Sisal Production and Soil Fertility Decline in Tanzania

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Sisal was a major foreign exchange earner for Tanzania in the 1960s, when annual production was 234 000 tonnes, or one-third of the world output. But by the mid 1980s, it was down to 30 000 tonnes, due to a decline in the area under sisal and in the yield per hectare. Sisal cultivation decreased because of low prices following competition with synthetic fibres, and productivity fell because of poor husbandry — specifically, continuous cultivation without fertilizer applications. There has been renewed interest in sisal cultivation since the mid 1980s, but the successful rehabilitation of old sisal plantations depends on good management of soil fertility, amongst other factors.

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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 into 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 so far 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. Heavy machinery is required for extraction of the fibre, and it is only economical over areas of 1000 ha or more. Therefore, the crop is grown in plantations and large sisal areas can be found between Tanga and Moshi, between Dar-es-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 unrepresentative of 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 temporary 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, which are the 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, the first leaves can be cut 2-3 years after transplanting to the field, and cutting may continue for up to 8 years. Thereafter 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 of fibre. After each cycle, the vegetation is cleared with heavy machinery, the debris is burned and the land is harrowed and replanted. Most sisal growers use a rotational system by which the land is left fallow for 10–20 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 and Van Kekem, 1994).

In the Tanga region, sisal is grown on soils derived from limestone (cambisols), which are found adjacent to the coast and have a favourable inherent fertility (Hartemink and Bridges, submitted). However, most sisal in Tanga region is grown further inland on soils derived from gneiss of the Precambrian age (ferralsols and 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

Tanzanian sisal production

The first exports of sisal from Tanzania occurred in 1898, and reached 7.5 tonnes in 1900. Exports rose to 1400 tonnes in 1905, increasing to 20 000 tonnes by 1913 (Figure 1). Sisal growing was then firmly established in Tanzania (Lock, 1969). With the construction of railways, plantations were started 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 the years after World War II, sisal production increased steadily, reaching its highest level in 1964 with 234 000 tonnes. In 1963 and 1964 sisal export earnings were more than US$60 million, 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 as in 1927.

Large rehabilitation programmes were launched to revive sisal production 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 have 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 (Figure 2). Brazil produced slightly less then, but in the early 1970s it 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.

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 demand for sisal. Afterwards, when sisal prices dropped, production declined again. The decline in sisal production is attributed to a number of causes. Figure 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.

Area decline

The area under sisal decreased from 227 000 ha in 1964 to 63 000 ha in 1986 (FAO, 1993). An important cause of this decline was lack of interest in sisal growing as result of low prices, which decreased from US$713/tonne in 1979 to US$519/tonne in 1987 (IMF, 1988). Sisal is a vegetable fibre and has to compete with synthetic fibres. So when

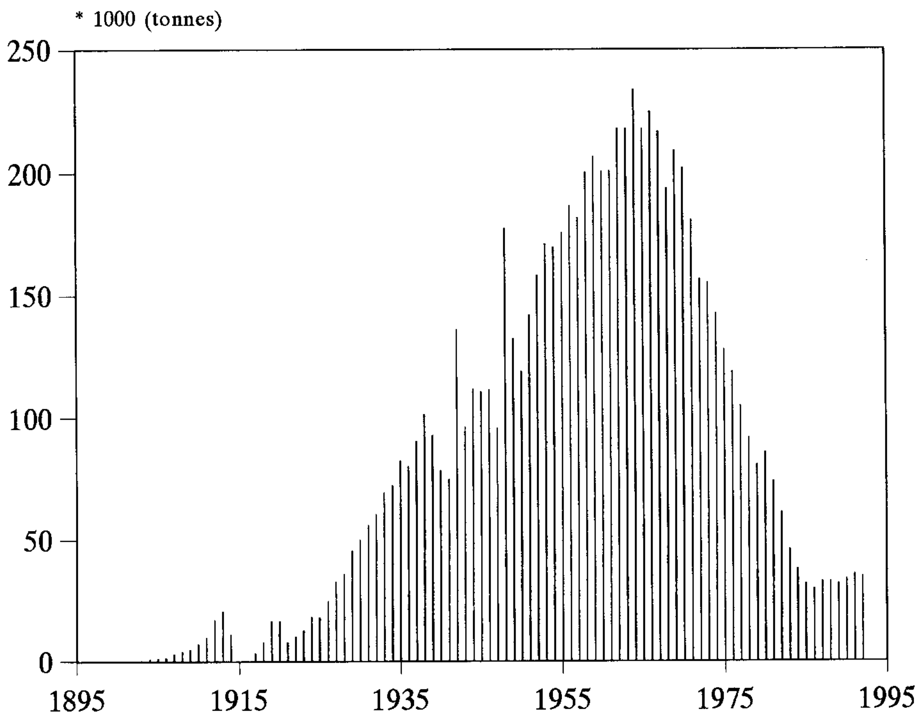


Figure 1 Total sisal production of Tanzania between 1895 and 1992 (sources: Lock, 1969; FAO production yearbook, various years; FAO, 1993).

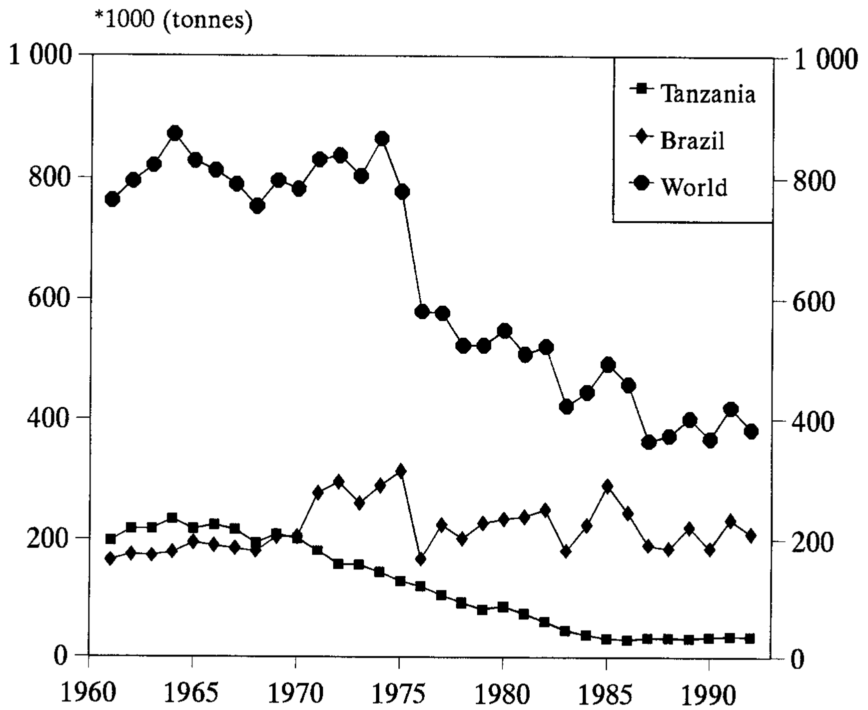


Figure 2 Tanzanian sisal production compared to that of Brazil and the world from 1961 to 1992 (sources: Lock, 1969; FAO production yearbook, various years; FAO, 1993).

the prices of synthetic fibres decreased as a result of low oil prices the demand for sisal fibre was depressed: for example, sisal binder twine was replaced by polypropylene. Recently, a 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.

Besides sisal prices, the decline in area was probably also the result of the nationalization of sisal plantations during the late 1960s and early 1970s. Lack of sufficient management capacity following nationalization resulted in the abandoning of many sisal plantations. Another factor which contributed to the decline was the shortage of labour due to the unpopularity of the work, coupled with low wages. Furthermore, problems of mechanization 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 practices resulted in a more extensive way of sisal growing. Crop husbandry standards fell and yield levels dropped. In Figure 4 the average fibre yield of five sisal plantations in Tanga region is shown, and there is a clear decreasing trend.

Leaf length also decreased, as may be seen from the percentage of fibre graded as 3L+1, representing the longest fibres (>90 cm). Figure 5 shows the 3L+1 percentage from a sisal plantation in Tanga region, and reveals that the content of long leaves decreased sharply over the last two 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' leaf yields 2.25 times more fibre than a 2' leaf, or in other words with the same number of leaves harvested, a field with 2' leaves yields 1 t/ha while a field with 3' leaves yields 2.25 t/ha.

Lower yields and shorter leaves have also been blamed on 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 hybrid 11648 but with another, less productive hybrid having 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 degenerate strain of hybrid 11648. The scale at which Kaptura is found, and the fact that at Mlingano during the many years following the selection of hybrid 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.

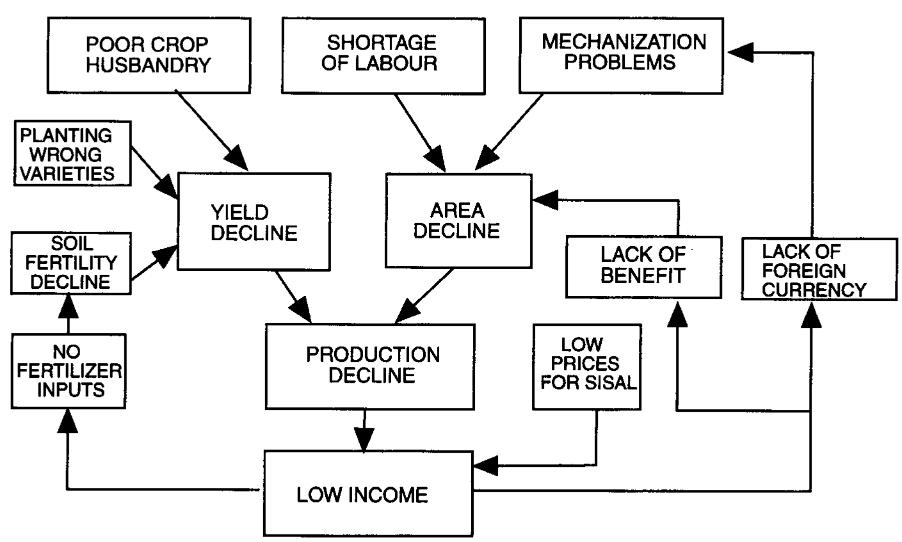


Figure 3 Simplified relational diagram showing factors governing sisal production decline in Tanzania.

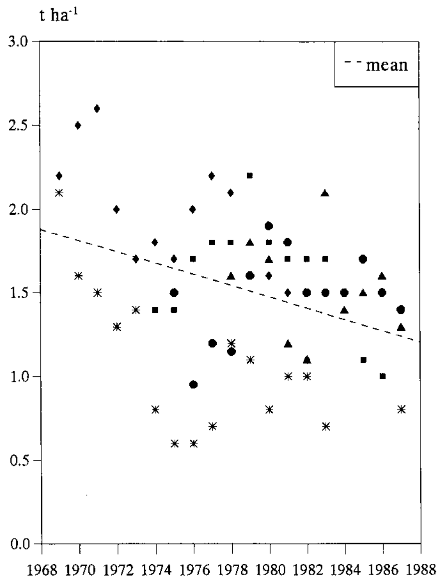


Figure 4 Average yields of five sisal plantations in the Tanga Region (represented by different symbols) during 1968–88.

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: first, soils on virgin land are compared to soils which have been under two or three cycles of sisal without fertilizers, and second, soil data of the 1950s and 1960s are compared with recent data from the same sisal fields. Finally, some results are presented relating soil fertility parameters to sisal yields. The 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 had been under two or three cycles of sisal and which had never been fertilized. These data were averaged and compared with data from a soil under forest vegetation. All soil fertility parameters were highest in the forest soil and lowest after three cycles of sisal (Table 1). 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 percentage points higher than under sisal, accompanied by a slightly lower C : N ratio. 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 three sisal cycles. The Ca, Mg and K removed with the sisal leaves equalled the decrease in the topsoil's content of these cations (Hartemink and 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

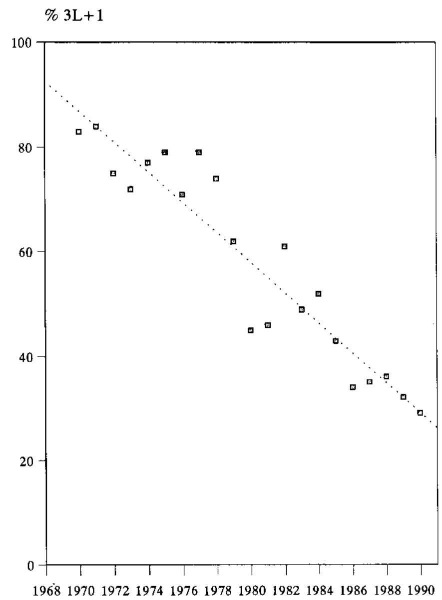


Figure 5 Trend in the percentage of long fibres (3L+1) of the total sisal production of a plantation in the Tanga Region.

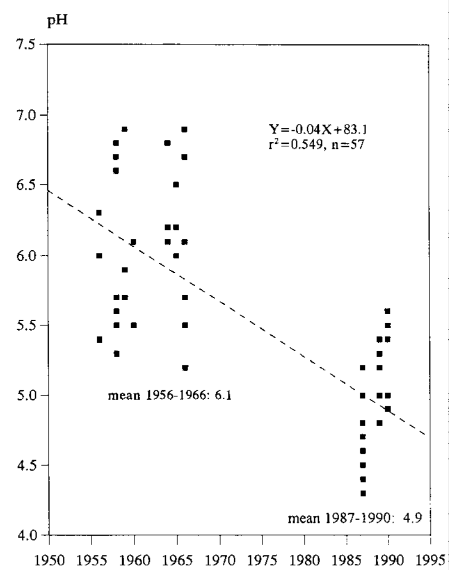


Figure 6 Trend in the soil pH of the topsoil (0–20 cm) of ferralsols under continuous sisal cultivation in the Tanga Region (data from three plantations).

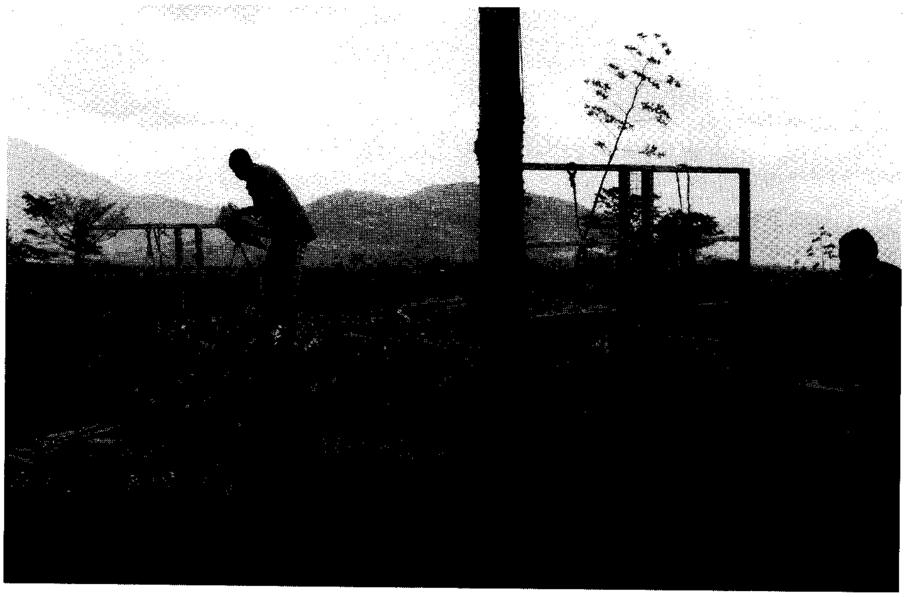
Table 1 Soil chemical data (ferralsols) from virgin land and after 2–3 cycles of sisal cultivation (data from one plantation).

	Virgin land[1]		Two cycles of sisal[2]		Three 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)	3	1	2	1	3	1
Exchangeable Ca (mmol/kg)	68	23	32	18	13	9
Exchangeable Mg (mmol/kg)	26	21	16	10	5	3
Exchangeable K (mmol/kg)	5	4	6	3	1	<0.05
CEC (NH_4OAc pH 7) (mmol/kg)	125	105	117	98	88	60
Base saturation (%)	80	54	48	32	21	20
Exchangeable Al (mmol/kg)	0	0	0	5	9	10
Al saturation (% CEC)	0	0	0	5	10	17

[1] Data of one composite topsoil sample (= 15 subsamples of about 0.5 ha).
[2] Mean of two composite topsoil samples.
Source: Hartemink (1991).

compared with recent data from the same sisal field, a decline in fertility can be seen (Table 2).

In 1966, the ferralsol topsoil had a pH of 6.9 and the subsoil a pH of 6.2. This level of pH was possibly explained by lime applications. Nearly 25 years of continuous sisal cultivation without any fertilization or liming resulted in a pH decrease of 1.9 units in the topsoil, and of 1.0 units in the subsoil. Organic C contents decreased by 0.4 percentage points in the topsoil and 0.5 percentage points in the subsoil. Exchangeable Ca contents decreased by 59 mmol/kg in the topsoil and 30 mmol/kg in the subsoil. Exchangeable Mg levels also decreased sharply, while subsoil K was exhausted after 25 years of sisal cultivation. As an example, the topsoil pH data of three plantations of the 1950s to 1990s are shown in Figure 6. In the 1950s and 1960s the average pH at the three plantations was 6.1 but it decreased to 4.9 over the three decades.



Loading sisal leaves from the field: there goes the soil fertility!

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/kg)	75	45	16	15
Exchangeable Mg (mmol/kg)	28	30	5	4
Exchangeable K (mmol/kg)	5	6	5	<0.5
Base saturation (%)	88	80	29	30

[1] Unpublished data from Sisal Research Station, Mlingano.
[2] Modified from Hartemink (1991).

Table 3 Sisal yields and soil fertility parameters of three sisal fields (ferralsols) at one plantation.

Yield (t/ha)	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)	5	1	4	<0.5	3	1
Exchangeable Ca (mmol/kg)	46	22	19	12	6	6
Exchangeable Mg (mmol/kg)	17	9	6	3	3	2
Exchangeable K (mmol/kg)	7	4	2	1	1	<0.5
CEC (NH_4OAc pH 7) (mmol/kg)	93	73	111	70	64	50
Base saturation (%)	79	51	25	23	16	17
Exchangeable Al (mmol/kg)	0	3	7	6	11	13
Al saturation (% CEC)	0	4	6	8	18	27

Source: after Hartemink (1991).

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 a few plantations record the yield data of individual fields. Hartemink (1991) linked soil fertility data with the sisal yields of a plantation in Tanga region (Table 3). Although the data are scanty, they show that the highest yield (2.3 t/ha) was obtained in the field with the highest pH, levels of exchangeable bases and base saturation in both the topsoil and subsoil. The lowest yield (1.5 t/ha) was obtained in a field with a topsoil pH of 5.0 and low base saturation levels (topsoil: 16%). No clear relation was found between organic C, total N or available P contents on the one hand, and yield levels on the other.

Conclusions

Sisal production in Tanzania has decreased during the past two decades as a result of a decline in area and yield. The decline in area is due to the low price of sisal, and yields have declined because of poor husbandry, propagation 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 have been severely depleted. Sisal rehabilitation programmes, which started in the mid 1980s, can only be successful if proper soil fertility management practices are included.

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