roots. Nematodes are controlled by soil fumigant, or nematocides, for example, ethylene dibromide or dibromo-chloropropane.

In 1931 and 1932 sugarcane production was considerably reduced because of destruction by locusts at Muhoroni and Miwani (table 17). No further outbreak of this pest is anticipated at the moment, but constant surveillance is vital to control any possible future outbreak.

At the end of December, 1972, armyworm, Spodoptera exempta walk, infestations were recorded in Kisumu area of Western Kenya.

Table 17

IMPACT OF LOCUSTS ON SUGARCANE PRODUCTION IN THE NYANZA SUGAR BELT, 1930-6

Year	MUHORONI (Sugarcane in tons)	MIWANI (Sugarcane in tons)
1930	750	7450
1931	250	3500
1932	310	2500
1933	604	2836
1934	450	6322
1935	563	9200
1936	750	11180

Source: District Commissioner, Kisumu-Londiani Annual Reports, 1930-6

The first larvae were reported on sugarcane at the Muhoroni Settlement Scheme.[7] But problems involved in developing effective action to eliminate the early epidemic in the first outbreak areas as occurred in some portions of Nyanza Province early in 1976, can be both complex and eleusive. Moreover, Chemical insecticides for armyworm control is often hazardous and expensive. As most smallholders are illiterate and lack extension services such as radio, an outbreak of armyworms is often realized after serious damage to crops has occurred.

Diseases

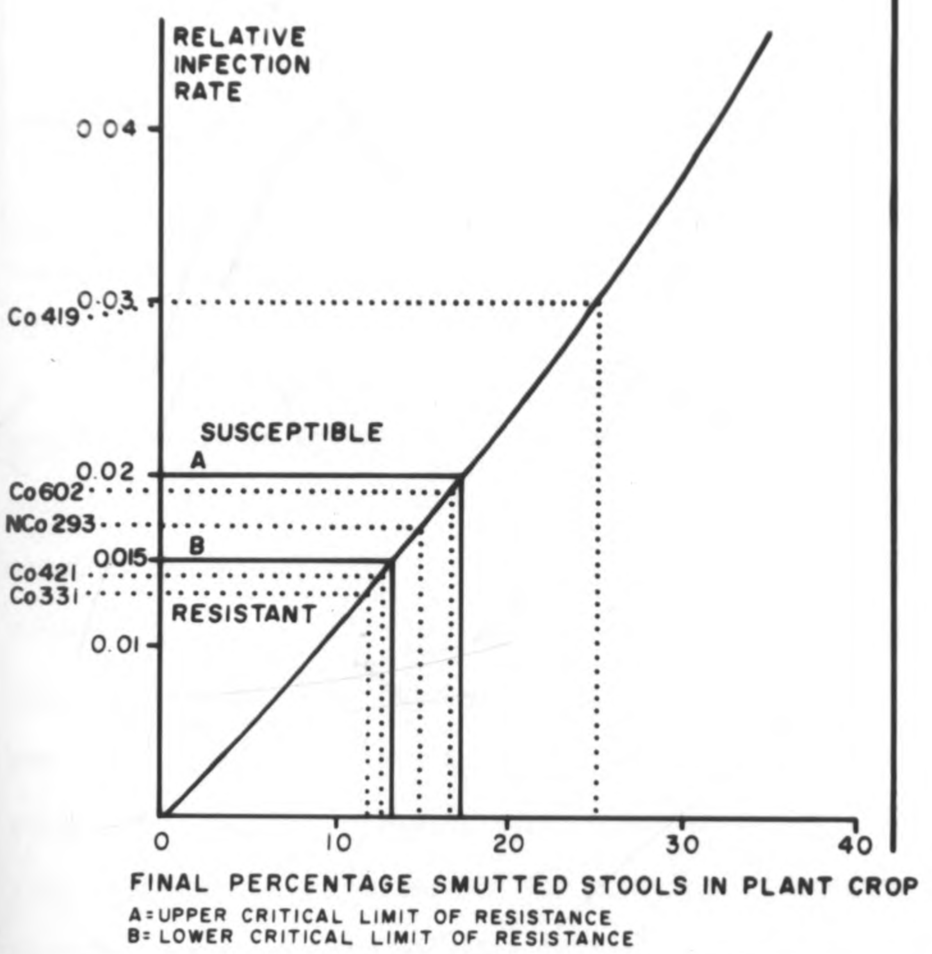
There are three major groups of cane deseases: bacterial, fungal and virus. Bacterial diseases are common in some cane growing countries, but not in Kenya, where the usual diseases are fungal or virus in origin.

Sugarcane smut, Ustilage scitaminea, is a fungal disease which is generally widespread throughout the entire belt, and it can cause heavy losses when susceptible varieties are planted. Smut was officially recorded in the area in 1958 and Robinson (1959) recommended a number of control methods at the initial outbreak.[8] These measures embraced the application of resistant varieties to the disease in other countries and consequently the disease was declared a "scheduled disease" under the plant protection Act and the eradication of smutted stools became compulsory.

There was a severe smut epidemic in the early 1960's and several susceptible varieties like Co 419 were withdrawn (fig. 36). In 1962 assessment was made of the relative susceptibilities of the commonly grown varieties, and legislation was accordingly enacted, prohibiting the planting of varieties which were susceptible to smut, and the relatively resistant varieties Co 331, Co 421 and B 41227 were recommended. The first two varieties are now widely grown by smallholders in the Sugar Belt.

From 1964, smut incidence declined due to an increasing hectarage under resistant varieties. Table 18 depicts the mean incidence of smut in the study area.

Predicted percentage of infested stools for the lower range of relative infection rates is shown in Figure 36.



Source : East African Agricultural and Forestry Journal, Vol. XXXII, No. 4 – April, 1967

FIG.36 RELATIVE INFECTION RATE AND PREDICTED FINAL PERCENTAGE OF SMUTTED STOOLS

Table 18

MEAN PERCENTAGE OF SMUTTED STOOLS

Years	NCo 293	Co 421	Co 602	Mean Incidence
1959/60	10	5	5	7
1961/62	17	13	22	17
1965/66	6	5	8	6

Source: East African Agricultural and Forestry Journal
Vol. XXXII, No. 4, April, 1967

Vatiation between actual and predicted values is fairly small for relative infection rates below 0.03. Co 602 and NCo 293 are both marginal as far as resistance under Sugar Belt conditions is concerned, and varieties having relative infection rates of more than 0.02 are too susceptible to be grown in the area. Co 331 and Co 421 are more common in the area because of their high resistance and other varieties with relative infection rates less than 0.015 are also recommended for planting. Consequently, planting varieties with relative infection rates more than 0.02 and substantial hectarages of varieites with ratings approaching this value would result in progressive increase in the epidemics and escalating losses as occurred between 1958 and 1962.

Symptoms of smut are indicated by the main stem or shoot which develops into a whip-like structure coated with black, sooty material. These are the spores of the fungus and if dispersed by wind or water may cause more diseased canes in the field.

Badly infested canes have a number of tillers and give the appearance of a bunch type grass growth. Smut affected canes must be handled with care to minimize spread of spores. It is recommended that the whole stool be covered with plastic bag followed by roguing and burning or burying the stool.

Recently, important and a high incidence of sugarcane mosaic virus (SCMV) has been observed in the Sugar Belt, especially at Homa Lime. About four decades ago, it was alleged to be a serious disease on the eastern shores of Lake Victoria.[9] A common manifestation of SCMV is characterized by a mottling of the youngest leaves where chlorphyll has been potentially destroyed forming islands of normal green or yellowish chlorotic areas. Affected cane has a general stunting or dwarfing symptoms which tremendously depress the growth of highly susceptible varieties and subsequently lowers the yield. Farmers should grow resistant varieties and reject setts with SCMV symptoms.

Another disease of economic importance is Ratoon stunting disease (RSD), which is considered to be endemic in East Africa. It is a serious disease, which becomes more pronounced in ratoon crops after it has affected the planted cane, and at the same time RSD will have affected the soil as well. There are no overt symptoms, although the disease is recognized by the stunted growth and thin stalks. When the cane is cut and split through the nodes, red vascular bundles are noticed.

Experiments conducted at National Sugar Research Station, Kibos indicate that the usually mistaken stunting growth in cane is not caused by RSD, but may be associated with other environmental factors affecting plant-soil-moisture relationship.[10] The Sugar

Belt is well-known for its heavy montmorillonite clay soils, which frequently suffer from serious moisture stress during droughts as has been referred to in Chapter III.

Heat treatment is used to eliminate RSD, but the technique involves immersing the setts in water boiling at 50°C for two hours.[11,12,13] Oduol (1974) gives this as 50°C for half an hour.[14] This creates a controversial issue because most sugar authorities agree that the length of heating should be 2 hours. Perhaps the half an hour mentioned is a misprint if not misquoted. but it poses an interesting point of investigation. However, the temperature must be precisely controlled since low temperatures fail to kill RSD, whilst high temperatures are lethal to setts. Despite these precautions a reduction in the germination percentage is noticed, although the decline is also a function of cane variety treated. Another problem is that heat treated cane cannot be planted immediately into commercial fields due to a possibility of poor germination and great amount of cane needed is prohibitively expensive.

Chemical treatment involves dipping cane in a solution of 250 gm. of Aretan in 100 litres of water. Furthermore, cutting knives or "pangas" should be sterilized by regular dipping in lysol. Although varietal resistance to RSD is unknown, RSD is more detrimental to some varieties.

Leaf Spots are caused by fungi, <u>Cercospora longipes</u>, which cause brown spots, and <u>Puccinia erianthi</u> causes rust. Brown spot is more important and commonly seen on the sugarcane plantations. A tentative estimate reveals a constant 5% loss on dry-farmed cane, but the loss on irrigated cane, where Co 421 grows is somewhat susceptible, roughly 10%. Growing resistant varieties is the only solution to leaf spot control at the moment.

Problems Associated with Weeds

Weed is regarded by agronomists as one of the most limiting factors in cane production and effects of weeds on cane yields are considered to be more adverse than most environmental factors. Peasants rely to a greater extent on their own effort in weed control than in other operations which are carried out by either Sugar Settlement Organization (SSO) or Sugar Belt Cooperative Union (SBCU). But weed control and other farm operations are extremely poor in communal blocks because the blocks belong to everybody or society, and therefore to nobody in the end. Consequently, the committee members are more interested in their privately owned sugar-cane plots, and in settled areas, most of the plot owners are absentee farmers. Weed control techniques employed in the smallholder area include mainly manual and mechanical weed control practices. However, hand weeding is the normal weed control practice in the Sugar Belt.

Hand weeding requires 5-10 man day per 0.4 ha., because predominant weeds in the cane fields are annual and perennial grasses, for example, Digitaria Scalarum, Cynodon dactylon, Striga hermonthica, Cypress rotundus, Rottboellia exaltata, Sporobulus robustus, Commelina Africana, Polygonium convulus, Sorghum spp. and other broad-leaved weeds. Each hand weeding costs K.Shs. 40.00-60.00 per 0.4 ha. Nevertheless, efficiency of hand weeding as a weed control practice in cane is low and during wet periods questionable. In the tropics, the greatest proportion of cropped land is weeded with simple tools, which is slow and usually commenced after weeds have began to exert a depressive effect on yield.[15] During rainy periods, hand weeding with simple tools becomes ineffective because weeds are merely transplanted and not destroyed. Moreover, weeds growing within the cane rows are difficult to remove with the hoe without causing damage to the crop. In addition, dominant perennial grasses such as Cynodon dactylon and Digitaria Scalarum are not controlled by hand weeding. Besides, close supervision is essential as there is always the tendency by labourers to weed only the beginning and the end of the rows, especially when the cane is about to form a canopy.

Mechanical weed control is cheap, costs about K.Shs. 20.00-25.00 per 0.4 ha., but only weeds between the cane row are controlled or buried, and the operation can only be carried out during dry periods. Furthermore, weeds like couch grass and star grass buried soon emerge on their surface and spread profusely. Mechanical weed control is limited in the area due to few tractors and implements; and the absence of tractor hire service which can be approached directly by small-scale farmers.

Chemical weed control is the most effective method of weed control, but it requires semi-skilled and skilled operators to make the operation successful. Only SSO has one spraying gang of a dozen people in the area capable of spraying about 4 ha. a day, which is inadequate in an area of over 14,000 ha. of cane. Chemical weed control costs about K.Shs. 60.00-75.00 per 0.4 ha. at the moment, which is expensive, but good weed control obtained is 6-10 weeks. But the best chemical weed control in sugarcane should be based on sound investigation into distribution of different types of weeds and soil types in the Sugar Belt.

It has been established that weeds account for 30-50% lower yields in the sugarcane under smallholders in the Sugar Belt. Ashby and Pfeiffer (1956) estimated that crop losses in the tropics are two to three times greater than in the temperate zones,[16] while yield decreases of 50% or more due to weeds within two or three seasons after clearing have been reported.[17,18] But in Nigeria, crop losses to weeds range from 20% for maize to 100% for upland rice.[19,20,21] It is therefore important for small-scale cane growers in the present study area to have flexible systems of weed control where manual, mechanical and chemical methods of weed elimination are all within their reach.

Conclusion

It is clear from this environmental study that small-scale sugarcane production is in jeopardy from environmental limitations: rainfall, soil fertility, soil texture, pests, diseases and weeds. Rain-fed sugarcane production is of utmost importance in the Sugar Belt. Field evidence shows that the decline in growth of sugarcane during dry months can be ascribed to short supply of available soil moisture. From this evidence, where rainfall is not ideal for optimum sugarcane growth and yield, irrigation is of vital importance. On the other hand, increased sugarcane production in the future is, generally speaking, dependent on improvement in sugarcane husbandry. Without application of Sulphate of Ammonia, sugarcane production in the future is doomed to failure.

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CHAPTER V

THE HUMAN ENVIRONMENTAL FACTORS LIMITING SUGARCANE PRODUCTION

THE HUMAN ENVIRONMENTAL FACTORS LIMITING SUGARCANE PRODUCTION

Introduction

It is well-known that agriculture is a "man-made" institution. In view of this statement, not all the obstacles to sugarcane development stem purely from the physical environment. There are pressures, both economic and sociological affecting sugar industry in the Sugar Belt. But it is difficult to generalize about the effects of socio-economic factors on this enterprise. This chapter attempts to analyse human environmental factors limiting sugarcane production in the present study area using field survey data.

Sugarcane Establishment

Land preparation is often done during dry spells (fig. 37), when soils are reasonably dry. Thus a proportion of 28% of the cane growers prepare land in December and 24.7% in January (table 19). This activity usually takes place throughout the year in the area depending on the weather conditions, soil type, and slope of the terrain. The last two features determine the degree of drainage. In April and May, there is less land preparation since they are the rainiest months associated with waterlogging in the predominantly montmorillonite soils.

Experience gained by the author from Ahero Irrigation Research Station, National Sugar Research Station at Kibos, and Chemelil Sugar Company, indicates that any sequence of land preparation used should aim at deep cultivation with a view to loosening soil and developing deep cane rooting system. This involves obtaining the necessary depth by primary operations. For smallholders it is done on contracts negotiated by SSO, and tractor hire firms. Chemelil Sugar Company also undertakes the same task for societies under SBCU. It was noticed that both SSO and SBCU have not got adequate personnel as well as technological and scientific know-how to supervise the tractor hire firms on the job, therefore smallholders have been the losers.

Although figure 38 indicates two prominent sugarcane planting peaks, planting is concentrated in February to April, but little planting occurs from May-July followed by October-December, because of a possibility of waterlogging or floods, and droughts respectively.

Table 19

FARM CALENDAR FOR SUGARCANE ACTIVITIES

Month	Land Preparation	Planting	Weeding	Top-dressing	Harvesting
Jan.	78	36	15	6	23
Feb.	40	59	25	6	5
Mar.	20	65	55	13	3
Apr.	13	50	108	17	2
May	4	8	99	11	5
Jun.	20	7	10	0	20
Jul.	29	8	4	1	11
Aug.	44	51	5	3	112
Sept.	36	47	19	32	23
Oct.	33	14	28	5	21
Nov.	42	14	12	4	28
Dec.	74	14	11	16	43

A second peak occurs from August-September, but planting generally goes on throughout the year in the area.

Field evidence shows that germination of planted seed cane on small-scale farmers' plots is generally poor. Although peasants use abnormally high rate of 6-10 tons per about 0.4 ha. which is 3-5 times the normal seed rate, cane germination is affected by apical dominance. Table 20 shows the effect of apical dominance on germination of whole cane planted by small-scale farmers.

Table 20

GERMINATION COUNTS AFTER THREE WEEKS

Treatment	Mean Germination per plot	% Germination
Long (whole) cane	5.0	2.5
3-nodded seed setts and standard Aretan Dip	43.3	21.6
3-nodded seed setts soaked overnight in $CaCO_3$ solution	93.5	46.8

Latin square Design (Mean Germination) at 5% level 31.3 and at 1% level 47.4.

Source: Chemelil Sugar Plantation Agronomic File; 1974

Preparation of planting materials by cutting into seed cane setts is more superior to planting long whole cane.[1] The results indicate that the breaking of bud dormancy for germination of sugarcane seeds is faster in cut seed setts than in long, whole seed cane.

Soaking seed cane setts overnight in Calcium Carbonate Solution of pH 8.0-8.5 further catalyses the process (table 20).

It was observed that planting long, whole seed cane is the common practice of sugarcane planting in the resettled areas, blocks and private sugarcane fields owned by smallholder individually or communally. Fields planted during periods of sufficient soil moisture have reasonable germination and plant population, although germination takes longer time than cut seed cane setts. During periods of high or unreliable rainfall, the germination of cane is poor and plant population too low for cane crop to cover and suppress weeds. The phenomenon of breaking bud dormancy should be exploited at this time. In cooperative societies the practice can easily be done by laying long whole seed cane in a furrow and then chopping seed cane at regular interval to reduce apical dominance. Consequently, trashing of seed cane should be avoided as the practice accounts for 3-5% poor germination because well developed apical buds are brittle and are easily stripped off with the trash. Soaking of seed cane in Calcium Carbonate solution should be exploited in gapping operations. The growth of soaked seed cane setts is more vigorous than those of long whole seed cane or seed cane setts. It enables gapped cane to catch up in growth with the rest of the cane when gapping is done 3-4 months after planting.

Specific Management Problems

Sugarcane varieties grown in the area are late maturing varieties, which take over 20 months before harvesting. A proportion of 90% of the small-scale farmers grow Co 421 (Manywere) and

40% grow Co 331 (siting). For harvesting, sugarcane is too bulky for family labour, and therefore additional hired labour is required, particularly, in August when most of the farmers harvest their canes (fig. 41). Weeding is mainly done from March-May during the "long rains" (fig. 39) while top-dressing which is mainly done by family is not a very common practice in the area (fig. 40). Those using organic or inorganic fertilizers seem to apply them mainly during the long rains and in September or December. Fertilizer applied during exceptionally wet periods may be partly lost through leaching, while fertilizers used during extremely dry months may have desiccating effect, resulting in cane wilting.

The problem of sugarcane transportation from cooperative societies areas is acute. Farmers have no control over cane transport system that operates within their zone and the factories where they deliver cane. Most of the societies do not have transport of their own and are thus forced to depend on Asian lorry owners, who, although willing to healp have a similar problem to deal with as well. Table 21 depicts that 84.3% of the smallholders

Table 21

FARMERS TRANSPORT OF CANES TO THE FACTORY THROUGH VARIOUS MEANS

	No. of farmers out of 300 transporting cane through various means	
Transport means	Number	Percentage
Cooperative society	253	84.3
Tractor hire	105	35.0
Factory arrangement	29	9.7
Other means	2	0.7

transport cane through cooperative societies who partly depend on tractor hire from private Asian owners and through factory arrangements. The immediate result is that some small-scale farmers have overmature cane of 30-36 months old in fields where they should have harvested two crops and this leaves the farmers with the prospects of financial loss and indebtedness,[2] while the harvesting arrangements in the settlements leaves a lot to be desired also. A very serious problem is that transporters usually overload transporting vehicle (fig. 42) and as such a lot of canes drop on the way or at the factory ground and nobody bothers to collect them, thus giving rise to relatively low cane weight and low cash received by the farmers. It has been shown in Chapter III that the most important and impressive development of sugar transportation has been the realignment, construction, grading and tarmacking of the most important link and net-work roads in the environs of the sugar factories.

Extension and Education

Agricultural extension services on sugarcane as a plantation crop is very thinly spread and in some areas these services hardly exist. This means that a field extension officer can pay little attention to each individual peasant. Table 22 shows summarized sources of extension services and indicates that 93.7% of the farmers receive their farm information from neighbours, however, there may be problem of language communication since the area is ethnically heterogeneous (Appendix A-4). The majority are Luo who form 77% of the farmers followed by Kipsigis 11.7%, Nandi 10%,

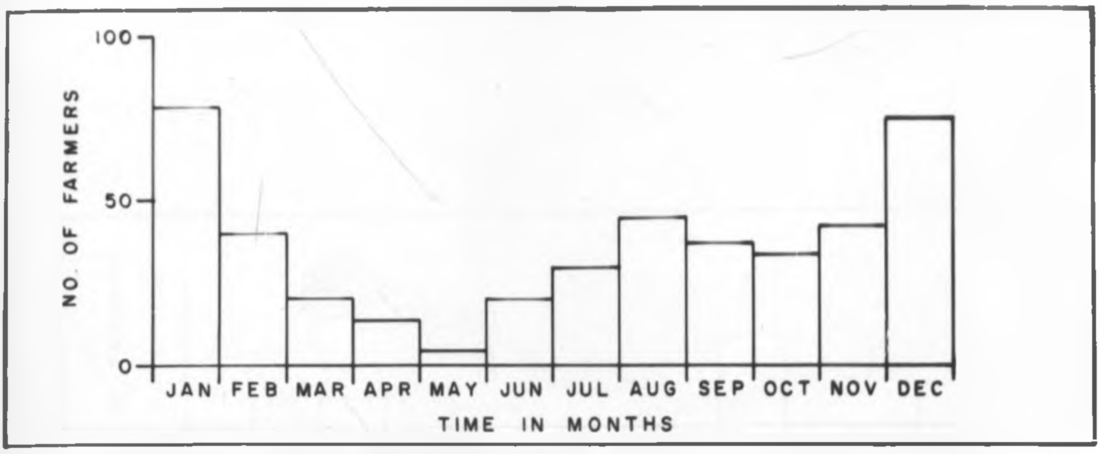

FIG.37 LAND PREPARATION FOR PLANTING CANE

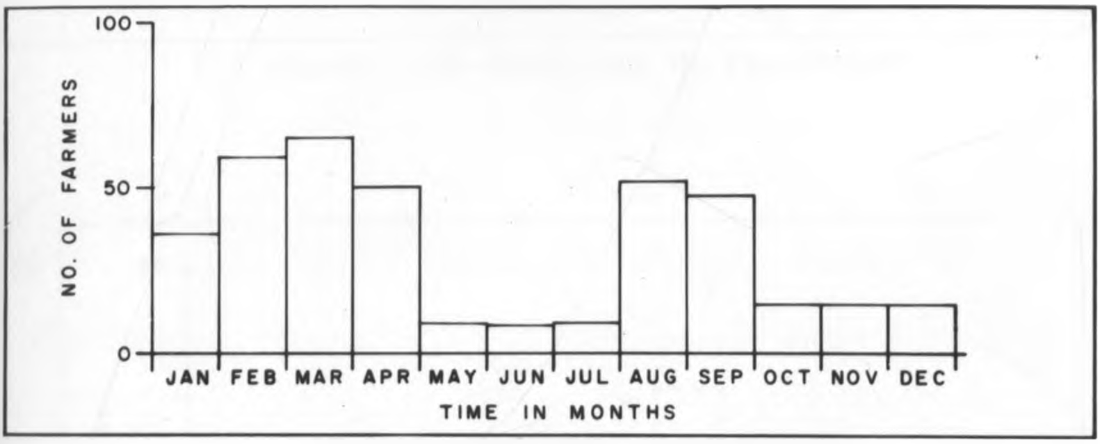

FIG.38 PLANTING SUGARCANE

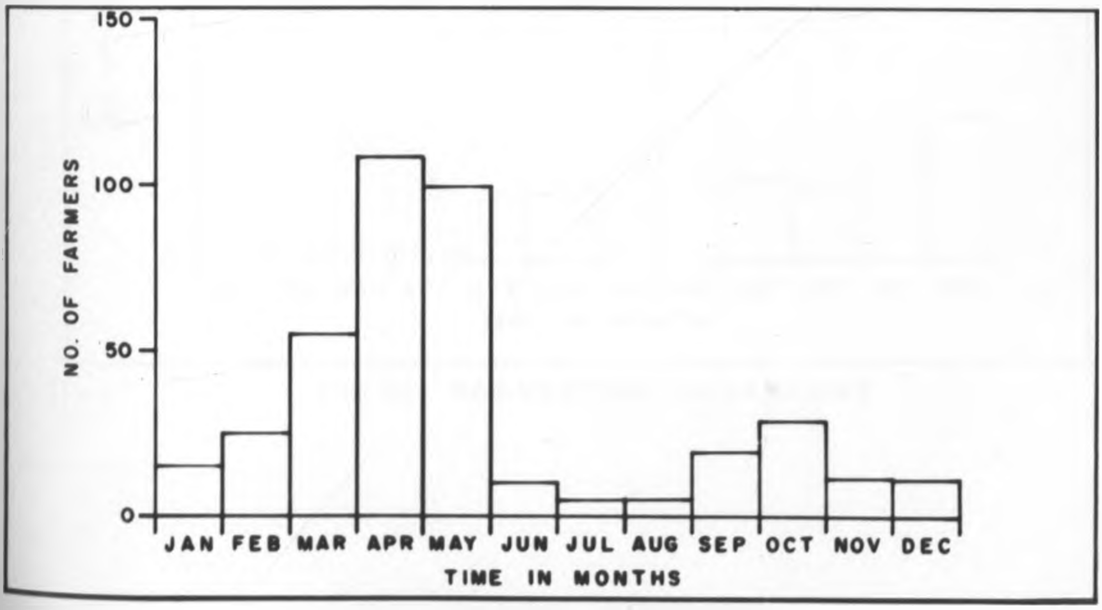

FIG.39 WEEDING SUGARCANE

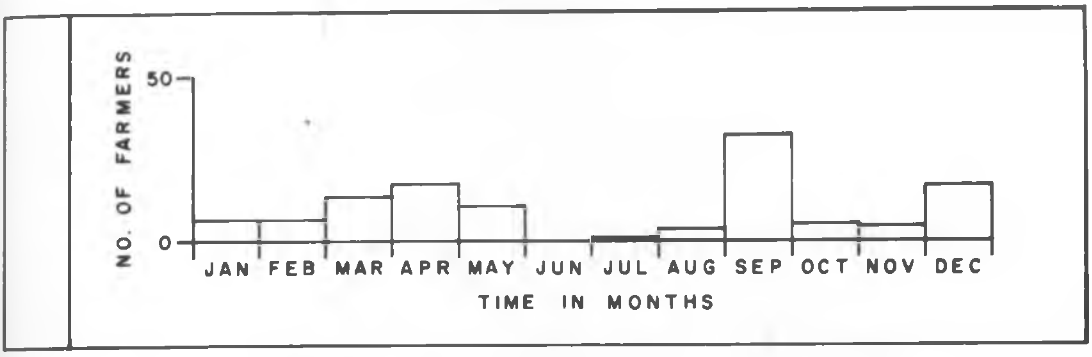

FIG.40 TOP-DRESSING IN SUGARCANE

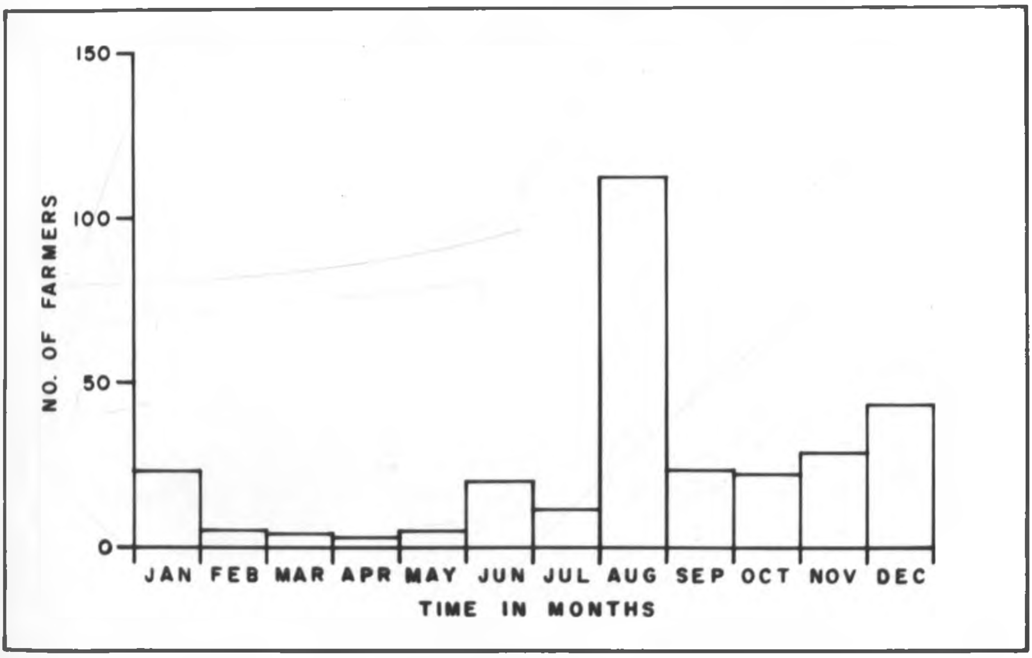

FIG.41 HARVESTING SUGARCANE

Fig. 42. Manual cutting and loading of sugarcane by hired casual labour. Overloading transporting vehicle results in some cane dropped on the way and less cane weight by the time it arrives at the factory

Table 22

FARMERS SOURCES OF EXTENSION SERVICES FOR SUGARCANE

Extension Services	No. of farmers out of 300 by sources of extension services	
	Number	Percentage
Radio	157	52.3
Press	90	30.0
Cooperative Society	160	53.3
Neighbouring farmers	281	93.7
Extension officers	199	66.3
Church	150	50.0
Meetings (Baraza)	240	80.0
Other	171	57.0

Luhyia 1% and Kikuyu 0.3%. About 80% of the farmers receive information from meetings (Baraza), while alternative sources include extension officers, cooperative society, radio, church, press and "other", which includes mobile cinema vans, agricultural show and posters (table 22). Research by various people suggests that early adopters hear of agricultural innovation mainly from newspapers, the radio or extension workers, whilst the majority of the late adopters hear of it from neighbouring farmers. Because extension services are so inadequate in the Sugar Belt, sugarcane development is likely to lag behind adopting innovations. Areas under SBCU have agricultural extension services not controlled by the government, and as the government does the overall planning for sugar industry in the area, the local planning and the national planning tend to conflict.

Although the above problems have tended to divert the interest of some small-scale sugarcane growers into subsistence crops and "fragmentation of consolidated block land into peasant plots, for example, in Chemase," their interest in cane can still be revived by active extension, and educating the farmers to consolidate their plots into units of production, and to absorb free and underdeveloped farm lands in the process. These factors may facilitate a more orderly system of efficient techniques for group farming and teach farmers to rely purely on their own efforts. The government ultimately should streamline the sugar industry and the smallholders should ultimately have shares in the sugar factories to which they deliver their cane, and some inputs into cane growing subsidized by the government for these farmers to be competititve in the industry. Moreover, these farmers should be encouraged to grow pulse crops like soya beans, haricot beans and peas in the inter-row spacing before sugarcane forms a canopy. This practice would help smallholders maximize on cane plots, reduce weeding as these are cover crops and increase nitrogen which is of benefit to cane at these stages by fixation, thus reducing fertilizer requirements.

Differences in the use of modern farm inputs and farm practices might have a lot to do with differences in education of the farmers.[3] As it was not simple to test the ability of the sugarcane growers to read and write English or Swahili, only those who attended lower primary up to standard four, upper primary, secondary, high school, and "other", which included technical courses or university were considered as literate in the final coding of data (Appendix A-5).

In view of these broad categories of educational standards, 60% of respondents can be considered literate. It was noticed that an increasing number of rural population that have access to education is increasingly becoming instrumental to employment in teaching, civil service, cooperatives andthe like. The literacy is likely to rise tremendously in the near future largely due to the mushrooming schools with free education in lower primary. In 1974/78 Development Plan, the Ministry of Education estimates of expenditure approximate £293 million. This is because the Government realizes too well that education is a key factor in the shaping of our cultural, economic and social advancement, as well as providing a tool for rectifying the imbalances created by the colonial education system that money spent in educating the masses takes a large proportion of national budget.

Due to illiteracy of about 40% of the farmers, there is lack of observation of the proper standard of sugarcane husbandry and, therefore some farmers fail to take sugarcane seriously as agri-business in the area. A farmer who can read, write and do elementary mathematics is likely to be a better farmer than one who cannot; this is supported by studies of farm practice adoption in both developed and developing countries. Farmers who adopt new practices first are invariably better educated than those who are late adopters.[4] The author observed such a situation in the Sugar Belt although it poses an interesting line of investigation.

Religion and Sugarcane Development

A great deal has been written on the effects of religion and religious beliefs upon agricultural development. Approximately 27.3% of the farmers belong to the Roman Catholic Church, 26.7% belong to Seventh Day Adventistists, 25.7% are Anglican and 6% are Muslims (table 23). The remaining 18.3% are not influenced by any of these

Table 23

HOLDERS' RELIGION IN RELATION TO ENCOURAGING OR DISCOURAGING GROWING SUGARCANE

Religion	No. Interviewed	Discourage		Encourage		Neither of these	
		No.	%	No.	%	No.	%
Seventh Day Adventists	80	0	0.0	50	62.5	30	37.5
Catholic	82	1	1.2	49	59.8	5	39.0
Muslim	6	0	0.0	1	16.7	5	83.3
Anglican	77	0	0.0	42	54.5	25	32.5
TOTAL	245	1	0.4	142	58.0	92	37.5

religion and retained their traditional beliefs, but a few of them may possibly belong to congregations which have separated from the origional christian churches and perhaps mix christianity with tribal beliefs.

Muslims tend to adhere to the teachings of their religion and pay less attention in helping solve current agricultural problems in the area. Islamic teachings should also be used at all levels to accelerate agricultural development in order to raise the standards of living of the "wananchi". Although there existed 1.2% negative response from catholics in encouraging cane production, they were the leading in encouraging its development (table 23). The information suggests that in the area it may be possible to reach a considerable number of smallholders with information through congregations that have regular services. Some churches may perhaps discourage the growing of this commodity since molasses, a by-product of sugar is used in the illegal manufacture of "changaa", which some church leaders preach against.

Disease and Malnutrition

The widespread occurrence of many debilitating human diseases in the area like cholera, malaria, Bilharzia, measles, typhoid, amoebic dysentery, sleeping sickness and malnutrition, automatically reduces the energy, initiative and mental capabilities of the cane outgrowers. Agricultural improvement and development in the area may be retarded by these diseases, some of which are endemic and prevalent (Appendix A-6). But there are wide spatial variations in disease incidence in the area and this may partly account for the spatial variations in cane yields. The presence of Bulinus truncatus (Bilharzia vector) has recently been demonstrated on the Kano Plain near Kisumu and this species; which is capable of acting as a host for the Mediterranean strain of Schistosoma haematobium may present and additional problem for the future.[5] Many farmers expressed that mosquito bites make them sleepless and "quench" their appetite for eating. Ogungo (1971) states that development is a function of many variables of different ingredients among which the psychological variable has a high level of importance, if not properly handled will negate any hope of rural development.[6] Presence of diseases in the area affect the initiative and the decision of the farmers psychologically, especially in avoiding locating sugar farms in areas infested by diseases.

Disease and malnutrition are often interrelated because malnutrition frequently reduces a farmer's resistance to disease, delays his recovery and renders him more liable to relapses. The diet of the majority of the area is predominantly vegetarian (table 24), only small quantities of proteins are infrequently consumed by the majority, sometimes once a month or a year. Moreover, farmers are very commonly dependent upon a single staple crop as their main supply of food. In the Sugar Belt this may be maize, sorghum, finger millet and occasionally cassava or sweet potatoes. Other elements in the diet are often in the nature of relishes, for example, alcohol and diet is markedly lacking in fresh fruits (table 24).

Table 24 also indicates calculated expenditure on diet per farm per annum, but it was not easy to do this due to lack of farm records and some farmers consume produce from the holdings to which they were unable to give financial estimates. Meat and fish each costs about 13.1% of farm food expenditure, while cereals comprise 18.2%, alcoholic drinks 14.5%, sugar and beverages 9.1%. Dr. Fredirick Nordisick says that sugar provides nothing to human nutrition, but calories.[7] He further states that sugar,

Table 21

FARMERS INFORMATION ON FREQUENCY OF DIET CONSUMPTION AND EXPENDITURE IN K.SHS.

Items	No. of farmers out of 300 by diet consumption frequency								Mean Expenditure per farm	% Expenditure
	Daily		Weekly		Monthly		Yearly			
	No..	%	No.	%	No.	%	No.	%		
Cereals	139	46.4	114	38.0	28	9.4	1	0.4	500	18.2
Meat	10	3.4	100	33.4	150	50.0	30	10.0	360	13.1
Fish	3	1.0	140	46.7	80	26.7	12	4.0	360	13.1
Milk/Eggs	98	32.7	82	27.4	32	10.7	3	1.0	250	9.1
Vegetables	225	75.0	43	14.4	2	0.7	0	0.0	200	7.3
Cassava/Sweet potatoes	42	14.0	98	32.7	56	18.7	3	1.0	100	3.7
Fruits	36	12.0	76	25.4	70	23.4	12	4.0	100	3.7
Sugar and Beverages	117	39.0	101	33.7	49	16.4	2	0.7	250	9.1
Alcoholic Drinks	93	31.0	34	11.4	20	6.7	0	0.0	400	14.5
Cooking oil	110	36.7	50	16.7	89	29.7	0	0.0	120	4.4
Other	29	9.7	80	26.7	48	16.0	42	14.0	120	4.4

or commercially processed and prepared foods such as jellies, fruits, cakes, candies and beverages with sugar ingredients can be a health hazard. High levels of sugar consumption have recently been shown to raise the blood pressure of both experimental animals and humans, and it affects all of the organs of the body that have to work against it. It is probably the major cause of heart disease, stroke, diabetes and kidney disease. Furthermore, high sugar consumption may facilitate tooth decay, especially in children. Despite all these problems, farmers need sugar for energy to work.

To some extent dietary deficiencies may be frequently accentuated by tribal food prejudices and taboos. The widespread inadequacy of both quality and quantity of food in most areas of Kenya is a matter of grave concern in planning agricultural improvement and development. Efforts are being made to persuade the local residents of the Sugar Belt to grow pulse crops, citrus fruits, bananas, particularly in the settlement schemes, and it is hoped that the recent spread of high grade cattle in the area will facilitate the consumption of more milk. Moreover, any movement towards lower milk prices will also ameliorate the nutritional position of the people of the present study area.

Sugarcane Growth Period and its Extension.

Many farmers feel that the long "gestation" (growth period) of sugarcane limits its extension because farmers may not have what to do or eat (table 25). The remaining 41% felt that they have no better alternative crop to substitute for cane. From

Table 25

NUMBER OF FARMERS WHO THINK THAT THE LONG GROWTH PERIOD OF SUGARCANE LIMITS ITS EXTENSION

Zone	Sample No.	Long growth period limits cane extension	
		No. of farmers	% of farmers
Miwani	97	54	55.6
Chemelil	84	51	60.7
Muhoroni	119	72	60.5
TOTAL	300	177	59.0

table 25 it is clear that length of cane growth as a limitation is comparatively greater in the Muhoroni and Chemelil zones where we find recently settled people.

The settlers were perhaps used to mixed cropping and to growing annual crops yet they settled in an area where cane monoculture was predominant. Here they are faced with the problem of growing a crop which takes about two years to bring income, and on the assumption that this crop is liable to arson, or failure due to other multifarious environmental factors such as rainfall unreliability, the farmers adopted poor attitude towards its expansion. Recently, earlier maturing cane varieties have been introduced in the area, and these mature in about 16 months time instead of the usual 22-24 months. Hence limitation imposed by long growth period of cane is now questionable on the grounds that most crops in the area are liable to total failure under drought as well as flood conditions, whereas sugarcane is more resistant to weather and carries with it, therefore, the assurance of a minimum return from its cultivation even when the weather is bad. This had an important bearing on the decisions of producers regarding sowing of crops in the area; generally a much larger proportion of area is devoted to the cultivation of sugarcane in the area.

Incomplete Migration of Family to Sugar Farm

Difficulty to complete migration of family to the sugar farm is likely to influence sugar production in the area. At least 41.4% of the smallholders were owning land in their original home areas (table 26) and it is likely that they have not completed migration with their families. Moreover, it is possible that some settlers perhaps found the area climatically and sociologically unsuitable, therefore, migrated back to their original areas.

Nyanza P.C., Chairman of Kenya Sugar Authority disclosed that the Government had cracked down on "telephone" and absentee farmers in the area where 6 farmers had been evicted and investigations were going on against 70 others who had deserted their farms.[8] He also criticised the poor cane husbandry in the Kibos areas, where farmers got only 8 tons per approximately 0.4 ha.

In table 27, 7% of the farmers were absentee farmers, while 36.3% were part-time. Absenteeism is a more common practice in Muhoroni and Chemelil Settlement areas, where farmers usually leave their cane plots to be managed by their friends and relatives. These friends and relatives alike are not the best employees because they lack experience and managerial ability.

Table 26

FARMERS OCCUPYING OTHER LAND ELSEWHERE

Land Size (Ha)	Farmers occupying other land elsewhere									
	Kaka-mega	Kericho	Kiambu	Kisii	Kisumu	Na-ndi	Sia-ya	Sou-th Nya-nza	Oth-er	Total
1	0	0	0	0	16	0	2	0	0	18
1-4.99	0	7	1	1	48	5	8	2	2	74
5-9.99	0	4	0	0	7	1	1	0	0	13
10-14.99	0	2	0	0	6	0	0	0	0	8
15-19.99	0	0	0	0	1	3	0	0	0	4
20-24.99	0	0	0	0	3	0	0	0	0	3
25-29.99	0	0	0	0	0	0	0	0	0	0
30+	0	0	0	0	4	0	0	0	0	4
TOTAL	0	13*	1	1	85*	9*	11	2	2	124

* indicates those occupying other land elsewhere in Kisumu, Kericho and Nandi Districts excluding the Sugar Belt.

Table 27

NUMBER OF FARMERS WHO ARE FULL-TIME, PART-TIME AND ABSENTEE FARMERS

Zone	Sample number	Full-time farmer		Part-time farmer		Absentee Farmer	
		No.	%	No.	%	No.	%
Miwani	97	59	60.8	35	36.1	4	4.1
Chemelil	84	60	59.5	27	32.1	7	8.3
Muhoroni	119	63	52.9	47	39.3	10	8.3
TOTAL	300	172	57.3	109	36.3	21	7.0

Distance from the Factory

Although the distribution of sugar outgrowers in the area is determined partly by physical features and competition from other crops, distance from the factory is also one of the most influential factors. Each smallholder has to transport cane by lorry, or tractor to either Miwani, or Chemelil, or Muhoroni for which the cost varies from K.Shs. 18.00-25.00, but now it varies from K.Shs. 20.00-28.00 per ton. This variation in transportation cost is a function of distance (table 28). For example, those

Table 28

NUMBER OF FARMERS BY DISTANCE BETWEEN THE FARM AND FACTORY IN KILOMETRES AND CORRESPONDING TRANSPORT CHARGES IN K.SHS. PER TON OF CANE IN 1975

Distance in kms.	No. of farmers by distance from factory according to transport charges					Transport charges
	Miwani	Chemelil	Muhoroni	Total	%	
1-10	25	35	85	145	48.3	18
11-16	33	9	25	67	22.3	20
17-24	39	40	0	79	26.3	22
24+	0	0	9	9	3.0	25

farmers located between 1-10 kms. from the factory pay K.Shs. 18.00 per ton, while those located over 24 kilometres are charged K.Shs. 25.00 per ton. Assuming that other factors are the same, locations close to the factories are likely to be more beneficial than those at a distant.

There is a rapid decline in the number of small-scale growers once it is necessary to transport the cane beyond 10 kilometres and the cultivation is very rare beyond 24 kilometres. Consequently, the type of road is almost irrelevant since the transport cost is the same for murram and tarmac roads. One of the main problems facing the outgrowers is high cost of transporting cane to the factory. Moreover, these farmers are not in a position to reduce costs since few have any direct control over transport and have to rely on haulage firms. In addition to this problem, farmers outside the factory zones are not allowed to grow sugarcane.

Land Tenure

82% of the farmers interviewed were individual land-owners (table 29). The principal disadvantage of unrestricted individual ownership, apart from fragmentation, are the tendency to abuse the land, or to hold land without using or developing it. The tenants were mainly encountered in the Muhoroni Settlement Schemes. It is a general consensus that landlords in the Sugar Belt charge exorbitant rents which paralyse incentive for good land use and improvement by the tenant. The tenants formed 15.7% and lesee 21.3% of those interviewed.

About 45% of the farmers owned land communally as grazing grounds or sugarcane block-systems. Much of the land under block-system in the Kano plains was originally clan or family land which had not been cultivated, thus in many cases the fields are far from homestead where more than one field is owned and that includes 44% of farmers.[9] This complicates the problem of supervision and

Table 29

HOLDERS BY TYPE OF LAND TENURE

Land	No. of holders			Total	
	Miwani	Chemelil	Muhoroni	Number	%
Individual	85	71	90	246	82.0
Freehold	81	71	74	226	75.3
Owner-occupier	85	68	73	226	75.3
Communal	45	68	22	135	45.0
Tenancy	10	1	36	47	15.7
Leasehold	19	7	38	64	21.3
Share-cropping	12	7	6	25	8.3

even lack of concern because the sugarcane field is not even seen as proper part of the homestead complex. In general terms, communal land cannot be used as security for development loans. Hence land use planning, farm planning and introduction of innovations concerned with better farming systems may be rendered difficult by this form of tenure in the area.

Land-Use

Information on the size of farms or holdings in the Sugar Belt is incomplete. The author obtained data on farm sizes through a sample of 300 farmers. Such data facilitated comparisons on spatial variations of the land use in the area. The people of Nyanza Sugar

Belt have a mixed economy where crop cultivation and animal husbandry are two vital components of land-use (Appendix A-7). Mean holding size is about 4.8 ha., while individual holdings and land use vary from society to society, ranging from 2.1-7.5 ha. in the case of holding size, while cane land vary from 0.6-3.4 ha., maize 0.2-1.8 ha., other subsistence crops 0.1-1 ha., grassland 0.2-3.3 ha., and land unused/under other uses 0-1.3 ha., (fig. 43).

Although the size of sugarcane land is determined partly by physical features (fig. 44), competition from other crops (Appendix A-7), grazing and other land uses also influence sugarcane production. The influence of topography in the Sugar Belt is reflected on the emphasis laid on the type of agricultural enterprise practised (table 30). The terrain and the soil in the area

Table 30

EFFECT OF TOPOGRAPHY ON THE TYPE OF ECONOMY IN A LOCAL AREA

Location	No. of farmers interviewed	Emphasis on cattle	Equal Emphasis on cattle and sugarcane	Emphasis on sugarcane
Hill-top farms	10	7	2	1
Hillside farms	8	3	2	3
Foothills and flat areas	11	2	1	8
TOTAL	29	12	5	12

Source: Ochung', A.W. The Muhoroni Sugar Settlement Schemes, 1969 render it, except in escarpments and hillsides economically suitable for sugarcane production (fig. 44). About 80% of out-growers had 6 ha. or less under sugarcane, although this varied according to society (Appendix A-8). The table further shows the spatial variation in sugarcane productivity (fig. 45). The average cane yield is 32.25 metric tons per 0.4 ha. (table 36). Average cane yield per 0.4 ha. obtained at Kilombero Valley Estate under natural rainfall is higher 36 metric tons.[10] Figure 46 delineates the frequency of sugarcane hectarage by sampled societies and indicates that a large proportion of these are below 5.99 ha. Despite the arbitrary division of the map, it illustrates that the whole area is characterized by smallholdings. Some writers argue that advances in sugarcane productivity are dependent upon increases in farm size. These views are difficult to substantiate because farm sizes are not the sole obstacle to sugarcane industry in the Sugar Belt.

Table 31 indicates cash and subsistence crops grown other than sugarcane, while sisal, <u>Agave sisalana</u>, which falls under "other" is commonly used to demarcate farm boundaries, although a few farmers grow it for fibre production.

Socio-economic value of livestock cannot be underestimated for capital is usually invested in cattle, sheep, goats, asses and poultry, which the owners in most cases convert into food or cash as need arises (table 32). A few asses were kept by some farmers for transportation of farm commodities to homesteads or markets, particularly, in areas lacking access roads or feeder roads and transporting facilities. Despite the value of livestock for prestige, most farmers regard livestock as a source of milk,

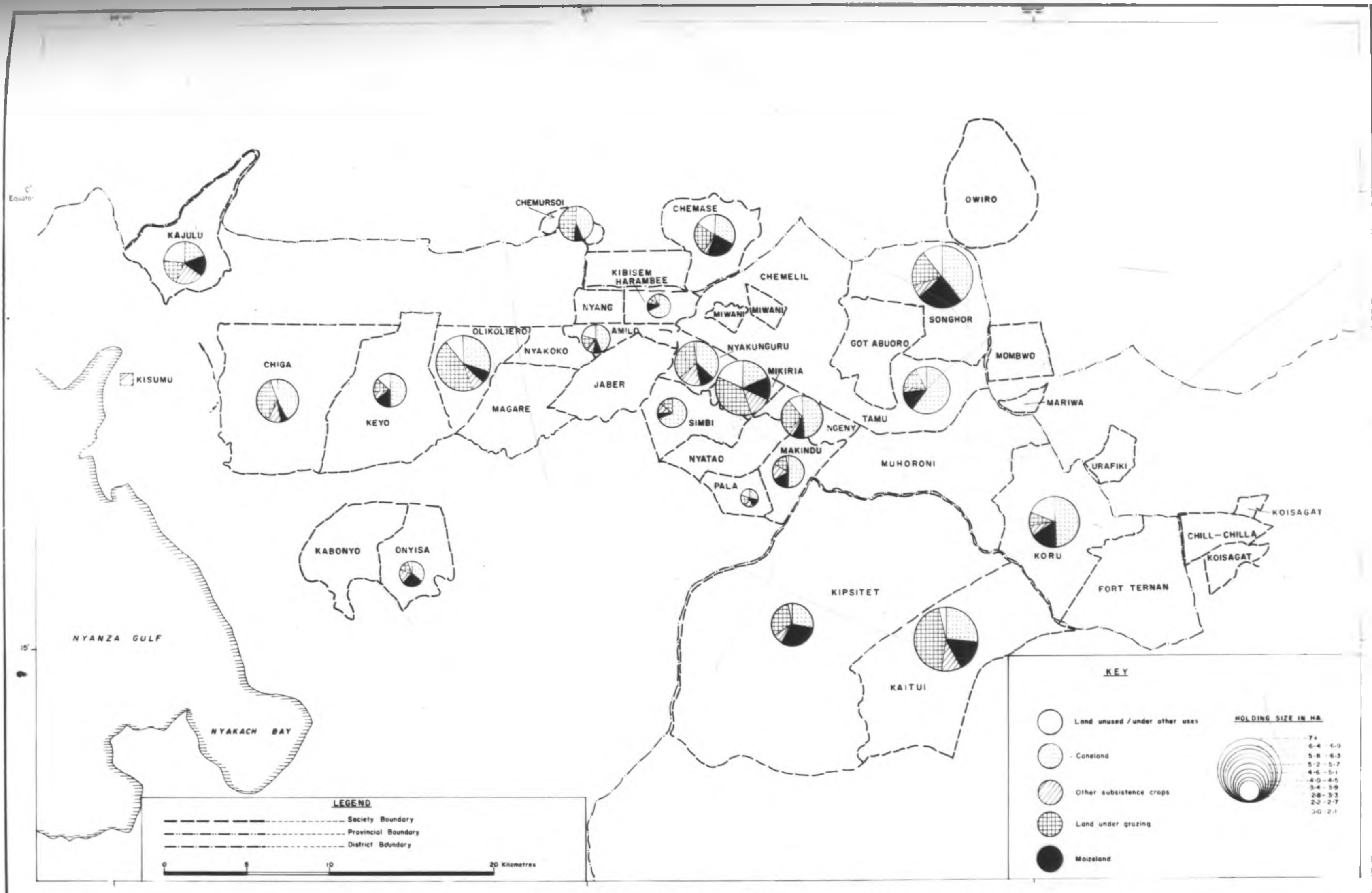

FIG.43 LAND USE ACCORDING TO SAMPLED SOCIETIES IN THE SUGAR-BELT

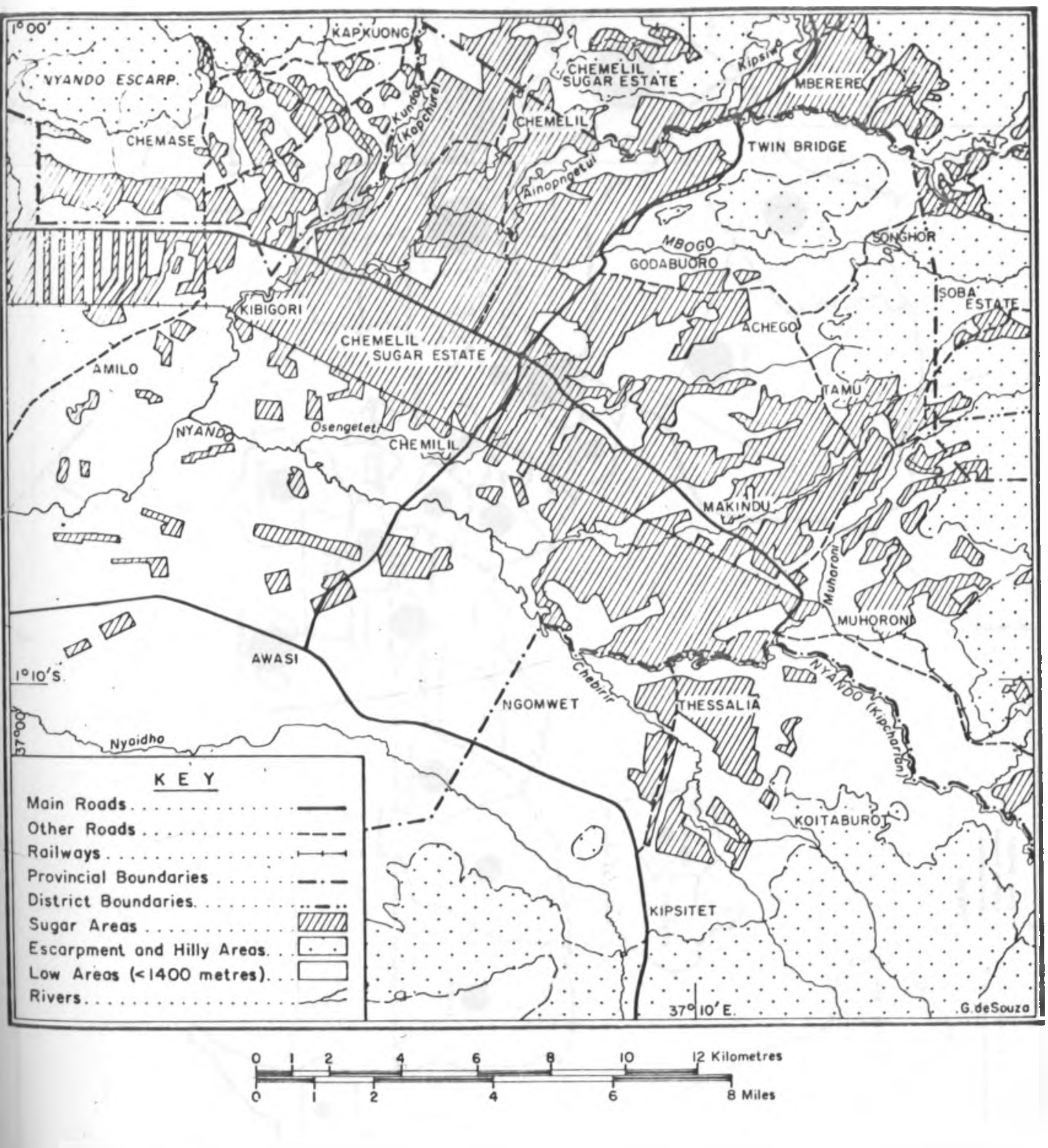

FIG. 44 LAND USE IN THE MUHORONI AND CHEMELIL ZONES OF THE SUGAR BELT.

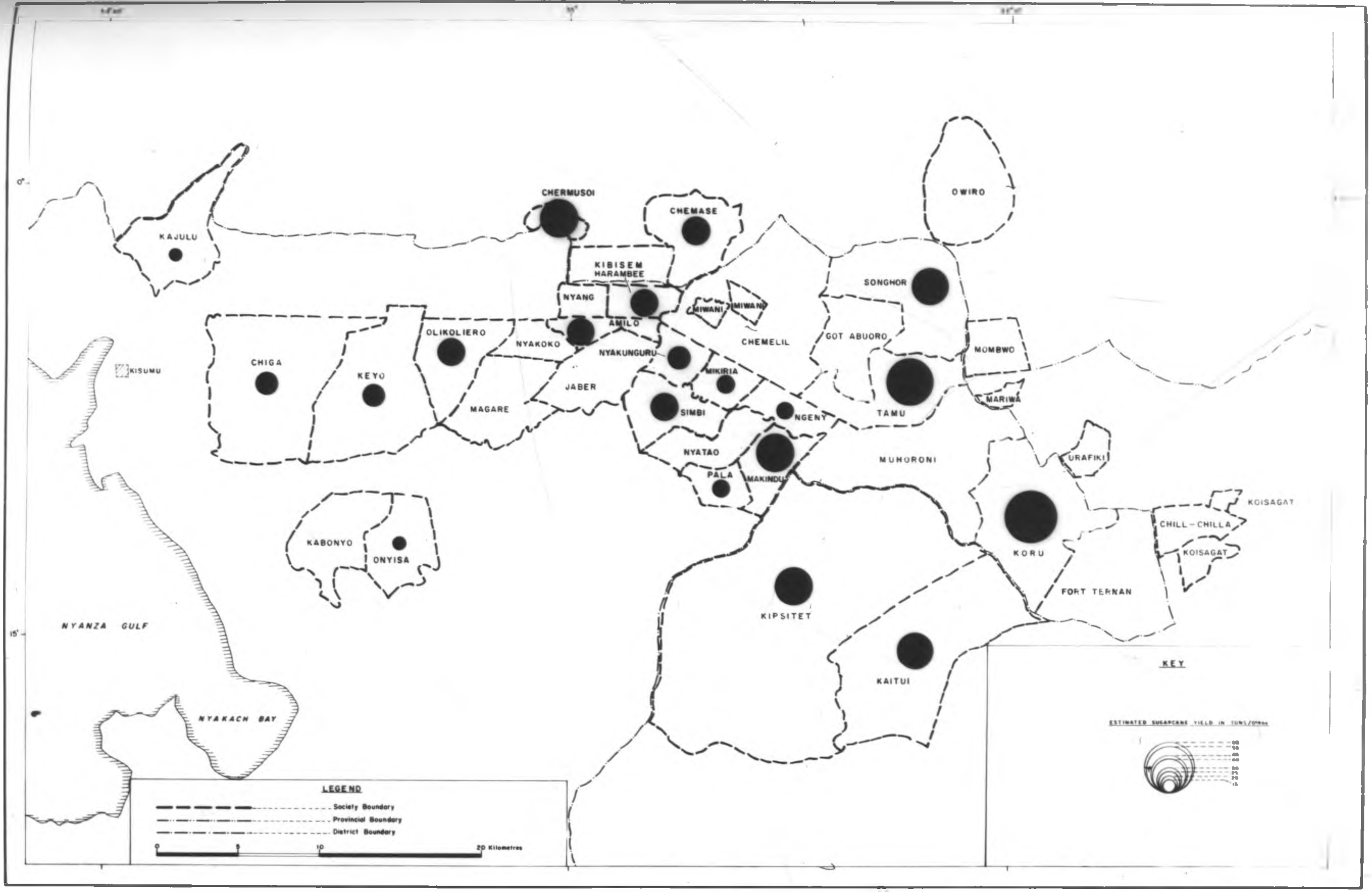

FIG.45 SPATIAL VARIATION IN SUGARCANE YIELD ACCORDING TO SAMPLED SOCIETIES IN THE SUGAR-BELT

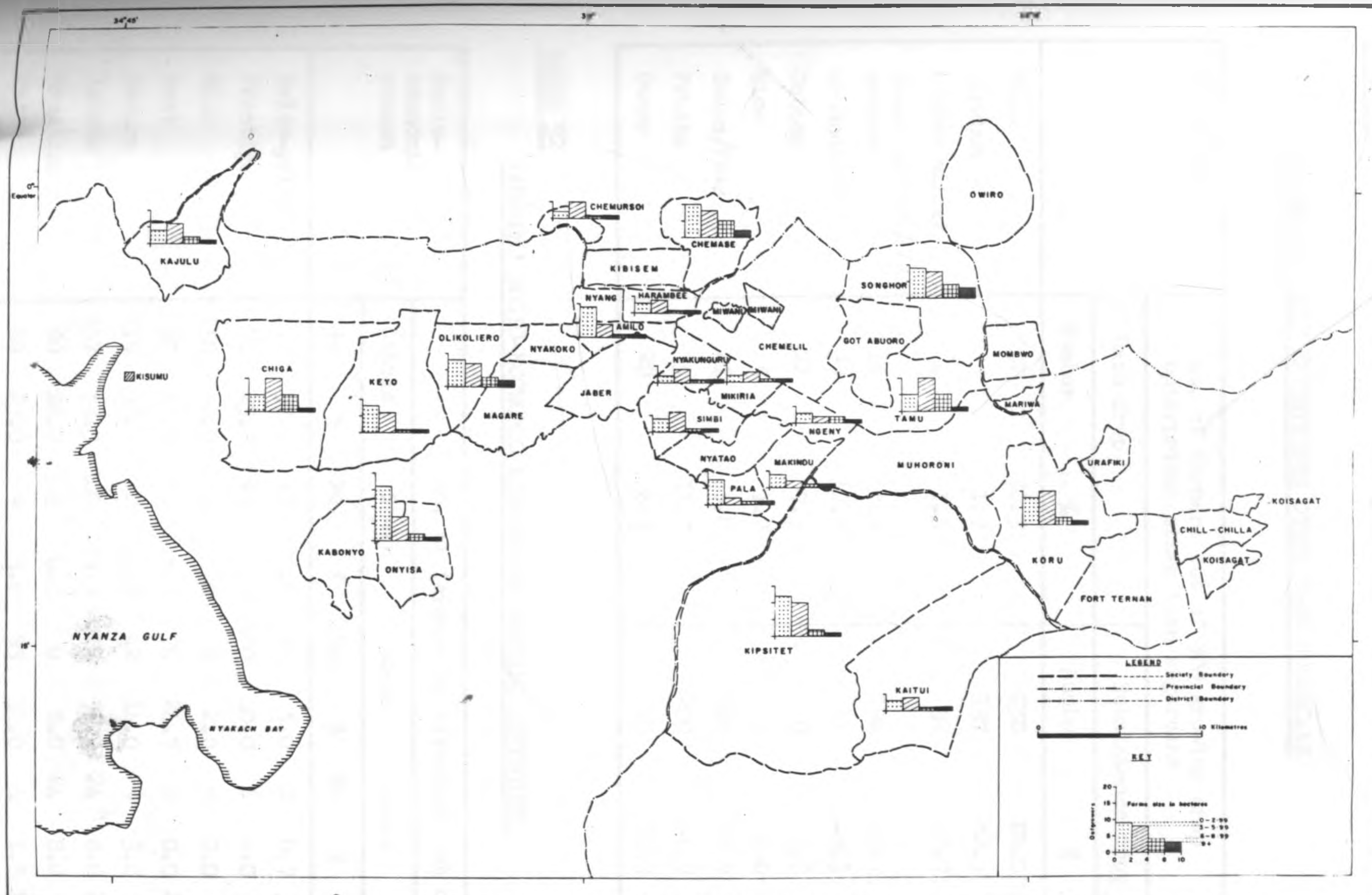

FIG.46 FREQUENCY OF SUGARCANE PLOT SIZES ACCORDING TO SAMPLED SOCIETIES IN THE SUGAR-BELT

Table 31

FARMERS BY CROP ENTERPRISES OTHER THAN SUGARCANE

Enterprises	No. of farmers out of 300 growing crop enterprises other than sugarcane			
	Cash Crop		Subsistence crop	
	Number	%	Number	%
Maize	61	20.3	258	86.0
Sorghum	5	1.7	187	62.3
Finger millet	4	1.3	32	10.7
Sweet potatoes/ cassava	19	6.3	194	64.7
Groundnuts	37	12.3	61	20.3
Cotton	22	7.3	0	0.0
Rice	5	1.7	3	1.0
Beans/Peas	21	7.0	107	35.7
Fruits	35	11.7	200	66.7
Other	20	6.7	223	74.3

Table 32

FARMERS' SOCIO-ECONOMIC REASON FOR KEEPING LIVESTOCK

Socio-economic reason	No. of farmers by livestock out of 300									
	Cattle		Sheep		Goats		Asses		Poultry	
	No.	%	No.	%	No.	%	No.	%	No.	%
Bride-price	111	37.0	12	4.0	15	5.0	2	0.7	0	0.0
Prestige	70	23.3	99	33.0	120	40.0	6	2.0	66	22.0
Milk	150	50.0	0	0.0	6	2.0	0	0.0	0	0.0
Meat	33	11.0	50	16.7	74	24.7	0	0.0	240	80.0
Manure	115	38.3	42	14.0	42	14.0	9	3.0	63	21.0
Income	157	52.3	100	33.3	118	39.3	24	8.0	140	46.6
Traction	80	26.7	0	0.0	0	0.0	24	8.0	0	41.3
Other	69	23.0	9	3.0	33	11.0	4	1.3	124	41.3

bride-price, meat, manure, income, traction, ghee, eggs, skins, hides and so on. Farmers consider livestock important and lucrative, although most of them tend to regard these animals with too much of a traditionally oriented mind, instead of purely economic advantage. Notwithstanding the interest of the farmers in keeping the cattle, the poor pasture, health care and husbandry techniques lead to cows with "needle-shaped backs", sharp-pointed backs, indicating cows with poor milk production. Such animals have little economic value and cause havoc to the environment, particularly in the steep slopes of Nyando escarpment and Awasi area.

Burning of Sugarcane

The analysis which is presented below is concentrated on deliberate agricultural burning of cane as opposed to arson which is malicious burning of sugarcane. Burning of sugarcane is undesirable condition in most cases since apart from lowering the quality and quantity of sugarcane or sucrose content, it may lead to displacement of the equilibrium of soil ecosystem by interfering with the mechanisms of soil micro- and macro-organisms which are indispensable in moulding soil minerals. The degree of disturbances depends on heat intensity supplied.

There are allegations that fire may promote weed seed germination by ending seed dormancy.[11,12,13] Burning with clearing, will also promote weed seed germination and growth by removing competition of other plants and litter, allowing more light to reach the soil surface and causing greater temperatures alternations in the upper soil layers between day and night.[14] Hence land burned too often frequently becomes overgrown with perennial grasses which may render it useless for agricultural production when simple tools are used,[15] and burning also stimulates the growth of some perennial weeds such as Imperata cylindrica.[16]

Malicious burning of sugarcane has recently become a very controversial issue in Nyanza Sugar Belt where 9000 tons of sugarcane were lost in 1973 in Chemelil zone alone (fig. 47 and table 33).

Table 33

ACCIDENTALLY BURNED CANE BY DECEMBER 1973

Zone	Tonnage burned	Tonnage delivered	Tons lost
Chemelil	26000	17000	9000
Miwani	15800	15800	-
Muhoroni	19000	19000	-
TOTAL	60800	51800	9000

In 1970, 6 experienced arson, and in 1971, 8 suffered from illegal cane fires, while in 1972, 17 farmers were affected with malicious cane fires which spread like wild fire, thus affecting 37 farmers in 1973, 41 in 1974 and 43 in 1975 (table 34). This accelerated increment was probably associated with a series of droughts and subsequent price increases during these years. The author ran a correlation analysis between increasing burnt cane and increasing cane price. This was positively significant at 95% level of probability, using "t" test (table 34).

Fig. 47. Burning of sugarcane by arsonists is a very controversial issue in the Sugar Belt that frustrates Government policy of Self-Sufficiency

Table 34

CORRELATION ANALYSIS BETWEEN INCREASING ILLEGALLY BURNT CANE AND INCREASING CANE PRICE IN K.SHS. PER METRIC TON

Year	Burnt Cane (Y)	Cane Price (X)	$y = Y-\bar{Y}$	$x = X-\bar{X}$	xy	y^2	x^2
1970	6	46	-19	-12	228	361	144
1971	8	46	-17	-12	204	289	144
1972	17	52	- 8	- 6	408	64	36
1973	37	52	-12	- 6	72	144	36
1974	41	62	16	4	64	256	16
1975	43	92	18	34	612	334	1156
	$\bar{Y} = 25$	$\bar{X} = 58$			$\sum xy=1128$	$\sum y^2=1438$	$\sum x^2=1532$

Correlation coefficient between Y and X is 0.8273

Burning sometimes results in cane harvested prematurely, thus resulting in low quality and quantity of cane or sucrose.

In the sample survey it was found that 85.3% of the farmers agreed that burning can be used as an agricultural method in cane harvesting, but there is illegal burning of cane (tables 35 and 36). Cane burnt intentionally by the owner makes harvesting less laborious because the trash is destroyed. Consequently, it is cheaper to cut burnt cane which costs roughly K.Shs. 7.30 per man per day, that is, 2 tons per day, while unburnt cane costs approximately K.Shs. 18.00 per ton. Moreover, burning is essential where non-stripping varieties are produced and where mechanical loading is used. About 45% of the farmers said that cane fire is caused by burning trash in shambas adjacent to the plots with growing cane, but 44% of them mentioned burning bush/grass in fallow land

Table 35

CAUSES OF GROWERS' OWN CANE FIRES

Causes of fires	No. of farmers out of 300 by various causes of growers' own cane fires	
	Number	Percentage
Burning cane for milling	256	85.3
Burning bush/grass	132	44.0
Burning trash	135	45.0
Other	40	13.3

Table 36

CAUSES OF CANE FIRES MALICIOUSLY SET

Causes of malicious fires	No. of farmers out of 300 by cane fires maliciously set	
	Number	Percentage
Dissatisfied labourers	148	49.0
Jealous neighbours	141	47.0
Other	180	60.0

as the source of fire. However, 13.3% said that there are other sources like cane prices increases and negligence from the Joint Milling Committee to provide transportation facilities, acceptance for milling and failure to provide loans for sugarcane development (table 35). Recently, a farmer protested in Central Province that he would uproot his coffee plantation and set 250 bags of coffee on fire for what he called the negative attitude towards farmers by the Kenya Planters Cooperative Union.[17] Some respondents in the study area expressed that they would uproot or burn sugarcane and plant maize due to lack of loans for cane production.

Malicious cane fires according to 49.3% of farmers are caused by dissatisfied labourers (table 36), whereas 47% associated this with jealous neighbours or cynical people, but 60% mentioned other causes associated with "changaa" drinkers, people smoking canabis sativa and unemployment. Concerted efforts should be exerted to stamp out lawlessness in the area where arsonists are rampant.

Other miscellaneous causes of arson are careless smoking in fields and/or roads, spread from non-growing cane areas, tractor working in cane fields, lightning and sundry causes like deliberate burning of cane (table 37). About 11.3% of the smallholders noted that lightning is a natural ecological factor whose damage is not widespread in the area, because it occurs mainly during rainy periods.

Labour Bottlenecks

Another problem facing smallholders is labour shortage because the production of sugarcane is characterized by the absence of mechanization in most activities (table 38). As a result human

Table 37

CANE FIRES CAUSED BY MISCELLANEOUS SOURCES

Miscellaneous Sources	No. of farmers out of 300 by cane fires caused by miscellaneous sources	
	Number	Percentage
Smoking in fields and/or roads	195	65.0
Spread from non-growing cane areas	120	40.0
Tractors	9	3.0
Lightning	34	11.3
Other causes	146	48.7

Table 38

HOLDERS BY MECHANIZED SUGARCANE ACTIVITIES

Farm activity	No. of farmers out of 300 having mechanized sugarcane activities	
	Number	Percentage
Ploughing	240	80.0
Harrowing	222	74.0
Planting	30	10.0
Weeding	12	4.0
Other	33	11.0

labour is required in very large amounts for harvesting, weeding, planting and to a small extent for land preparation and top-dressing. With respect to this problem smallholders using tractor for various activities are weeding 4%, planting 10%, ploughing 80%, harrowing 74% and 11% "other" - including loading. However, large-scale mechanized rainland farming will pose serious problems unless appropriate legislation for rational utilization and conservation of the agricultural land is implemented.

Small-scale outgrowers are forced to use supplementary hired labour at critical periods (table 39). The majority of farmers

Table 39

LABOUR SOURCES FOR VARIOUS SUGARCANE ACTIVITIES

Activity	Labour Sources					
	Family labour		Casual Labour		Permanent labour	
	Number	%	Number	%	Number	%
Land preparation	147	49.0	95	31.7	35	11.7
Planting	256	85.3	185	61.7	42	14.0
Weeding	264	88.0	216	72.0	45	15.0
Top-dressing	156	52.0	33	11.0	35	11.7
Harvesting	134	44.7	204	68.0	17	5.7

cannot employ permanent labour because they cannot afford to provide the necessary conditions like accommodation and land for labourers to plant their subsistence crops. The number of farmers with permanent labour for various activities range from 5.7-15%, while those providing accommodation form 18.3%, and 13% of these offer free land to farm labour for their own use. About 72% of smallholders complained of labour shortage, which vary from zone to zone (table 40). This labour shortage was mainly attributed to

Table 40

HOLDERS EXPERIENCING LABOUR SHORTAGE

Zone	Sample number	Labour shortage		No labour shortage	
		Number	%	Number	%
Miwani	97	53	54.6	44	45.4
Chemelil	84	58	69.0	26	31.0
Muhoroni	119	105	88.2	14	11.8
TOTAL	300	216	72.0	84	28.0

dissatisfied labourers with wages. In view of this latter problem, there is competition for labour between smallholders with meagre income and the large-scale farmers mainly Indian plantation owners who induce labour with better payment.

It is apparent that the position of the small-scale farmers could deteriorate rather than improve, since it is unlikely that they will be able to increase rates of payment and with the soaring fertilizer prices and transport charges, may even reduce wages further.

The family provides the bulk of the total labour inputs, but

51.4% of the household consists of juveniles aged 14 years or below (table 41). Most of these are school children, or too

Table 41

AGE AND SEX DISTRIBUTION ON FARM HOUSEHOLD AND HOLDER

Age group	Age and sex composition of farm household				Holder			
	Codes				Codes			
	1	2	1 + 2	(1+2)%	1	2	1 + 2	(1+2)%
0-14	610	555	1165	51.4	0	0	0	0
15-19	170	153	323	14.3	1	0	1	0.3
20-29	100	109	209	9.2	36	0	36	12.0
30-39	80	99	179	7.9	53	0	53	17.7
40-49	73	70	143	6.3	53	4	67	22.3
50-59	72	68	140	6.2	65	4	69	23.0
60+	72	35	107	4.7	72	2	74	24.7
TOTAL	1177	1089	2266	100.0	290	10	300	100.0

Code: 1 = Male; 2 = Female

young to do any heavy manual work, while 4.7% are aged over 60 years and are physically weak to do similar work. Hence about 56.1% of household members considerably minimize the effective labour force.

It was found that labour supervision is mainly done by farmers. The women may not always be full-time supervisors because they are often committed to other house duties and have to rest when they are pregnant. Absentee farmers usually delegate their supervision to managers, relatives and friends who may not be enthusiatic and thorough in their work, thus resulting in poor farm management and low cane yields. Furthermore, some of the farmers who supervise their own work are over 60 years, indicating that they may lack managerial ability in sugar industry.

Roughly 66% of the cane growers have never attended farmer training courses, and are unaware of their usefulness (table 42).

Table 42

HOLDERS WHO HAVE ATTENDED AND WHO FOUND FARMER TRAINING COURSES USEFUL

Age group	Sample number	Holders who attended and found course useful	
		Number	Percentage
15-19	1	0	0.0
20-29	36	14	38.9
30-39	53	24	45.3
40-49	67	25	37.3
50-59	69	20	30.0
60+	74	19	25.7
TOTAL	300	102	34.0

On the other hand, 25.7% who have attended such courses are over 60 years, thus they perhaps contribute less in implementing agricultural innovations and diffusion of ideas (table 42).

Monetary Returns and its Subsequent Effects

In addition to farming table 43 shows that 9.7% of the farmers are businessmen, while 5% are fishermen, 5.7% teachers and 27% have other occupations like driving. However, sugarcane is the most important source of income in the area (table 44). During

Table 43

HOLDERS BY OTHER OCCUPATIONS

Zone	Business		Fishing		Teaching		Other	
	Number	%	Number	%	Number	%	Number	%
Miwani	10	10.3	15	15.4	2	2.1	22	22.7
Chemelil	10	11.9	0	0.0	6	7.1	21	25.0
Muhoroni	9	7.6	0	0.0	9	7.6	38	31.9
TOTAL	29	9.7	15	5.0	17	5.7	81	27.0

the course of investigations in the area, it was reported that sugarcane is grown because it is a government order. It was also stressed that sugarcane fetches more value per unit area than any other crop.

Furthermore, table 44 indicates that the majority of farmers have income of less than K.Shs. 5000.00 per annum from cane, while summary of sugarcane realization for production societies (Appendix A-9) shows that one of the major problems facing these societies is tranportation cost, which takes well over a third of the gross income. Other deductions contributing to low net payment or zero income are loan recovery, union commission, society

Table 44

HOLDERS' INCOME PER ANNUM FROM VARIOUS SOURCES IN K.SHS.

Income	Sources of income									
	Agriculture		Sugarcane		Pension		Other		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
500	51	41.0	52	42.0	0	0.0	21	17.0	124	100
500-999	37	41.0	33	37.0	0	0.0	20	22.0	90	100
1000-1499	27	38.0	27	38.0	1	1.4	16	23.0	71	100
1500-1999	23	44.0	23	44.0	0	0.0	6	12.0	52	100
2000-2499	25	36.0	28	40.0	0	0.0	17	24.0	70	100
2500-2999	19	42.0	19	42.0	0	0.0	7	16.0	45	100
3000-3499	19	42.0	19	42.0	0	0.0	7	16.0	45	100
3500-3999	6	35.3	6	35.3	0	0.0	5	29.4	17	100
4000-4499	14	54.0	7	27.0	2	8.0	3	11.0	26	100
4500-4999	4	44.4	1	11.1	0	0.0	4	44.5	9	100
5000+	47	37.3	42	33.3	0	0.0	37	29.4	126	100
TOTAL	272	40.3	257	38.1	3	0.4	143	21.2	675	100

commission, and the cost of cutting and loading of cane. A test was run to show the relationship between net payment (Y) and amount of cane sold, X (fig. 48). The coefficient of correlations, r = 0.8539 was significant at 99% level of probability using "F" test, and about 72.92% of the variations in net payment was explained by the variations in the amount of cane sold. The remaining percentage may be accounted for by other factors like transport cost, loan recovery, union and society commissions. Cutting and loading also

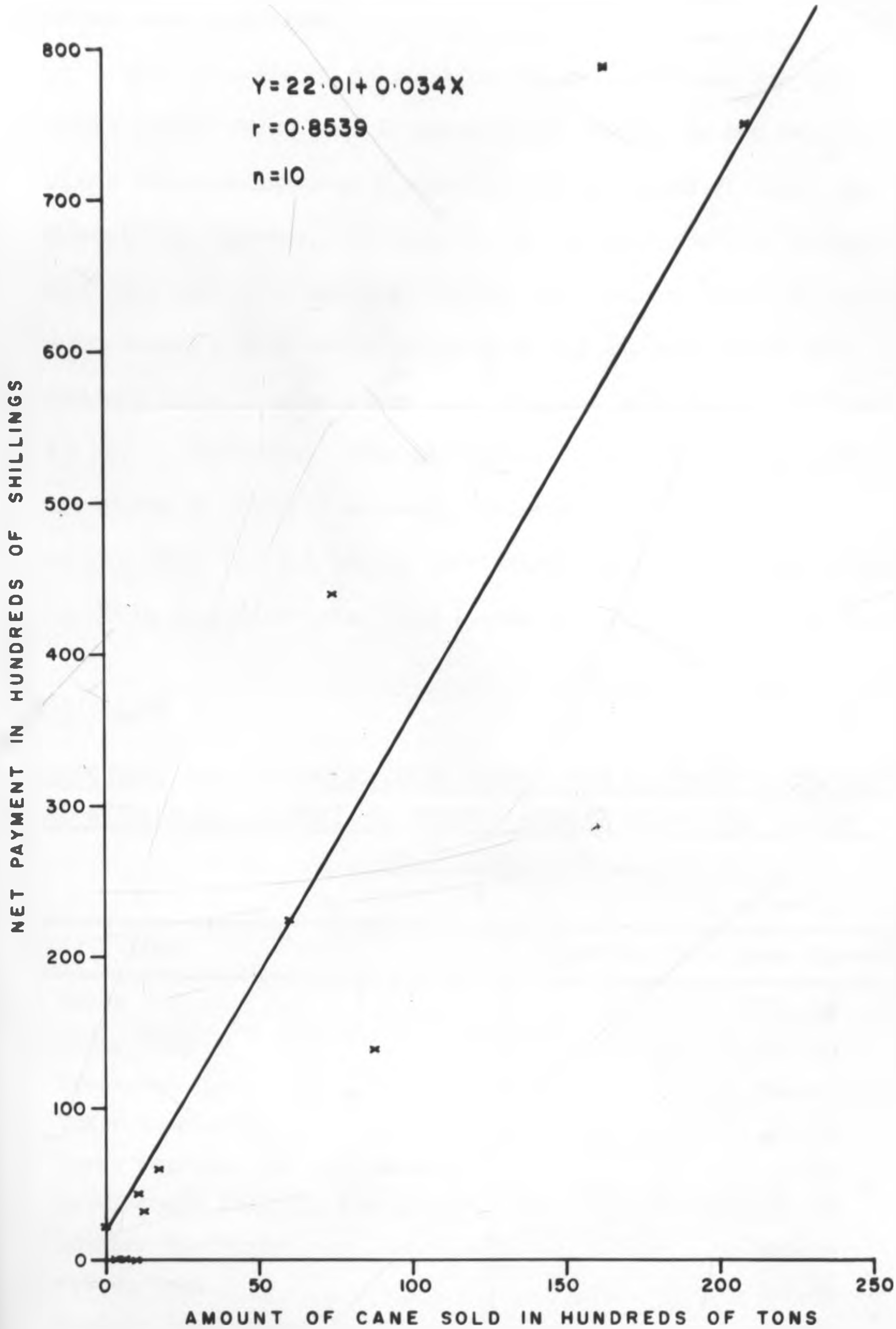

FIG.48 RELATIONSHIP BETWEEN AMOUNT OF CANE SOLD AND NET PAYMENT

affect some societies.

Data on costs of cultivation are not available for individual farms. Even less is known about changes in the value of inputs and techniques of production over a period of time. An attempt has, however, been made in the present study to collect some data regarding monetary returns per farmer. With the help of respondents, a very rough estimate of 4.8 ha. per farmer was obtained as well as monetary gain from the cultivation of about 0.4 ha. of sugarcane. This may provide a much more meaningful comparison in terms of economic achievement. The gross net returns (GNR) per 0.4 ha. of cultivated sugarcane averaged K.Shs. 254.20 in societies under SBCU (table 45) and K.Shs. 398.80 in those under SSO (table 46).

Table 45

DEDUCTIONS FROM SUGARCANE GROSS INCOME FROM SOCIETIES UNDER SBCU, AND AVERAGE NET PAYMENT PER FARMER (AVERAGE OUTPUT PER 0.4 HA. = 35.72 TONS)

Item	Deduction from gross income (K.Shs)
Gross	2214.65
Coop. loan	707.70
Transport	642.95
Union Commission	35.70
Lorry donation for the union	35.70
Development fund for the Union	35.70
Advance recovered	300.00
A.F.C. Loan	167.00
Society Commission	35.70
Net Payment	254.20

Table 46

DEDUCTIONS FROM SUGARCANE GROSS INCOME FROM SSO SOCIETIES AND AVERAGE NET PAYMENT PER FARMER (AVERAGE OUTPUT PER 0.4 HA = 37.9 TONS)

Item	Deductions from gross income (K.Shs)
Gross	2349.80
Annual levy	375.00
Transport	568.00
Harvesting	130.75
Loan repayment	325.00
Coops. cess	75.75
Water charges	96.00
Net Payment	398.80

The monetary returns are relatively high in SSO societies partly because of comparatively better cultural practices. Differences in the variations in income may be due to differences in deductions. However, this is not to deny that there may be more efficient and progressive farmers among SBCU farmers than SSO.

Nearly all farmers interviewed had little or no money to spend on subsequent farm inputs for sugarcane development (table 47). While figures of this kind are notoriously unreliable, the survey revealed that over 80% of the smallholders were experiencing difficulty in obtaining farm inputs due to lack of money.

Table 47

FARMERS HAVING LITTLE OR NO MOENY TO SPEND ON FARM INPUTS

Inputs	Little Money		No money	
	Number	%	Number	%
Tools	35	11.7	265	88.3
Seeds	48	16.0	252	84.0
Fertilizers	23	7.7	277	92.3
Hired labour	28	9.3	272	90.7
Other farm essentials	20	6.7	280	93.3

Perception of the Environment

Studies in the developing coutries by agricultural geographers reveal a high degree of ecological perception on the part of the indigenous cultivator, as indicated by the farmer's ability to select those systems of production and techniques of management that make the most efficient use of available environmental resouces. These researches sparked the author's interest in examining the role of environmental perception in sugarcane production in the Sugar Belt.

The variation in the ages of the farmers, their original home areas, and time of occupying sugar farm may contribute to differences in environmental perception. 90.3% of the farmers were aware of the importance of seasonal rainfall distribution in relation to cane growth (table 48). The 9.7% who were unaware of

Table 48

FARMERS WHO CONSIDER THE SEASONAL DISTRIBUTION OF RAINFALL TO HAVE GREATER SIGNIFICANCE IN SUGARCANE GROWTH THAN TOTAL ANNUAL RAINFALL

Zone	Sample number	Significane		No significance	
		Number	%	Number	%
Miwani	97	91	93.8	6	6.2
Chemelil	84	71	84.5	13	15.5
Muhoroni	119	109	91.6	10	8.4
TOTAL	300	271	90.3	29	9.7

this importance were perhaps new in the enterprise as 92.6% of the farmers had not grown cane for more than 15 years, while 30.3% had grown cane for only 1-5 years (Appendix A-10). Climatic conditions, particularly the frequency of drought and flood in the area appear to have contributed to the variations in the perceptions of the farmers, thereby leading to differences in cane hectarages and yields. Generally, most farmers do not recognize the dew formation as a vital factor in cane production, although Pereira (1973) stated that dew is an important source of water for plants.[18]

In table 49, 29.7% of cane growers had seen their canes arrowing (flowering). Although this is a relatively smaller proportion, flowering is an undesirable characteristic for sugar production since it marks the end of physiological growth of sugarcane and sugar accumulation. The bigger the body of the cane the more sugar is accumulated in the cells, but if cane ceases to

Table 49

FARMERS WHO HAVE SEEN THEIR CANE FLOWERING

Zone	Sample number	Seen arrowing		Unseen arrowing	
		Number	%	Number	%
Miwani	97	31	32.0	66	68.0
Chemelil	84	18	21.4	66	78.6
Muhoroni	119	40	33.6	79	66.4
TOTAL	300	89	29.7	211	70.3

grow, its size is remarkably reduced. Sugar technicians say that flowering is not necessarily a sign of maturity, but it depends on a very delicate balance of ecological factors mainly light and temperature. Flowering is a more common phenomenon at the Kenya Coast where virtually nearly all the canes flower at the age of about 12 months, thus resulting in relatively lower cane yields. Rarely do we have flowering in Western Kenya, as a common feature in cane, although it is also a varietal character.

A total of 98.3% of the respondents were aware of the need for irrigation during drought, although they lack the facilities for this, while 86.3% knew that fertilizers are used during wet periods, and 52.7% associated pests and/or diseases with wet periods (table 50). Pests and/or diseases seem to be more problematic in dry seasons as mentioned by 75% of cane growers (table 50). A high proportion of respondents, 97.7% linked weeds with rainy seasons, but a 100% of respondents were aware of occurrence of soil

Table 50

FARMERS WHO ARE AWARE OF CONSIDERATIONS ASSOCIATED WITH WET AND/OR DRY PERIODS

Considerations	Rain (wet)		Drought (dry)	
	Number	%	Number	%
Irrigation	1	0.3	295	98.3
Fertilizers	259	86.3	50	16.7
Pests and/or diseases	158	52.7	225	75.0
Weeds	293	97.7	8	2.7
Erosion	300	100.0	1	0.3
High cane yields	300	100.0	0	0.0

erosion and the same number associated high cane yields with rainfall reliability. However, the fact that some farmers wrongly associated these factors with wet or dry periods is not surprising because only a few of them have ever received information from extension officers on methods of improving sugarcane yields.

Table 51 shows that 53.7% of the farmers had detected the seriousness of Striga Hermonthica (Hayongo) in their plots, whereas 60% detected couch grass (ombugu) and 30.3% detected other weeds like cynodon dactylon (modhno) in their cane shambas.

During the survey, 39.7% of the farmers reported that they had experienced flood problems (table 52), but there is no cyclical rhythm from which to predict flood disasters. Wind damage, hailstones, and lightning seem to be less common, while 51% were aware of effect of drought on sugarcane, however, 50% of growers have

Table 51

FARMERS WHO HAVE DETECTED THE SERIOUSNESS OF DANGEROUS WEEDS ON THEIR SUGARCANE PLOTS

Dangerous weeds	Detection of dangerous weeds from cane plots	
	Number	%
Striga (Hayongo)	161	53.7
Couch (Ombugu)	180	60.0
Other	91	30.3

Table 52

NUMBER OF FARMERS WHO HAVE EXPERIENCED ENVIRONMENTAL HAZARDS ON THEIR SUGAR PLOTS

Environmental hazards	Experienced environmental hazard on sugarcane plots	
	Number	%
Floods	119	39.7
Wind damage	48	16.0
Drought	153	51.0
Hailstones	33	11.0
Lightning	20	6.7
Diseases and/or pests	150	50.0

experienced disease and/or pest hazards.

About 96.3% of the farmers felt that economic circumstances connected with cane prices, transport and loan provision were limiting cane extension (table 53). Moreover, farm conditions in

Table 53

THE CONSTRAINTS ESPECIALLY FELT BY A FARMER AND THAT LIMIT SUGARCANE EXTENSION

Constraints	Limiting		Unlimiting	
	Number	%	Number	%
Land	214	71.3	86	28.7
Management	174	58.0	126	42.0
Weather	206	68.7	94	31.3
Diseases and/or pests	154	51.3	146	48.7
Personal Preference	158	52.7	142	47.3
Economic circumstances	289	96.3	11	3.7
Technological inputs	240	80.0	60	20.0
Subsistence crops competition	191	63.7	109	36.3
Expertise	180	60.0	120	40.0

regard to farm layout, major road, feeder road, access road, fences and field drainage were generally poor in the area. But 80% of cane producers thought that technological inputs like fertilizers and sprays were affecting sugar industry. About 71.3% of smallholders considered land shortage as a constraint in cane extension, while 68.7% were affected by weather hazards and competition from subsistence crops affected 63.7% of farmers. Roughly 60% of small-scale farmers were lacking expert advisors, whereas management affected 58%, personal preference 52.7%, disease and/or pests 51.3% of outgrowers (table 53).

Despite all these problems most people have increased cane hectarage because it brings relatively better income than any other cash crop and 83.3% of the smallholders said that it was a government policy to plant more and more cane in order to make the country self sufficient (table 54). The development of a cooperative

Table 54

FARMERS' REASONS FOR PLANTING MORE AND MORE SUGARCANE

Farmers reasons	Correct		Incorrect	
	Number	%	Number	%
Drought resistance	50	16.7	250	83.3
Disease and/or pest resistance	30	10.0	270	90.0
Weed resistance	14	4.7	286	95.3
Government policy	250	83.3	50	16.7
Grows in a wide range of soils	77	25.7	223	74.3
Better income	300	100.0	0	0.0
Needs no fertilizers	4	1.3	296	98.7
Easy to grow	15	5.0	285	95.0
Grows in waterlogged soils	82	27.3	218	72.7

marketing system for sugarcane in the present study area, the various facilities and inducements provided to the producer for sugarcane cultivation, for example, the fixation of a guaranteed minimum price and its announcement in advance by the Government, and the assurance of a market at that price, have also helped to ensure and accelerate the expansion of sugarcane hectarage. Apart from these reasons, there were a host of other reasons given by the farmers (table 54).

In view of increased environmental constraints in the area, many farmers would like to use inputs such as irrigation, insecticides, herbicides, fertilizers and the like in cane development (table 55). The only drawback is the escalating costs of technological inputs, especially, fertilizers. According to analysis of field evidence, 93% of the farmers have recently seen RSD in their cane plots (table 56).

Table 55

FARMERS WHO WOULD LIKE TO USE TECHNOLOGICAL INPUTS IN SUGARCANE DEVELOPMENT

Technological inputs	Miwani		Chemelil		Muhoroni		Total	
	No.	%	No.	%	No.	%	No.	%
Irrigation	95	97.9	84	100.0	106	89.1	285	95.0
Sprays	93	95.8	84	100.0	105	88.2	282	94.0
Fertilizers	95	97.9	84	100.0	107	89.9	286	95.3
Tractor	95	97.9	84	100.0	107	89.9	286	95.3

These farmers argue that the existence of RSD is encouraged by man because it seems to exist in plant crops which are over-mature, thus

Table 56

FARMERS WHO HAVE SEEN DISEASES AND/OR PESTS IN THEIR SUGARCANE PLOTS RECENTLY

Diseases and/or pests	Seen		Unseen	
	Number	%	Number	%
Army-worms	121	40.3	179	59.7
Termites	267	89.0	33	11.0
Locusts/Grasshoppers	141	47.0	159	53.0
Stem borers	258	86.0	42	14.0
Sugarcane Smut	246	82.0	54	18.0
Rats	276	92.0	24	8.0
Ratoon stunting	279	93.0	21	7.0

it is mainly common in ratoon crops. Occurrence of rats in cane plots was reported by 92% of the farmers, termites 89%, stem borers 82%, grasshoppers 47% and armyworms 40.3%. However, rats are more common in farms where weeding is neglected.

Many farmers suggested that Striga Hermonthica are mainly caused by sugarcane monoculture. This suggestion is supported by scholars whose observations suggest that as cultivation of one crop continues, the weed problem increases to such an extent that the farmer is eventually forced to abandon his land,[19,20] and in the first few years weeds increase in inverse proportion to the length of time the land has lain fallow.[21] Increased weed problems made 8 farmers to abandon growing sugarcane (table 57). Soil erosion caused abandonment of other crop fields, but not

Table 57

FARMERS' REASONS FOR ABANDONING VARIOUS CROP FIELDS

Reasons	Codes								Total
	1	2	3	4	5	6	7	8*	
Poor soil	11	28	5	15	3	2	8	16	88
Diseases and/ or pests	3	10	3	5	0	2	2	3	28
Weeds	8	9	3	3	1	1	3	3	31
Erosion	0	4	0	4	3	2	3	0	16
Crop not profitable	12	21	5	10	2	0	5	11	66
Available labour	10	27	6	12	5	2	7	10	79
Drought	1	6	5	6	2	2	1	6	29
Insufficient drainage	5	12	3	7	2	3	1	5	38
Other**	57	84	22	34	12	8	16	50	283

Codes: 1-Sugarcane; 2-Maize; 3-Sorghum; 4-Finger millet; 5-Beans/Peas; 6-Cotton; 7-Cassava/Sweet potatoes; 8*-Other (Groundnuts, rice, cabbages, and pasture)

** 'other' include land disputes, wild animals, cultural practices, transportation problems, personal preference, and lack of credits.

Sugarcane, sorghum and cotton. Sugarcane after developing sufficient canopy is able to intercept raindrops and reduce soil erosion.

About 57 farmers (19% of the total) abandoned cane fields due to land disputes, wild animals, cultural practices, transportation, personal preference and lack of farm credit. Some 12 farmers abandoned this enterprise because it was not profitable, while 11 farmers had soil problems and 10 famers were experiencing labour shortage. Nevertheless, 5 farmers had problem of waterlogging, while one farmer abandoned his cane field because of drought and 3 farmers took similar step due to diseases and/or pests. Similar reasons were rendered for abandoning mainly cereal crops, which are often attacked by avifauna (bird population).

With the exception of subsistence crops, sugarcane was recommended by 96% of the farmers for the development of the area (table 58). Other enterprises recommended were maize, cotton, rice, cattle and the like. All these emphasize the need for agricultural diversification.

Of the farmers interviewed, 88% preferred flat land for planting sugarcane, 80% selected moderately sloping land, 69% chose valleyside, and 50% were conversant with other sites (table 59). A few people recommended planting cane in steep slope, rugged land and waterlogged land. This latter aspect suggests the reason for recent expansion of cane cultivation to even the most unsuitable sites.

More than 90% of the outgrowers recognized the role of various soil factors in agriculture (table 60). If these factors are perceived to be unfavourable, the farmers may abandon cane

Table 58

ENTERPRISES WHICH THE FARMERS FEEL ARE MOST IMPORTANT FOR THE DEVELOPMENT OF THE STUDY AREA

Enterprise	No. of farmers per zone			Total	
	Miwani	Chemilil	Muhoroni	Number	%
Maize	91	78	112	281	93.7
Sugarcane	96	78	114	288	96.0
Cattle	85	68	114	267	89.0
Cotton	64	63	76	203	67.7
Rice	40	0	00	40	13.3
Other	95	84	118	297	99.0

Table 59

FARMERS' PREFERRED SITE FOR PLANTING SUGARCANE

Sugarcane planting site	Preferred site		Not preferred site	
	Number	%	Number	%
Steep slope	57	19.0	243	81.0
Flat land	264	88.0	36	12.0
Rugged land	33	11.0	267	89.0
Moderate slope	240	80.0	60	20.0
Valley-side	207	69.0	93	31.0
Waterlogged land	30	10.0	270	90.0
Other places	150	50.0	150	50.0

cultivation.

Table 60

NUMBER OF FARMERS CONSIDERING SOIL FACTORS WHICH ARE IMPORTANT IN AGRICULTURE OF SUGARCANE

Soil Factors	Important		Unimportant	
	Number	%	Number	%
Soil colour	291	97.0	9	3.0
Soil moisture	290	96.7	10	3.3
Soil structure	297	99.0	3	1.0
Soil texture	273	91.0	27	9.0
Soil drainage	295	98.3	5	1.7
Leaching	282	94.0	18	6.0
Soil erosion	282	94.0	18	6.0
Soil conservation	289	96.3	11	3.7
Soil organisms	296	98.7	4	1.3
Soil temperature	291	97.0	9	3.0

Table 61 shows that 98% of the farmers were aware of deep ploughing, while 85.3% had knowledge of controlling weeds by hand pulling, but 63% knew the significance of uprooting or roguing disease and/or pest infested canes. Although over 50% of the farmers were aware of spraying, they rarely apply this measure in eliminating weeds, diseases and pests. Furthermore, fallowing as a method of adjustment to the environment was mentioned by 56% of the respondents, but it is not a common practice in the

Table 61

FARMERS HAVING KNOWLEDGE OF CONTROLLING PESTS, DISEASES AND WEEDS BY APPLYING VARIOUS METHODS

Control methods	Have knowledge		Have no knowledge	
	Number	%	Number	%
Deep ploughing	294	98.0	6	2.0
Uprooting infested canes	189	63.0	111	37.0
Burning infested canes	99	33.0	201	67.0
Hand-pulling or hoeing	256	85.3	44	14.7
Spraying	174	58.0	126	42.0
Crop rotation	129	43.0	171	57.0
Fallowing	168	56.0	132	44.0
Biological control	0	0.0	300	100.0

area due to land shortage. All the farmers had no knowledge of biological control of pests and diseases. The abundance of animal and insect species has always been kept in check by the depredation of natural enemies and the modern concept of biological control of pests and diseases in sugarcane include the controlled use of predators and parasites.[22] This may be more practical in the Sugar Belt and may lead to more efficient and sound economic methods of control than haphazard spraying without sufficient knowledge of the particular species of pests, diseases, and weeds and their bionomics. But the use of some of these biological measures like fungi, protozoa, bacteria and virus are still far more a delicate matter requiring detailed investigation. Other methods of control mentioned were crop rotation and burning infested canes.

Over 80% of the farmers said that cane variety, prices, burning, age and planting date affect sugarcane yields (table 62).

Table 62

FACTORS AFFECTING FARMERS' CANE YIELDS

Factors	No. of farmers per zone			Total	
	Miwani	Chemelil	Muhoroni	No.	%
Cane variety	91	81	112	284	94.7
Prices	96	81	117	294	98.0
Burning cane	90	84	115	289	96.3
Cane age	97	83	119	299	99.7
Distance from factory	80	69	87	236	78.7
Fertilization	40	45	61	146	48.7
Weed control	37	45	57	139	46.3
Diseases and/or pests	40	46	56	142	47.3
Planting date	83	77	103	263	87.7

Another important factor mentioned by 78.7% of the farmers was distance from the factory. Fertilization, weed control, diseases and pests were mentioned too as other factors affecting cane yields. These factors may partly account for the variations in cane yields in the area.

The farmers were asked various environmental variables governing sugarcane yields and were asked to place in order of importance the alternatives shown in table 63. Total for each alter-

Table 63

ENVIRONMENTAL VARIABLES WHICH GOVERN FARMERS' SUGARCANE YIELDS ACCORDING TO ORDER OF IMPORTANCE

Environmental variables	No. of farmers according to order of importance
Rainfall reliability	468
Soil quality	701
Temperature	1196
Sunshine	1397
Weeds	1452
Diseases and/or pests	1524
Dew formation	1901
Wind velocity	1947

native is given, the smaller figure indicating the greatest importance. Rainfall reliability is perceived as the greatest hazard followed by soil quality, temperature, sunshine, weeds, diseases and/or pests, dew formation and wind velocity.

Contour farming is the agronomic practice used by 70% of the sugarcane growers and 70% use intercropping or mixed cropping (table 64). Intercropping of cane with maize should be stopped because both are cereals which compete for nutrients, light, and carry similar diseases or pests. About 62% were using heaps and ridges, while other practices were mixed farming, shifting culti-

Table 64

AGRONOMIC PRACTICES USED BY FARMERS AT THE MOMENT AND THAT ARE REGARDED AS ADJUSTMENTS TO THE ENVIRONMENT

Agronomic practice	Environmental adjustment	
	No. of farmers	% of farmers
Shifting cultivation/Bush fallowing	30	10.o
Heaps and ridges	186	62.0
Intercropping/mixed cropping	210	70.0
Crop rotation	57	19.0
Mixed farming	165	55.0
Mulching	75	25.0
Contour farming	210	70.0

vation, or bush fallowing, mulching and crop rotation.

According to information presented in table 65, the farmers know by experience the best and poorest plant indicators for land potentiality in the Sugar Belt. This has assisted them in choosing the most suitable sites for planting sugarcane, but land shortage has minimized the selection of such areas.

Table 66 confirms the common observation that vegetation induces rainfall; provides cover which shelters the soil from the impact of wind, rain, sun and enriches the soil with decaying leaves and litter. But a few farmers were aware of some Lantana spp., or Acacia spp., which either exhaust the soil or play no role

Table 65

NUMBER OF FARMERS WHO NAMED PLANT INDICATORS FOR AGRICULTURAL POTENTIALITY AND UNPOTENTIALITY

Indicator	Potentiality		Unpotentiality	
	Number	%	Number	%
Acacia Seyal (ale)	18	6.0	90	30.0
Hyparrhenia rufa (Oboro)	94	31.3	2	0.7
Cynodon dactylon (Modhno)	123	41.0	0	0.0
Euphorbia candelabrum (Bondo)	0	0.0	103	34.3
Balanites aegyptiaca (Othoo)	0	0.0	51	17.0
Pennisetum clandestinum (Kikuyu grass)	130	43.3	0	0.0
Ficus capensis (Ngow)	74	24.7	1	0.3
Striga hermonthica (Hayongo)	0	0.0	45	15.0
Loudetia kagerensis (Buoye)	0	0.0	17	5.7
Combretum molle (Keyo)	26	8.7	4	1.3

in soil. This sort of perception is useful in guiding the farmer to decide on maintaining vegetation cover for soil conservation purposes.

Farmers were asked if they had any difficulty in obtaining any of the 8 inputs presented in table 67; the number indicates the total of those having difficulty and corresponding percentage of each number. A high proportion of farmers encounter difficulty in getting inputs except seed cane. Lack of these inputs is likely

Table 66

FARMERS WHOSE EXPERIENCES SHOW THAT VEGETATION AID THE SOIL WITH A NUMBER OF THINGS AND INDUCE RAINFALL

Items	Vegetation aid soil and induce rainfall	
	No. of farmers	% of farmers
Induce rainfall	241	80.3
Shelter the soil from wind	288	96.0
Shelter the soil from rain	294	98.0
Shelter the soil from sun	249	83.0
Enrich the soil	291	97.0
Exhaust the soil	42	14.0
Play no role in the soil	15	5.0

Table 67

NUMBER OF FARMERS HAVING DIFFICULTY IN OBTAINING INPUTS

Input	Miwani	Chemelil	Muhoroni	Total	
	No.	No.	No.	No.	%
Seeds	50	40	33	123	41.0
Fertilizers	83	68	80	231	77.0
Farmyard manure	80	66	76	222	74.0
Sprays	93	80	72	245	81.7
Tractor	81	42	95	218	72.7
Credit	94	84	108	286	95.3
Irrigation	85	76	104	265	88.3
Labour	70	66	92	228	76.0

to affect cane production

The farmers were also asked how they would use their income and had to arrange in order of preference the alternatives shown in table 68. Generally land came first for many farmers followed

Table 68

INVESTMENT PREFERENCES OF FARMERS

Investment	Total of preference places
More land	662
Borehole	1001
Subsistence crops	1040
Draught animals	1041
Technological inputs	1137
Other	1331

by borehole, subsistence crops, draught animals, and technological inputs. Many farmers needed boreholes because most rivers in the area are reported to be polluted by factory effluents, human waste matter from settlements close to the rivers, and there is seasonal water shortage.

Most farmers lack many essential amenities, (table 69), which may lead to migration of these producers to the areas where they are available. Apart from these problems wildlife were also considered a nuisance by many farmers (Appendix A-11), hence farmers need fences to protect crops from baboons, monkeys, porcupines, and bush pigs. As the farmers perceive the environmental

Table 69

FARMERS BY CONDITIONS OF AMENITIES IN REGARD TO THE FARMS

Amenities	Conditions of Amenities in regard to farms			
	Good		Poor	
	Number	%	Number	%
Markets	131	43.7	169	56.3
Schools	140	46.7	160	53.3
Hospitals/clinic	66	22.0	234	78.0
Churches	149	49.7	151	50.3
Clubs	55	18.3	245	81.7
Telephone	4	1.3	296	98.7
Electricity	5	1.7	295	98.3
Bank	30	10.0	270	90.0

problems, they realize the importance of technological inputs like sprays, fertilizers, irrigation and the like, but most of these cannot be used by the majority due to high prices. In order to overcome these constraints, the farmer has partly to diversify his production by practising mixed cropping and mixed farming.

Conclusion

These human impediments to even piecemeal extension are contributing to failures to achieve sugarcane production targets at the moment in the study area. They clearly show that technical advice cannot be given except in a farm management context and technical and managerial advice are not therefore separated but are inextricably united. The formation of a farm management advisory service to spearhead this important task would accelerate future sugarcane development. It is clear that producer's use of his resources depends on his perception of them rather than any objective measure of their characteristics. His perception of their value depends on his background, information and ability; and his yardstick is based on his past experience of them. Any farmer's evaluation of land quality would also be determined by his perception of other resources and the returns from them as a whole. Furthermore, it was noted that able farmers obtain greater returns from the same land type than their less able neighbours, often through a more intensive use of the same land resource.

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CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Enough has been said in the preceding chapters of this thesis that sugarcane production in the Nyanza Sugar Belt cannot be attributed solely to one environmental factor. The population of farmers in the Sugar Belt has greatly increased but the arable land remains unaltered, and on the contrary, continued to be depleted of its nutrients through soil erosion, overgrazing, sugarcane monoculture, burning and felling of vegetation without commensurate inputs like farm-yard manure, compost manure, green manure, chemical fertilizers and similar soil conservation measures. Indeed considering that sugarcane is grown in nearly all parts of the area with their wide diversity of soils, one might feel inclined to conclude that the nature of the soil is of no account in the cultivation. But rich, porous clays, and alluvial soils on lowlands through which rivers flow are the most suitable for cane cultivation. This means that sugarcane should be grown where they are well adapted and where efficient production is the rule.

The predominant "black cotton" soils in the area become plastic and impermeable when wet, but water infiltration rates are so low, while evapotranspiration rates are so high that drought symptoms quickly develop in ensuing dry spells. During prolonged drought, the black clays form hardpans and huge cracks which are detrimental to sugarcane roots, thus resulting in wilting. The alluvial and colluvial soils from the fringing escarpments and hills in the area are mostly accumulated in the scattered swamps or the plains which are mostly submerged. But these extensive tracts of land are suitable for cotton, rice and sugarcane cultivation.

Tectonic and ecological processes in the Sugar Belt have produced several hills and escarpments whose slopes offer suitable habitats for human settlement. But the most striking feature of its topography is, in fact, its obvious suitability for construction of irrigation schemes and for the spread of mechanized agriculture. However, the prevalence of bilharzia, cholera, dysentery and malaria among the farm household are attributable mainly to the poor environmental conditions.

Some of the sugarcane fields have been under sugarcane for about 1-20 years without application of organic or inorganic fertilizers despite the fact that it is a very exhausting crop, which extracts large quantities of inorganic matter from the soil. Chemical analysis of the soil samples from sugarcane cultivated plots revealed that the soils are generally slightly acid, pH 5.2-8.1. The soils of the Sugar Belt are well supplied with most nutrients except nitrogen, organic carbon and partly phosphorus. Nitrogen was deficient in 90% of the sampled plots, while phosphorus levels were low and deficient in 18.3% of the cane plots. The most important limiting factor in the area is nitrogen whose low levels and deficiencies in the Sugar Belt are associated with low levels of humus, 0.6-2.86%. A correlation analysis between cane yields and nitrogen contents in the soils indicated a positively high significant linear relationship. This relationship was insignificant, but positive in the case of cane yields and potassium. But the relationship between cane yield and phosphorus was negatively insignificant. A negative relationship suggests that an overdose of phosphorus could be toxic to sugarcane. It was noted that nitrogen deficiency leads to absolutely low cane yields. However, the relationship between fertilizer used and increased cane yields is dubious unless irrigation and good sugarcane husbandry are practised in areas with less than 1500 mm. of rainfall per annum. It is clear that sugarcane has critical husbandry dating schedules, or those dates by which particular husbandry operations have to be completed if yield loss or, in extreme cases, total crop failure, are to be avoided. Although sugarcane is grown nearly in all parts of the study area, both rainfall and soils are not ideal for optimum growth and yield.

Rainfall is another most important limiting factor in the production of sugarcane in the area. The analysis of standard deviation, and coefficient of variation gave very high values of rainfall variations in the Sugar Belt. The rainfall probabilities and variations have serious repercussions upon small-scale agriculture. It is clear from the analysis that the decline in sugarcane yield and poor growth during the dry periods in the area is ascribed to the short supply of available soil moisture. Rainfall is unpredictable and variable in the months normally devoted to land preparation, planting, weeding, topdressing and harvesting as well as transportation. As has been shown, the torrential nature of the rains encourages heavy sheet wash and hail damage to agricultural crops in the Sugar Belt.

Sugarcane is essentially a tropical crop; it will grow well in the subtropical climates, but it does not give the best yields. A hot moist climate alternating with periods of dry weather is the typical climate for cane. The crop does not do well in highlands over 1525 metres, where temperatures are relatively low, because it takes a long time to mature and ceases to give remunerative yields. In the Sugar Belt, the cane fields lie mainly between 1130 and 1525 metres above sea level, Sugarcane production is not limited by temperature and radiation in the area.

Digitaria Scalarum and Striga hermonthica are the most problematic weeds in the Sugar Belt. These pernicious weeds must be removed completely as soon as they emerge since they compete with sugarcane for nutrients, light and soil moisture available. Furthermore, weeds permit the development of an ideal micro-climate for pests and diseases apart from severely hampering both modern and traditional system of harvesting. But cane with full canopy protects the soil from erosion and is able to suppress weeds. Faulty practices in weeding have led to stunted canes and decline in yields in some areas like Kajulu. Since cane has a rather shallow-rooting system, weeds which tend to dehydrate the topsoil will deplete moisture available to the crop. The main competition from weeds comes in the dry season when the moisture present in the topsoil is at a minimum. Wilting of sugarcane occurs if the soil moisture is lower than 40% of the field capacity.

Field evidence indicates that productivity of sugarcane depends on the following conditions:

(1) Growth habit: good germination and tillering, rapid stalk elongation, general vigour, tolerance of drought, absence of developing buds and roots on stem, extensive root system, minimum production of late tillers, early "covering down"

combined with reasonably erect stalks, uniform stalk length at maturity, and absence of tendency to flower.

(2) Regularity of maturity, persistence of quality at maturity, high sucrose content and hectarage yield, and free trashing.

(3) Good ratooning power, quick sprouting of shoots after previous crop has been reaped, profitable yields, minimum fall in production of sugar for successive ratoons over full period of crop-cycle.

(4) Immunity or high degree of resistence to major diseases. Good response to protective treatment when it can be applied and minimum attraction to pests, for example, hardness of rind as a deterrent to rats, wild pigs and baboons, which are rampant in the Sugar Belt.

At the moment Co 421 and Co 331 sugarcane varieties are being grown by small-scale farmers. They are relatively less susceptible to the smut disease and are high yielding in terms of production per unit area. However, the endeavour to grow better varieties in the Sugar Belt is doomed to scant success without solution to proper education and managerial ability of the peasants.

One of the major problems is malicious sugarcane fire. Sugar-cane fields occasionally catch fire in the Sugar Belt, resulting in great losses to producers and to the country. The fires are caused by careless disposal of lighted cigarette ends, burning grass, burning trash, dissatisfied labourers, jealous neighbours, family feuds, prices changes and unemployment. Although arson is mainly a human ecological factor, it is also a natural ecological phenomenon that is triggered by lightning, but the damage is minimal since it occurs during wet weather. During drought, the cane leaves are very dry and there is constant threat of arson. Accidentally burnt cane frustrates the government policy of self-sufficiency and self-reliance in this commodity. Five reasons are vital for putting an end to the practice of firing the cane fields.

(1) The constant return to and incorporation in the soil of crop residues, will, over a period of time, improve the texture of the heaviest soil, making drainage easier and facilitating cultivation.

(2) In the West Indies, recently, investigations have revealed a significant positive correlation between the burning of trash and the incidence of stem borer, which is prevalent in the Sugar Belt.

(3) Sugarcane residue is helpful in improving soil water holding capacity.

(4) Trash is useful in suppressing weed growth between the rows.

(5) Another argument advanced against firing cane is the necessity for cutting and carting all burnt cane within 24 hours instead of the usual 48 hours for unburnt cane, as inversion of sucrose starts immediately after firing, even before cutting the cane.

Common causes of sugarcane shortage, inter alia are partly due to the aftermath of arson, and diversion of cane from white sugar zones to jaggery factories in the area. The jaggery is mainly used for the manufacture of illicit Nubian gin known under various names as "changaa", "pure", "Boss", "kill me quick", or "check point".

One of the peculiarities of the small-scale farms in the Sugar Belt is their subsistence and commercial dichotomy. The basic means of subsistence are maize, sorghum, rice, groundnuts, cassava, finger millet, sweet potatoes, vegetables, citrus fruits and livestock products. At the same time some farmers produce cotton besides sugarcane for the market economy. Thus the small-scale farmers have to decide what combination of cash and subsistence enterprises to produce. Sugarcane is, therefore faced with competition for land, labour, capital and technological inputs, which must be allocated to other agricultural enterprises including livestock.

At the time of the survey it was clear that population pressure on the land has resulted in a decline in the sizes of holdings as well as land fragmentation. Generally speaking, fragments distant from the homestead cannot be given dressings of farm-yard manure by the farmers lacking transportation facilities nor can they be used for the production of sugarcanes requiring frequent protection from arson, wild animals, thieves and miscellaneous cultural practices. But the smallholders in the area fear having sugarcane close to the homesteads because they form refuge for poisonous snakes, rustlers and night thugs. Apart from increasing the labour and time needed in sugarcane advisory work, the small size and irregular shape of the plots often result in waste of land and hampers mechanization.

While sugar yields in the Sugar Belt are much higher than sugar yields from the Kenya Coast, the disadvantages of spiralling labour costs and greater distance from the market have largely offset this natural advantage. A labour shortage occurs partly because of the general lack of labour in some areas, and partly accentuated by the very low rates of pay offered by the smallholders. Consequently, most of the available labour is deprived by the Asian plantation owners who offer better pay inducement. As a result labour is lacking during planting, weeding and harvesting. It appears that the position of the smallholder could deteriorate rather than improve, since it is unlikely that they will be able to increase rates of pay and with the escalating prices of technological inputs, will even have to reduce wages.

Distance from the sugar factory is another important influential factor, determining the distribution of the smallholders in the area. Each farmer has to transport sugarcane by lorry or tractor to the factory for which the transport varies according to the distance and the weight. The farms located near the factory are more profitable than those at a distance and the transport costs eventually limit the distance at which sugarcane is grown. But lack of transport facilities, particularly during the wet periods means that at peak periods most cane is left to overmature and deteriorate in the fields, thereby affecting the morale of the producers a great deal.

The author found that sugarcane could be grown within less than 24 kilometres of the factory with reasonable profits, but beyond this distance transport charges become exorbitant. Moreover, the smal-scale farmers are not in a position to reduce costs since they have no direct control over transport and they have to rely on haulage firms or cooperatives, which have their own problems.

Although there is duplication in the operation of farm activities, planting sugarcane at different periods ensures that the factories receive constant supply of cane in order to keep the factories functioning throughout the year. Furthermore, planting cane at different times enables the growers to get income after a short interval. However, no general rule can be laid down about cane establishment, as climate and local circumstances must be considered.

The long growth period of sugarcane does not militate against its extension, although the smallholders occasionally have nothing to do or eat. There is no better substitute for this cash crop, which yields about 25-150 tons per hectare in the Sugar Belt. However, these figures must be taken as fair averages for cane culture, although in certain instances the returns are larger, or smaller depending on the peculiarities of soil, climate, biological factors and cultural practices.

Other problems of agricultural production are determined by the farmer's age, health, lack of title deed, lack of dynamic leadership, absenteeism, land disputes, incomplete migration of family to the sugar farm, illiteracy, religion, available credit schemes and fencing materials against wild animals. It is clear that the entrepreneur's perception of the physical environment is determined by his social and economic environments. However, leaders do not necessarily mean formal leaders recognized by the government. Informal leaders often exist in different contexts and they can be identified and enrolled in sugarcane development as well as formal leaders. Traditional, informal leaders can often be interested in innovations and several cases were recorded in the area where they were officials of Unions and cooperative societies.

The Sugar Belt has an excellent and impressive programme of sugarcane research, but the serious tendency of the expatriates to dominate all phases of the sugar industry has prevented this research from being effectively translated into production.

Furthermore, other countries like Mexico have clearly demostrated that layer upon layer of bureaucracy is not conducive to effective operation in a competitive industry. Sugar leaders who spend an inordinate amount of time dealing with the government do not have adequate time to deal with daily operating responsibilities, thus resulting in inefficiency.

Smallholder sugarcane development has lagged more behind social and political considerations than behind capital and physical environment. During colonial rule sugarcane was not considered suitable for peasant production, but there has been tremendous progress recently. Although the industry is still in its infancy, the future expansion depends to a large extent on the development of cultivation on peasant farms. But for the near future, one cannot envisage any possible alterations in the complications in the system of small-scale sugarcane production. Prediction of any economical and labour-saving devices being employed in sugarcane husbandry is impossible because of soaring prices, but success will partly depend on the place accorded sugarcane development in the overall scope of agricultural growth, willingness and/or ability of the government to support sugarcane production. Even if the farmer has reasonable income, the controlling factor will depend on the farmer's willingness and/or ability to avail himself of research and information and interpret the finding on the various environmental aspects influencing sugarcane growth and productivity. While there are no simple answers to the problems of smallholder sugarcane production, the recommendations given below are possible solutions to these problems. It is clear that sugarcane production must accelerate if future demands are to be met. The author hopes that the research will assist in planning and execution by those involved in the practical aspects of sugarcane development. Lastly, the research should stimulate future scholars who are interested in conducting similar researches in the Sugar Belt area.

Recommendations for policy-planners and decision-makers

(1) In theory the farmers are well-informed about the significance of fertilizers but in practice they do not use fertilizers in cane production. It is advisable for the farmer to supply the deficiency by using a manure rich in constituents wanted in the soil. Where nitrogen is deficient, Ammonia Sulphate Nitrate (ASN) should be added, although the amount required depends on the response of particular cane variety. Soils deficient in phosphorus should receive double superphosphate. But soils deficient in both nitrogen and phosphorus should be treated with Diammonium Phosphate (DAP).

(2) A collaboration with agricultural chemists, pedologists, micro-biologists, geographers and even agronomists is indispensable for the complete study and integral solution of such a difficult and complex problem as the scientific and practical understanding of the soil, considered from a purely agricultural point of view.

(3) Increase in sugarcane production will be critical in the future unless substantial nitrogenous fertilizers are used. However, sugarcane can grow vigorously as well as benefit from fertilization if and only if proper land preparation, good cane establishment, correct plant population, surface drainage, good weeding, adequate precipitation and proper mechanical cane cultivation are correctly employed.

(4) The farming practice in the Sugar Belt should be reoriented on conservation principles in order to put the system back into an ecological "balance".

(5) The author recommends that the teaching of soil conservation, and environmental pollution as part of the agricultural curriculum at secondary schools and at Young Farmers Clubs should also be reinforced because the children while at home, could educate and help parents to institute better agricultural husbandry including soil conservation.

(6) Overgrazing is critical in the area, but it can be alleviated by stimulating the local residents to adopt a quality concept on cattle instead of the present quantitative one.

(7) The farmer still requires despite technological advances reasonable and few soil limitations for successful sugarcane production. Due to rainfall uncertainty, it is imperative that the timing of the cropping operations, the locations and the nature of cane varieties should be selected with a view to avoiding the most deleterious circumstances. Farmers can combat uncertain weather by planning flexible cropping programmes and diversifying production system.

(8) Weeds should be removed at the end of the rains to prevent competition for moisture during dry season. Moreover, it is vital for small-scale farmers to have flexible system where manual, mechanical, and chemical techniques of weed control are all accessible to them.

(9) Land shortage in the Sugar Belt can partly be solved by the extension of cane cultivation on to the swamp lands, which can be reclaimed by assistance from U.N. and other international agencies.

Furthermore, it can be partly solved by intensification and diversification of cropping. The greater intensification and diversification of crop and animal production will enable smallholders and family and hired labour to be constantly engaged and spread evenly over the year, thereby reducing unemployment and underemployment. Sugarcane intensification can take three forms: increase in the planting of sugarcane; the use of chemicals, irrigation and other methods to obtain higher yields; and the introduction of the new rotation or farm management practices to increase or minimize waste. Crop diversification is vital in order to avoid "putting all eggs into one basket", because they can crack during unfavourable conditions of prices, weather, diseases, weeds, pests and farmers' apathy or general inability to cope with sugarcane cultivation.

(10) The smallholders should be encouraged to grow pulse crops like Soya beans, haricot beans, groundnuts, peas and other leguminous crops in the inter-row spacing before cane forms a dense canopy to suppress weeds and prevent soil erosion. The practice would help these farmers to maximise sugarcane yield per hectare and increase nitrogen, which is beneficial to sugarcane plant.

(11) Land consolidation, adjudication and registration should be speeded up and completed so that the farmers can be issued with title deeds to act as security for obtaining loans for agricultural development. The smallholders with their meagre capital resources are in dire need for government assistance in providing credits and subsidies.

(12) With constant appeals, prosecutions of arsonists, fire breaks and fire brigades at the factories, Kenya hopes to counteract arson, but basically we have to be more careful and join hands in a determined effort to stamp out fires that have recently ruined a large

hectarage of sugarcane. Steps should be taken to prevent trespassing. Prompt detection, location and reporting of fire outbreaks is obviously of highest importance. An organized team of fire-control service should devise a system of watch-keeping, and reporting during the dry season when fire risks are serious. Efficiency of cane harvesting is required for burnt cane.

(13) To the Sugar Belt smallholders, Muhoroni and Miwani factories belonged to Asians, while Chemelil is a whiteman's factory. The psychological belief that the local farmers are producing sugarcane for aliens rather than the government could negate cane production in the future. In view of this problem, the government should streamline the sugar industry and the smallholders should ultimately have shares in the sugar factories.

(14) Farmers growing sugarcane in the Settlement Schemes should be provided with sufficient alternative land for planting subsistence cereal crops.

Recommendations for further research and Re-evaluation

The following research lines warrant intensive investigation in the short-and long-term if commercial sugarcane is to remain economically feasible and attractive to producers in the Sugar Belt.

(1) A further investigation into the problem of sugarcane-soil-water relationships should be established.

(2) There is need for more sophisticated development of resistant sugarcane varieties to drought, diseases, pests and weeds by breeding. A research should be conducted on the bionomics, and biological techniques of controlling these organisms. A continuous and energetic research is needed on pre- and post- emergence

herbicide spraying in various ecological zones in association with cultural practices and to specific weeds.

(3) An integrated approach to study large- and small-scale farmers in the Sugar Belt is required to facilitate a comparison of the conditions of these two sectors of agriculture.

(4) The occurrence of land fragmentation as a result of population pressure calls for continuous research and re-evaluation for the following reason : a microscopic view should emphasize on the economic factors of sugarcane production at work in every single holding viz land, labour and capital. This should include the optimum size of holding, the amount of labour which can be economically employed viz family and hired labour or machinery and the extent to which production requisites can best be brought into operation.

(5) A research on the efficiency of block-system of cane cultivation is needed. It is suggested that until the cooperatives prove capable of effectively organizing those basic activities with which they are charged, the imposition of more extensive responsibilities may be untimely.

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APPENDIX A

STATISTICAL TABLES

Appendix A-1

MECHANICAL ANALYSIS OF SOIL SAMPLES FROM CULTIVATED SUGAR-CANE PLOTS ON FARMS

(Drilling Depth 0-30 cms.)

Field Designation	Lab. No.	% Sand	% Silt	% Clay	Texture Grade
1	5725	20	12	68	C
2	5726	18	14	68	C
3	5727	20	14	66	C
4	5728	18	22	60	C
5	5729	20	16	64	C
6	5730	20	16	64	C
7	5731	20	16	64	C
8	5732	24	16	60	C
9	5733	16	24	60	C
10	5734	20	24	56	C
11	5735	16	24	60	C
12	5736	-	-	-	-
13	5737	14	18	68	C
14	5738	14	22	64	C
15	5739	22	20	58	C
16	5740	22	20	58	C
17	5741	12	16	72	C
18	5742	10	16	74	C
19	5743	18	18	64	C
20	5744	18	16	64	C
21	5745	-	-	-	-
22	5746	14	12	74	C

Appendix A-1

Field Design-ation	Lab. No.	% Sand	% Silt	% Clay	Texture Grade
23	5747	-	-	-	-
24	5816	18	12	70	C
25	5817	20	14	66	C
26	5818	20	14	66	C
27	5819	22	18	60	C
28	5820	20	16	64	C
29	5821	20	12	68	C
30	5822	20	12	68	C
31	5823	16	16	68	C
32	5824	20	20	60	C
33	5825	28	18	54	C
34	5826	32	18	60	C
35	5827	38	14	48	C
36	5828	28	26	46	C
37	5829	40	4	56	C
38	5830	20	24	56	C
39	5831	16	14	70	C
40	5832	18	22	60	C
41	6471	30	14	56	C
42	6472	-	-	-	-
43	6473	28	12	60	C
44	6474	32	20	48	C
45	6475	28	12	60	C
46	6476	18	18	64	C
47	6477	-	-	-	-
48	6478	28	8	64	C
49	6479	26	14	60	C
50	6480	66	6	28	SCL
51	6481	-	-	-	-
52	6482	28	24	48	C

Appendix A-1 ....

Field Designation	Lab. No.	% Sand	% Silt	% Clay	Texture Grade
53	6483	20	20	60	C
54	6484	-	-	-	-
55	6485	-	-	-	-
56	6486	54	14	32	SCL
57	6487	46	18	36	SC
58	6488	40	20	40	C
59	6489	38	14	48	C
60	6490	40	20	40	C

NB., C = Clay; S = Sand; Si = Silt; SC = Sandy Clay; SCL = Sandy Clay Loam; - = Blank due to less soil

Appendix A-2

ESTIMATION OF AVAILABLE SOIL WATER

Month	Rainfall (mm)	Evapo-transpiration (mm)	Available Water from 0-50 cm is 100 mm	Deficit (mm)	Date
JAN.	116.0	53.0	63.0	0.0	1-10
	5.7	60.1	0.0	-54.4	11-20
	0.5	72.8	0.0	-72.8	21-31

cont.........

Appendix A-2

Month	Rainfall (mm)	Evapo-trans-piration (mm)	Avail-able Water from 0-50 cm is 100 mm	Deficit (mm)	Date
FEB.	5.5	66.2	0.0	0.0	1-10
	40.5	60.6	0.0	-20.1	11-20
	0.0	71.7	0.0	-71.7	21-28
MAR.	66.0	59.6	6.4	- 0.6	1-10
	6.7	62.9	0.0	-56.2	11-20
	114.5	58.3	56.2	0.0	21-31
APR.	182.9	47.6	100.0	0.0	1-10
	100.7	52.3	100.0	0.0	11-20
	56.8	52.1	100.0	0.0	21-30
MAY	68.3	47.2	100.0	0.0	1-10
	9.3	46.2	63.1	-63.1	11-20
	16.8	53.6	26.3	-36.8	21-31
JUN.	53.1	47.5	41.9	0.0	1-10
	24.4	46.9	9.4	-22.5	11-20
	59.4	42.5	26.3	0.0	21-30
JUL.	60.7	34.9	62.4	0.0	1-10
	47.3	40.2	69.2	0.0	11-20
	83.9	47.3	100.0	0.0	21-31
AUG.	4.5	48.3	56.2	43.2	1-10
	11.4	49.5	18.1	38.1	11-20
	61.3	37.9	31.5	0.0	21-31
SEPT.	20.6	45.1	7.0	-24.5	1-10
	44.5	48.8	2.7	- 4.3	11-20
	13.1	51.8	0.0	-38.7	21-30

cont........

Appendix A-2 ......

Month	Rainfall (mm)	Evapo-trans-piration (mm)	Avail-able Water from 0-50 cm is 100 mm	Deficit (mm)	Date
OCT.	30.7	52.4	0.0	-21.7	1-10
	30.9	53.7	0.0	22.8	11-20
	22.8	60.8	0.0	25.8	21-31
NOV.	21.6	49.4	0.0	27.8	1-10
	5.6	56.5	0.0	50.9	11-20
	25.5	58.1	0.0	33.2	21-31
DEC.	6.8	59.2	0.0	52.4	1-10
	50.8	57.4	0.0	6.6	11-20
	5.4	67.0	0.0	61.6	21-31

Source: Chemelil Sugar Company Ltd. Agronomic Annual Report, 1974.

Appendix A-3

CHEMICAL ANALYSIS OF SOIL SAMPLES FROM CULTIVATED SUGARANE PLOTS ON THE FARMS

(Drilling Depth 0-30 cms)

Field Designation	Lab. No.	pH	Na m.e. %	K m.e. %	Ca m.e. %	Mg m.e. %	Mn m.e. %	Pppm	N %	C %	Estimated Cane yield in tons/ 0.4 ha.
1	5725	6.3	1.52	0.97	16.8	5.5	0.58	24	0.13	1.45	25
2	5726	6.3	1.24	0.97	16.8	5.8	0.70	20	0.14	1.68	25
3	5727	6.4	1.42	0.93	19.4	4.4	0.48	25	0.14	1.86	26
4	5728	5.9	1.24	0.93	18.4	5.0	0.66	18	0.16	1.88	30
5	5729	6.4	1.24	0.88	17.8	6.2	0.58	26	0.12	1.48	20
6	5730	6.2	1.28	1.02	16.4	6.6	0.74	24	0.11	1.48	22
7	5731	6.2	1.02	1.00	16.8	6.8	0.72	20	0.15	1.65	28
8	5732	6.2	0.96	1.00	14.0	4.8	0.54	16	0.14	1.62	25
9	5733	6.0	1.02	1.00	12.8	4.6	0.77	14	0.15	1.48	30
10	5734	6.0	0.64	1.13	11.0	5.0	0.98	16	0.12	0.81	24
11	5735	6.0	0.90	1.10	12.3	5.5	1.00	18	0.12	1.07	24
12	5736	6.6	1.12	1.00	15.4	6.4	1.18	57	0.11	0.99	20
13	5737	6.6	0.68	0.97	14.6	6.4	0.98	36	0.10	1.01	15
14	5738	6.7	0.76	0.88	15.4	6.4	0.98	67	0.09	0.75	12
15	5739	7.3	0.64	1.38	17.8	6.0	1.02	85	0.10	0.93	15
16	5740	7.2	0.80	1.00	16.4	6.0	1.00	64	0.09	0.81	13
17	5741	6.5	1.34	0.74	15.4	6.2	0.74	46	0.13	1.36	25
18	5742	6.7	0.87	0.82	14.6	6.4	0.72	52	0.09	1.13	10
19	5743	6.8	0.80	0.97	15.2	6.9	0.94	62	0.09	0.96	15
20	5744	7.0	1.80	0.78	14.0	6.6	0.92	85	0.09	1.04	15

Appendix A-3

Field Desig-Nation	Lab. No.	pH	Na m.e. %	K m.e. %	Ca m.e. %	Mg m.e. %	Mn m.e. %	Pppm	N %	C %	Estimated Cane yield in tons/ 0.4 ha.
21	5745	6.6	0.60	1.28	16.8	6.6	1.04	190	0.12	1.65	20
22	5746	6.6	1.24	0.78	14.8	6.2	0.90	41	0.09	1.10	10
23	5747	7.0	1.20	0.66	15.0	6.2	0.88	64	0.09	0.90	10
24	5816	5.9	1.11	1.28	14.0	8.2	0.96	34	0.11	1.37	21
25	5817	6.0	0.98	1.08	15.6	8.2	0.82	38	0.16	2.50	30
26	5818	5.8	0.78	1.06	15.2	7.2	0.84	27	0.16	1.85	30
27	5819	5.7	0.90	0.86	13.6	4.8	0.04	25	0.13	1.48	24
28	5820	5.8	1.02	0.78	16.4	3.8	0.50	20	0.15	1.96	28
29	5821	6.1	1.16	0.86	15.2	4.0	0.64	25	0.13	1.28	26
30	5822	6.5	1.24	1.06	18.0	4.8	0.42	45	0.16	2.30	34
31	5823	5.9	0.86	0.78	16.0	4.0	0.72	27	0.17	2.30	35
32	5824	5.9	0.98	0.50	12.8	3.4	0.64	20	0.13	1.68	25
33	5825	6.0	0.86	0.40	12.4	3.2	0.56	20	0.16	1.93	36
34	5826	6.4	1.06	0.86	9.6	4.6	0.46	20	0.13	1.45	25
35	5827	6.7	1.20	1.06	7.8	4.1	0.98	20	0.10	1.05	15
36	5828	6.0	0.44	0.70	10.0	3.6	0.74	25	0.15	1.65	33
37	5829	6.2	1.02	0.60	13.4	4.4	0.78	23	0.11	1.28	20
38	5830	6.1	0.70	0.64	10.0	3.4	0.62	20	0.09	0.97	15
39	5831	5.9	1.48	0.66	19.4	4.0	0.54	21	0.14	1.79	33
40	5832	6.1	1.02	0.71	11.8	3.1	0.48	12	0.12	1.65	25
41	6471	6.2	0.21	1.60	17.0	7.0	0.60	20	0.23	2.77	58
42	6472	5.8	0.08	1.10	15.9	7.2	0.60	31	0.24	2.83	64
43	6473	5.6	0.04	0.90	13.0	6.8	0.88	17	0.21	2.30	50
44	6474	5.4	0.06	0.76	12.8	6.4	0.70	21	0.22	2.21	55
45	6475	6.4	0.18	0.50	18.5	4.6	0.38	30	0.17	1.69	48
46	6476	5.5	0.04	0.66	11.8	6.0	0.83	21	0.18	1.86	48
47	6477	5.5	0.14	0.76	14.2	6.4	0.90	12	0.23	2.86	60
48	6478	6.6	0.10	1.18	19.8	6.6	0.70	43	0.19	2.77	50
49	6479	6.0	0.08	1.28	17.0	8.4	0.62	112	0.21	2.39	55
50	6480	6.28	0.08	0.48	12.8	9.2	0.56	308	0.07	0.60	10
51	6481	6.8	1.60	0.72	15.3	5.8	0.72	186	0.10	1.28	15

Appendix A-3

Field Desig-Nation	Lab. No.	pH	Na m.e.	K m.e.	Ca m.e.	Mg m.e.	Mn m.e.	Pppm	N %	C %	Estimated Cane yield in tons/0.4 ha.
52	6482	6.4	0.21	1.00	19.6	5.8	0.86	324	0.18	2.16	40
53	6483	6.9	0.32	0.98	16.4	4.5	0.78	100	0.13	1.51	35
54	6484	8.1	3.10	0.48	19.5	4.4	0.28	52	0.09	1.16	15
55	6485	7.8	1.04	0.62	19.0	7.3	0.36	25	0.13	1.49	25
56	6486	6.9	Trace	0.54	5.4	1.2	0.52	21	0.10	1.46	15
57	6487	5.9	0.04	0.38	8.2	2.4	1.04	36	0.12	1.54	20
58	6488	6.1	0.24	0.31	10.0	3.0	0.60	16	0.13	1.51	30
59	6489	5.5	0.14	0.20	5.8	2.7	0.60	11	0.11	0.96	20
60	6490	5.2	Trace	0.28	3.2	1.8	0.36	10	0.08	0.70	12

Appendix A-4

HOLDERS' TRIBE

Society	Sample number	Tribe Codes					
		1	2	3	4	5	6
Onyisa	26	26	0	0	0	0	0
Kipsitet	25	0	0	0	25	0	0
Chemase	25	0	21	3	1	0	0
Songhor	24	24	0	0	0	0	0
Koru	21	20	1	0	0	0	0
Tamu	21	21	0	0	0	0	0
Olikoliero	20	20	0	0	0	0	0
Keyo	16	16	0	0	0	0	0
Amilo	15	15	0	0	0	0	0
Kajulu	13	13	0	0	0	0	0
Chiga	13	13	0	0	0	0	0

Appendix A-4 cont.......

Society	Sample number	Tribe Codes					
		1	2	3	4	5	6
Simbi	12	12	0	0	0	0	0
Pala	11	11	0	0	0	0	0
Harambee	9	9	0	0	0	0	0
Kaitui	9	0	0	0	9	0	0
Chemursoi	9	0	8	0	0	1	0
Ngeny	8	8	0	0	0	0	0
Makindu	8	8	0	0	0	0	0
Nyakunguru	8	8	0	0	0	0	0
Mikiria	7	7	0	0	0	0	0
TOTAL	300	231	30	3	35	1	0
Percentage		77.1	10.0	1.0	11.7	0.3	0.0

Codes: 1 - Luo; 2 - Nandi; 3 - Luhyia; 4 - Kipsigis; 5 - Kikuyu; 6 - Other

Appendix A-5

HOLDERS' EDUCATIONAL STANDARD

Society	Sample number	Codes					Total literate
		1	2	3	4	5	
Onyisa	26	4	7	2	1	0	14
Kipsitet	25	7	2	6	0	0	15
Chemase	25	5	13	3	0	0	21
Songhor	24	7	9	3	1	0	20
Koru	21	5	7	3	0	0	15
Tamu	21	9	7	3	0	0	19
Olikoliero	20	8	5	0	0	0	13
Keyo	16	3	2	0	0	0	5
Amilo	15	3	0	3	0	0	6
Kajulu	13	3	0	2	0	0	5
Chiga	13	3	2	0	0	0	5
Simbi	12	3	0	1	0	0	4
Pala	11	5	0	0	0	0	5
Harambee	9	2	0	0	0	0	2
Kaitui	9	3	0	5	0	0	8
Chemursoi	9	1	4	2	0	0	7
Ngeny	8	4	0	0	0	0	4
Makindu	8	2	0	0	0	0	2
Nyakunguru	8	2	0	2	0	0	6
Mikiria	7	2	2	2	0	0	6
TOTAL	300	81	60	37	2	0	180

Codes: 1 - Lower Primary (Std. IV); 2 - Upper Primary
3 - Secondary; 4 - H.S.C.; 5 - Other

Appendix A-6

NUMBER OF FARMERS WHO HAVE CASES OF DISEASE AT THEIR FARMS

Society	Sample number	No. of farmers reporting disease cases				
		Cholera	Malaria	Bilharzia	Sleeping sickness	Other
Onyisa	26	10	25	4	0	26
Kipsitet	25	2	20	0	0	25
Chemase	25	0	25	0	0	24
Songhor	24	6	24	6	1	24
Koru	21	6	21	0	0	21
Tamu	21	4	21	4	0	20
Olikoliero	20	5	20	3	0	19
Keyo	16	9	15	4	1	15
Amilo	15	10	11	2	3	15
Kajulu	13	8	13	6	2	13
Chiga	13	11	11	3	0	13
Simbi	12	7	12	1	1	12
Pala	11	6	8	0	0	11
Harambee	9	4	8	4	1	9
Kaitui	9	2	9	0	0	7
Chemursoi	9	0	8	0	0	7
Ngeny	8	4	8	4	0	8
Makindu	8	3	8	2	0	8
Nyakunguru	8	3	8	2	0	8
Mikiria	7	4	7	4	0	7
TOTAL	300	104	282	49	9	292
Percentage		34.7	94.0	16.3	3.0	97.3

Appendix A-7

LAND USE ACCORDING TO SAMPLED SOCIETIES IN THE SUGAR BELT

Society	Sample number	Average Hectarage under various Uses						Cane Area as % of total holding
		Average holding size	Cane land	Maize land	Other subsistence	Land under-grazing	Land unused or under other uses	
Onyisa	26	3.3	1.2	0.8	0.6	0.5	0.2	36.4
Kipsitet	25	5.0	1.4	1.5	0.4	1.5	0.2	28.0
Chemase	25	4.9	1.6	1.1	0.2	1.2	0.8	32.7
Songhor	24	7.4	2.9	1.8	0.5	1.4	0.8	45.3
Koru	21	6.1	3.0	1.0	0.4	0.5	1.2	49.2
Tamu	21	5.6	3.4	0.7	0.2	0.8	0.5	61.8
Olikoliero	20	6.5	2.0	0.4	0.5	2.9	0.7	30.8
Keyo	16	4.0	2.0	0.6	0.3	0.5	0.6	50.0
Amilo	15	3.4	1.5	0.3	0.3	0.6	0.7	44.1
Kajulu	13	5.1	1.0	0.8	1.1	1.0	1.2	19.6
Chiga	13	5.0	2.1	0.2	0.5	1.9	0.3	42.0
Simbi	12	3.5	2.4	0.2	0.4	0.5	0.0	68.6
Pala	11	2.1	0.6	0.3	0.3	0.5	0.4	28.6
Harambee	9	2.8	1.9	0.3	0.2	0.2	0.2	67.9
Kaitui	9	7.5	2.0	1.1	0.8	3.3	0.3	26.7
Chemursoi	9	4.1	1.8	0.3	0.0	2.0	0.0	43.9
Ngeny	8	5.1	2.5	0.4	0.3	1.3	0.6	49.0
Makindu	8	3.7	1.9	0.6	0.6	0.5	0.1	51.4
Nyakunguru	8	5.2	1.9	0.5	0.9	1.8	0.1	36.5
Mikiria	7	7.0	1.3	0.9	0.9	2.6	1.3	18.6
Average		4.8	1.9	0.7	0.5	1.3	0.5	
Land use as a % of total holding			39.6	14.6	10.4	27.1	10.4	

Appendix A-8

NUMBER OF FARMERS BY HECTARAGE UNDER SUGARCANE

Society	Sample number	Hectarage under Sugarcane				Estimated sugarcane (plant crop) in metric tons yield 0.4 ha.
		0-2.99	3-5.99	6-8.99	9+	
Onyisa	26	16	7	2	1	15
Kipsitet	25	12	10	2	1	45
Chemase	25	10	8	5	2	30
Songhor	24	9	8	4	3	40
Koru	21	8	10	2	1	60
Tamu	21	5	10	5	1	55
Olikoliero	20	8	7	3	2	30
Keyo	16	8	6	1	1	25
Amilo	15	9	4	1	1	30
Kajulu	13	4	6	2	1	15
Chiga	13	6	4	2	1	25
Simbi	12	4	6	1	1	30
Pala	11	7	2	1	1	20
Harambee	9	3	4	1	1	30
Kaitui	9	3	4	1	1	40
Chemursoi	9	2	5	1	1	45
Ngeny	8	3	2	2	1	20
Makindu	8	4	2	1	1	45
Nyakunguru	8	2	4	1	1	25
Mikiria	7	2	3	1	1	20
TOTAL	300	125	112	39	24	32.25

Appendix A-9

SUMMARY OF SUGARCANE REALISATION FOR PRODUCTION SOCIETIES: 1972

Society	Hectarage harvested	Tonnage (X)	Gross income (K.Shs)	CSC Loan Recovery (K.Shs)	Transport Charges (K.Shs)	Cutting and Loading (K.Shs)	Union Commi-ssion K.Shs	Society Commi-ssion K.Shs	Members' net payment K.Shs. (Y)
Nyatao	17.4	1028.98	37820.95	16809.40	13333.20	5620.35	1028.05	1029.05	NIL
Ngeny	36.9	1225.96	63750.95	32509.20	15982.30	4671.00	1226.00	1226.00	3136.45
Mikiria	52.0	1039.87	51857.40	27344.65	16488.45	1579.95	1034.70	1034.60	4375.05
Nyakunguru	13.4	267.25	11828.00	6384.45	3779.80	1149.50	257.15	257.15	NIL
Amilo	31.8	561.56	2853.70	18149.85	9265.75		261.65	561.65	NIL
Jaber	43.9	1655.70	86096.45	45299.05	26933.10	4675.55	1665.65	1655.75	5857.33
Harambee	166.1	7502.28	386829.90	205078.20	12241.05	306.05	7502.30	7502.30	44024.00
Nyang'	196.4	16448.40	499202.75	245770.25	154041.75		10448.55	10448.55	78493.65
Kibisem	127.5	8689.97	414305.20	224881.35	121393.25	37452.25	8690.10	5689.90	13861.40
Chemase	106.9	21138.01	984215.25	494868.55	267092.55	105218.40	21137.80	21137.80	74760.15
GRAND TOTAL	792.3	59557.50	2564445.55	1316431.95	750749.15	160673.05	53542.22	53542.72	224507.8

Source: Annual Report 1972: Sugar Belt Zone, Ministry of Cooperative and Social Services

Appendix A-10

NUMBER OF YEARS THE FARMERS HAVE BEEN GROWING SUGARCANE

Society	Sample number	No. of farmers according to length of time of growing sugarcane				
		1 - 5	6 - 10	11 - 15	16 - 20	20+
Onyisa	26	11	4	8	3	0
Kipsitet	25	12	0	13	0	0
Chemase	25	6	4	15	0	0
Songhor	24	2	16	6	0	0
Koru	21	2	13	6	0	0
Tamu	21	1	8	12	0	0
Olikoliero	20	5	3	8	2	2
Keyo	16	3	5	1	5	2
Amilo	15	5	7	2	0	1
Kajulu	13	7	2	0	0	4
Chiga	13	8	3	2	0	0
Simbi	12	1	8	3	0	0
Pala	11	2	5	4	0	0
Harambee	9	1	6	2	0	0
Kaitui	9	9	0	0	0	0
Chemursoi	9	6	1	2	0	0
Ngeny	8	0	4	4	0	0
Makindu	8	3	2	0	1	2
Nyakunguru	8	3	2	3	0	0
Mikiria	7	4	2	1	0	0
TOTAL	300	91	95	92	11	11
% of farmers		30.3	31.7	30.7	3.7	3.7

Appendix A-11

NUMBER OF FARMERS WHO CONSIDER WILDLIFE TO BE A NUISANCE IN THE AREA

Society	Sample number	Codes						
		1	2	3	4	5	6	7
Onyisa	26	18	21	4	22	6	6	14
Kipsitet	25	25	25	21	25	25	21	21
Chemase	25	24	25	25	25	24	25	24
Songhor	24	18	17	16	16	10	21	17
Koru	21	17	19	15	16	5	20	12
Tamu	21	15	16	13	16	8	20	13
Olikoliero	20	14	19	7	16	12	11	15
Keyo	16	11	12	6	13	7	11	11
Amilo	15	14	8	6	8	9	7	7
Kajulu	13	13	10	8	11	11	10	10
Chiga	13	11	13	9	13	6	10	10
Simbi	12	6	9	11	9	8	10	10
Pala	11	9	10	11	10	9	9	10
Harambee	9	7	8	3	8	3	8	7
Kaitui	9	9	9	3	9	9	9	9
Chemursoi	9	8	9	9	8	9	9	9
Ngeny	8	6	6	4	7	4	3	6
Makindu	8	4	6	5	6	3	7	6
Nyakunguru	8	5	8	7	8	6	7	7
Mikiria	7	7	6	0	6	5	6	7
TOTAL	300	241	256	183	252	179	230	223
Percentage		80.3	85.3	61.0	84.0	59.7	76.7	74.3

Codes:
1 = Predators to domestic animals
2 = Snakes
3 = Monkeys/baboons
4 = Birds
5 = Antbears
6 = Wild pigs
7 = Other

APPENDIX B

RECORDING SCHEDULE

CONFIDENTIAL

FARM SURVEY, 1975

RECORDING SCHEDULE FOR INTERVIEWING SMALLHOLDER SUGARCANE GROWERS IN NYANZA SUGAR-BELT, KENYA

A. GENERAL INFORMATION

Interviewer's name ______________________

Interviewing date ______________________

Cooperative's name ______________________

Farm Code ______________________

B. HOLDER AND HOUSEHOLD MEMBERS

1. To which of the following tribes does the holder belong?

Luo	1	________
Nandi	2	________
Luhyia	3	________
Kipsigis	4	________
Kikuyu	5	________
Other	6	________

2. Age of holder and Family: Code Male = 1; Female = 2

	Holder		Family	
	1	2	1	2
0-14	____	____	____	____
15-19	____	____	____	____
20-29	____	____	____	____

	Holder 1	Holder 2	Family 1	Family 2
30-39	______	______	______	______
40-49	______	______	______	______
50-59	______	______	______	______
60+	______	______	______	______

3. Holder's Education Standard

Lower primary	1	______
Upper primary	2	______
Secondary	3	______
H.S.C.	4	______
Other	5	______

4. Have you attended Farmer's training courses?

No	1	______
Yes	2	______

5. Do you think the courses have been useful to you?

No	1	______
Yes	2	______

6. To which of the following religion do you belong?

Seventh Day Adventists	1	______
Catholic	2	______
Muslim	3	______
Anglican	4	______

7. Does your religion encourage or discourage the growing of sugarcane?

Discourage	1	______
Encourage	2	______
Neither of these	3	______

8. Do you have a function in any of the following?

Cooperative Society/Union 1 ____________

Clubs 2 ____________

Teaching 3 ____________

Civil service 4 ____________

Other 5 ____________

9. Is the farmer: full-time farmer? 1 ____________

part-time farmer? 2 ____________

absentee farmer? 3 ____________

10. Other occupations are:

Business 1 ____________

Fishing 2 ____________

Teaching 3 ____________

Other 4 ____________

11. State your income per annum from the following sources in K.Shs.

a. Agriculture ____________

b. Sugarcane ____________

c. Pension ____________

d. Other ____________

C. LAND TENURE

1. When did the farmer occupy the holding, and where was the farmer originally living?

a. Time of occupying holding ____________

b. Original living place of farmer ____________

2. Who was the previous holder?

European settlers/Government 1 ____________

Holder's father 2 ____________

Holder's brother 3 ____________

Holder's uncle 4 ____________

Other 5 ____________

3. Does the farmer occupy other land elsewhere?

a. District ________________

b. Size of land in hectares ________________

4. Name the type of land tenure

Individual holding 1 ____________

Freehold 2 ____________

Owner-occupier 3 ____________

Communal land 4 ____________

Tenancy 5 ____________

Leasehold 6 ____________

Share-cropping 7 ____________

5. Do you have title deed?

No 1 ________

Yes 2 ________

D. LABOUR

1. Who supervises the labour?

Farmer 1 ____________

Farmer's wife/husband 2 ____________

Both husband and wife 3 ____________

Manager 4 ____________

Other 5 ____________

2. State the sources of labour for the following farm activities and state month of operation.

	Family	Casual	Permanent	Month of operation
Land preparation	______	______	______	______
Planting	______	______	______	______
Weeding	______	______	______	______
Top-dressing	______	______	______	______
Harvesting	______	______	______	______

3. Is the land given freely to the farm labour for their own cultivation?

   No 1 ______

   Yes 2 ______

4. Is there any labour shortage?

   No 1 ______

   Yes 2 ______

5. Do you provide houses for labourers?

   No 1 ______

   Yes 2 ______

6. Are your labourers satisfied with their salary?

   No 1 ______

   Yes 2 ______

   I don't know 3 ______

7. Which farm activities are mechanized?

   Ploughing 1 ______

   Harrowing 2 ______

   Planting 3 ______

   Weeding 4 ______

   Other 5 ______

E. EXTENSION SERVICES

1. What are your sources of information in sugarcane development?

Radio	1	______
Press	2	______
Cooperative society	3	______
Neighbouring farmers	4	______
Extension officers	5	______
Church	6	______
Meetings (Baraza)	7	______
Other	8	______

2. Have you received information from extension officers on the following methods of improving sugarcane yields?

Crop rotation	1	______
Land consolidation	2	______
Weed control	3	______
Manuring/Fertilizing	4	______
Drainage	5	______
Soil Conservation	6	______
Sowing date	7	______
Recommended spacing	8	______
Ploughing	9	______

F. SUGARCANE FIRES

1. Have your canes been burnt illegally since you planted them and when were they burnt?

   a. No 1 ______

   Yes 2 ______

   b. Date of burning ______

2. Do you think that growers own fires are caused by the following?

Burning cane for milling 1 ____

Burning bush/grass 2 ____

Burning trash 3 ____

Other 4 ____

3. Is it true that fires maliciously set are caused by:

Dissatisfied labourers? 1 ____

Jealous neighbours? 2 ____

Other 3 ____

4. Are fires caused by the following miscellaneous sources?

Smoking in fields and/or roads 1 ____

Spread from non-growing cane areas 2 ____

Tractors 3 ____

Lightning 4 ____

Other causes 5 ____

G. FARMERS' ENVIRONMENTAL PERCEPTION

1. Do you consider the seasonal distribution of rainfall to have greater significance in sugarcane growth than total annual rainfall?

No significance 1 ____

Significance 2 ____

2. Are you aware of the seriousness of any of the following types of erosion occurring on your farm?

Sheet erosion 1 ____

Rill erosion 2 ____

Gully erosion 3 ____

3. Is the formation of dew important in sugarcane growth?

   No 1 ______

   Yes 2 ______

4. Have you seen your canes flowering?

   No 1 ______

   Yes 2 ______

5. Which of the following considerations do you associate with rain or drought?

	Rain	Drought
Irrigation	______	______
Fertilizers	______	______
Pests and/or diseases	______	______
Weeds	______	______
Erosion	______	______
High cane yields	______	______

6. Have you experienced the following environmental hazards on your sugarcane plot?

   Floods 1 ______

   Wind damage 2 ______

   Drought 3 ______

   Hailstones 4 ______

   Lightning 5 ______

   Diseases and/or pests 6 ______

7. Have you detected the seriousness of the following dangerous weeds on your sugarcane plot?

   Striga (Hayongo) 1 ______

   Couch (Ombugu) 2 ______

   Other 3 ______

8. What are the constraints especially felt by you as a farmer and that limit sugarcane extension?

Land	1	________
Management	2	________
Weather hazards	3	________
Diseases and/or pests	4	________
Personal preference	5	________
Economic circumstances	6	________
Technological inputs	7	________
Subsistence crops competition	8	________
Expertise	9	________

9. Farmers are planting more and more sugarcane because it:

Is drought resistant	1	________
Is disease resistant and/or pest resistant	2	________
Is weed resistant	3	________
Is government policy	4	________
Grows in a wide range of soils	5	________
Brings better income	6	________
Needs no fertilizer	7	________
Is easy to grow	8	________
Grows better in water-logged soils	9	________

10. Would you like to use the following technological inputs in sugarcane development?

Irrigation	1	________
Sprays	2	________
Fertilizers	3	________
Tractor	4	________

11. Have you seen the following diseases and/or pests in your sugarcane plot recently?

Army-worms	1	______
Termites	2	______
Locusts/Grasshoppers	3	______
Stem borers	4	______
Sugarcane smut	5	______
Rats	6	______
Ratoon stunting	7	______

12. Name the crops whose fields have been abandoned

Sugarcane	1	______
Maize	2	______
Sorghum	3	______
Finger millet	4	______
Beans/peas	5	______
Cotton	6	______
Cassava/potatoes	7	______
Other	8	______

13. What are the reasons for abandoning the fields mentioned in 12?

Poor soil	1	______
Weeds	2	______
Erosion	3	______
Crop not profitable	4	______
Available labour	5	______
Drought	6	______
Insufficient drainage	7	______
Other	8	______

14. Which of the following enterprises do you feel are most important for the development of the area where your farm is situated?

Maize	1	______
Sugarcane	2	______
Cattle	3	______
Cotton	4	______
Rice	5	______
Other	6	______

15. Where would you like to plant sugarcane?

On a steep slope	1	______
On a flat land	2	______
On a rugged land	3	______
On moderate slope	4	______
On a valley side	5	______
On a waterlogged land	6	______
Other places	7	______

16. Are the following soil factors important in agriculture of sugarcane?

Soil colour	0	______
Soil moisture	1	______
Soil structure	2	______
Soil texture	3	______
Soil drainage	4	______
Leaching	5	______
Soil erosion	6	______
Soil conservation	7	______
Soil organisms	8	______

Soil temperature 9 ________

17. Do you have any knowledge of how to control pests, diseases and weeds by applying any of the following methods?

Deep ploughing	1	________
Uprooting infested canes	2	________
Burning infested canes	3	________
Hand-pulling or hoeing	4	________
Spraying	5	________
Crop rotation	6	________
Fallowing	7	________
Biological control	8	________

18. Do the following factors affect cane yields?

Cane variety	1	________
Prices	2	________
Burning cane	3	________
Cane age	4	________
Distance from the factory	5	________
Fertilization	6	________
Weed control	7	________
Diseases and/or pests	8	________
Planting date	9	________

19. Which of the following environmental variables governs sugar-cane yields? Number according to order of importance using 1, 2, 3 8

Rainfall reliability	1	________
Temperature	2	________
Sunshine	3	________
Wind velocity	4	________

Soil quality 5 ____________

Dew formation 6 ____________

Diseases and/or pests 7 ____________

Weeds 8 ____________

20. Which of the following agronomic practices do you use at the moment as an adjustment to the environment.

Shifting cultivation/bush fallowing 1 ________

Heaps and ridges 2 ________

Intercropping/mixed cropping 3 ________

Crop rotation 4 ________

Mixed farming 5 ________

Mulching 6 ________

Contour farming 7 ________

21. Name three plants which indicate land potentiality.

a. ____________________________

b. ____________________________

c. ____________________________

22. According to your own experience, does the vegetation:

Induce rainfall? 1 __________

Shelter the soil from wind? 2 __________

Shelter the soil from rain? 3 __________

Shelter the soil from the sun? 4 __________

Enrich the soil? 5 __________

Exhaust the soil 6 __________

Play no role in the soil? 7 __________

23. Do the following aid in improving the soil?

Cane-tops 1 _________

Trash 2 _________

Grass 3 ________

Green manure crops 4 ________

Compostt manure 5 ________

24. Do you have difficulty in obtaining the following inputs?

Seeds 1 ________

Fertilizers 2 ________

Farmyard manure 3 ________

Sprays 4 ________

Tractor 5 ________

Credit 6 ________

Irrigation 7 ________

Labour 8 ________

25. How would you like to spend your income on the following items?
Arrange in order of preference using 1, 2, 3, ... 6

Borehole 1 ________

Moreland 2 ________

Technical inputs 3 ________

Draught animals 4 ________

Subsistence crops 5 ________

Other 6 ________

26. Which of the following wildlife do you consider to be a nuisance here?

Predators to domestic animals 1 ________

Snakes 2 ________

Monkeys/baboons 3 ________

Birds 4 ________

Antbears 5 ________

Wild pigs 6 ________

Other 7 ________

27. Has the farmer and/or his family suffered from any of the following diseases?

Cholera	1	______
Malaria	2	______
Bilharzia	3	______
Sleeping sickness	4	______
Other	5	______

H. AGRICULTURAL ENTERPRISES

1. State the following economic factors (sizes in hectares) which are related to internal organization of the farm.

   a. Size of holding ______
   b. Size of cane land ______
   c. Size of maize land ______
   d. Size of other subsistence crops ______
   e. Size of land under grazing ______
   f. Land unused/under other uses ______

2. For how long have you been growing sugarcane? ______

3. Name the cane varieties grown by you:

Co 421 (Manywere)	1	______
Co 331 (Siting)	2	______

4. Do you think that the long growth period of sugarcane limits its extension because farmers may not have what to do or eat?

No	1	______
Yes	2	______

5. Crop enterprise in the farm other than sugarcane

	Cash crop	Subsistence
Maize	______	______
Sorghum	______	______
Finger millet	______	______
Sweet potatoes/cassava	______	______
Groundnuts	______	______
Cotton	______	______
Rice	______	______
Beans/peas	______	______
Fruits	______	______
Other	______	______

6. Do you keep livestock because of the following socio-economic reasons?

	Cattle	Sheep	Goats	Asses	Poultry
'Bride price'	____	____	____	____	____
Prestige	____	____	____	____	____
Milk	____	____	____	____	____
Meat	____	____	____	____	____
Manure	____	____	____	____	____
Income	____	____	____	____	____
Traction	____	____	____	____	____
Other reasons	____	____	____	____	____

I. MISCELLANEOUS INFORMATION

1. What is the distance between the farm and factory in kilometres?

1-10	1	______
11-16	2	______

17-20	3	______
21-24	4	______
24+	5	______

2. What is the transport cost of canes per ton in K.Shs. ______

3. How do you transport your canes to the factory?

Through cooperative society	1	______
By tractor hire	2	______
Through factory arrangement	3	______
Other means	4	______

4. Do you have little or no money to spend on:

	Little money	No money
Tools	______	______
Seeds	______	______
Fertilizers	______	______
Hired labour	______	______
Other farm essentials	______	______

5. Tell me about the following farm conditions:

	Good	Poor
Farm layout	______	______
Situation in regard to major road	______	______
Situation in regard to feeder road	______	______
Situation in regard to access road	______	______
Condition of fences	______	______
Field drainage	______	______

6. Now tell me about the following amenities in regard to the farm:

	Good	Poor
Markets/shops	____	____
Schools	____	____
Hospital/clinic	____	____
Churches	____	____
Clubs	____	____
Telephone	____	____
Electricity	____	____
Bank	____	____

7. Name your sources of water supply to buildings, farm and fields:

	Buildings	Farm	Fields
River/stream	____	____	____
Borehole/well	____	____	____
Roof tank	____	____	____
Pipe	____	____	____
Rainfall, dams & springs	____	____	____

8. Is there seasonal shortage of water?

No 1 ______

Yes 2 ______

9. Variable cane inputs in K.Shs. per 0.4 hectare

a. Seed ______

b. Fertilizer ______

c. Hired labour ______

d. Land preparation ______

e. Other ______

10. Give me sugarcane output data:

a. Total cane yield per annum in tons ________

b. Cane yield per 0.4 hectare in tons ________

c. Income from 0.4 hectare per annum in K.Shs. ________

11. Farmers' information on frequency of Diet consumption, and expenditure per annum.

	Consumption Frequency				Price in K.Shs/ annum
	A	B	C	D	
Cereals	___	___	___	___	_____
Meat	___	___	___	___	_____
Fish	___	___	___	___	_____
Milk/Eggs	___	___	___	___	_____
Vegetables	___	___	___	___	_____
Cassava/potatoes	___	___	___	___	_____
Fruits	___	___	___	___	_____
Sugar and beverages	___	___	___	___	_____
Alcoholic drinks	___	___	___	___	_____
Cooking oil	___	___	___	___	_____
Other	___	___	___	___	_____

NB. A = Daily

B = Weekly

C = Monthly

D = Yearly