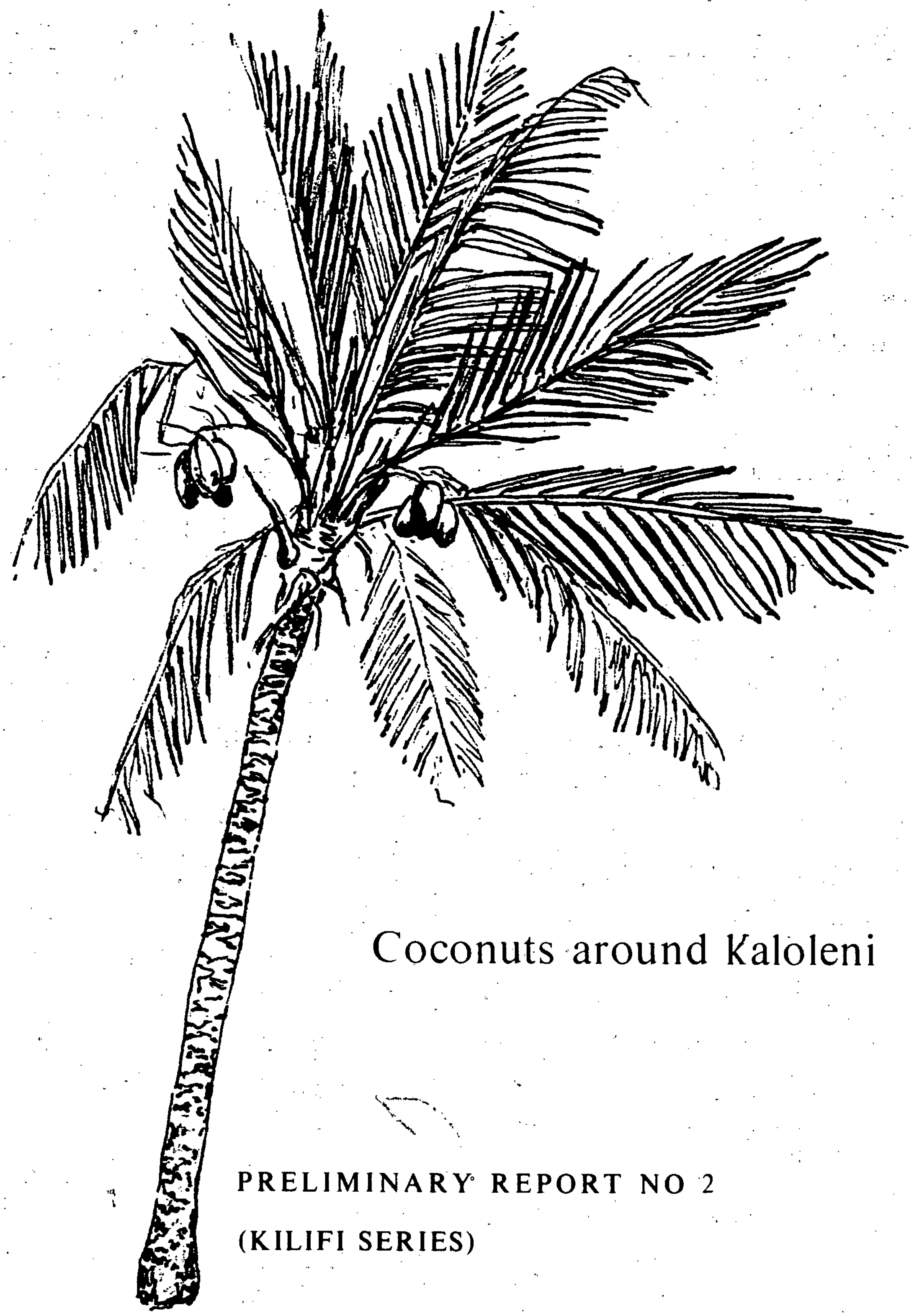
TRAINING PROJECT IN PEDOLOGY

KILIFI KENYA



Coconuts around Kaloleni

PRELIMINARY REPORT NO 2

(KILIFI SERIES)

AGRICULTURAL UNIVERSITY

WAGENINGEN - THE NETHERLANDS

COCONUTS AROUND KALOLENI (KILIFI DISTRICT, KENYA)

Study on some aspects of coconut growing in the area of Kaloleni with special references to plant characteristics and nutrient status in relation to soil type and type of intercrop and undergrowth

by

J. Floor

Preliminary Report no 2
(Kilifi Series)
March 1981

TRAINING PROJECT IN PEDOLOGY, KILIFI, KENYA
AGRICULTURAL UNIVERSITY, WAGENINGEN, THE NETHERLANDS

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GENERAL INFORMATION ON THE TRAINING PROJECT IN PEDOLOGY*

The Training Project in Pedology was started in 1972 in the Kisii area. The soil studies in that area resulted in the publication of mapsheet 130 (mapsheet Kisii) of the soil map of Kenya, scale 1:100,000 and a report on its soils, with chapters on geology, vegetation, agriculture and land evaluation (in print). Some 30 preliminary reports on various subjects were issued or are in preparation.

In 1979 the project was transferred to the Kilifi area at Kenya's Coast, and project activities started in September. Also this project has as its major aim the production of a mapsheet (Kilifi) on scale 1:100,000 in the frame of the Soil Map of Kenya.
The mapsheet is prepared in cooperation with the Soil Survey of Kenya (Ministry of Agriculture). There are also links with the faculty of Agriculture of the University of Nairobi.

The project is meant for training of postgraduate students of the Agricultural University at Wageningen and for providing research opportunities for the staff. The activities of students and staff are directed to obtain a better knowledge of the soils and the agricultural conditions of the project area as a basis for further agricultural development of the area.

The project at Kilifi is conducted by:
Dr.Ir. T. de Meester (Principal)
Teaching and research

Ing. H.W. Boxem (Manager)
Management and teaching

Visiting specialists from the Agricultural University at Wageningen help to solve special problems.

* Postal address: Private Mailbag, Kilifi, Kenya.

PREFACE

This is a Preliminary Report of the Training in Pedology (T.P.I.P.) at Kilifi (Kenya) of the Agricultural University at Wageningen, the Netherlands. It is the second of a new series to be presented to Kenya officials.

This publication reports on a post graduate study carried out by Mr. Jaap Floor, student at the Agricultural University, in close cooperation with the Coast Agricultural Research Station (C.A.R.S.) at Kikambala. The study is in part fulfilment of the requirements of two minors viz Tropical Crop Science and Soil Fertility.
Field work took place in January and February 1980. The author compiled the data and analysed samples in subsequent months at Kilifi and Wageningen.
The text of the final report was revised and edited by Dr. M. Wessel of the Department of Tropical Crop Science.

With reference to the "Acknowledgments" by the author, it should be emphasized that we are especially grateful for the help and cooperation received from the authorities of the Kilifi District: the D.C. (Mr. Omuse), the D.O. of Kaloleni Division and the Chiefs of Kaloleni and Chonyi and their staff. We want to acknowledge also the D.A.O. of Kilifi (Mr. Were) and in particular the A.A.O. of Kaloleni (Mr. Kabara) for their assistance and hospitality during the field work.

We hope to return with these reports a small part of the great debt we owe to Kenya in general and to many Kenyans in particular for their valuable contribution to this project.

The project supervisor
J. Bennema
(Professor in Tropical Soil Science)

ACKNOWLEDGMENT

Without the help of many people it would have been impossible for me to undertake this study. In particular I would like to thank the following persons and institutions:

- The T.P.I.P. for giving me the opportunity to do this study; the staff members de Meester and Boxem and their families for the fruitful discussions, technical assistance and hospitality.
- The Officer in charge of the Coast Agricultural Research Station (C.A.R.S.), Dr. Warui, and his staff.
- The tree crop officer of the C.A.R.S., Prof. van Eijnatten, for his help with the design, his constructive ideas, the use of his desk-computer and for the hospitality. His enthousiasm for the coconut has greatly encouraged me.
- My supervisors Dr. Janssen and Dr. Wessel of Wageningen University and Dr. de Bruyn of the University of Nairobi, for their help with the design, analyses and the discussions of the results.
- The Local Authorities of the Kilifi District, Southern Division, including the District Officer at Kaloleni, the Chiefs of Kaloleni and Chonyi and their staff.
- The District Agricultural Officier of the Kilifi District and his staff, in particular the A.A.O. at Kaloleni, Mr Kabara for his assistance and hospitality during the fieldwork.
- The farmers in the area studied for their cooperation, hospitality and pombe.
- The assistants who contributed to the fieldwork, Messrs. Suleiman, Martin and Katana, and the palmclimbers Messrs. Charo and Kazungu. The laboratory assistant Mr Muramba.
- Ir. Verdooren and Dr. Koorevaar for their help with the statistics.
- Ir. Ohler of the Royal Tropical Institute at Amsterdam, the Netherlands, for the fruitful discussion.
- Mrs Hoogendijk for her help with the leaf analyses.

August 1980 Jaap Floor

SUMMARY

The coconut palm is the most important tree crop in the coastal area of Kenya. Most palms are found in the Kilifi District. In a part of this district, viz. the area around Kaloleni, the effects of soil type and different types of intercropping on palm growth and nutrition were studied. The observations were made on palms on two soil types in plots with three types of intercropping: coconut palms intercropped with food crops, palms interplanted with cashew trees and palms with bush undergrowth. The soils were a clayey soil derived from Kambe limestone and a sandy one derived from Mariakani sandstone.
For each of the six different soil/intercrop combinations ten smallholders' plots were selected. On each plot morphological characteristics of three palms were described. Chemical analyses of fruits, leaves and soils were also made.

Both soils were found to be low in nitrogen and phosphate. The pH-water of the clayey and the sandy soil were about 7 and 6 respectively.

As to soil effects the results show that the palms on the sandy soil have better growing conditions than those on the clayey soil. The coconut palms on the clayey soil suffer more from drought, which is expressed in: a smaller trunk diametre, more leaf scars per metre, fewer inflorescences and female flowers, a lower rank number of the leaf with the oldest inflorescence and shorter leaves. The soil effect on the nutrient content of the leaflets is not very pronounced.

As to intercropping effects the results indicate that intercropping with food crops gives the best growing conditions for coconut palms. On the food crop plots palms had more leaves, more inflorescences and female flowers, and a higher rank number of the leaf with the oldest inflorescence. The effect of the type of intercropping on the nutrient content of the leaflets is complex. In general the lowest nutrient levels were found in palms with bush undergrowth. The observation period was too short to investigate the effects of soil/intercropping combinations on yield. The preliminary data suggest that the amount of copra per nut was not affected.

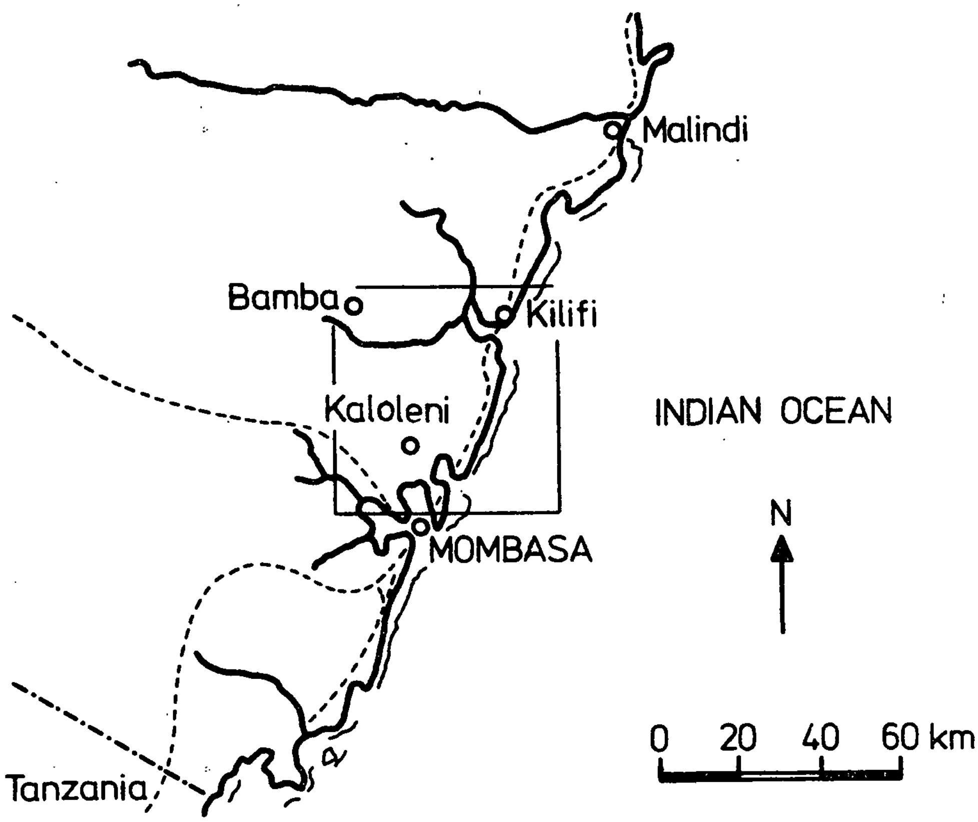

Figure 1: Location of the Kilifi area studied by the Training Project in Pedology.

1 INTRODUCTION

The coconut tree (Cocos nucifera, tall variety) is the most important tree crop in the wetter areas (over 900 mm/year) of the Coast Province. Intercropping with food crops and other tree crops is common in this area. Sofar only a limited amount of research has been carried out in Kenya.

The aim of this study is twofold. In the first place to get an idea of the agronomic aspects of coconut cultivation in the Kaloleni area, and in the second place to study the effects of soil and type of intercropping on the growth, yield and nutrient status of the coconut palm. The study fits in both the long-term research programme of the Coastal Agricultural Research Station (C.A.R.S.) at Mtwapa and in the research programme of the Training Project in Pedology (TPIP) at Kilifi.

As time for field work was limited, coconut trees were only studied on two different soils with three types of intercropping undergrowth (i/u) vegetation. Various aspects of the sites and soils are discussed in Chapter 3. Some aspects of coconut cultivation including the detailed description of the i/u types are described in Chapter 4, which gives also field and laboratory procedures, nut analyses and statistical methods. The results are presented in Chapter 5. In 1977 van Eijnatten et al. did some related research work on coconuts in the same district. Their findings are compared with the results of this study in chapter 6. Conclusions and recommendations for further research are given in Chapter 7. A review of relevant literature is presented in Chapter 2.

The study has clear limitations and shortcomings as it can only give an instantaneous photograph of the life of mature coconuts. Long-term observations are needed to give a more reliable and complete picture. It is also obvious that other factors than soil and undergrowth affect plant, fruit and nut characteristics and yield. These factors include: season (Pillai and Satyabalan, 1960; Cooman, 1974), environment (Pankayakshan, 1961) and genetic factors (Peter and Jayaman, 1977).
Another shortcoming is that the plots were located at 60 different sites. The trees and these plots differed in age, plant densities and management, while their history was largely unknown. Furthermore high and low yielding trees are known to differ largely in some plant characteristics and in nutrient content of leaves (Satyabalan et al. 1969; Thomas, 1974).

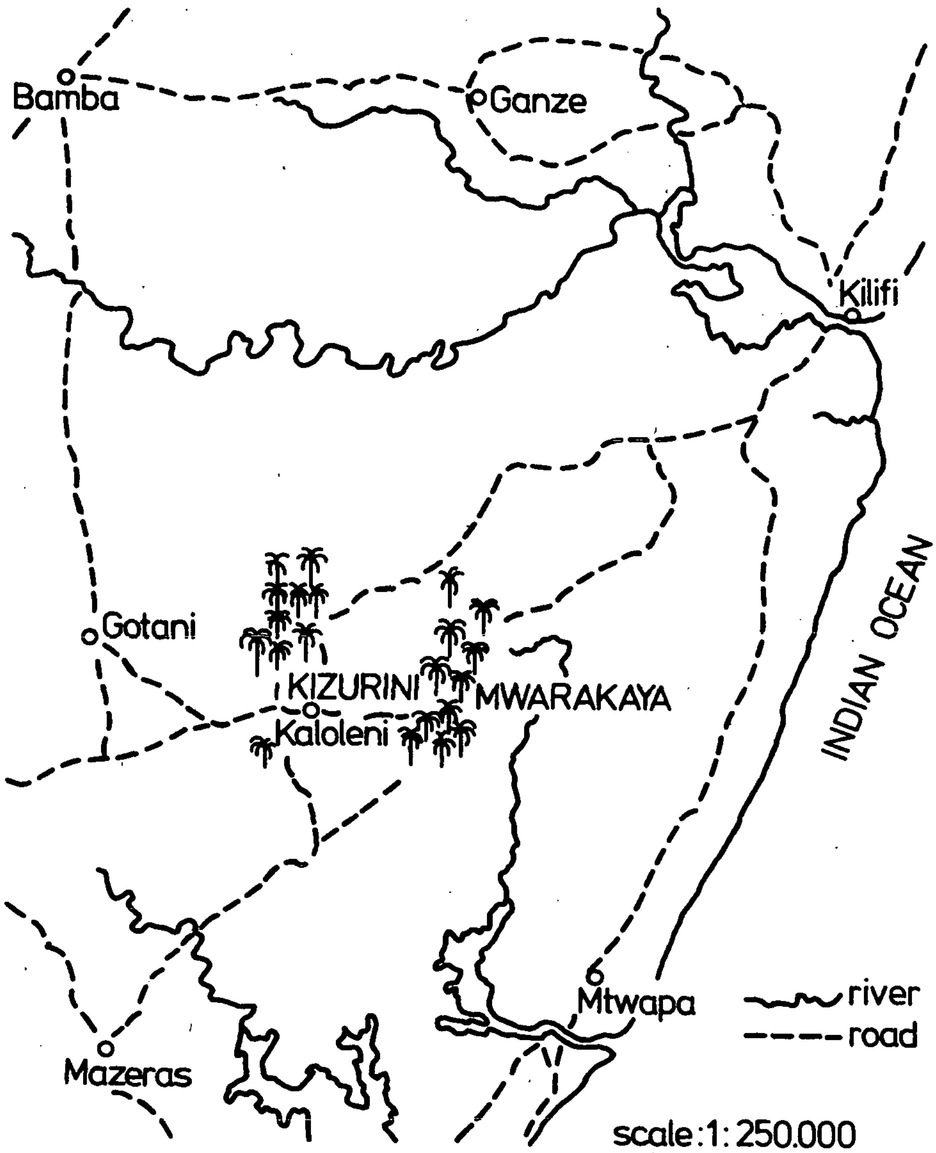

Figure 2: Location of the area of the coconut study.

2. LITERATURE REVIEW

This chapter deals with the following aspects:
- The coconut palm and its structure.
- The ecological requirements of the coconut.
- Mineral nutrition and fertilization.
- Intercropping with coconuts.

2.1 The coconut palm and its structure

This paragraph is largly based on the information given by Purseglove (1972). There are two varieties of the coconut palm (Cocos nucifera): the tall variety (nucifera) and the dwarf variety (nana). The coconuts studied belong to the tall variety, and are sometimes called "Kenya Tall" or "East African Tall" (Acland 1971).
The coconut tree, sometimes described as "the tree of Heaven" or as "one of nature's greatest gifts to man", is one of the most important tree crops in the world. The uses of the palm are numerous. It provides food, drink, oil, medicin, fibre, timber, thatch, mats, fuel, and domestic utensils. Copra (= dried endosperm) is the most important commercial product.
The main production area is South East Asia: Indonesia, Malaysia, the Philippines, Papua New Guinea and New Guinea. The coconut palm is also widespread in India, Sri Lanka, and on islands in the Pacific Ocean. It is less abundant in Africa, and mainly found in some coastal areas in West Africa (Ivory Coast, Benin, Nigeria) and East Africa (Mozambique, Tanzania, Kenya).
In Kenya, the total population amounts to 2.500.000 trees (1977), planted on about 30.000 ha (Van Eijnatten, 1979). The majority of the trees is found in the Kilifi District.

The structure of the palm:

- Roots: The roots of the coconut tree are adventitious, produced from the bole, which is the swollen basal 60 cm of the stem. The first roots tend to penetrate the soil vertically, subsequent roots usually spread horizontally. According to some authors (e.g. Nair, 1979) most roots are concentrated in the first metre of the soil, and within 1.5-2.0 m from the stem. This agrees with a study mentioned by Sumathy Kutty Alma and Chacko Mathew (1979) on the uptake of nutrients by roots with the aid of radio-active fertilizers. Other people stress the value and contribution of deeper roots.

It has been estimated that the coconut tree has 2000-3000 living main roots and numerous short rootlets; the latter being replaced during favourable conditions. Roothairs are absent. The absorption of water and nutrients takes place through a single layer of thin walled epidermal cells just behind the root cap. Oxygen for internal tissues is absorbed through white, cap-like structures or pneumathodes. Roots cannot tolerate stagnant water, but can continue to grow again after temporary water logging.

- Stem: The visible trunk is only formed when the palm is several years old. As there is no cambium, a trunk can only be formed when the apical meristem has attained its full diametre. The height of the stem increases rapidly in the 6-10 year pre-bearing period. Thereafter the stem maintains a slow steady growth until the onset of senility, when palms are 60-80 year old. Throughout the life of the palm, any check in the nutrient supply to the meristem, as may occur through partial defoliation, drought or other reasons will lead to a temporary or permanent reduction of the diametre of the trunk. The scars of encircling petioles are clearly seen when leaves have fallen.

- Leaves: A "normal" tree consists of 25-35 opened leaves and a central bud. The leaf primordia are differentiated about 30 months prior to emergence of lamina from the fibrous leaf sheath which encircles the bud and persists for some time until the leaf matures. The phase of rapid elongation takes 4-6 months and a fully mature leaf remains on the palm for 2.5-3 years before falling. An average adult palm has 8-10 leaves from which bunches have been harvested, 10-12 leaves supporting fruit bunches, and 10-12 opened leaves with axillary spadices. The number of leaves in the crown of an adult palm remains practically constant during its bearing life. In periodes of water shortage the oldest leaves suffer first and the rate of shedding may be higher than the rate of leaf production. Leaves are 4.5-6.0 m long and have 200-250 leaflets along the upper three quarters of the petiole. The rate of leaf production is controlled by age and vigour of the palm, the cultivar and environmental conditions. Menon and Pandalai (1958) report seasonal conditions, soil fertility, and cultural practises as important factors affecting the leaf production rate.

- Inflorescense (spadix): in regular bearers the rate of production of leaves and inflorescences is the same i.e. about 12 per year.
The inflorescense is monoecious with numerous male (200-300) and few (20-40) female flowers. The developing flowers are protected by two sheaths (spathe).

Due to pressure of the inflorescence inside, the spathe emerges but may fall off. The inflorescence consists of a central axis with up to 40 lateral branches with 1-3 female flowers at the base and many male flowers. The flowering is protandrous.

- The fruit: The mature fruit takes 12 months to mature and consists of:
  - the outer skin or exocarp, which is smooth and hard, and the fibrous layer or mesocarp (coir). These two form the "husk".
  - the shell or endocarp, which is hard and stony.
  - a single seed with a thin brown testa, closely appressed to the endocarp and adhering firmly to the endosperm (or meat).

The latter is initially liquid and becomes solid later on. The endosperm supplies the copra (= dried endosperm), from which the oil is extracted. Copra contains 60-68% oil. Locally, the oil is mainly used for cooking and making soap, while exported oil is used for the manufacturing of soap and margarine and some other products.

2.2 The ecological requirements of the coconut

Many authors (Menon and Pandalai, 1958; Child, 1964 and 1974; Pigot 1964; Frémond et al, 1966; Woodroof, 1979) discuss the ecology of the coconut tree. The ecological requirements can be summerized as follows:

- The coconut palm is a sun-loving tree. It needs at least 2000 hrs of sunshine per annum. When the palm is shaded it does not grow well and becomes excessively long and thin.
- The optimun temperature ranges from 24-28°C.
- The palm needs high air humidity of at least more than 60% and preferably 80-90%.
- The moisture requirements are high. In general, a well distributed annual rainfall of 1400-2300 mm is regarded as optimal. Grimwood (1975) gives as minimum 130 mm rainfall per month during the growing season and not more than three dry months per year. (A month is considered dry when there is less than 50 mm of rain). As mentioned in Chapter 3.2 the total annual rainfall in the Kilifi area lies between 1000 and 1200 mm. This means that the climatic conditions in the Kilifi District are marginal for coconut cultivation.

It is therefore of interest to know from literature what kind of influence water stress can have on the growth of coconuts. In the previous paragraph the effect of drought on the diametre of the trunk and early shedding of old leaves was already mentioned. Woodroof (1979) gives the following effects of water stress: yellowing of fronds, drooping of leaves, breaking of petioles, shedding of young nuts and buttons, abortion of spadices.
Fenwick (1961) reports the phenomenon that the old, dead leaves are not shed, but remain attached to the trunk. He also mentions a reduction in production of female flowers. Child (1974) adds to this list a reduction of nut size. Low rainfall can also result in nitrogen deficiency due to a reduction of the period in which mineralisation takes place and the absorbtion mechanism of the roots is active. Generally speaking water stress causes reduced growth and a drop in yield. The effects of drought become visible after 1.5-2 years, because of the time lapse between inflorescence initiation and ripening of the fruits.
As to physical and chemical conditions the coconut is not very demanding. The tree has a great adaptability and is grown on many types of soil. The six main soil types on which coconut occur are: sandy coastal soils, lateritic soils, alluvial soils, vulcanic soils, and peat soils. All textures are regarded as suitable, except for extremes such as: heavily leached sandy soils, strongly swelling and shrinking clays. Very alkaline or acid soils are also not suitable. Some generally accepted values of chemical soil characteristics as reported by Manicot et al. (1979/80) are given in Table 1.

Table 1 Critical chemical values for coconut soils (Manciot et al. 1979, 1980).

pH-water	: 5-8	K	: 0.15 - 0.20 (meq./100g)
org. C	: 1%	Mg	: 0.20 - 0.50 (meq./100g)
org. N	: 1‰	Mg/K	: > 2.5
p -Olsen	: 25 ppm	Sum of exch.bases	: > 1 meq./100 g

The value of 25 ppm P is probably not correct. Chapman (1966) gives as values of P -Olsen, low : less then 5 ppm; moderate : 5-11 ppm; high : over 11 ppm.

2.3 Mineral nutrition and fertilization

This paragraph is mainly based on the comprehensive articles of Manciot et al. (1979-80) on the mineral nutrition and fertilization of the coconut around the world. The following methods are used for studying the nutritional requirements of the coconut:

- whole plant analysis
- leaf or nut analysis
- soil analysis
- fertilizer trials

Whole plant analysis

Various research workers have studied the nutrient uptake of the whole palm. Their figures vary greatly. Reasons for these large differences can be attributed to environmental conditions, yield level of the palms, plant densities, methods of computation, and other factors (Nair, 1979).

The nutrient uptake of coconuts in kg/ha/year is given in Table 2. The uptake of different parts of the coconut was studied by Ochs & Ouvrier and by Khanna & Nair. Their results are presented in Table 3. The difference between potassium uptake of nuts and bunches is rather strange. The uptake of some other elements is given in Table 4.

Table 2 Nutrient uptake of coconut palms in kg/ha/year, as found by various research workers.

Author(s)		Plant density, yield	N	P	K
Jacob & Coyle	1927		64	29	95
Eckstein	'37		91	40	131
Cavalho	'47	156 palms/ha	104	36	126
Cooke	'50	144 p/ha, 25 nuts/p/yr	29	9	27
Pillai & Davies	'63		56	27	85
Ramadsan & Lai	'66	175 palms/ha	97	48	148
Khanna & Nair	'77	175 p/ha, 100 nuts/p/yr	157	28	288
Ouvrier & Ochs	'77	156 palms/ha, 1.5 t	95	9	117

Table 3 Annual uptake of nutrients for different parts of the coconut palm.

Authors	Part	N	P	K
Khanna & Nair (India)	Nuts only (175 p/ha) (100 nuts/p)	120	18	86
	Whole palm	157	28	288
Ochs & Ouvrier (Ivory Coast)	Bunches (6 t/ha)	94	30	210
	Whole palm	174	20	249

Table 4 Annual uptake of Ca, Mg, Na, Cl and S.

Author(s)		Ca	Mg	Na	Cl	S (Kg/ha/yr)
Georgie & Tain	'32	17	32			
Cooke	'50	14.5	22.5	4.5		
Ochs & Ouvrier	'78	70	39	54	249	30

The production of bunches requires annually 10-20 kg Ca, Mg, Na, S, while Cl amounts to 125 kg/ha.

Nut and leaf analysis

Nut analysis has a high variability and is therefore not often used anymore. Leaf analysis on the other hand proved to be the best and easiest way to study the mineral nutrition. The concentration of nutrients in the leaves varies with the relative position of the leaf and with the age of the palm. Concentrations of phosphorus and potassium are noted to drop with age, while calcium and magnesium contents increase. The 14th leaf is nowadays used as a standard leaf, as this leaf has reached the stage of physiological maturity and has not yet entered the phase of senescence (Frémond et al. 1966). For this leaf critical values have experimentally been established which are shown in Table 5. A critical value in defined as a value of a nutrient below which application of the appropriate fertilizer is likely to give an increase in yield (Frémond, 1966). There are two important aspects when comparing nutrient concentrations and critical values:

- The action on one element is not always independent of others and interactions have to be taken into account. This in the reason that Smith (1969) suggests to use ratios between elements.
- Climate conditions affect nutrient concentrations directly or indirectly (Coomans, 1974). This means that special periods of sampling should be chosen.

Nair (1979), referring to Chapman and Coténie and Richards and Bevege, mentions as disadvantages of foliar analysis:

- Nutrient concentrations in the leaf do not reflect the nutrient supplying capacity of the soil.
- The nutrient levels depend on a number of non-nutritional factors such as environment and plant characters.

Table 5 Critical values for nutrients in coconut leaves

Author/Country	Leaf nr.	Nutrient content (% of D.M.)					
		N	P	K	Ca	Mg	Cl
Frémond (1966)	1	1.7	0.17	1.7			
	6	2.5	0.16	1.3			
	11	2.4	0.14	0.8			
	16	2.1	0.12	0.6			
	21	1.9	0.11	0.5			
I.H.R.O. (1966)	14	1.8-2.0	0.12	0.8-1.0	0.3	0.024	0.05
Sri Lanka (1973)	14	2.0	0.13	0.8-1.0			
Kanapathy (1971) (Malaysia)	14	1.8	0.12	0.8-1.1			

Soil analysis

Besides the leaves also the soil on which the coconut trees are growing can be analysed. However, not many relations have been found between chemical soil characteristics and plant characteristics and yield. Therefore, as Child (1974) states, soil analysis is only useful when combined with foliar analysis. Chew (1978) summarizes some research that has been carried out on soil analysis and coconuts. Nethsinhe (1961), in Sri Lanka, was unsuccesful in finding differences in exch. Mg between sites with appearently healthy and affected palms at the same plantation. Saldago (1951) found no response to potash on soils with 0.2 meq exch. K. Where responses were obtained the exch. K level was 0.02 meq. In Jamaica no correlation was found between yield and soil N, K and pH. The pH was related to the rate of leaf production in one trial, and to bunch production in another.

2.4 Intercropping with coconuts

Intercropping with coçonuts is an old practice, but only recently research has taken interest in it. Intercropping has both technical and economic aspects. This paragraph is only dealing with some technical aspects, some economical ones are briefly summarized.

The incentive for intercropping is essentially an economic one (FAO, 1966). The Coconut Bulletin (1977) gives five reasons for intercropping (in India).

- as a means of increasing the number of sources of income
- as a means of income to rehabilitate neglected land

- as a means of income of new plantations/plantings
- improving soil conditions without much costs
- as a means of providing more employment.

The government of Sri Lanka (FAO, 1966) stresses the need for local food crop production in order to save foreign exchanges.
The choice of the intercrop depends on many factors: soil conditions, shade level, availability of water, local farmers' knowledge, size of (small) holding, availability of market, labour resources.

Nelliat and Khisshna (1976) give as most important factor in the choice of an intercrop the acceptability of the crop to the farmer. A crop that is staple food for the family would always get preference. Nair (1979), referring to Allen and Hartley, describes the requirements of the second or subsidiary crop. This crop should be:

- tolerant to partial shade
- not grow as tall as the main crop, and its rootsystem should exploit different soil horizons
- not be more susceptible than the main crop to diseases they have in common
- not have an economic life longer than the main crop
- the soil should be suitable fot both crops
- the combined yield should be greater in monetary terms, compared to the yield of the main crop
- there may not be an effect on the yield of the main crop, if the second crop comes to the end of its bearing life.

According to Nair, intercropping of coconuts is possible for the following reasons:

- only about 25% of the total area is utilized by coconut roots*, in a pure stand of coconuts at 7.5 x 7.5 m planting density and under normal management conditions, and
- the light transmission through the canopy amounts to over 40% in the first 6-8 years, see fig. 3.

* This is based on the assumption that the coconut roots are concentrated within 2 m of the trunk (see 2.1).

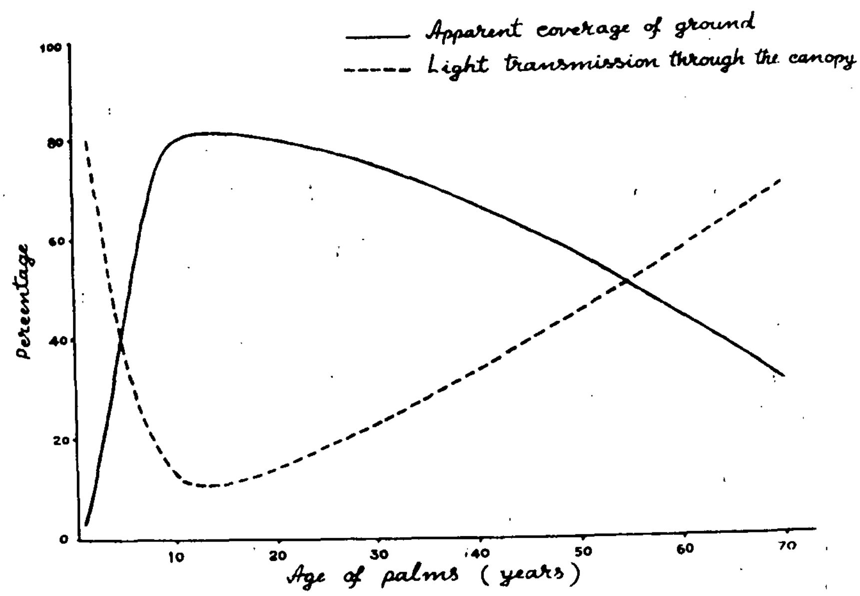

Figure 3: Apparent coverage of ground by coconut canopies of various age groups

To provide more space for the intercrop many authors suggest to plant at lower densities or to plant the coconut trees at closer spacing in the rows than between rows.

Crops grown as intercrop with coconuts

India:

annuals:	pulses, rootcrops, oil crops, spice crops, vegetables; in areas with low rain fall: finger millet, sorghum and maize
semi-annuals:	pineapple, sugarcane, passion fruit, pastures
perennials:	cocoa, coffee, pepper, mulberry

Malaysia:

on estates:	cocoa
on smallholdings:	banana, pineapple, cassava, yam, vegetables, rice, pasture, betel leaf, sugarcane, maize, tobacco and fruit trees

Papua/New Guinea: coffee, cocoa and pasture

Sri Lanka:

on estates:	cocoa, rubber, pasture
on smallholdings:	arecanut, kitul*, mango and jak**, citrus, banana, pineapples, yams and vegetables.
The Philippines:	rice, maize, cassava, camote, abaca, sweet potatoes, banana, lanzones, cocoa, coffee and citrus
Brasil:	cassava
Pacific Islands:	pasture and cocoa
East Africa:	cassava, maize, peas, beans and pasture.

Nair (1979) stresses the importance of tubers as intercrop, as these are rather shade tolerant. Also grain legumes have to be considered because of their short growing period and high protein output. However, these crops are in general affected by shade. Child (1974) discourages the growing of sweet potatoes, groundnuts and soyabeans as they attract rats. He reports succesfull growing of cassava in Sri Lanka during the Second World War. In general, intercropping is less practiced on estates then on smallholdings, where income is needed during the period the coconuts are not yet productive.

Yields under coconuts

As mentioned in the introduction information on intercropping is rather scarce. This is particulary true in respect of yield data of the intercrop. An exception is cocoa but as this crop is not grown in Kilifi it is not considered. The yield of some rainfed intercrops in Karasgagod, India is given in Table 6 (Nair, 1979). Other promising crops are pineapple and banana.

* Probably Fish-tail or Toddy palm (*Caryota urens* L.).
** Probably Jack bean (*Canavalia ensiformis* L.).

Table 6 Yield of some rainfed intercrops in Karasgagod, India.

Crop	Yield (ton)	Net area of intercrop (%)	Net return per unit cost
Yam (Elephant foot)	13.46	70	1.39
Cassava	14.82	75	1.52
Sweet potatoes	8.38	70	0.93
Ginger	8.61	70	1.92

In Malaysia, at the MARDI station in Hilar Perak (Denamany et al. 1979) and on some selected smallholdings some experiments have been started in 1975. The coconuts were about 40 years old and were planted 9 m in a triangle. The yield of the different crops (in kg/ha/yr) was:

Coconut:	850-900	Pineapple:	7550-10060
Banana:	600-745	Coffee:	445-570
Maize:	3000	Cocoa:	440-670

Taking prices and costs of production into consideration, shallots provided the best income to the farmer, followed by chilli and tomatoes. Maize and pineapple gave the lowest additional income to the farmer.

Effect of intercropping on the growth and yield of coconuts

According to Denamany et al. (1979) intercropping with perennial or short-term crops had no adverse effect on the yield or growth of coconuts. But in the past many coconut experts (Sampson, 1923; Copeland, 1931; Child, 1964) were against intercropping. In Malaysia (FAO, 1966), an increase in yield of coconuts of 30% has been recorded with the introduction of cocoa as intercrop. In India, Karasgagod, (in 1975) an experiment was started with five different intercrops (cassava, yam, sweet potatoes, ginger and turmeric). The results so far show that the female flower production, setting percentage and yield of coconuts were not adversely affected. In this experiment both main and intercrop are fertilized and are well managed (Nair, 1979).

Benificial effects of intercropping can, to a certain extent, be attributed to the regular cleaning and weeding of the planting. In this respect it is worthwile to mentions two studies, which had nothing to do with intercropping, but studied the effect of clearing. Charles (FAO, 1969) in a report on coconut establishment trials in New Guinea, reports that clean weeding compared to slashing of weeds around coconut seedlings, resulted in 90% better growth of the seedlings. Regular slashing gave better growth than infrequent slashing. Pandalai and Krishna Mara (1964) studied the influence of ferilization and cultivation on the yield of coconuts in India. Over an observation period of 25 years they found that the yield of coconuts on fertilized and cultivated plots amounted to 56.6 nuts per tree per year, on only cultivated plots 48.2 and on neglected plots 15.3. Child (1974) reports benificial effects of soil cultivation.

3. GENERAL INFORMATION OF THE AREA STUDIED

3.1 Location and population

The study took place in the Kizurini and Mwarakaya area near Kaloleni which is located at 3°50' south and 39°20' east in the Southern Division of Kilifi district (figure 1 and 2). The areas are covered by the topographic map, sheet Mazeras 198/3, scale 1:50.000.
Kaloleni is the administrative centre and also the site of the main market. The area is densely populated by people belonging to the Giriama tribe.

3.2 Climate

The climate is of the monsoon type, with a bimodal rain distribution pattern. The temperature is rather constant during the year; average minimum and maximum temperature are about 22° and 30°C respectively.
Hours of sunshine amount to 7-8 hours/day, with lowest values in the two rainy seasons (April to July and October-November). The total amount of rainfall does not differ much between the two areas. The Kizurini Area has a rainfall of 900-1100 mm/year, the Mwarakaya Area recieves 1000-1200 mm/year. The mean monthly rainfall (mm) for Kaloleni Station over 11 year period (1967-1978) is given below.

J	F	M	A	M	J	J	A	S	O	N	D	total
31	25	43	121	175	102	77	81	96	141	134	62	1088

The potential evapotranspiration is high, 2000-2200 mm/year. In terms of the U.S. Soil Taxonomy the soils have an ustic soil moisture regime and an isohyperthermic temperature regime.

3.3 Geology and geomorphology

Geologically the two areas are part of a large system of Mesozoic sedimentary rocks, deposited against the "African Shield". The Kizurini area consists of the so-called Mariakani Sandstone, of Triassic age. The Mariakani Sandstone are fine grained, deltaic and lacustrine, sandy deposits. They can be devided into Upper, Middle and Lower; the area under study consists of the Upper Mariakani Sandstone. The Mwarakaya Area consists of the so called Kambe Limestone. This limestone is of Jurassic age.

Both areas are part of the coastal uplands. The limestone forms a plateau, bordering the shales. Many typical karst features can be observed in this area, including hums and dolines. The topography is undulating, with deeply incised rivers and streams. Altitude ranges from about 120 m in the South, to 215 m in the North. Within the sandstone area some levels can be observed with differences in soil development. (P. Oostrom, personal communication). It is beyond the scope of this study to discuss this in more detail. The observation plots are located on the two lowest levels, at altitudes ranging from 215 m to 260 m. The topography is rolling.

3.4 Soils

As pointed out in the introduction two soil types are taken into account and these will be discussed in this paragraph.

A. Soils developed on Kambe Limestone

The soils developed on the Kambe Limestone are in general deep to very deep soils. Shallow soils only occur in the direct surroundings of limestone outcrops ("hums"). The soils are well drained. The limestone soils have a 35-70 cm thick topsoil (A_1 of 15-30 cm; B_1 of 20-40 cm). The colour of this topsoil is reddish brown or weak red, and the textures range from silty clay loam to clay.
The sub-soil (B_2 or B_{2t} horizon) has yellowish red to red colours and a clayey texture. Signs of clay eluviation are frequently present (clay skins). The structure of the sub-soil is weak to moderate, fine angular blocky. Most profiles have some gravel and some sand admixtures in their top soil, while locally profiles occur that are gravelly throughout the profile.

The few chemical data available show a low nutrient status and especially a low nitrogen and phosphorus content (see 5.4.). The mapping unit of this soil on the Preliminary Reconnaissance Soil Map is: UL 1. (see Floor et al., 1980). On the detailed soil map of the Kaoleni Sample Area the soils are mapped as: ULcC 1 and ULcC 2 (Ligthart, 1981). The soils are classified as: eutric Nitosol (FAO) and udic Paleustult (USDA).

B. Soils developed on the Mariakani Sandstone

The soils developed on the Mariakani Sandstone are very deep and are well to excessively drained. In general they are intensively weathered and show a weak profile development. The top soil, 15-50 cm thick, has light yellowish brown to dark brown colours and sandy or loamy texture. The sub soil has colours ranging from brown to light red. Generally, the more sandy profiles have brownish colours, and the more loamy profiles reddish colours. The texture of this subsoil ranges from sand to sandy loam, locally sandy clay loam. The structure is a single grain structure or weak, medium subangular blocky. These soils are even lower in nutrients than the limestone soils except for phosphate (see 5.4).

On the Preliminary Reconnaissance Soil Map the sandstone soils are mapped as USK 1. (Floor et al., 1980). On the detailed soil map of the Kaloleni Sample Area the soils are mapped as USbf (the loamy sand soils) and UScC3 (the sandy loam soils) (Ligthart, 1981). The classification of these soils is: distric arenic* Nitosol and albic Arenosol (FAO) and oxic Paleustult and ustoxic Quartzipsamment (USDA).

3.5 Land use

A. The Mwarakaya Area.

This area has a very high population density (up to 210 inhabitants/km^2) and all the land, except for the sacred places, the so-called Kaya Forest, is under cultivation. The settling of people started a long time ago, and due to inheritance, which mostly involves partitions of the land among the sons, the farm size is small (2-10 acres).

Coconut is the main tree crop in the area followed by cashew, mango and citrus. The relative distribution is: approximately coconut 55%, cashew 25%, citrus 15%, and mango 5%. Coconuts are mainly grown mixed with cashewnut trees or with foodcrops as intercrop. Pure stands of coconuts are rather rare. Maize is the main foodcrop, followed by cassava. Sim-sim, bananas, and cowpeas are also grown. Foodcrops are mostly grown in a mixed cropping system. Some fields are cultivated each year, others are cropped for two years and are left under fallow for at least two years. Most farmers have a flock of poultry and one or more goats which graze under the coconuts. Only very few farmers have cows.

B. The Kizurini Area.

This area has a smaller population than the Mwarakaya area (120 inhabitants/km^2). Settling of people started in the beginning of this century. As a result the

* Arenic suborder proposed by K.S.S. and T.P.I.P.

farm size is much larger (10-30 acre), and also due to the somewhat drier conditions, the lands are less intensively cultivated.
Also in this area coconut is the main tree crop, but there is more cashew compared to the Mwarakaya Area. The relative distribution is approximately: coconut 60%, cashew 30%, and mango and citrus 10%. Maize and cassava are the most important foodcrops. They are grown in a mixed cropping system, with or without tree crops. Fields have usually a fallow period. In some places pure stands of coconut and cashew are found. Grazing is more important in this area and most farmers have some goats and cows (see also Mulder & Smaling, 1980).

4. MATERIAL AND METHODS

4.1 Data on coconuts in the Kaloleni area ("the material")

In this paragraph some aspects of the coconuts in the experimental plots are discussed, which mainly refer to the agronomy and occurrence of pests.

4.4.1 Some aspects of the farming- and cropping systems

A. Mwarakaya Area

Coconuts are the main tree crop on the small scale farms (2-10 acre). Intercropping of coconuts with food crops and other tree crops is practised in most holdings. Food crops are sometimes grown in rotation with a two year fallow. Therefore it was rather difficult to find proper "bush-plots" as described under 4.2. The men are looking after the tree crops, while the women are dealing with the food crops. The most common management practice includes the clearing of the undergrowth. This is done one to three times per year depending on future use of the field, availability of labour and/or capital. The part on which the family intends to grow food crops during the next rainy season is cleared thoroughly during January or February. The weeds and other vegetation are thrown on heaps and burned.

Mulching with old leaves and husks is not common. Goat (or cow) dung is hardly used as manure except sometimes for young plants.

Plant density of coconuts varies largely. The average plant density, as found in this study, is:

A. Coconut with food crops : 100 trees/ha.

B. Coconut with tree crops : 90 trees/ha.

C. Coconut with bush : 90 trees/ha.

Where coconuts were grown together with tree crops, the following ratios were found, coconut : cashewnut : mango and citrus = 10 : 7.5 : 2.5. The spacing between the coconut (and other) trees is very irregular. Palms of different ages are found in the same plot.

Generally speaking there are very tall trees (over 20 m high, and 70-80 years old) in and in the direct surroundings of the vilages (e.g. Mwarakaya and Mbuyuni) and lower trees (± 10 m high, and 30 years old) outside the villages.

This indicates, as confirmed by some farmers, that to a certain extent (re-) settlement took place in the early fifties.

About 5% of the nuts are harvested for consumption ("dafu"), and the rest for copra production. Coconuts for copra production are plucked in "mnazi" or "mbata" stage. The harvesting time differs from farm to farm. Some farmers only harvest during January and February, while others harvest the whole year round (monthly or bi-monthly). In general nuts are not plucked during the rainy season, because of lack of sunshine to dry the copra. Some farmers, however, send their nuts to Mombasa or try to dry the copra over open fires. Nuts are dehusked with a stick with a sharp point, fixed into the soil. The husks are used for firewood. After the dehusking the coconuts are split, water is drained out and the two halves of the split nuts are placed on the bare soil for sun drying; after two days the endocarp is removed and drying is continued for 2-4 days.
The tapping of trees is discussed in paragraph 4.1.3.

B. Kizurini Area

Also in this area coconut is the main tree crop. The farm size ranges from 10-30 acres. Probably due to farm size and less favourable soil and climate conditions, intercropping is less practised. A considerable part of the holding is left under weeds and is grazed. Food crops are mostly grown in rotation with 2-3 years fallow, but there were also fields on which maize was grown for 5 consecutive years.

Plant densities are comparable to those in the Mwarakaya area:

A. Coconut with food crops	: 100 trees/ha.
B. Coconut with tree crops	: 90 trees/ha.
C. Coconut with bush	: 90 trees/ha.

The difference in plant densities between the "food crop" and "bush" plots is remarkable. This probably means that "bush" plots are not "food crop" plots in a fallow phase, but plots which for some reason have been neglected for a long period and where no rejuvenation has taken place.

The ratio between coconut trees and other tree crops (in case B) amounts to: coconut : cashew : mango and citrus = 10 : 6.5 : 1.
The number of nuts ("dafu") used for consumption is also about 5% in this area.

Harvesting is done the whole year round, except in the rainy season. It was impossible to get yield data from the farmers.

4.1.2 Pests

Two major pests were observed in the area: The rhinoceros beetle, (Oryctes monoceros, Oliver; family Scarabacidae) and the coconut bug (Pseudotheraptus wayi; family Coreidae), the local name for this bug is "maji moto ant", which is in fact incorrect because this ant (Oecophylla) is the predator of the coconut bug. The rhinoceros beetle, a 4.5 cms long and 2 cms wide, dark-brown beetle, lays its eggs in the rotting wood of dead (coconut) trees. The adult beetle attacks the terminal buds in the crown. Usually, the beetle does not reach the centre of the bud, which is the actual growing point, but eats its way to an exit on the side of the bud. In this case the new leaf can unfold but shows V-shaped incissions in the leaf. When the beetle reaches the centre of the bud, the tree is killed. A bare trunk with no leaves is the sad remnant of such an attack. The control of the rhinoceros beetle is not easy. Most promising is the removal of decaying coconut logs and boles. In general this is rarely done. Observations on rhinoceros beetle attack are given in Table 7.

Table 7 Percentage of observed trees with signs of rhinoceros beetle attack (n = 180).

	no signs	1-3 leaves shaved	3-6 leaves shaved	over 6 leaves shaved	only trunk left
% of observed trees	30	50	15	5	< 1

The coconut bug is also a major pest. The bug attacks the very young nuts causing them to drop off or the development of abnormally shaped nuts. These nuts show longitudinal scars and contain no or very little copra of a very poor quality.

Observations on coconut bug damage on the nuts of the one but last inflorescence are given in Table 8.

Table 8 Percentage of trees with nuts on the one but last inflorescence with signs of coconut bug effects (n = 180).

	no signs	less than 33% of nuts affected	33-66%	over 66%
% of observed trees	30	25	15	30

No observations were made on the severity of the damage. Slightly affected nuts can still contain a considerable amount of copra. No control measures are taken. It is said that the predatory ant, Oecophylla, could help in the control. This ants prefers cashewnut- and citrus trees, but this study did not show any differences in damage incidence between cashew plots and the other plots.
The fact that there are less missing inflorescences between the leaf with the first and the last inflorescence in the combination coconuts with cashewnut trees than in the other combinations (Table 10) might, however, indicate some degree of control by the predatory ant.

4.1.3 The tapping of coconut trees

Tapping of coconut trees is very common in the Kaloleni area; about 5-15% of the total number of trees is tapped. The palmwine (toddy) is used for own consumption or is sold to middlemen, who transport it to the Mombasa and Voi markets twice a day.

The method of tapping is as follows. The still unopened spathe is prepared by brushing it and is tightly bound round with the short leaflets of the corresponding frond. After two to three weeks the inflorescence is ready to produce palmwine. A little cut is made in the top of the spathe which is gradually bent. A calabash is placed on the top of it and emptied twice a day. Tapping of one spadix may continue for 3-4 weeks. Some farmers tap the tree during its whole life period, while others only tap for three to four years consecutively. According to the farmers there is a large difference in toddy production between trees. Some are very suitable for tapping, others are not. Wine yields are difficult to give. According to most farmers, a tree produces one to two bottles palmwine (0.5-1 l) a day.

Trees are tapped by the farmer himself, his sons, hired people. One man can tap up to 25 trees a day. Trees which are or have been tapped can easily be recognized. They have steps, cut in the trunk, and the short leaflets at the base of the fronds are missing and when being tapped, the spathes are bound and provided with a calabash.

The influence of tapping on future copra yields is not known. The absence of female flowers after a long period of tapping has been reported by Pendalai and Menon (1957).

4.1.4 The type of the coconuts

As mentioned in paragraph 2.1 the coconuts in the Kaloleni area are referred to "Kenya Tall" or "East African Tall". In respect of "girth of the trunk" and "number of leafscars per metre" they are related to the "Mozambique Tall" coconut (de Nucé de Lamothe & Wuidart, 1979). (See also 5.1.1 and 5.1.2).

An important characteristic of a coconut tree is its fruit colour and shape. No detailed observations were made on these fruit characteristics. The colour of the fruits was usually green and its shape oblong.

Some farmers mentioned that trees with orange-brown fruits were better (regularly high yielding) trees than the ones with green fruits.

Comparison of the nut characteristics (% of husk material) with the findings of Harries (1978) shows that the Kenya Tall is related to coconuts which are also grown on the Atlantic Coast of West Africa, in India and Sri Lanka, and on the Seychelles. According to Harries they belong to the "Nia kafa" type, which means that the nuts have a high percentage of husk material (± 50-60%), and are naturally evolved. This in contrast to coconuts with 30-40% husk material, which are supposed to have resulted from deliberate selection.

4.2 Field methods

The relationships between coconuts and soil types and interplanting/undergrowth types were studied in 60 plots: 30 on the Kamble Limestone and 30 on the Mariakani Sandstone. On each plot three trees were described. The 30 plots per soil type comprised three groups of 10 plots, each group representing a different interplanting/undergrowth type.

A. Coconuts with foodcrops

These plots have been cultivated with food crops for at least two years (1978 and 1979), in most cases with one crop a year. Of the area under food crops 50% of the land is used for maize, 30% for cassave, 15% for cowpeas and sim-sim and the remaining land for other crops such as bananas, pigeon peas and vegetables. Cleaning, slashing and burning is done 1 to 3 times a year. When there are no food crops on the field goats are grazing under the coconuts. Some other tree crops, such as cashewnut trees, mango or citrus may occur, but these are always less then 15% of the total number of trees on the plot.

B. Coconuts with cashewnut trees

The undergrowth on these plots mainly consists of grasses and herbs, or the ground is bare. There is not enough light for cultivation of food crops. The undergrowth is cleared once a year. Sometimes goats are grazing under the trees. The ratio coconut trees/cashewnut trees varies from 1:2 to 2:1. The cashewnut trees are usually 10-25 years old.

C. Coconuts with bush undergrowth

As bush plots are considered plots on which for at least two years no food crops have been grown. On most bush plots there were no food crops during the last three years. The vegetation predominantly consists of shrubs, mainly Lantana camara. There is usually extensive grazing.

In this study a plot is a part of a smallholders' coconut planting. Depending on the uniformity and size of the holding plot sizes of 0.1 to 0.2 ha were used. A pre-survey showed that the description of the characteristics of only three coconut trees per plot and ten plots per combination was sufficient for reliable statistical calculations of most of the plant characteristics. However, there were two exceptions: the number of female flowers on the youngest opened inflorescence and the number of nuts on the one but last inflorescence. As to the first exception it was impossible to increase the number of trees per plot as this required a lot of extra time which was not available. In case of the nuts the number of observations was increased to 20 trees per plot. However, in some cases it was impossible to find twenty suitable coconut trees in one plot. In these cases nuts were counted on as many trees as possible.

It was tried to select the trees in the plots at random but some factors made this difficult:

- The palm climbers could not enter the crown of a tree if this was very dense at its base or if the tree was inhabited by sting flies.

- It was impossible to make a proper groundcheck of the number of leaves etc. if the tree was more than 15 m high. In this case also the counting of the number of leafscars would have taken two much time.
- As also nut characters were studied, trees with mature nuts had to be selected.
- In many cases the trees on one plot were owned by different owners. It turned out to be very difficult to contact even one of the owners for permission to carry out observations. This reduced the number of trees which could be used.
- Trees with a very poor performance, probably caused by factors which were not part of this study, had to be left out.

The trees eventually selected were growing in plots on soil types and with the undergrowth described above. They were 7 to 12 metres high and not growing too close to each other. The trees were described using a "Plant Character Observation Sheet", based on the type which is in use at C.A.R.S. at Mtwapa.

The characteristics that were measured are supposed to give information on the growing conditions of the coconut tree. Factors effecting these characteristics are partly discussed in Chapter 2 and will be discussed furthermore in the paragraphs dealing with the individual plant characteristics.
Of each tree the following characteristics were recorded:
- Girth at 170 cm from the surface
- Height of the tree up to the base of the crown
- Total number of leafscars
- Total number of leaves
- Rank number of the leaf with the youngest inflorescence
- Rank number of the leaf with the oldest inflorescence
- Total number of inflorescences
- Total number of female flowers on the youngest opened inflorescence
- Number of nuts on the one but last inflorescence
- Length of one leaf (last)
- Length of longest leaflet
- Number of leaflets (one side only)

The last three items are less important.

Besides the observations of plant characteristics also two mature nuts ("mnazi" stage) were plucked. However, several trees appeared to have only one nut or

even none. Nuts severely damaged by the coconut bug (see Paragraph 4.1.2) were not collected.
The damage caused by this bug to nuts and by the rhinoceros beetle to the trees was also recorded. In case of rhinoceros beetle attack the grade of attack was recorded in terms of number of leaves that showed the characteristic V-shaped incisions. The effect of the coconut bug was assessed in terms of number of affected nuts on the one but last inflorescence.

A leaf sample was taken from each tree according to the standard method of the I.H.R.O. (Frémond, 1975): six leaflets, three on each side of the leaf, taken from the middle part of the 14^{th} frond. From each of these leaflets a 10 cm long part on either side of the mid-ribs was taken. The material from 6 leaflets was combined in one sample.
Soil sampling took place at 1.50 m distance from each recorded trees. Sampling depth was to 15-50 cm. The soil samples of the three trees were combined in one sample per plot.
The farming and cropping systems were studied with the aid of a questionnaire shown in Appendix 1-c. The tree density was calculated by counting the number of coconut trees (and other trees) on a selected part of the holding.

4.3 Laboratory methods

4.3.1 Water and copra content of the nuts

Weights of the husk, nut water, endocrap, and copra were determined at the TPIP Laboratory at Kilifi. In total some 300 nuts were collected. About 15% turned out to be too young or were too much affected by the coconut bug. The observations included:

- the weight of the fresh fruit
- the weight of the nut after the removal of the husk
- the weight of the nut without the nut water
- the weight of the fresh copra
- the weight of the dry copra

A copy of the record sheets is given in Appendix 1a.

In the beginning samples were dried in an oven at 80°C for 40 hours. As this period was too short the drying period was extended to 52 hrs.

4.3.2 Leaf analyses

Leaf samples were cleaned and dried at the TPIP Laboratory at Kilifi. Cleaning was done by hand, by washing the samples with water and rinsing with demineralised water. The samples were dried at 70°C during 24 hours. In total 90 samples were analysed at the laboratory of the Department of Soils and Fertilizers of the Agricultural University at Wageningen, the Netherlands. Analyses included: nitrogen, nitrate, phosphorus, potassium, sodium, calcium, magnesium and chlorine. The methods used for the chemical analyses are basically those in current use in most international laboratories.

4.3.3 Soil Analyses

Air dried soil samples of 500 gr each were sent to the Netherlands, and lateron also analysed at the Department of Soils and Fertilizers in Wageningen. In total 16 soil samples (9 from the Kambe Limestone and 7 from the Mariakani Sandstone) were analysed for: pH, total nitrogen and available phosphate.

4.4 Statistical methods

To find out whether soil and/or type of intercropping/undergrowth had a significant effect on plant characteristics and nutrient contents of the leaflets an analysis of variance was carried out. Differences between pairs of means were tested for significance according to the sequential Newman-Keuls method (Snedecor and Cochran, 1967).
The analysis of variance was set out as shown below. Analysis of variance was not carried out when the largest variance of a combination divided by the lowest variance of a combination was more than three.

Variation	df	remarks
Correction	1	Soils and i/u were tested against
Soils	1	plots
i/u	2	
Soils x i/u	2	
Plots	54	Plots were tested against trees
Trees	120	

5 RESULTS AND DISCUSSION

5.1 Plant characteristics in relation to soil and intercropping

The average values of each characteristic are presented in Table 9. The individual plant characteristics are discussed in separate paragraphs.

5.1.1 Girth at 170 cm from the soil surface

The girth of a tree depends on genetic and environmental factors. A study in the Ivory Coast (de Nucé de Lamothe & Wuidart, 1979) showed that four different varieties of coconuts of about the same age and uniformly treated, show remarkable differences in girth of the stem at 150 cm from the soil surface: West African Tall has a girth of 85 cm, Polynesian Tall 92 cm and Mozambique Tall and Malaisian Tall 100 cm. The effect of the environment is discussed on page 5.

In this study the effect of soil is significant ($P < 2.5\%$), as well as the effect of plots ($P < 1\%$). The combination sandstone/bush turned out to have a significantly larger girth than all the other combinations ($P < 5\%$).

5.1.2 Number of leaf scars per metre

Also the number of scars per metre depends on genetic and environmental factors. In the study in Ivory Coast already mentioned, Polynesia Tall coconuts had 25.5 leafscars between 1 and 2 m from the soil surface, Mozambique Tall 15.5, and West African tall and Malaisian Tall 13.3 and 13.8 respectively.
Effects of environmental factors have been reported by Fenwick (1961). He found that coconuts growing under optimal conditions had 13 to 39 leafscars per metre, but that this number was reduced to 3 (!) if the coconuts were growing under shade.

The figures in Table 9 are the average number of leafscars per metre for the whole trunk. Also here the effects of soil and plot are significant ($P < 5\%$). The Newman-Keuls test showed that the combination limestone + food crops has more leafscars/metre then the combination sandstone + cashew.

Table 9 Average values of plant characteristics and results of sequential Newman-Keuls Test.

Characteristic	LIMESTONE			SANDSTONE		
	food crop	cashew	bush	food crop	cashew	bush
code	IA	IB	IC	IIA	IIB	IIC
1	96 a ±13	96 a ±12	97 a ±10	99 a ±12	100 a ±12	106 b ±13
2	17.74a ± 2.33	16.29ab ± 2.84	16.39ab ± 2.90	16.05ab ± 2.92	15.20 b ± 2.92	16.15ab ± 3.33
3	29.97a ± 3.01	29.27ab ± 3.52	26.00d ± 4.44	28.50abc ± 3.66	27.23bcd ± 3.95	26.70cd ± 3.72
4	7.90a ± 0.76	7.63a ± 0.67	7.53a ± 0.77	7.77a ± 1.00	7.95a ± 0.83	7.37a ± 1.07
5	25.33ab ± 2.81	24.05b ± 4.46	±22.77b ± 4.01	27.27a ± 3.34	24.50b ± 4.60	24.43b ± 4.26
6	15.13b ± 2.60	14.37b ± 3.41	12.70c ± 2.67	17.17a ± 3.31	15.20b ± 3.91	14.97b ± 2.87
7	37.00 ±31.77	32.67 ±28.34	33.03 ±44.93	55.23 ±67.60	44.90 ±49.64	25.57 ±20.51
8	4.75b ± 0.65	5.05a ±0.43	5.02a ± 0.60	5.36a ± 0.57	5.27a ± 0.58	5.11a ± 0.59
9	111.6 ab ± 9.83	107.2 abc ± 7.97	112.7 a ± 8.63	106.0 bc ± 8.09	104.2 c ±11.27	110.2 abc ±10.43
10	136 ab ±14	141 a ±10	133 bc ±14	140 a ±14	140 a ±14	129 c ±14

Newman-Keuls Test: values followed by the same letter do not differ significantly.

1 : Girth at 170 cm (in cm)
2 : Scars per metre
3 : Number of leaves
4 : Rank number of leaf with youngest inflorescence
5 : Rank number of leaf with oldest inflorescence
6 : Total number of inflorescences
7 : Number of female flowers on youngest opened inflorescence
8 : Length of one leaf (last) (in m)
9 : Number of leaflets (one side only)
10: Length of longest leaflet (in cm)

** Standard deviation (S.D.) is refering to individual palms; S.D. of the soil/ intercropping combination is $\frac{S.D.}{\sqrt{n}}$

It is remarkable that these two characteristics associated with the trunk, together with the length of the last leaf, are the only ones which are not influenced by the type of intercropping, but only depend on the type of soil (and plots).

5.1.3 Total number of leaves

The number of leaves is an important indication for the growing conditions of a tree. Analyses of variance showed that the effect of type of i/u was highly significant ($P < 0.5\%$) and that the effect of soil and the interaction between soil and intercropping were significant at only 10% level.
The combination limestone + food crops had significantly more leaves than the combinations limestone + bush, sandstone + cashew, and sandstone + bush. Combination limestone + cashew had significantly more leaves than combinations limestone + bush, and sandstone + bush. Combination sandstone + food crops had significantly more leaves than combination limestone + bush ($P < 5\%$).

5.1.4 Rank number of leaves with youngest inflorescence

This, and the following two plant characteristics were recorded to calculate the number of inflorescences that are missing between the leaf with the youngest and oldest inflorescence. Analyses of variance showed that only the type of intercropping effect was significant ($P < 10\%$). None of the combinations appeared to be significantly different form another.

5.1.5 Rank number of leaves with the oldest (living) inflorescence

Analyses of variance showed that the effect of type of intercrop was highly significant ($P < 0.5$), and to a lesser extent the effect of soil ($P < 5\%$). Combination sandstone + food crops differed significantly from the combinations limestone + cashew, limestone + bush, sandstone + cashew, sandstone + bush.

5.1.6 Total number of inflorescence

The total number of inflorescences is also an important plant characteristic. Environmental factors effecting this characteristic are discussed in paragraph 2.1, 2.2 and 2.3.

According to the analyses of variance the observed differences can be attributed to the soil and intercropping effect (P < 0.5%) and to the plot effect (P < 5%). The combination sandstone + food crops turned out to have significantly more inflorescences than all the other combinations, while all combinations had significantly more inflorescences than the combination limestone + bush (P < 5%).

5.1.7 Number of female flowers on the youngest opened inflorescence

The main environmental factors effecting the number of female flowers are drought and malnutrition.
No analyses of variance of the number of female flowers in Table 9 was done, because of the large differences in the variances of the various combinations. There were large variations in number of female flowers between trees in the same plot. The figures indicate that the trees on the Sandstone had more female flowers than the trees on the Limestone. The effect of the different types of intercropping seemed to be present on the Sandstone, but absent on the Limestone. On the Sandstone some trees were observed without any female flowers on the youngest opened inflorescence.

It is interesting to see that the trees on the Kambe Limestone tend to have in general more leaves than the trees on the Sandstone, but that the opposite is true in respect to the number of inflorescences (and number of female flowers). Normally each inflorescence is corresponding with one leaf. There are two reasons: a) the lower leaves of the trees on the Kambe Limestone have no inflorescences, b) there are more inflorescences missing between the youngest and oldest inflorescence on the Limestone than on the Sandstone, see Table 10 (figures derived from data of Table 9).

Table 10 Number and relative percentage of missing inflorescences between youngest and oldest inflorescence.

	LIMESTONE			SANDSTONE		
	+ f.c	+ c	+ b	+ f.c.	+ c	+ b
Inflorescences missing	3.3	3.0	3.5	3.2	2.5	3.0
% missing of potential infl.	17.9	17.2	21.6	15.6	14.2	16.6

The average loss on the Limestone is 18.9%, while the loss on the Sandstone amounts only up to 15.5%. Remarkable is also the smaller loss when coconuts are interplanted with cashewnut trees: 15.7% on the average, against 16.8% and 19.1% when they are intercropped with food crops or having a undergrowth of bush respectively. This might be explained by the presence of a predator of the coconut bug in cashewnut and citrus trees. (The coconut bug attacks the young nuts, causing them to drop and a die-back of the whole spadix). This view is not confirmed by observations on affected nuts on the one but last inflorescence and the number of nuts on that inflorescence.

The loss of an inflorescence can be caused by an abortion of the spadix in an early stage or severe shedding of young, immature nuts ("button shedding"). Woodroof (1979) gives some reasons that cause "button shedding": poor bearing capacity, severe drought, nutritional deficiency (N,P,K), poor soil conditions and diseases. Severe drought can cause the abortion of the whole spadix.

The figures on inflorescences of Table 9 and 10 might indicate that trees on the Limestone suffer more from drought than trees on the Sandstone, and that as a result of this tree tries to survive (in first instance) by a higher production of vegetative parts against generative parts. The latter has also been observed with oil palm (Hartley, 1976).

5.1.8 Length of one leaf (last)

The analysis of variance showed that the soil and plot effects were significant ($P < 0.5\%$), and that all combinations have longer leaves than combination IA ($P < 5\%$).

5.1.9 Number of leaflets (one side only)

The analysis of variance showed that the soil and intercropping/undergrowth effects and the plot effect were significant ($P < 5\%$), and that combination IC differed significantly from IIA and IIB, and combination IA from IIB.

5.1.10 Length of longest leaflet

The analysis of variance showed a significant intercropping/undergrowth effect ($P < 0.5\%$), and that all combinations differ significantly from IIC; and IIA, IIB and IB from IC. The leaves of the coconut trees on the Limestone are smaller than on the Mariakani Sandstone but the latter has a smaller number of leaflets. The length of these leaflets depends on the type of intercropping/undergrowth.

5.1.11 The number of nuts on the one last inflorescence

Analysis of variance was not done because the variance of the different combinations differed too much, and observations were made on a variable number of trees per plot. The figures in table 11 are not very high and can only be considered as a rough indication. A better picture can only be obtained when observations cover at least a period of one year.

Table 11 Mean number of nuts on the one but last inflorescence (n = ±1000)

Combinations*	IA	IB	IC	IIA	IIB	IIC
	3.82	2.67	3.53	3.46	3.30	3.07

* For an explanation of the code: see Table 9.

5.1.12 Leaf production rate

Although no observations were made on leaf production rate an approximate figure can be calculated from the number of leaf scars on the trunk and the approximate age of the palm as given by the farmer. This figure gives a production of 6 to 8 leaves per year, far below the normal value of 12 reached elsewhere. This low rate results probably from drought.

5.2 Nut characteristics

The results of the nut analyses are presented in Table 12 and 13.

Table 12 Mean weights of nuts and its components (in grammes)

Combination	Weight fresh fruit	Weight husk	Weight nut water	Weight endocarp	Weight water in copra	Weight dry copra
IA	1953	1191	225	209	158	170
IB	1858	1078	217	195	174	194
IC	1631	915	217	180	155	164
IIA	1669	993	179	189	143	165
IIB	1849	1100	221	206	159	163
IIC	1696	988	186	205	152	165

Statistics are not used, as the number of samples per tree, plot and combination are not equal. Moreover the difference between the variances of the combinations is likely to be very large. As a result no definite conclusions can be drawn from these figures. It is remarkable that, although the mean fresh fruit weight may differ considerably, the ultimate mean weight of the dry copra does not differ much. This is also shown in Table 13 which gives the relative distributions expressed in percentages of the fresh fruit weight. This table and Table 12 show that the differences result mainly from differences in husk weights. The mean weight of dry copra is 170 g copra/nut. This does not agree with the observations of Bulder in 1975 who found an average of 142 g copra/nut and with observations made in 1914 which gave an average of 140 g copra/nut (Van Eijnatten, 1979). On the other hand, Sethi (1953) reports that 36 lb copra is obtained from 100 nuts, which means an average weight of 163 g copra/nut.

Table 13 Relative distribution of nut components, expressed in percentage of fresh fruit weight

Combination*	% husk material	% nut water	% endo-carp	% copra water	% dry copra
IA	61	12	11	8	9
IB	58	12	11	9	10
IC	56	13	11	10	10
IIA	59	11	11	9	10
IIB	59	11	11	9	9
IIC	58	12	12	9	9

5.3 Nutrient contents of leaflets

For each combination the mean nutrient content of the 14th leaf of is given in Table 14.

Table 14 Nutrient contents of 14th leaf (in % of D.M.)

Element	Limestone			Sandstone		
	food crops	cashew	bush	food crops	cashew	bush
N	1.68	1.72	1.49	1.72	1.63	1.56
P	0.11	0.11	0.11	0.12	0.12	0.11
K	1.45	1.73	1.69	1.49	1.41	1.35
Ca	0.32	0.26	0.36	0.21	0.27	0.29
Mg	0.26	0.24	0.21	0.25	0.30	0.31
Na	0.08	0.07	0.07	0.14	0.13	0.19
Cl	0.67	0.54	0.60	0.64	0.65	0.72

One has to realise that the leaflets were taken in the middle of the dry season and that the nutrient contents do fluctuate during the year (Coomans, 1974). In particular nitrogen and potassium contents are related to rainfall and water supply.

Nitrogen

Nitrogen turned out to be the most deficient element. All values are below the critical level (see Table 5). This is not unexpected as also the soils contain very little organic nitrogen (Table 18). The analysis of variance showed that the intercrop effect was significant ($P < 1\%$), and that combination IB and IIA contain more nitrogen than IC and IIC ($P < 5\%$). The relatively high values of the food crop plots are rather surprising, as each year the food crop also consumes nitrogen. The relatively low levels of the bush plots are, probably, mainly due to the exhausting N-consumption by grasses and Lantana camara.

Phosphorus

The phosphorus levels are also low. The phosphorus content of the leaves of coconuts on the Limestone are below the critical level, that of the trees on the Sandstone just meet the critical level. This P deficiency, which in unusual in coconut, might be explained by the dry conditions of the Kilifi District.

Potassium

The potassium levels are high. They exceed 1.5 to 2 times the critical value. The analysis of variance showed that the soil ($P < 10\%$) and the plot effect ($P < 5\%$) were significant. Reasons for the high K levels cannot be given as no figures for soil-K are available. It is, however, thought that the lower K levels on sandstone are related to the fact that sandy soils have a lower CEC than the clayey limestone soils and hence a lower K content.

Thomas (1974) gives some figures of leaf-K of coconuts on the coast of Tanzania (Tanga, Bagamoyo). He found that low bearing trees have a higher leaf-K than high bearing trees. The K levels he found were ranging from 1.12 to 1.70%. Like Smith, he stresses the importance of N/K-ratio as a criterion for evaluating the nutrient status of the palm. High potassium levels are often associated with low nitrogen levels. The high K level may also be an adaptation of the coconut tree to the dry conditions of the Kilifi District, as K plays an important role in the water economy of the plant.

Calcium

The calcium levels are at about the critical level. On the limestone they are a little higher than on the sandstone, as could be expected. Analysis of variance was not done as the variances of the different combinations differed too much.

Magnesium

Magnesium levels are also at about the critical level. On the sandstone they are a little higher than on the limestone. Also here analysis of variance was not done, as the variances of the different combinations differed too much. The observed K/Mg antagonism is discussed in 5.5.1.

Sodium

Sodium levels are low. On the sandstone they are higher than on the limestone. This is probably due to higher Na levels in the sandy soil than in the clayey soil. Analysis of variance was not done for the same reason as for Ca and Mg.

Chlorine

Chlorine levels are above the critical value. The analysis of variances showed that the "interplot" effect ($P < 5\%$) and to a lesser extent the soil effect ($P < 10\%$) were significant.

Nitrate

Nitrate was measured as well. The results show that there is no nitrate in the 14^{th} leaf. Realising that the nitrogen contents were low, this is not very surprising.

Nutrient ratio's

The ratio of $\frac{K}{Ca+Mg}$ and $\frac{Ca}{Mg}$ (on equivalent basis) are given in Table 15.

Table 15 Ratio of $\frac{K}{Ca+Mg}$ and $\frac{Ca}{Mg}$ (on equivalent basis) for all six combinations

Ratio	Combination*					
	IA	IB	IC	IIA	IIB	IIC
$\frac{K}{Ca+Mg}$	0.99	1.35	1.23	1.22	0.95	0.86
$\frac{Ca}{Mg}$	0.75	0.66	1.05	0.52	0.54	0.56

* For explanation of code: see Table 9

The ratio's of N/P (as % of DM) are given in Table 16. According to the critical levels the optimum values should be: N/P = 15 - 16 and N/K = 2.

Table 16 The N/P and N/K ratio's for all six combinations

Ratio	Combination					
	IA	IB	IC	IIA	IIB	IIC
N/P	15.1	15.6	13.5	14.3	13.6	14.2
N/K	1.16	1.00	0.88	1.15	1.16	1.16

Variability

a. Within one tree.

Normally six leaflets of the 14^{th} trees are combined in one sample. To get an idea of the differences in nutrient content between the leaflets, pairs of leaflets were sampled separately for two trees. The results given in Table 17a show rather large differences.

Table 17[a] Nutrient contents of sub-samples of 14th frond in % of DM.

Plot	N	P	K	Na	Ca	Mg	Cl
IIB1	1.53	0.11	0.81	0.30	0.21	0.33	0.55
tree 4	1.50	0.13	0.71	0.31	0.21	0.34	0.58
	1.41	0.13	0.83	0.34	0.20	0.32	0.64
IIB1	1.68	0.18	1.07	0.17	0.16	0.43	0.52
tree 2	1.65	0.18	1.25	0.20	0.15	0.40	0.62
	1.53	0.19	1.29	0.20	0.14	0.38	0.59
S.D.	0.12	0.02	0.23	0.07	0.03	0.03	0.05

b. Between trees

The standard deviations of the values of the different plant nutrients of individual trees per combination are given in Table 17[b]. The S.D. values are rather constant in case of N, P, K an Cl, while the others differ much. Remarkable are the large standard deviations of K, Ca, Mg and Na (20-90% of the mean value, against 8-15% of the mean value in case of N and P). The S.D. values are higher than those in Table 17[a].

Table 17[b] Standard deviations of different plant nutrients of individual trees per combination.

	IA	IB	IC	IIA	IIB	IIC
N	± 0.23	0.18	0.15	0.17	0.24	0.25
P	0.01	0.01	0.02	0.01	0.01	0.01
K	0.37	0.32	0.32	0.32	0.33	0.23
Na	0.03	0.06	0.03	0.08	0.08	0.08
Ca	0.07	0.05	0.10	0.09	0.07	0.05
Mg	0.06	0.07	0.08	0.05	0.12	0.11
Cl	0.09	0.13	0.09	0.15	0.15	0.14

Visual deficiency symptoms

Yellowing of leaves, especially older leaves, is frequently observed. This indicates N deficiency (Child, 1974). A brown to reddish-brown spotting of the leaflets was also observed. This is usually an indication of K deficiency, but this is not likely as the K values of the leaflets are high.

5.4 Nutrient status of the soil

The results of the soil analyses are given in Table 18 and in Fig 4. The N and P status of the soil and the pH are discussed below while the relation between the nutrient status of the soil and the nutrient contents of the leaves is discussed in paragraph 5.5.2.

Nitrogen

The nitrogen levels of both soil types are very low. About 67% of the soils derived from the limestone have a total nitrogen content between 0.05 and 0.10% N., while 100% of the soils derived from the sandstone have a total nitrogen content of less than 0.05% N (see fig 4c and 4d)! Only two plots have a nitrogen content above the critical values, see Table 1. These plots are situated in the limestone area.

Phosphorus

The phosphorus levels are also low. 89% of the limestone values and 71% of the sandstone values are, according to the classification of Chapman (1966), low (less then 5 ppm, see fig. 4a and 4b). Our own findings show a critical level of 2.5 ppm P. (see 5.5.2). This would mean that 66% of the P values of the limestone and 58% of the P values of the sandstone soils should be classified as very low.

Soil pH

The pH-water of the limestone soils is about 7; the pH-KCl is between 5 and 6. On the sandstone both pH values are somewhat lower, about 6 for pH-water, and between 4 and 5 for pH-KCl (see also fig. 4e and 4f).

5.5 Relationships between nutrients in the leaflets, the soil and plant characteristics

5.5.1 Relationships between individual nutrients in the leaflets

As discussed in paragraph 2.3 the uptake of certain plant nutrients depends also on the availability of other plant nutrients. This phenomenon is reflected in the nutrient contents of the leaflets. Some relevant correlations between nutrient contents of the leaflets are calculated in this study, and the corresponding correlation coefficients (r) are given in Table 19. As the number of samples that could be analysed is rather small, the intercropping/undergrowth types of the same soil type are grouped together and the correlation coefficients are calculated for each soil type separately.

Table 18 Soil analytical data

Plot*	Total N (%)	P-Olsen (ppm)	pH	
			H_2O	KCl
Limestone				
IA1	0.06	16.3	6.94	5.82
IA2	0.07	0.8	6.01	4.79
IA4	0.09	0.3	6.91	5.96
IA6	0.14	1.3	6.98	6.05
IB2	0.10	0.5	6.26	5.19
IB4	0.06	2.6	8.46	7.98
IC2	0.09	1.0	7.60	6.18
IC3	0.07	0.8	6.43	5.34
IC5	0.05	3.8	6.89	5.95
Sandstone				
IIA3	0.03	1.2	5.65	4.39
IIA9	0.03	6.8	7.82	7.63
IIB1	0.04	4.7	5.78	4.38
IIB3	0.05	5.9	6.13	4.97
IIB7	0.03	0.8	5.87	4.68
IIC8	0.04	2.1	6.36	5.48
IIC10	0.03	0.4	5.97	4.51

* For explanation of code: see Table 9.

Table 19 Correlation coefficients (r) between some nutrients in leafsamples of coconuts

Soil type	N and P	N and K	K and Ca	K and Mg
Kambe limestone (n = 39)	0.46^{xx}	-0.08	-0.31^{x}	-0.73^{xx}
Mariakani sandst.	0.68^{xx}	0.39^{x}	-0.32^{x}	-0.45^{xx}

xx = significant at 1%.
x = significant at 5%.

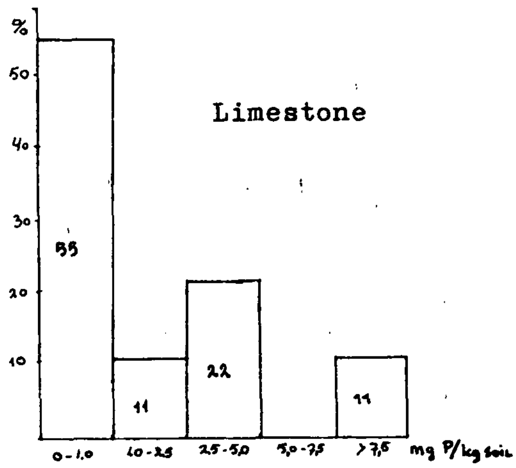

Fig 4a, frequency distribution of soil-P on Limestone

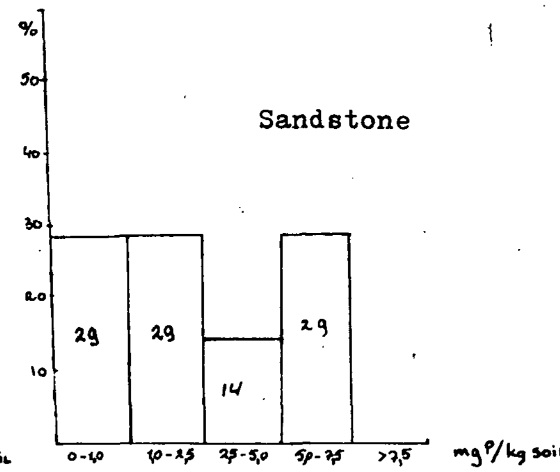

Fig 4b, -do- ,on Sandstone

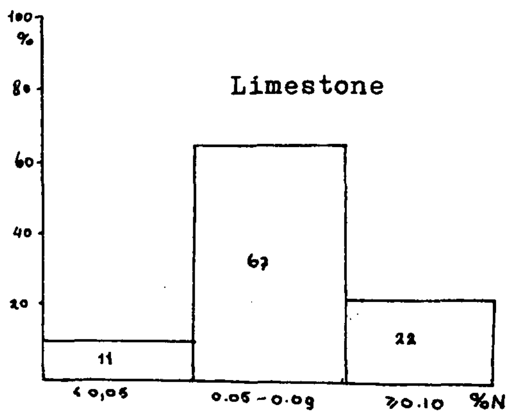

Fig 4c, Frequency distribution of total org. N on Limestone

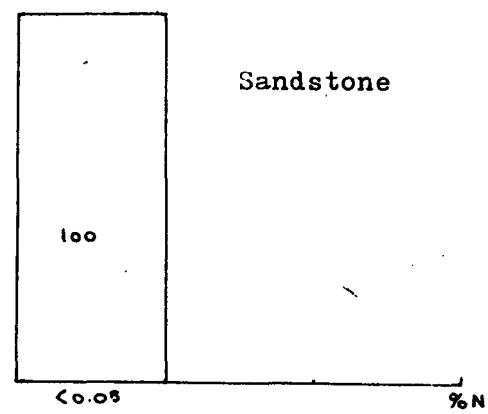

Fig 4d, -do- on Sandstone

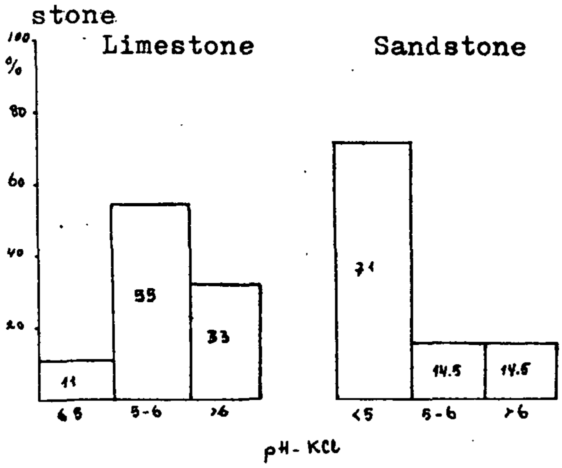

Fig 4e, frequency distribution of soil pH-KCl, on Lime- and Sandstone

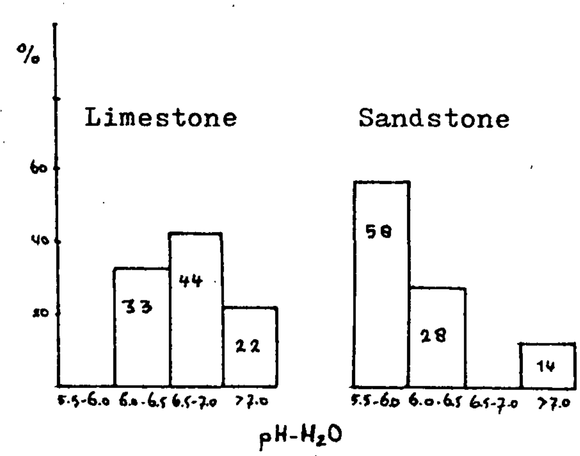

Fig 4f, frequency distribution of soil pH-water, on Limestone and Sandstone

The data show a positive relationship between N and P. Also antagonisms between K and Ca, and K and Mg were observed, the latter the most outspoken. The positive relationship between N and K on the sandstone, which is absent on the limestone can be explained by the fact that the CEC (and with that the exch..K) of the sandy soil mainly depends on the organic matter content (and thus on the org. nitrogen content), while the CEC of the clayey soil also depends on the clay fraction. The poor relation between soil org. N and leaf N (see 5.5.2), however, does not support this view. No correlation was found between K and Na in the leaflets and between Cl and the total of K+Ca+Mg+Na.

5.5.2 Relationships between the nutrients of leaves and the soil

N and P

The relationship between soil-N and leaf-N is very poor (figure 5a). For P there is a clear relationship. The correlation coefficient is 0.77 on limestone and 0.70 on sandstone with 1 and 5% significance respectively. With the Cate and Nelson (1971) method a critical level for soil P has been introduced (figure 5b).

Soil-pH (KCl) and Ca- and Mg-levels in the leaflets

As no data were available on the soil-Ca and soil-Mg content, the relationship was studied between leaf-Ca and leaf-Mg and pH (KCl) as shown in figure 6a and 6b. The underlying idea is that pH values reflect the levels of exchangeable bases. The lines in the graphs are plotted so that they include the vast majority of the values, but one has to realise that the number of observations is very small. The graphs show that leaf-Mg is certainly above the critical level when pH-KCl is higher than 6, and that leaf-Ca is above the critical level when pH-KCl is higher than 5.5. Below these pH-values the leaf contents of Mg and Ca might be adequate or insufficient.

Potassium

As also the K content of the soil is unknown, leaf-K is plotted against soil characteristics which might give an indication for soil-K: pH-KCl and % org. N (figures 6c and 6d). Organic-N was chosen because of the usually close relationship between this parameter and the cation exchange capacity.

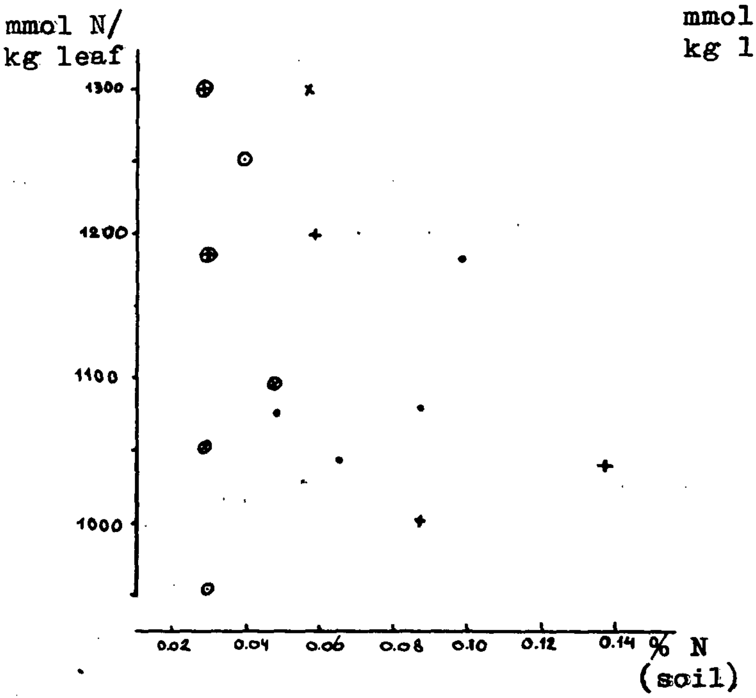

Fig. 5a. Relationship between soil-N and leaf-N.

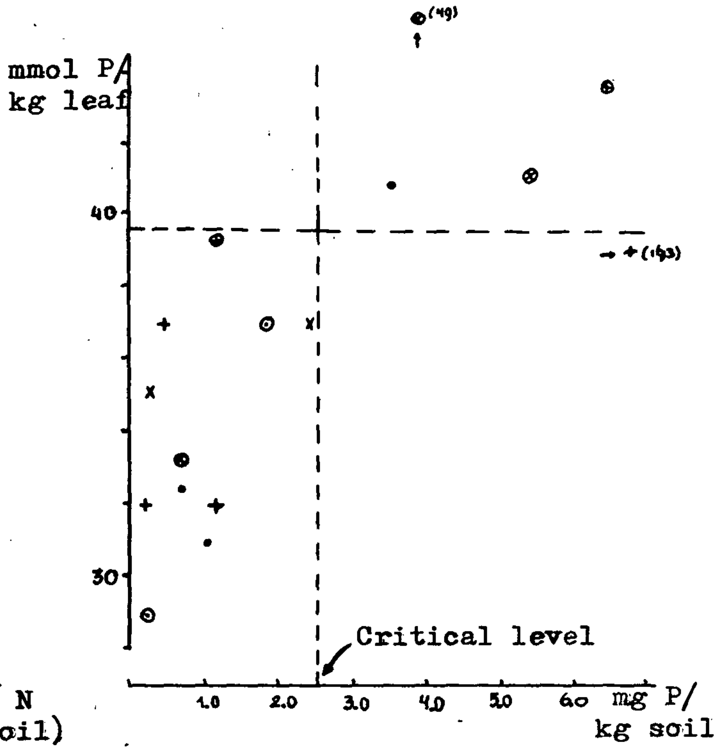

Fig. 5b. Relationship between leaf-P and soil-P.

(For explanation of marks see fig. 6).

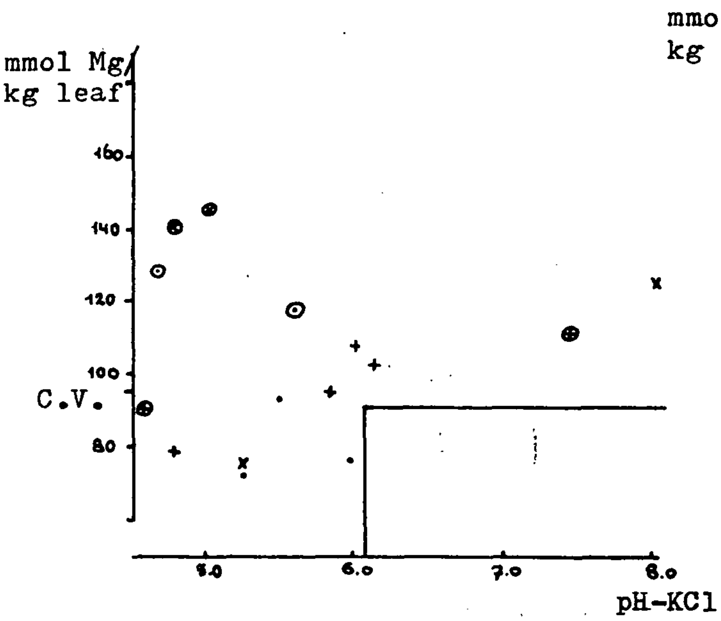

Fig. 6a. Relationship between leaf-Mg and pH-KCl of the soil.

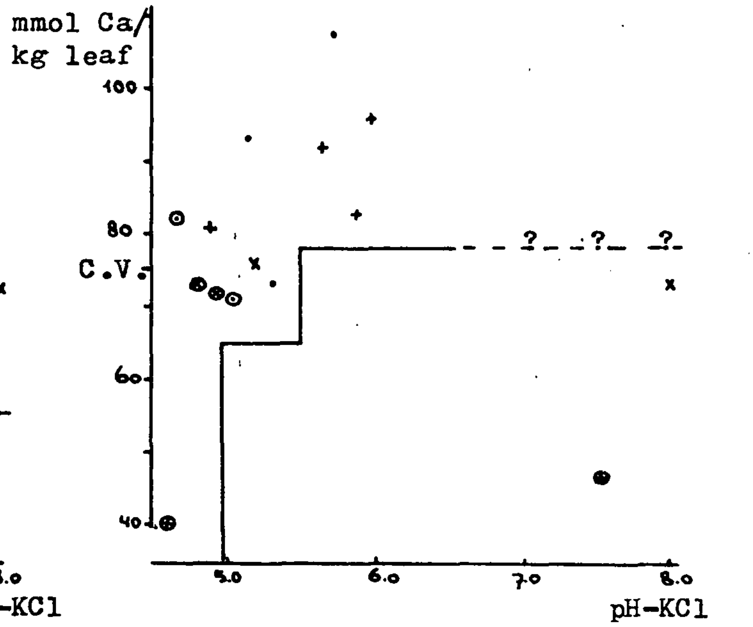

Fig. 6b. Relationship between leaf-Ca and pH-KCl.

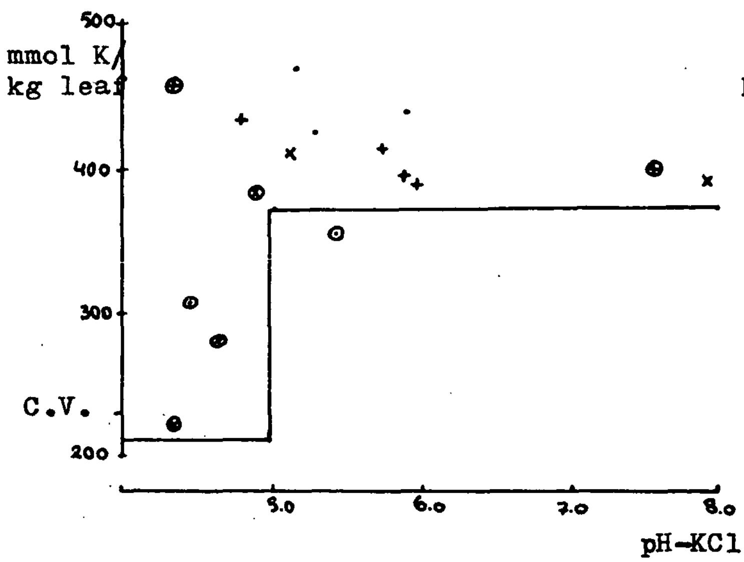

Fig. 6c. Relationship between leaf-K and pH-KCl of the soil.

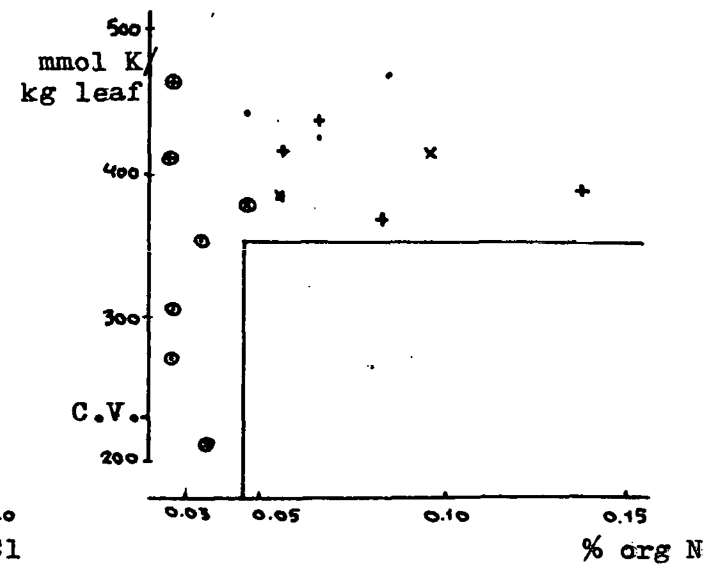

Fig. 6d. Relationship between leaf-K and soil org. N.

\+ = Limestone + food crops
x = " + cashew
. = " + bush
C.V. = Critical Value.

⊕ = Sandstone + food crops
⊗ = " + cashew
⊙ = " + bush

5.5.3 Relationships between nutrients in the leaflets and plant characteristics

As nitrogen turned out to be the element that is in the minimum, it is likely that those characteristics that are mainly influenced by the nitrogen levels, are related to the N levels. These characteristics are mentioned in 2.3. For each soil correlation coeffficients were calculated between leaf N content and:

- girth at 50 cm and at 170 cm
- number of leaves
- number of inflorescences
- the length of a leaf
- the number of female flowers
- copra/nut.

The results showed very low correlation coefficients. On the Kambe limestone only the length of a leaf seems to a small extent (significant at $P < 10\%$) to be correlated with the N levels, while on the Mariakani sandstone the number of leaves ($P < 5\%$), copra/nut ($P < 10\%$), and the number of female flowers ($P < 10\%$) are correlated with the leaf-N levels.

No significant correlations were found between leaf-P and the length of a leaf, and the number of female flowers, as well as between leaf-K and the number of leaves and between leaf-Cl and number of leaves.

5.5.4 Relationships between plant characteristics

Correlation coefficients were calculated between a number of plant characteristics. Unfortunately the number of female flowers and the number of nuts on the one but last inflorescence had to be left out because of the large variability of these characteristics. In the calculations the intercropping/undergrowth types on the same soil type were grouped together. The relationships between plant characteristics on both soil types are given in Table 20.

The relation between the total number of leaves and the total number of inflorescences is clear as could be expected. However, the relationship between rank number of leaf with the youngest inflorescence and the total number of leaves is surprising. This seems to indicate that a poorer vegetative growth (= number of leaves) is partly compensated by an earlier emergence of the inflorescence. This is also illustrated by the figures of Van Eijnaten et al. (Table 21), where fewer leaves are assiociated with a lower rank number of the leaf with the youngest inflorescence.

Tabel 20 Correlation coefficients between some plant characteristics (n = 90, for both soil types).

Plant characteristic	1	2	3	4
1		L: 0.49^{xxx} S: 0.56^{xxx}	-	L: 0.60^{xxx} S: 0.67^{xxx}
2			L: 0.33^{xx} S: 0.55^{xxx}	-
3				L: 0.70^{xxx} S: 0.80^{xxx}

1 = total number of leaves
2 = rank number of leaf with youngest inflorescence
3 = -do-, with oldest
4 = total number of inflorescences
L = Limestone, S = Sandstone; xxx = significant $P < 0.1\%$,
xx = significant $P < 1\%$.

6 DISCUSSION OF RESULTS

Previous research on coconuts in Kenya

The only detailed information on the growing of coconuts at Kenya's Coast can be found in van Eijnatten et al. (1977). This study describes the characteristics of a normal population of coconut trees in the Tezo Roka Settlement Scheme, and relates characteristics of "best" trees to "normal" trees. As the soils and the effects of intercropping were not studied, the comparison between this study and the TPIP study can only give an idea of the influence of climatic factors. The Tezo Roka area is situated 5-10 km North of Kilifi Town, and rainfall in that area amounts to 900 mm/yr. The rainfall in the five years preceding the year (1977) in which van Eijatten et al. carried out their observations amounted to only 760 mm/yr, and this is likely to influence the figures. From Table 21 it can be seen that all characteristics of trees in the Tezo Roka area have lower values than those in the other two areas.

Table 21 Comparison between plant characteristics, as found by Floor and van Eijnatten et al. (1977).

Area	Rainfall mm/yr	Number of observed trees	Year	Plant characteristics				
				1	2	3	4	5
Tezo Roka	± 900	132	March '77	23.29	6.35	17.45	9.11	28
Kizurini	± 100	90	Febr. '80	27.48	7.69	25.40	15.96	42
Mwarakaya	± 1100	90	Febr. '80	28.41	7.77	24.05	14.07	34

1 = number of leaves
2 = rank number of leaf with youngest inflorescence
3 = -do- with oldest
4 = number of inflorescenses
5 = number of female flowers on youngest opened inflorescence

Present research

From the results presented in the previous paragraphs and from Table 21, it is possible to get an overall picture of the effect of soil type of intercropping/ undergrowth on the coconuts. When comparing trees, growing on the limestone (Mwarakaya area), to trees growing on the sandstone (Kizurini area), it appears that the trees on the limestone:

- have a smaller diametre of the trunk
- have more leafscars per metre
- have a lower rank number of the leaf with the oldest inflorescence, which might indicate an early die-back of the oldest inflorescence as a result of (water-) stress
- have a lower number of inflorescences, as more inflorescences are missing between the youngest and oldest inflorescence, and that the oldest leaves have no inflorescences anymore
- have less female flowers
- have shorter leaves and shorter leaflets but have more leaflets per frond.

As to the total number of leaves, there exists no clear distinction between the trees on both soil types.

These results combined with the results of van Eijnatten et al. (Table 21) indicate that trees on the limestone are growing under more stress than trees on the sandstone. As there are no large differences in nutrient status of the two soils and in nutrient content between the leaflets this stress is probably a water stress. This is rather surprising, as it can be expected that the clayey-limestone soil has a higher available water storage capacity. A better rootsystem of the trees on the sandstone, especially in layers below one metre is a possible explanation for better growth and development.
Table 21 also shows that the generative parts of trees growing under (water-) stress are more affected than the vegetative parts. This is illustrated by the following figures: palms of the drier Tezo area have 15% less leaves and 43% less inflorescences than trees growing in the Kizurini area; for the Mwarakaya area these figures are 18% and 35% respectively.

The comparison among the different types of intercropping/undergrowth shows that the practice of intercropping with food crops is beneficial for the coconut trees in respect of:
- total number of leaves
- total number of inflorescences
- rank number of leaf with the oldest inflorescence
- number of female flowers.

The effect on the nutrient content of the leaflets is less clear. Small differences are observed between the two soil types, but in general no dramatic decrease in nutrient content of the leaflets is observed when coconuts are intercropped with food crops.

The positive effect on coconuts of intercropping with foodcrops can be explained by the temporary absence of food crops during the dry season when in other plots there is strong competition for water between coconuts and cashew trees or bush vegetation. An other reason for the positive effect migh be soil tillage which is not practiced in the other intercrop/undergrowth combinations.

7 CONCLUSIONS AND RECOMMANDATIONS FOR FURTHER RESEARCH

It is impossible to make definite statements on the effect of soil type and type of intercropping/undergrowth on the yield of coconuts on the basis of this study. Such statements can only be made when based on observations over many years. Also with the interpretation of the results of this study one has to bear in mind that the observations were only made once. It should further more be realised that the effect of soil type and type of intercropping/undergrowth (i/u) on plant characteristics and nutrient contents of the leaflets was studied without a detailed investigation of relevant soil properties (rooting volume, availability of water).

The conclusions of this study are given under three headings. The first one deals with general agronomic aspects and the last two with the study itself.

7.1 Agronomic aspects of coconut cultivation

Coconuts are grown by smallholders on holdings of 2 to 10 acres in the Kambe limestone area, and of 10 to 30 acres in the Mariakani sandstone area. Tree densities vary largely. Depending on the type of intercropping there are on average 90 to 110 palms per ha. On fields where coconuts are interplanted with other tree crops (mainly cashewnut trees) the ratio coconut trees to other trees is 1 : 1 (limestone area) or 1 : 0.75 (sandstone area).
There is a poor control of insect pests. About 70% of the trees show signs of rhinoceros beetle attack, and of 70% of the trees the nuts on the one but last inflorescence are affected by the coconut bug.
The leaf production rate per annum is low between 6 and 8.
Tapping of coconut trees is very common; about 10% of the trees are tapped.

7.2 Effect of soil type and type of intercropping/undergrowth

Plant characteristics

a. The effect of soil type is significant on plant characteristics associated with the trunk (girth at 170 cm and number of leafscars per metre), number of inflorescences, rank number of leaf with the oldest inflorescence, the length of the last leaf, and number of leaflets.
b. From the observed differences in plant characteristics, including the number of female flowers (see c), it is clear that coconuts on the limestone soil suffer more from water stress than the coconuts on the sandstone soil.

c. The number of nuts on the one but last inflorescence and the number of female flowers on the youngest opened inflorescences differ largely per tree and per combination. No definite conclusions can be drawn from the number-of-nuts figures, while the figures of the number of female flowers indicate that trees on the sandstone have more female flowers. Trees intercropped with food crops have also more female flowers than those with other i/u types.
d. The effect of type of i/u is significant in respect of number of leaves and inflorescences, rank number of leaf with the oldest inflorescence, and number and length of the leaflets. Generally speaking, the effects of i/u have a higher significance level than the effects of soils.
e. The coconuts intercropped with food crops have in general the highest values for the most important plant characteristics while lowest values are obtained when coconuts are grown with a bush undergrowth. This means that intercropping with food crops provides better growing conditions for coconuts than the two other types of intercrops/undergrowth.
f. Positive relationships were found between total number of leaves and the rank number of the leaf with the youngest inflorescence, and the total number of inflorescences. Positive relationships existed also between rank number of leaf with the oldest inflorescence and rank number of the youngest inflorescence and the total number of inflorescences.
g. There is no clear relationship between plant characteristics and nutrient content of the leaflets.

<u>Nut characteristics</u>

a. The effect of soil type and type of i/u on the various fruit components is not clear.
b. Fresh fruit weights vary largely. The mean values of the combinations range from 1.6 kg to 2.0 kg.
c. The mean dry copra weights of the combinations do not differ much, and amount to ± 165 g. copra per nut. This is more than generally assumed.

<u>Nutrient content of the leaflets</u>

a. Statistical analyses were only made for N, P, K and Cl, as for the other elements (Ca, Mg, Na) the variances between the soil-intercropping combinations were too large. Where statistical calculations were made the effect of soil type was not significant. The Mg and Na levels tended to be higher on the sandstone, while the opposite was true for the Ca levels.

b. The effect of type of i/u is only significant for the N levels. The other elements do not give a clear picture.
c. Generally speaking, the N levels are low, as well as the P and Na levels; the K level is (very) high, while the other element levels are moderate (around the critical level).
d. A relationship between leaf-N and leaf-P is found. There are antagonisms between K and Ca, and K and Mg, the latter the most outspoken.
e. The relationship between nutrient concentrations in the leaflets and nutrient levels of the soil is low except for P.

7.3 Chemical characteristics of the soils

a. The clayey limestone soil is low in nitrogen and phosphorus, its pH-water is between 6 and 7. The sandy sandstone soil is also low in N and P, the latter is somewhat higher than in the limestone soil. The pH-water is between 5 and 6.
b. The intercrop/undergrowth vegetation has no effect on the N and P content and the pH of the soil.

7.4 Suggested topics for further research

1. A study of the root system of coconuts of different ages and growing on different soil types.

2. A study of the rotation systems of food crops grown under and between coconuts.

3. Effect of coconuts on yields of food crops.

4. A study of the annual pattern of leaf production of coconuts.

5. The effect of tapping on present and future copra production.

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APPENDICES

Appendix Ia	Plant characteristics observation sheet
Appendix Ib	Harvesting observation sheet
Appendix Ic	Questionnaire
Appendix II	Location of plots
Appendix III	Some words concerning coconuts in Giriama and Swahili language

Appendix I-a

PLANT CHARACTERS OBSERVATION SHEET — COCONUTS

PLOT NR.	....	OBSERVER	....
TREE NR.	....		....
LOCATION	....	FARMER	....
SOIL TYPE	....	SPACING	....
SLOPE	.........%	PLOT SIZE	....
SLOPE POSITION	....	AMOUNT OF TREES	....
ALTITUDE	....	UNDERGROWTH	....
DRAINAGE	....	CODE	....

DIAMETER TREE	- BOLE	....
	- AT 1.50 m	....
HEIGHT OF TREE UP TO BASE OF CROWN		....
NUMBER OF LEAF SCARS ON TRUNK		....
TOTAL NUMBER OF LEAVES		....
RANK NUMBER OF LEAF WITH YOUNGEST INFLORESCENCE		....
RANK NUMBER OF LEAF WITH OLDEST INFLORESCENCE		....
TOTAL NUMBER OF INFLORESCENCES		....
NUMBER OF INFLORESCENCES WITHOUT FEMALE FLORETS		....
NUMBER OF FEMALE FLORETS ON YOUNGEST OPENED INFLORESCENCE		....
NUMBER OF NUTS ON THE ONE BUT LAST INFLORESCENCE		....
NUMBER OF NUTS AFFECTED BY PSEUDOTERAPTUS		....

LENGTH OF ONE LEAF	....
NUMBER OF LEAFLETS ON ONE LEAF (ONE SIDE ONLY)	....
LENGTH OF LONGEST LEAFLET ON ONE LEAF	....

LEAF SAMPLED	YES/NO	NUMBER OF LEAF SAMPLED	....
SAMPLE NUMBERS	1.	4.	
	2.	5.	
	3.	6.	
SOIL SAMPLED	YES/NO	SAMPLE NUMBER	....

Appendix I-b

HARVESTING OBSERVATION SHEET COCONUT

PLOT NR. .... OBSERVER ....
TREE NR. .... DATE ....
LOCATION .... FARMER ....

	WEIGHT OF FRUIT	WEIGHT DEHUSKED		WEIGHT COPRA	
		WITH WATER	WITHOUT	WET	DRY
NUT NR.	.....	.....	.....	.....	.....
NUT NR.	.....	.....	.....	.....	.....

PLOT NR. .... OBSERVER ....
TREE NR. .... DATE ....
LOCATION .... FARMER ....

	WEIGHT OF FRUIT	WEIGHT DEHUSKED		WEIGHT COPRA	
		WITH WATER	WITHOUT	WET	DRY
NUT NR.	.....	.....	.....	.....	.....
NUT NR.	.....	.....	.....	.....	.....

PLOT NR. .... OBSERVER ....
TREE NR .... DATE ....
LOCATION .... FARMER ....

	WEIGHT OF FRUIT	WEIGHT DEHUSKED		WEIGHT COPRA	
		WITH WATER	WITHOUT	WET	DRY
NUT NR.	.....	.....	.....	.....	.....
NUT NR.	.....	.....	.....	.....	.....

Appendix I-c

QUESTIONNAIRE FOR COCONUT STUDY IN THE AREA OF KALOLENI

Jaap floor - 1980 T.P.I.P./C.A.R.S.

Name of the farmer; .... Date: ....

Location .... Plot No. ....

Age of the farmer .... Religion: ....

Since when is he working on the plot? ....

Owner? .... if not who else? ....

How many people are working on the farm? ....

And how many are dealing with the coconuts? ....

What is the size of the total farm? ....

Division of crops:

TREE CROPS: Coconut ....% FOODCROPS: Maize ....%

Cashew ....% Cassava ....%

Mango ....% Cowpease ....%

Citrus ....% Banana ....%

Fallow: ....%

In possession of goats or cows? ....

If yes, do they walk and graze under the coconut trees? ....

Does he use cow or goat dung? .... coming from where? ....

Does mulching occur under the coconut trees? ....

Age of coconuts: ....

Management: ....

....

Yield of coconuts: ....

When does he harvest his nuts? ....

What does he use his coconuts for? 1. Copra ....% of nuts

2. Dafu ....% of nuts

3. Toddy ....% of trees

Appendix II.

Location of Plots.

Plot		Location	Name of the farmer
1	IIC1	Madaba	Not known
2	IC1	Mwarakaya	Mwajanja
3	IIB1	Kizurini	Cheng
4	IB1	Mwembekati	Mwazonga Baya Kalama
5	IIA1	Kizurini	Ngumbao Kabozo
6	IIB2	-do-	Kitzao
7	IIC2, IIB3	-do-	Nyahi Katana
8	IA1	Mwarakaya	Mwashe Malito
9	IA2	-do-	-
10	IB2	Mbuyuni	Alice Jacob Golijo
11	IC2	Jibana	Charles Mngoma
12	IB3	Mwarakaya	Karima Kizuma
13	IB4	Mbuyuni	Bwomu Nyale
14	IB5	Mwarakaya	Kombe Nzai
15	IB6	-do-	Frederick Katana
16	IA3	Gandini	Brangi Kombe
17	IA4	Banda ra Salama	Wasigne Ngujete
18	IA5	-do-	Michael Goda
19	IA6	Mbuyuni	Munga Nyamawi
20	IIA2	Kizurini	Joshua Mbuba
21	IIA3	Mihingoni	-
22	IIA4	Kizurini	Kahino Masha
23	IA7	Mbuyuni	Andrea Muhumi Chome
24	IB7	Gandani	Stephen Tinga
25	IB8	-do-	Nji Giromwe
26	IA8	Mbuyuni	Mukunja Mwamzenga
27	IC3	Mereni	James Daniel Menza
28	IC4	Pangani	Benjamin
29	IC5	Tsagwa	Fundi Nberia
30	IC6	Banda ra Salama	Peira

Appendix II (continued)

Plot		Location	Name of farmer
31	IC7	Chasimba	John Mwatata
32	IC8	-do-	-do-
33	IIA5	Chalani	Kazungu Katana
34	IIB4	-do-	-do-
35	IIB5	Chanigandi	Charo Omari
36	IIA6	Chalani	Katana Mwaro
37	IIA7	-do-	Kazungu Toya
38	IIC3	-do-	Rebmann Kazungu
40	IIB7	Mihingoni	Lorence Kazungu Mazavi
41	IIB8	-do-	Ngowa Mutemi
42	IIA8	Chalani	Charo Mangi
43	IIB9		-
44	IIC4	Kinani	-
45	IIA9	-do-	Karuso Charo Hare
46	IIC5	-do-	Karisa Nsara
47	IIA10	Mleji	Charo
48	IIC6	Vishikani	Syria Kalonzi
49	IIB10	Mikomani	Matata Mutungi
50	IIC7	Kizurini	Mangi
51	IIC8	Mikiriani	-
52	IIC9	Mihingoni	Kadenge Rua
53	IIC10	Kinani	Katzoa
54	IA9	Mwarakaya	Philip Ngari
55	IC9	-do-	Emanuel Gambe
56	IB9	-do-	-do-
57	IC10	-do-	Kalama Konde
58	IA10	-do-	Maschaido
59	IB10	Gandani	Fredrick Katana

Appendix III

Some words concerning coconuts in Giriama and Swahili language.

English	Kiswahili	Giriama
Base of spear (cabbage)	Masala	?
Leaf	Makumbi	Makumbi
Inflorescence	Shawi	Mahanda
Female florets	Vidaka	Vithale
Male florets	Punga	Tangadza
Leaflets	Makuti	Kandza
Spear	Kilele (incha)	Lwenza
Spathe	?	Kanga
Palm climber	Mgara	Mjema

Different stages of the nuts: (in order of increasing age)

- Vidaka
- Dafu: young nut, full of water and used for food and beverage
- Coroma
- Mnazi: old nut, little water and plucked for copra
- Mbata: completely dry nut.