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SISAL PRODUCTION AND SOIL FERTILITY DECLINE IN TANZANIA

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TABLE OF CONTENTS

SISAL CULTIVATION 1

SISAL PRODUCTION 2
    Tanzania sisal production 2
    World sisal production 3
    Area decline 4
    Yield decline 4

SOIL FERTILITY DECLINE 7
    Number of sisal cycles 7
    Historical soil data 8
    Sisal yields and soil fertility 9

CONCLUSIONS 11

REFERENCES 12

FIGURES

Fig. 1 Total sisal production of Tanzania between 1895 and 1992 2
Fig. 2 Tanzanian sisal production compared to that of Brazil and the world from 1961 to 1992 3
Fig. 3 Simplified relational diagram showing factors governing sisal production decline in Tanzania. 4
Fig. 4 Average yields of 5 sisal plantations in the Tanga Region between 1968-1988. 5
Fig. 5 Trend in the percentage of long fibres (3L+1) of the total sisal production of a plantation in the Tanga Region. 6
Fig. 6 Trend in soil reaction of the topsoil (0-20 cm) of Ferralsols under continuous sisal cultivation in the Tanga Region (data from 3 plantations). 9

TABLES

Table 1 Soil chemical data (Ferralsols) from virgin land and after 2 or 3 cycles of sisal cultivation (data from 1 plantation; modified from Hartemink, 1991). 7
Table 2 Soil fertility status of a sisal field on a Ferralsol sampled in 1966 and again in 1990. 8
Table 3 Sisal yields and soil fertility parameters of 3 sisal fields (Ferralsols) at one plantation 10

SISAL CULTIVATION

Sisal (*Agave sisalana*), the plant which yields the sisal fibre, derives its name from the port of Sisal in Yucatan in Mexico. The exact origin of *A. sisalana* is, however, not known (Gentry, 1982). Sisal accounts for a large proportion of the world supply of hard fibres which form the raw material for cordage (ropes, cords, strings and agricultural twines).

Sisal was introduced in Tanzania in 1893 by Dr Richard Hindorf. The first 62 sisal plants were planted near Pangani in the Tanga region, and these plants were the foundation of the sisal industry in East Africa (Lock, 1969). The German settlers had not found a crop which would thrive in the coastal plain where it was too dry for Hevea rubber and other plantation crops. Sisal, being fairly drought resistant, appeared well adapted to the environmental conditions and the first plantations were established in 1900.

In Tanzania, sisal has never been grown extensively by smallholders. For extraction of the fibre, heavy machinery is required which is only economical if there is 1000 ha or more planted with sisal. Therefore, the crop is grown at plantations and large sisal areas can be found between Tanga and Moshi, between Dar er Salaam and Morogoro and in the south near Mtwara and Lindi.

Sisal research was started after World War I in the Usambara mountains but the site was ecologically not representative for the main sisal growing areas, and in 1934 the Sisal Research Station Mlingano in Tanga region was founded. One of the achievements of this station was the breeding of a long fibre agave hybrid, no. 11648 (Wienk, 1970). Today, most of Tanzania's sisal fields are planted with hybrid 11648 which replaced the lower yielding *A. sisalana*. The hybrid, however, is more susceptible to diseases than *A. sisalana*, and cannot withstand temporarily waterlogging (Wienk, 1968). The fibre from the hybrid is similar to that of *A. sisalana* and commercially no distinction is made. In this paper, both crops will be referred to as sisal.

Sisal is propagated from bulbils, i.e. small plantlets that appear in large quantities in the inflorescence after anthesis (particularly in *A. sisalana*), or from suckers which are taken from productive sisal fields. The best planting material is obtained from bulbils which are raised in nurseries for about 2 years. In general, 2 to 3 years after transplanting to the field, the first leaves can be cut, and cutting may continue up to 8 years. Hereafter the plants start flowering and leaf production ceases. From planting to flowering lasts about 10 years and this is termed a cycle. The length of a cycle depends on the growth rate of the sisal plants which is influenced by soil fertility, temperature and rainfall. On good soils and with proper management, one cycle of hybrid 11648 may yield 25 t ha^{-1} of fibre. After each cycle, the vegetation is cleared with heavy machinery and the debris is burned whereafter the land is harrowed and replanted. Most sisal growers use a rotational system by which the land is left fallow for 10 to 20 years after each cycle of sisal. In spite of the considerable amounts of nutrients removed with the harvested leaves, manuring or fertilization have never been widely adopted by sisal growers (Hartemink & Van Kekem, 1994).

In the Tanga region, sisal is grown on soils derived from limestone (Cambisols) and these soils are found adjacent to the coast and have a favourable inherent fertility (Hartemink & Bridges, submitted). However, most sisal in Tanga region is grown further inland on soils derived from gneiss of Precambrian age (Ferralsols & Acrisols). These soils are red, very deep and are intensely leached with a low chemical fertility (National Soil Service, 1998; Hartemink *et al.*, submitted).

SISAL PRODUCTION

Tanzania sisal production

The first exports of sisal from Tanzania occurred in 1898, and reached 7.5 tonnes in 1900. Exports rose to 1,400 tonnes in 1905 increasing to 20,000 tonnes by 1913 (Fig. 1).

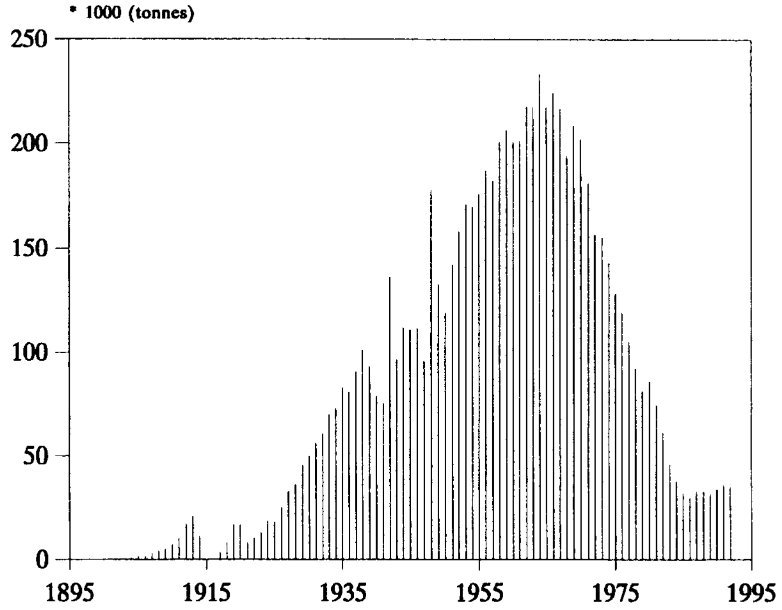

Fig. 1 Total sisal production of Tanzania between 1895 and 1992 (sources: Lock, 1969; FAO production yearbook, various years; FAO, 1993)

Sisal growing was then firmly established in Tanzania (Lock, 1969). With the construction of railways, sisal was planted away from the coast and production rapidly increased. War in 1914 brought a halt to the expansion and production of sisal-growing in Tanzania. During the British administration that followed, production was revived and annual exports rose to nearly 50,000 tonnes in 1930. During the world economic crisis of the 1930s there was no decline in sisal production and annual exports reached 100,000 tonnes by 1938.

After the Japanese invasion of the Philippines and Indonesia towards the end of 1941, East Africa became the world's main hard fibre producer. During years after World War II, sisal production increased steadily and reached its highest production in 1964 with 234,000 tonnes. In 1963 and 1964 sisal export earnings were more than 60 million US$, or one-third of the total agricultural export earnings of Tanzania (FAO, 1993). In those years, agricultural export earnings were more than 80% of the national income. From 1964 production began to decline and 20 years later sisal production was down to 38,000 tonnes. It further decreased to 32,000 tonnes in 1989 which was the same production level as in 1927.

In order to revive sisal production, large rehabilitation programmes were launched in the mid 1980s. Foreign companies were allowed to buy shares in the nationalized estates and many abandoned fields were replanted. Although sisal prices are low, the results of the liberalization of politics in the country has enabled many of the rehabilitation programmes to be profitable.

World sisal production

In the 1960s, Tanzania produced nearly one-third of the world's sisal output (Fig. 2). Brazil produced slightly less, but in the early 1970s Brazil became the main sisal producing country. The current production of Brazil is more than half of the world's sisal output. Unlike Tanzania, sisal in Brazil is grown mainly by smallholders and quality is usually lower.

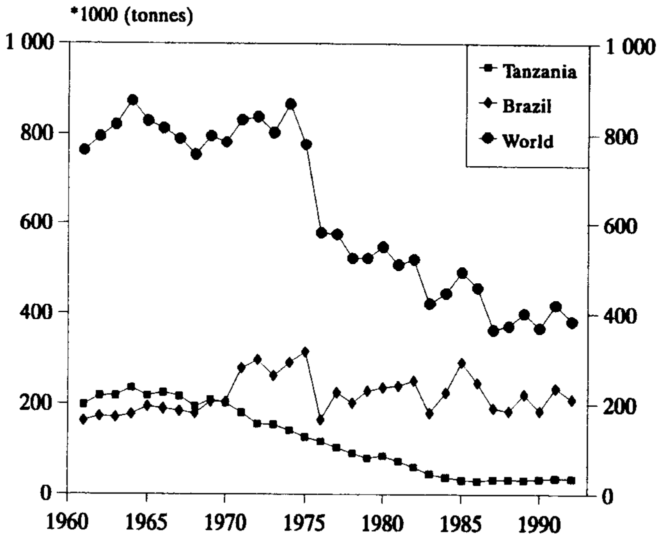

Fig. 2 Tanzanian sisal production compared to that of Brazil and the world from 1961 to 1992 (sources: Lock, 1969; FAO production yearbook, various years; FAO, 1993)

Total world annual sisal production decreased from about 800,000 tonnes in the 1960s to 400,000 tonnes in the 1990s. A very sharp increase occurred between 1974 and 1976 when the oil crisis temporarily stimulated a high demand for sisal. Afterwards, when sisal prices dropped, production declined again. The decline in sisal production is attributed to a number of causes. Fig. 3 shows schematically the relation between some of the factors which contributed to the production decline. The decline in area and yields are considered main factors and both are discussed below.

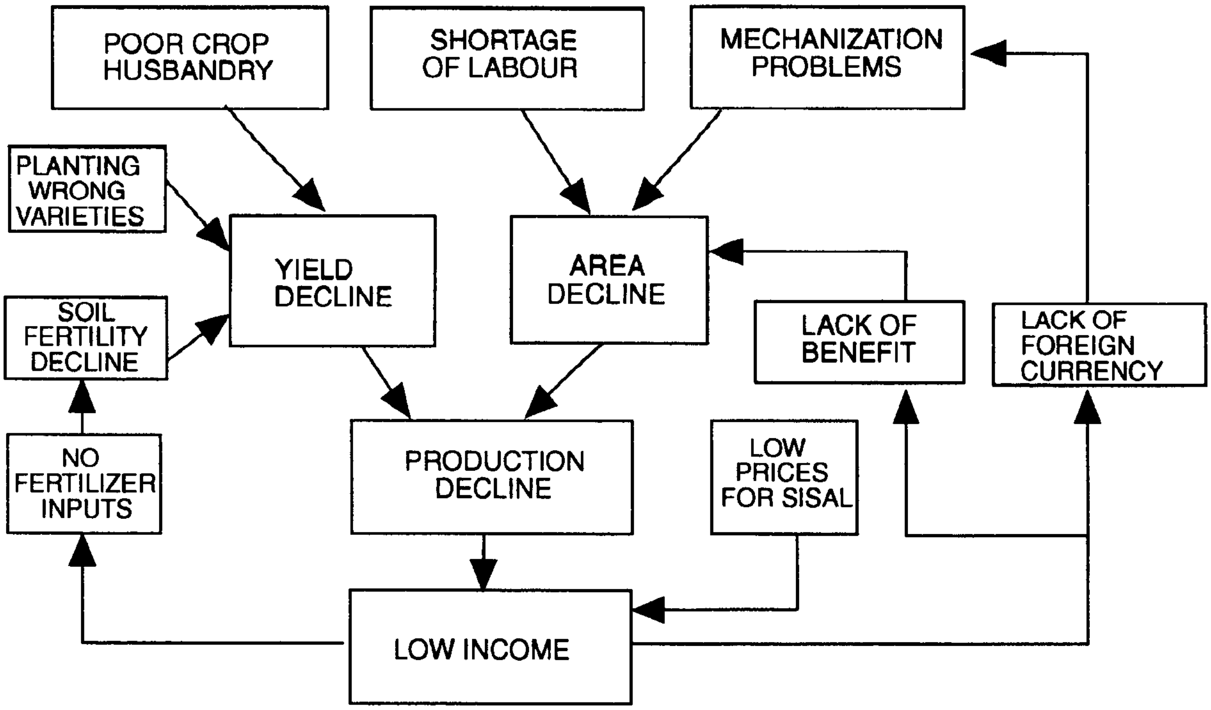

Fig. 3 Simplified relational diagram showing factors governing sisal production decline in Tanzania.

Area decline

The area under sisal decreased from 227,000 ha in 1964 to 30,000 ha in 1986 (FAO, 1993). An important cause for this decline is lack of interest in sisal growing as result of low sisal prices (low income) which decreased from 713 US$ t^{-1} in 1979 to 519 US$ t^{-1} in 1987 (IMF, 1988). Sisal is a vegetable fibre which has to compete in cost with synthetic fibres. So when the prices of synthetic fibres decreased as a result of low oil prices the demand for sisal fibre was depressed, and for example, sisal binder twine was replaced by polypropylene. A recent decrease in sisal prices followed the collapse of the former Soviet Union which was a major sisal importer. The countries of the newly formed CIS lacked the hard currency needed for importing sisal and this also decreased the prices. Besides sisal prices, the area decline was probably also the result of the nationalization of sisal plantations during the late 1960s and early 1970s. Lack of sufficient management capacity following the nationalization, resulted in the abandoning of many sisal plantations. Another factor which contributed to the area decline was the shortage of labour through unpopularity of the work, coupled with low wages. Furthermore, mechanization problems resulting from the unavailability of spare parts and a lack of investment for tractors, lorries and decorticators resulted in a reduction of the area on which sisal was grown.

Yield decline

The combination of low prices and inadequate management practises, resulted in a more extensive way of sisal growing. Crop husbandry standards fell and yield levels dropped. In Fig. 4 the average fibre yield of 5 sisal plantations in Tanga region is shown, and there is a clear decreasing trend.

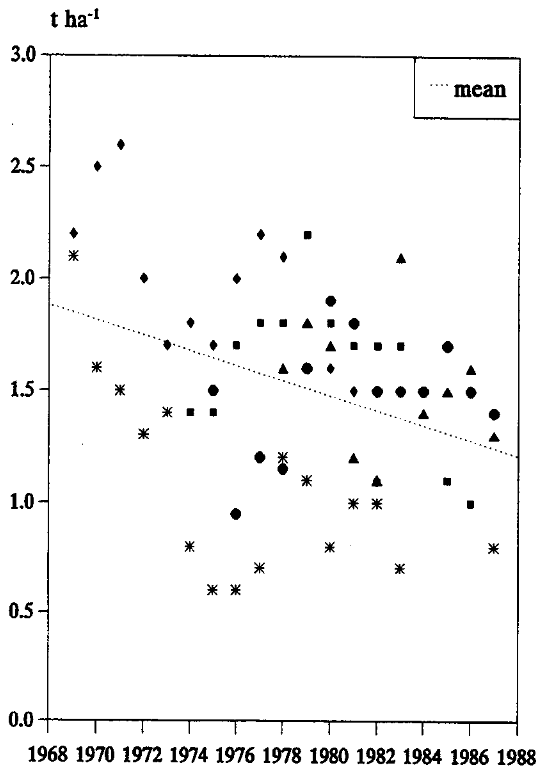

Fig. 4 Average yields of 5 sisal plantations in the Tanga Region between 1968-1988.

Leaf length also decreased as may be seen from the percentage fibre grade 3L+1 representing the longest fibres (> 90 cm). Fig. 5 shows the %3L+1 from a sisal plantation in Tanga region, and reveals that the content of long leaves decreased sharply during the past 2 decades.

Leaf length has a marked effect on fibre yield and although the fibre percentage is not influenced by the leaf length, the weight of a leaf is proportional to the square of its fibre length (Wilson, 1951). This means that long leaves yield relatively more fibre than short leaves. For example, with the fibre percentage being constant, a 3-ft leaf yields 2.25 times more fibre than a 2-ft leaf, or in other words with the same number of leaves harvested, a field with 2-ft leaves yields 1 t fibre ha^{-1} while a field with 3-ft leaves yields 2.25 t fibre ha^{-1}.

Lower yields and shorter leaves were also attributed to the unintentional planting of less productive Agave hybrids. In the late 1980s, some evidence came to light that many fields had not been planted with the high yielding Agave hybrid no. 11648 but with another, less productive hybrid with shorter leaves. This hybrid, which was nicknamed 'kaptura' (Swahili for shorts), had probably spread as a result of uncontrolled dissemination of planting material. Some growers believe that 'kaptura' is a mutant or a genetically degenerated hybrid no. 11648. The scale at which 'kaptura' is found, and the fact that at Mlingano during the many years following the selection of hybrid no. 11648 no short-leaved types were encountered, does not make this a likely explanation.

Another important reason for the yield decline might be the depletion of soil fertility as most sisal was grown with very little fertilizer or manuring.

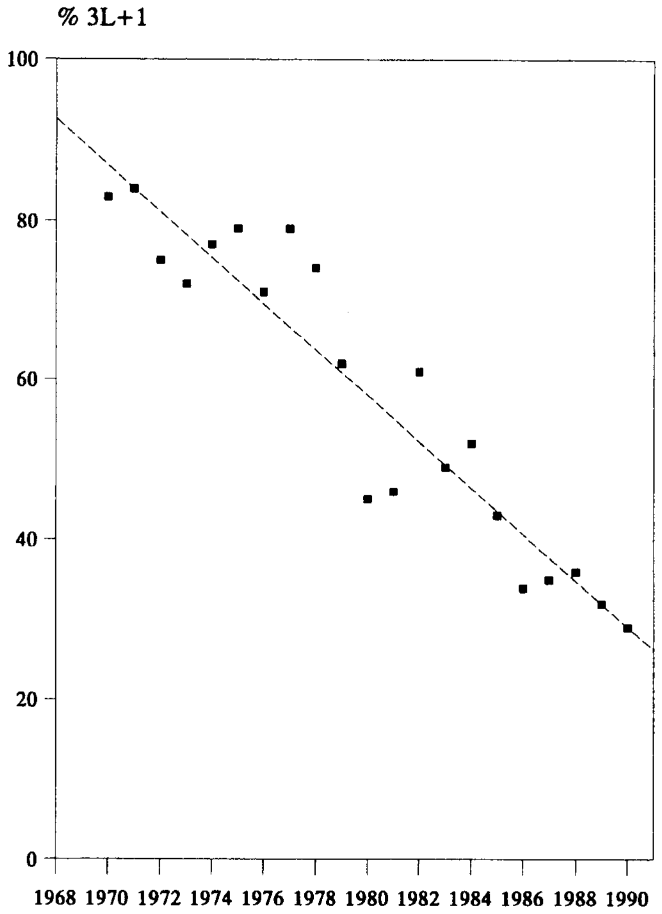

Fig. 5 Trend in the percentage of long fibres (3L+1) of the total sisal production of a plantation in the Tanga Region.

SOIL FERTILITY DECLINE

In the previous section, possible explanations for the decline in sisal production were given. In this section, the impact of soil chemical degradation on sisal yields is examined. Two different approaches are used here to illustrate the impact of continuous sisal cultivation on soil fertility: (i) soils under virgin land are compared to soils which have been under 2 or 3 cycles of sisal without fertilizers, (ii) soil data of the 1950s and 1960s are compared with recent data of the same sisal fields. Finally, some results are presented relating soil fertility parameters to sisal yields. The data presented data were obtained from soil survey reports of the National Soil Service of Tanzania and of various other publications. In these and other reports, detailed information on data collection, methods of soil sampling and analysis can be found (Hartemink, 1991).

Number of sisal cycles

Hartemink (1991) presented soil chemical data from a number of sisal fields which have been under 2 or 3 cycles of sisal and which have never been fertilized. These data were averaged and compared with data of a soil under forest vegetation. All soil fertility parameters were highest in the forest soil and lowest after 3 cycles of sisal (Table 1).

Table 1 Soil chemical data (Ferralsols) from virgin land and after 2 or 3 cycles of sisal cultivation (data from 1 plantation; modified from Hartemink, 1991).

	virgin land[1]		2 cycles of sisal[2]		3 cycles of sisal[2]	
soil depth (cm)	0-20	30-50	0-20	30-50	0-20	30-50
pH (water) 1:2.5	6.2	5.7	5.7	5.2	5.2	5.1
pH (KCl) 1:2.5	5.7	4.4	4.5	4.0	4.0	4.0
Organic C (%)	2.1	0.9	1.7	0.6	1.7	0.6
Total N (%)	0.19	0.08	0.13	0.05	0.14	0.06
C:N	11	11	13	12	12	10
Available P (Bray I) (mg kg^{-1})	3	1	2	1	3	1
Exchangeable Ca (mmol$_c$ kg^{-1})	68	23	32	18	13	9
Exchangeable Mg (mmol$_c$ kg^{-1})	26	21	16	10	5	3
Exchangeable K (mmol$_c$ kg^{-1})	5	4	6	3	1	<0.05
CEC (NH$_4$OAc pH 7) (mmol$_c$ kg^{-1})	125	105	117	98	88	60
Base saturation (%)	80	54	48	32	21	20
Exchangeable Al (mmol$_c$ kg^{-1})	0	0	0	5	9	10
Al saturation (% CEC)	0	0	0	5	10	17

[1] data of 1 composite topsoil sample (= 15 subsamples of about 0.5 ha)

[2] mean of 2 composite topsoil samples

An exception is the soil P content which was very low in all three soils. The pH decreased by 0.5 of a unit in the topsoil with an extra cycle of sisal but organic C contents were not influenced by the number of sisal cycles. Organic C contents under forest were 0.3% points higher than under sisal accompanied by a slightly lower C:N. Although the samples are few, this confirms that the organic matter content decreases following forest clearance for cultivation. The exchangeable Ca, Mg and K contents decreased considerably with an extra cycle of sisal, and K was exhausted after 3 sisal cycles. The Ca, Mg and K removed with the sisal leaves equalled the decrease in the topsoil's content of these cations (Hartemink & Van Kekem, 1994). The decrease in pH and exchangeable bases resulted in an increase of the exchangeable Al content. The decline of exchangeable cations is greater in the subsoil and this is accompanied by moderate to high levels of exchangeable Al which is very unfavourable for sisal.

Historical soil data

If soil analytical data of the 1960s are compared with recent data of the same sisal field, a declining fertility can be seen (Table 2).

Table 2 Soil fertility status of a sisal field on a Ferralsol sampled in 1966 and again in 1990.

year of sampling:	1966[1]		1990[2]	
sampling depth (cm):	0-20	20-40	0-20	20-30
pH (water) 1:2.5	6.9	6.2	5.0	5.2
Organic C (%)	1.8	1.2	1.4	0.7
Exchangeable Ca (mmol$_c$ kg^{-1})	75	45	16	15
Exchangeable Mg (mmol$_c$ kg^{-1})	28	30	5	4
Exchangeable K (mmol$_c$ kg^{-1})	5	6	5	< 0.5
Base saturation (%)	88	80	29	30

[1] unpublished data from Sisal Research Station Mlingano.

[2] modified from Hartemink, 1991.

In 1966, the topsoil of Ferralsol had a pH of 6.9 and a subsoil pH of 6.2. This level of pH was possibly caused by some lime applications. Nearly 25 years of continuous sisal cultivation without any fertilization or liming resulted in a pH decrease in the topsoil of 1.9 unit, and 1.0 pH unit in the subsoil. The organic C contents decreased by 0.4% points in the topsoil and 0.5% points in the subsoil. Exchangeable Ca contents decreased with 59 mmol$_c$ kg^{-1} in the subsoil and 30 mmol$_c$ kg^{-1} in the subsoil. The exchangeable Mg levels also decreased sharply while subsoil K was exhausted after 25 years of sisal cultivation.

As a graphic example, the topsoil pH H_2O data of 3 plantations of the 1950s to 1990s were plotted (Fig. 6).

In the 1950s and 1960s the average pH at the 3 plantations was 6.1 but it decreased to 4.9 in 3 decades.

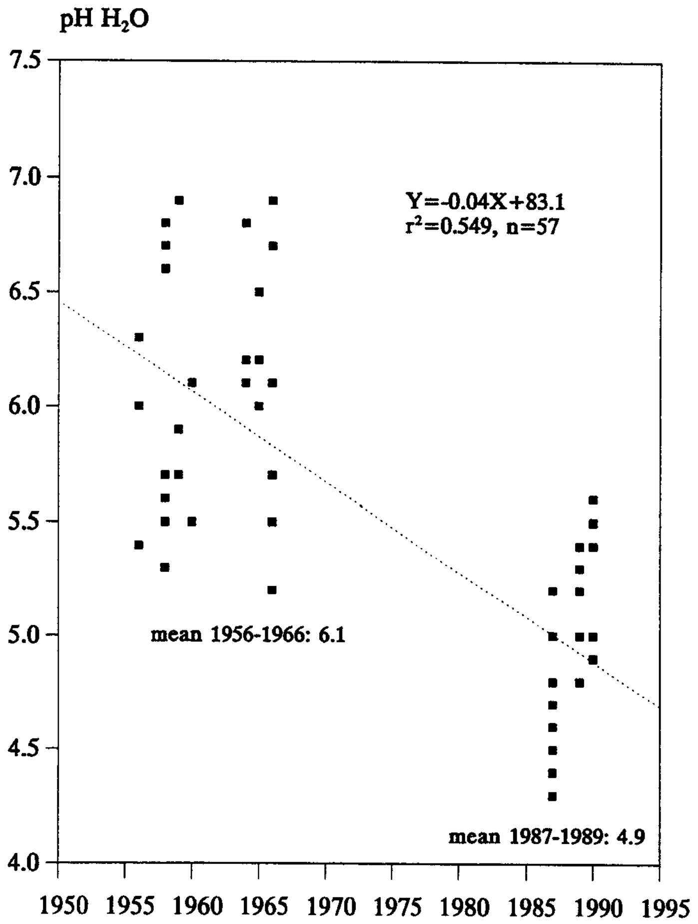

Fig. 6 Trend in soil reaction of the topsoil (0-20 cm) of Ferralsols under continuous sisal cultivation in the Tanga Region (data from 3 plantations).

Sisal yields and soil fertility

No data are available which directly link soil fertility parameters with sisal yields. The reason is the complexity of such a relationship and the lack of sufficient research which is directly linked to the limited interest in the crop. At a plantation level, soil fertility and sisal yields could be linked easily but only few plantations record yield data of individual fields. Hartemink (1991) linked soil fertility data with sisal yields of a plantation in Tanga region (Table 3).

Although the data are only few, it shows that the highest yield (2.3 t ha^{-1}) was obtained in a field with the highest pH, levels of exchangeable bases and base saturation in both topsoil and subsoil. The lowest yield (1.5 t ha^{-1}) was obtained in a field with a topsoil pH of 5.0 and low base saturation levels (topsoil: 16%). No clear relation between organic C, total N or available P contents with the yield levels was found.

Table 3 Sisal yields and soil fertility parameters of 3 sisal fields (Ferralsols) at one plantation (modified after Hartemink, 1991).

yield (t ha^{-1})	2.3		1.8		1.5	
soil depth (cm)	0-20	30-50	0-20	30-50	0-20	30-50
pH (water) 1:2.5	6.5	5.3	5.4	5.2	5.0	4.9
pH (KCl) 1:2.5	5.3	4.2	4.1	4.1	3.9	3.9
Organic C (%)	1.6	0.8	1.9	0.6	1.5	0.5
Total N (%)	0.11	0.05	0.16	0.07	0.12	0.04
C:N	15	16	12	9	13	13
Available P (Bray I) (mg kg^{-1})	5	1	4	< 0.5	3	1
Exchangeable Ca (mmol$_c$ kg^{-1})	46	22	19	12	6	6
Exchangeable Mg (mmol$_c$ kg^{-1})	17	9	6	3	3	2
Exchangeable K (mmol$_c$ kg^{-1})	7	4	2	1	1	< 0.5
CEC (NH_4OAc pH 7) (mmol$_c$ kg^{-1})	93	73	111	70	64	50
Base saturation (%)	79	51	25	23	16	17
Exchangeable Al (mmol$_c$ kg^{-1})	0	3	7	6	11	13
Al saturation (% CEC)	0	4	6	8	18	27

CONCLUSIONS

Sisal production in Tanzania has decreased during the past 2 decades as a result of a decline in area and yield. The area decline is caused by the lack of interest in sisal growing (low prices). Yields declined because of poor husbandry, propagating of the wrong varieties and a decrease in the length of the sisal leaves. An important factor in the decline of yields is the depletion of plant nutrients from the soil and the lack of manuring and fertilizers to replace the nutrients removed by the crop. Soils under continuous sisal cultivation were severely depleted resulting in unfavourable chemical properties for sisal. Sisal rehabilitation programmes which started in the mid 1980s, can only be successful if proper soil fertility management practises are included.

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