MONITORING LONG TERM SOIL FERTILITY TRENDS IN THE SOUTH AFRICAN SUGAR INDUSTRY USING THE FAS ANALYTICAL DATABASE

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Abstract

The South African sugar industry greatly depends on soil and leaf analyses conducted by its Fertiliser Advisory Service (FAS) for identifying nutrient disorders in sugarcane. As the industry uses more than 200 000 tons of fertiliser annually, it is important that trends in soil fertility and plant nutrient uptake are monitored to ensure that fertiliser practices are economically justified and in harmony with the environment. A database has been complied from the analyses of more than 200 000 soil and 70 000 leaf samples conducted since 1980. This has yielded valuable information on the effects of fertiliser use in different regions and on different soils. Results of changes in nutrient availability in different extension areas over a 15 year period are reported in relation to four bioclimatic regions, six soil parent materials, the main cane varieties and also crop age. A significant trend towards increased acidification of soils derived from basement granite and Natal Group Sandstone parent materials has occurred in the rainfed coastal regions. This contrasts with the observed increase in soil alkalinity in the irrigated areas of Mpumalanga. There has been a steady build-up of soil potassium in many areas, suggesting over application of this nutrient. Further examples are given of the use of the database to improve the efficiency of fertiliser use.

Introduction

Traditionally cane growers have placed great reliance on the value of soil and leaf analyses conducted by the Fertiliser Advisory Service (FAS) of the Experiment Station for not only diagnosing and correcting nutrient deficiencies but also providing cost effective fertiliser recommendations. Industry wide nutrient surveys based on soil and leaf sample analysis have also been invaluable to both research and extension staff at the Experiment Station for monitoring fertility changes in various parts of the industry and identifying potential new areas for soil fertility research. In 1970, an extensive survey of over 500 cane fields in the Midlands cane growing areas showed that Al toxicity and P fixation were growth limiting factors in areas that were previously under wattle (Meyer *et al.,* 1971). In irrigated areas, K deficiency in cane growing on soils with predominantly 2:1 lattice clay minerals was associated with K fixation in soils (Wood and Burrows, 1980). Such information greatly assisted in the planning of subsequent research programmes which have led to the recommendation of lime application using the soil exchangeable Al index (EAI) (Moberly and Meyer, 1975) and, more recently, Al saturation index values (Schroeder *et al.*, 1995) and K requirement based on soil texture (Donaldson *et al.,* 1990). Also, in other fields, recommendations included the determination of soil P fixation using the phosphorus desorption index (PDI) (Meyer and Dicks, 1979), and tests for determining the Zn (Meyer, 1976) and S status of soils (Meyer, 1985).

Apart from the survey, little use had been made of analytical data for examining trends in soil and leaf data until the computerisation of FAS recommendations in 1980. A programme referred to as the Nutrient Information Retrieval System (NIRS) was developed specifically to capture and store soil and leaf analysis data and to carry out surveys in which the frequency distribution of important soil and plant nutrients is categorised into various stages of sufficiency for different extension areas (Meyer *et al.*, 1989).

The initial assessment based on the capture of 130 000 soil and 50 000 leaf samples showed that there was a relatively high proportion of leaf samples deficient in K (28%), somewhat fewer deficiencies in N (13%) and P (12%), and only minor deficiencies of Ca (4%), Mg (1%) and Zn (8%) within the whole industry. As sugarcane is grown under a monocropping system which requires a large input of fertilisers compared with other field crops, it has become important to monitor and report on the changes in soil fertility for the various extension areas on a regular basis to ensure that fertiliser practices are in harmony with the environment. This paper provides an update on the direction and magnitude of changes in nutrient availability in the main extension areas since the last survey that was conducted in 1988.

Materials and methods

The four natural regions covered in this study included the lowveld, coast lowlands, coast hinterland and midlands mistbelt. The main parent materials, soil forms and distribution of soil and leaf samples for the 15 extension areas studied are given in Table 1. Each soil and leaf data set was further subdivided into seven periods (1980-82, 1983-85, 1986-88, 1988-90, 1990-93, 1993-95, 1996-97).

The main soil data set comprised pH (H_2O), plant available P, K, Ca and Mg values for about 205 000 soil samples which were analysed by FAS between 1980 and 1997. In addition, soil samples were related to the extension area, bioclimatic system and soil parent material. Supplementary analyses for about 75 000 samples provided additional information on N mineralisation potential (Meyer *et al.*, 1986), PDI and EAI values. Fewer analyses were available for Zn and S (about 25 000) as these tests were introduced for the first time during the 1980s. The leaf data set was smaller than the soil data set and comprised N, P, K, Ca, Mg, S and Zn analyses for about 75 000 samples including site details, extension area, parent material, variety, month and age of sampling.

The same analytical methods as described in the 1988 survey were used as well as the various class intervals for interpreting soil and leaf analyses into various stages of sufficiency (Meyer *et al.*, 1989).

Table 1. Distribution of soil and leaf samples in relation to extension areas, 1980-1997.

Natural region	Extension area	Dominant soil parent material		Common soil forms	Number of samples	
					Soil	Leaf
Lowveld (irrigated)	Mpumalanga	Swazi basic/basalt	38%	Shortlands, Hutton	7 152	1 789
	Swaziland (North)	Vryheid Sediments	40%	Estcourt, Sterkspruit	9 938	11 446
	Swaziland (South)	Dolerite/basalt	40%	Hutton, Shortlands	6 060	6 050
	Pongola	Alluvium	56%	Hutton, Shortlands	7 367	1 589
	Umfolosi	Alluvium	45%	Bonheim, Hutton		
North Coast lowlands and hinterland	Zululand North	Recent sands	50%	Hutton	12 422	1 472
	Zululand Central	Natal Group Sandstone	30%	Hutton, Inanda	9 609	2 105
	Zululand South	Vryheid Sediments	30%	Westleigh	19 277	2 340
	North Coast	Natal Group Sandstone	27%	Cartref, Glenrosa	42 046	8 526
	North Coast (I)	Dwyka Tillite	40%	Cartref, Glenrosa	4 250	381
	Durban North Coast	Natal Group Sandstone	35%	Cartref, Glenrosa	21 951	14 602
Midlands mistbelt	Midlands North	Natal Group Sandstone	60%	Inanda	21 186	9 915
	Midlands South			Hutton	14 366	7 860
South Coast lowlands and hinterland	South Coast	Granite	40%	Glenrosa	16 741	6 844
	Lower South Coast	Natal Group Sandstone	36%	Cartref, Glenrosa	11 060	1 825
	KwaZulu small scale growers	Granite	50%	Glenrosa, Cartref	3 060	217
				Overall totals	206 485	75 530

Results and discussion

The mean values obtained from nearly 205 000 soil analyses (pH, K, Ca, Mg, S, Zn, PDI and EAI) from the main extension areas as well as the percentage of samples rated as deficient are summarised in Table 2. A more detailed breakdown of these data for the seven time periods between 1980 and 1997 is shown for the whole industry in Appendix 1. A similar breakdown is available for each of the 15 extension areas (data not shown). For leaf samples the mean values obtained for all the nutrients analysed are summarised on an extension area basis in Table 3, while a detailed breakdown for the seven time periods is given in Appendix 2. The main changes in nutrient composition of leaf samples submitted to FAS since 1980 are summarised below.

Nitrogen

- Of the leaf samples analysed since 1980, 20% were classified as deficient in N. Since the 1980-82 period the average N level has steadily declined with the incidence of N deficiency increasing from 10 to 26%. This increase in N deficiency is considered to be due mainly to rationalisation of fertiliser use during the 1993-1995 drought and the continuing threat of *Eldana saccharina* Walker (Lepidoptera: Pyralidae), which is known to cause more damage at higher levels of N fertilisation. The decline in leaf N content may also be attributed to the increased use of varieties N12 and N14, which are both known to have a relatively lower N uptake pattern than NCo376.
- Cane areas with the lowest average leaf N content and the highest proportion of samples deficient in N included KwaZulu small scale growers (57%), Zululand South (40%), North Coast small scale growers (33%), North Coast (27%), Zululand North (27%) and South Coast (25%) (Figure 1). These areas are also associated with the greatest number of low N mineralising soils (Category 1) that have least potential for supplying the crop with N released from soil organic matter.
- Cane areas showing the highest average N content and the lowest incidence of N deficiency included Swaziland (10%), Durban North Coast (17%), Midlands South (17%) and Midlands North (19%). Nonetheless, in the Midlands North extension area with extensive areas of high to very high N mineralising soils, the proportion of leaf samples deficient in N has increased from nil in 1980-82 to 25% in the 1996-97 period. This suggests that the organic matter content, which is the main native source of mineral nitrogen in the soil, is slowly degrading under a system of cane monoculture. Degradation of soil organic matter is a major problem on the muck soils in Florida in the USA.

Phosphorus

- In general soil samples submitted by KwaZulu small scale growers have shown the lowest average P status (12 ppm) compared with the irrigated lowveld areas, which ranged from 28 to 37 ppm and 35 to 41 ppm respectively. From 1980-1986, the industry soil P average initially increased

Table 2. Comparison of average nutrient content of soil samples from different extension areas.

Extension region	No. samples	pH	P ppm	K ppm	Ca ppm	Mg ppm	S ppm	Zn ppm
Mpumalanga	7152	6,87	40	180	1860	593	25	3
Swaziland	9938	6,79	35	210	2436	754	25	1
Pongola	6060	6,69	41	202	1219	293	23	2
Umfolosi	7367	6,40	41	185	1223	285	35	2
Zululand North	12422	5,58	28	142	751	190	17	2
Zululand Central	9609	5,71	28	142	650	180	38	2
Zululand South	19277	5,37	36	117	616	170	31	2
North Coast	42046	5,40	31	120	581	147	26	1
North Coast (I)	4250	5,36	29	120	481	144	14	2
Durban North Coast	21951	5,29	36	120	484	127	21	2
Midlands North	21186	5,16	31	126	369	102	31	2
Midlands South	14366	5,24	37	126	534	144	106	2
South Coast	16741	5,24	34	126	554	152	19	2
Lower South Coast	11060	5,20	28	106	381	115	21	2
Kwazulu Growers	3060	5,62	12	131	682	213	25	1
% Samples deficient		28	12	20	14	5	6	6

Table 3. Comparison of average nutrient content of leaf samples from different extension areas.

Extension Region	No. samples	N%	P%	K%	Ca%	Mg%	S%	Zn ppm
Mpumalanga	1 789	1,81	0,20	1,14	0,33	0,28	0,19	19
Swaziland	11 446	1,91	0,23	1,25	0,31	0,24	0,16	18
Pongola	6 050	1,86	0,20	1,16	0,33	0,24	0,17	17
Umfolosi	1 589	1,83	0,20	1,24	0,27	0,23	0,15	17
Zululand North	1 472	1,77	0,20	1,26	0,25	0,21	0,17	19
Zululand Central	2 105	1,82	0,19	1,31	0,25	0,22	0,15	18
Zululand South	2 340	1,69	0,19	1,17	0,24	0,22	0,17	19
North Coast	8 526	1,77	0,23	1,33	0,25	0,21	0,17	18
North Coast (I)	381	1,74	0,19	1,36	0,23	0,21	0,17	16
Durban North Coast	14 602	1,90	0,20	1,19	0,28	0,22	0,16	18
Midlands North	9 915	1,83	0,19	1,36	0,27	0,22	0,19	18
Midlands South	7 860	1,91	0,19	1,37	0,29	0,23	0,18	19
South Coast	6 844	1,82	0,20	1,24	0,26	0,21	0,14	17
Lower South Coast	1 825	1,95	0,19	1,24	0,30	0,20	0,17	22
KwaZulu Growers	217	1,68	0,15	0,98	0,30	0,23	0,14	21
% Samples deficient		20	21	7	2	1	2	7

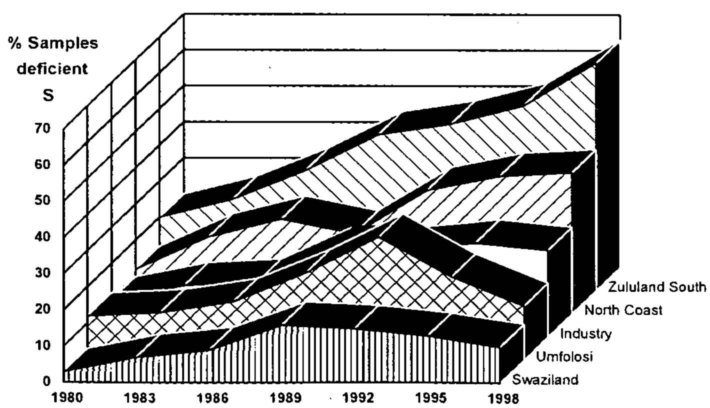

Figure 1. Frequency of leaf samples deficient in nitrogen for selected areas.

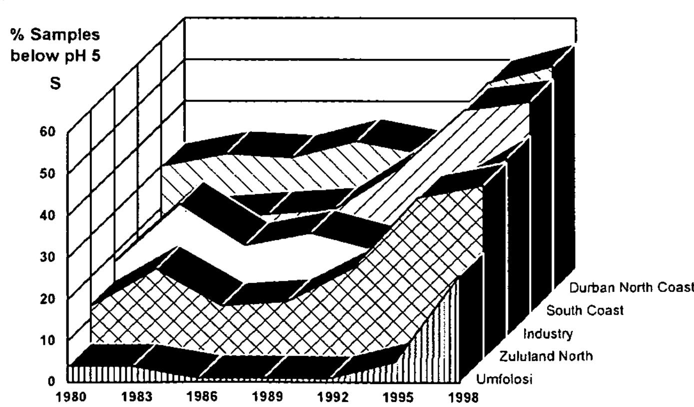

Figure 2. Rate of soil acidification in selected areas of the industry.

increased from 30 to 36 ppm but has since declined to 32 ppm in the 1996-97 period. On an industry wide basis only 12% of the soil samples appeared to be deficient in P based on the 11 ppm critical value used for ratoon cane.

- While the trend in soil P levels generally indicated a fairly low incidence of P deficiency throughout the industry, this should be seen against a rising trend in the number of samples deficient in leaf P. Between 1980 and 1986, average industry leaf P contents were initially 0,25% and higher, but have steadily declined to 0,19%. The decline in leaf P and the associated increase in the incidence of P deficiency from 7 to 31% between 1980 and 1997 is due mainly to a reduction in P usage in the industry between 1983 and 1996. Increased grower resistance to the sharp increase in P fertiliser prices over this period may partly account for the reduced usage.
- Cane areas showing the greatest increase in percentage of leaf samples deficient in P include Lower South Coast (35%), Midlands North (34%), Zululand South (31%) and Pongola (27%). On the other hand, areas showing an improvement in soil P status between 1980 and 1997 include Swaziland from 28 to 34 ppm, Durban North Coast from 30 to 37 ppm and Umfolosi from 39 to 48 ppm.
- In terms of P fixation, 67% of soils derived from dolerite, 60% from Vryheid sediments, 39% from Natal Group sandstone (TMS mistbelt) and 40% from Swaziland Basic rocks were rated as moderately to strongly P fixing.

Potassium

- Of the three major nutrients N, P and K, current plant available soil K reserves rank as the most favourable for most of the cane areas. Although changes in the K status of soils on an industry wide basis initially declined from an average of 131 ppm in 1980-82 to 116 ppm in 1988-90, soil K levels have steadily improved, averaging 158 ppm in 1993-95 before slipping back to 127 ppm in 1996-97 (see Appendix 1). Average leaf K levels closely mirrored the trend in soil K levels. Apart from the presence of residual soil K from unused fertiliser during the drought, other factors such as K release from slowly available forms of soil K as well as an increased usage of K fertiliser have contributed to this favourable position
- The cane area that has shown the greatest improvement in K uptake between 1980-82 and 1996-97 was Mpumalanga, with a reduction in the incidence of leaf K deficiency from over 60 to 15% respectively. This may be ascribed to the impact of the new K reommendations that were introduced for the irrigated lowveld following a five year programme of research (Donaldson *et al.*, 1990).
- Leaf analysis can also be used be used for diagnosing luxury consumption of K when levels are in excess of 1,5%. Areas showing a clear indication of luxury K usage during the past three years include Zululand North (32%), Durban North Coast (27%), Midlands North (23%), Midlands South (22%) and Zululand Central (20%).

Soil acidity and Al toxicity

- Industry wide there was a marked increase in soil acidification with average soil pH (H_2O) values declining from a value of 6,17 in 1980-82 to 5,61 in 1996-97. This represents a 5,6 fold increase in acidification in terms of hydrogen ion activity over this period. The extent of acidification may also be assessed from the increase in the proportion of soil samples that were below pH 5,0 from 18% in 1980 to 43% in 1997.
- Traditionally, soil acidity problems have been confined mainly to cane growing in the high altitude areas. The survey results show that the coastal areas are acidifying at a more rapid rate than their midlands counterparts. Since 1980, areas that have shown the biggest increase in the proportion of samples that are strongly acid (below a pH of 5,0), include the South Coast (from 13 to 51%), North Coast small scale growers (from 19 to 61%), Zululand South (from 14 to 48%) and Zululand North (from 13 to 42%) (see Figure 2).
- The results of a recent investigation based on the use of a soil profile acidification model have shown increased soil acidification on an estate in Zululand and other areas (Schroeder *et al.*, 1994).

Accelerated acidification of soils under cultivation is most often due to the combined effect of oxidation of ammoniacal fertilisers to nitric acid, mineralisation of organic matter and leaching of basic cations from the soil.

- Although industry wide there has been little change in the buildup of Al levels in the soils, there are indications of an increased incidence of Al toxicity in soils from certain areas. Between 1980 and 1997 the proportion of samples with toxic levels of Al increased in the Zululand North area from 0 to 28%. Increases were of the same order for Zululand South and the South Coast. The detrimental effects of toxic levels of exchangeable Al on cane growth are well documented in the South African sugar industry (Schroeder *et al.*, 1995). Clearly, there will be a greater need for ameliorating problem soils with dolomitic lime, particularly the loamy sands derived from Natal Group Sandstone and Basement Granite.

Calcium and magnesium

- The incidence of both Ca and Mg deficient soil samples have increased between 1980 and 1997, from 13 to 17% for Ca and 4 to 7% for Mg. Areas showing the greatest Ca deficiency include Durban North Coast (26%), Lower South Coast (26%), North Coast (25%) and Zululand Central (22%). Leaf sample analyses have also shown an increased incidence of Ca deficient samples, but the proportion of samples affected were generally below 5% of the total number of samples submitted.
- Areas showing the highest incidence of Mg deficiency based on soil analysis included Durban North Coast which increased from 0-14% between 1980 and 1997 (Figure 3). Other areas showing an increased incidence of declining Mg levels included North Coast and Zululand North.

Although the frequency of leaf samples showing deficient levels of Mg was less than 5% for these areas it was interesting to note that the frequency of samples with low but not deficient Mg (0,10 to 0,19%) has increased from less than 10% in 1980 to over 40% in 1997 (Figure 4). This strongly suggests that plant available reserves of Mg in soils are diminishing at a rapid rate as a consequence of crop removal and soil acidification.

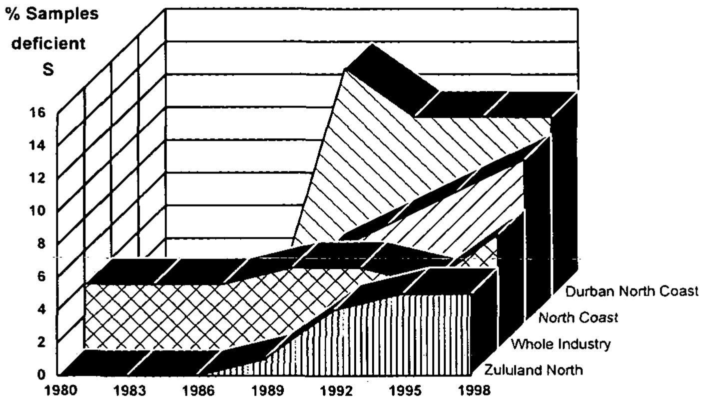

Figure 3. Frequency of soil samples deficient in magnesium for selected areas.

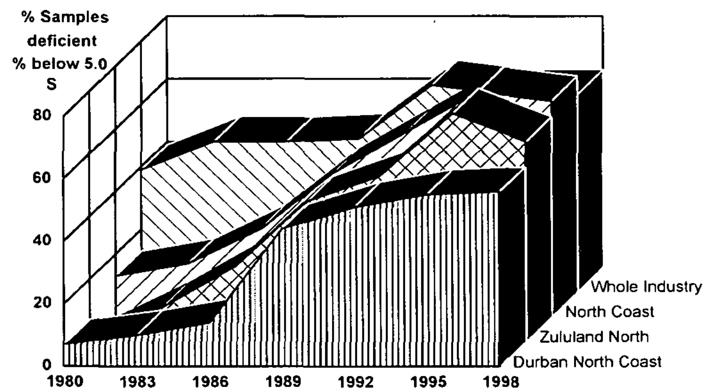

Figure 4. Frequency of leaf samples showing marginal magnesium for selected areas.

Other nutrients

- Compared with the 1980-82 period, the proportion of leaf samples deficient in S has declined on an industry wide basis from 10 to 1% owing to the re-introduction of S in a number of fertilisers. Average soil S levels for each of the sampling periods initially increased from 23 to 42 ppm between 1980-82 and 1988-90 but have since stabilised at about 25 ppm.
- Zinc deficiency has increased in some areas since the 1980-82 sampling period. Areas that showed the highest incidence of Zn deficient leaf samples include Pongola (13%), South Coast (13%), Durban North Coast (12%) and Mpumalanga (9%).

Conclusions

Compared with the 1988 survey, the main outcomes may be summarised as follows:

- A steady increase in N deficiency, particularly in the coastal cane areas which is mostly due to growers cutting back on fertilisers following the drought as well as the continuing eldana threat.
- There is also evidence from both leaf and soil data that soil P levels are showing signs of being depleted. It is likely that the decline in soil organic matter levels, identified as an important outcome in the recent paired site survey (van Antwerpen and Meyer, 1996), will also result in less natural N and P being available through mineralisation of organic matter, implying the need for higher inputs of N and P through fertilisers.
- The build-up of soil K and the evidence for luxury K uptake in leaf samples from many areas suggest an over-use of K by growers. There is scope for increasing N and P and reducing K fertiliser, in accordance with FAS recommendations now that economic conditions in the industry have improved. Leaf sampling as a diagnostic tool for correcting nutrient imbalances is still very under-utilised by growers. In some parts of the industry the ratio of the number of soil to leaf samples submitted is well in excess of 5:1. Greater use should be made by growers of DRIS diagnosis of leaf sample analysis, which takes nutrient balance into account (Meyer, 1981).
- There is a marked increase in soil acidification, with increased evidence of Ca and Mg deficiencies, particularly in the coastal cane areas south of Empangeni. Current threshold values for soil Ca and Mg levels will require revision for maintenance recommendations of limestone.

The results of this investigation demonstrate the potential value of NIRS based on soil and leaf analyses. In future the extension service will be better placed to use NIRS, not only on a regional scale but also at the farm level. Investigations combining the FAS databank with the Field Record System (FRS) and Geographical Information System (GIS) will also play an increasingly important role in relating field productivity to fertility trends (Hellman *et al.*, 1995). A trend that is emerging in the USA and Europe is towards site specific management, where Global Positioning System (GPS) controlled fertiliser applicators can vary the amount of fertiliser applied to a field according to soil test results. FAS will also be well placed to advise growers when this technology becomes available in the sugar industry.

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APPENDIX 1

Average nutrient content of soils on an industry-wide basis for seven periods between 1980 and 1997.

NUTRIENT	PERIOD	No. of SAMPLES	MEAN ppm	PERCENTAGE OF TOTAL			
				LOW	MARGINAL	ADEQUATE	HIGH
				<10	11 - 29	30 - 49	>50
PHOSPHORUS	1980-1982	32 996	30	14	46	17	23
	1983-1985	40 916	32	12	44	20	24
	1986-1988	26 935	36	9	42	21	28
	1988-1990	22 229	33	9	45	25	21
	1990-1993	33 393	34	12	42	23	23
	1993-1995	34 395	35	12	38	23	27
	1996-1997	22 936	32	15	42	22	21
	AVG (Trend)	30 543	33	12	43	22	24
		213 800		<110	111 - 155	156 - 245	>246
POTASSIUM	1980-1982	31 803	131	22	29	30	19
	1983-1985	38 728	133	20	29	31	20
	1986-1988	29 398	126	21	32	32	15
	1988-1990	22 230	116	24	31	31	10
	1990-1993	35 254	148	16	27	36	20
	1993-1995	36 145	158	12	25	39	24
	1996-1997	24 066	127	27	28	29	16
	AVG (Trend)	31 089	134	20	29	33	18
		217 624		<150	151 - 350	351 - 1 000	>1 000
CALCIUM	1980-1982	32 707	737	13	23	34	30
	1983-1985	40 844	720	13	24	33	30
	1986-1988	26 935	768	11	26	35	28
	1988-1990	22 230	535	15	31	38	16
	1990-1993	35 254	773	15	26	34	25
	1993-1995	36 146	771	17	25	31	27
	1996-1997	24 066	757	17	25	31	27
	AVG (Trend)	31 169	723	14	26	34	26
		218 182		<26	27 - 53	54 - 132	>133
MAGNESIUM	1980-1982	32 707	148	4	34	60	2
	1983-1985	40 844	144	4	38	54	4
	1986-1988	26 941	215	4	38	36	22
	1988-1990	22 230	154	5	16	35	44
	1990-1993	35 254	243	5	14	30	52
	1993-1995	36 146	229	4	14	30	52
	1996-1997	24 066	225	7	15	28	51
	AVG (Trend)	31 170	194	5	24	39	32

Continued...

APPENDIX 1 continued

NUTRIENT	PERIOD	No. of SAMPLES	MEAN ppm	PERCENTAGE OF TOTAL			
				LOW	MARGINAL	ADEQUATE	HIGH
		218 188		<10	11 - 20	21 - 50	>50
SULPHUR	1980-1982	741	23	7	61	23	9
	1983-1985	1 659	24	0	55	38	7
	1986-1988	893	34	1	27	54	18
	1988-1990	59	42	0	2	75	24
	1990-1993	794	27	7	34	53	6
	1993-1995	815	25	19	44	31	6
	1996-1997	1 249	26	8	37	48	7
	AVG (Trend)	887	29	6	37	46	11
		6 210		<1,00	1,01 - 1,49	1,50 - 2,99	>3,00
ZINC	1980-1982	0	0	0	0	0	0
	1983-1985	0	0	0	0	0	0
	1986-1988	0	0	0	0	0	0
	1988-1990	6 175	2	11	18	37	34
	1990-1993	8 580	2	10	15	34	41
	1993-1995	7 993	2	9	18	33	41
	1996-1997	5 038	2	10	18	34	38
	AVG (Trend)	3 969	1	6	10	20	22
		27 786					

MISCELLANEOUS NO. 1

PROPERTY	PERIOD	No. of SAMPLES	MEAN	LOW	MODERATE	HIGH	VERY HIGH
				<5,00	5,01 - 7,00	7,01 - 8,00	>8,01
pH	1980-1982	31 490	6,17	18	72	7	3
	1983-1985	40 584	5,91	32	60	5	3
	1986-1988	26 941	5,88	22	69	6	3
	1988-1990	22 229	5,55	25	72	2	0
	1990-1993	35 253	6,08	21	70	7	2
	1993-1995	35 944	5,89	34	59	6	1
	1996-1997	24 079	5,61	43	49	7	1
	AVG (Trend)	30 931	5,87	28	64	6	2
		216 520		<0,20	0,21 - 0,40	0,41 - 1,00	-
PDI	1980-1982	10 658	0,54	11	15	74	0
	1983-1985	14 450	0,51	12	17	71	0
	1986-1988	9 686	0,55	11	19	70	0
	1988-1990	8 778	0,57	7	13	80	0
	1990-1993	12 034	0,58	7	16	77	0
	1993-1995	12 599	0,55	10	14	76	0
	1996-1997	7 327	0,56	8	14	78	0
	AVG (Trend)	10 790	0,55	9	15	75	0
		75 532		<26	27 - 80	81 - 108	>109
Al toxicity	1980-1982	13 656	30	66	24	4	6
	1983-1985	22 339	25	72	19	6	3
	1986-1988	12 624	29	67	22	8	3
	1988-1990	12 069	33	60	29	6	6
	1990-1993	15 432	33	58	32	5	5
	1993-1995	19 748	28	65	27	4	4
	1996-1997	14 135	32	60	31	5	4
	AVG (Trend)	15 715	30	64	26	5	4
		110 003					

APPENDIX 2

Average nutrient content of leaf samples on an industry wide basis for seven periods between 1980 and 1997.

NUTRIENT	PERIOD	No. of SAMPLES	MEAN ppm	PERCENTAGE OF TOTAL			
				DEFICIENT	MARGINAL	ADEQUATE	HIGH
				<1,6	1,6 – 1,8	1,8 – 2,7	>2,7
	1980-1982	5 450	2,01	10	20	65	5
	1983-1985	14 210	1,99	14	22	61	3
	1986-1988	15 254	1,90	15	21	60	4
NITROGEN	1988-1990	14 790	1,79	24	28	48	0
	1990-1993	14 834	1,80	24	30	45	1
	1993-1995	10 835	1,76	26	31	42	1
	1996-1997	9 531	1,80	24	25	50	0
	AVG (Trend)	12 129	1,86	20	25	53	2
		84 904		<0,17	0,17 – 0,19	0,20 – 0,30	>0,30
	1980-1982	5 454	0,27	7	25	62	6
	1983-1985	14 219	0,24	13	32	51	4
	1986-1988	15 260	0,25	15	33	48	4
PHOSPHORUS	1988-1990	14 790	0,19	24	24	51	1
	1990-1993	14 833	0,19	28	23	48	1
	1993-1995	10 835	0,20	27	20	52	1
	1996-1997	9 531	0,19	31	22	46	1
	AVG (Trend)	12 132	0,22	21	26	51	3
		84 922		<0,86	0,86 – 1,05	1,05 – 1,50	>1,50
	1980-1982	5 454	1,33	11	20	53	16
	1983-1985	14 219	1,34	7	21	57	15
	1986-1988	15 260	1,40	7	18	58	17
POTASSIUM	1988-1990	14 790	1,27	7	17	62	14
	1990-1993	14 833	1,20	7	20	60	13
	1993-1995	10 835	1,26	7	19	59	15
	1996-1997	9 531	1,29	4	12	63	21
	AVG (Trend)	12 132	1,30	7	18	59	16
		84922		<0,15	0,15 – 0,20	0,20 – 0,40	>0,40
	1980-1982	5 454	0,34	1	14	74	11
	1983-1985	14 219	0,34	2	17	73	10
	1986-1988	15 260	0,35	3	17	70	20
CALCIUM	1988-1990	14 790	0,28	3	15	74	8
	1990-1993	14 833	0,32	2	14	76	8
	1993-1995	10 835	0,30	2	13	75	9
	1996-1997	9 531	0,30	2	13	79	6
	AVG (Trend)	12 132	0,32	2	15	74	9
		84 922		<0,10	0,10 – 0,20	0,20 – 0,40	>0,40
	1980-1982	5 454	0,29	0	39	56	5
	1983-1985	14 219	0,27	1	48	48	3
	1986-1988	15 260	0,27	1	48	48	3
MAGNESIUM	1988-1990	14 790	0,22	0	49	50	1
	1990-1993	14 833	0,25	1	66	33	1
	1993-1995	10 835	0,22	1	63	35	1
	1996-1997	9 531	0,24	1	63	36	1
	AVG (Trend)	12 132	0,25	1	54	44	2
		84 922		<0,10	0,10 – 0,15	0,15 – 0,30	>0,30
	1980-1982	1 078	0,15	10	50	36	4
	1983-1985	5 426	0,15	4	55	38	3
	1986-1988	15 260	0,16	2	40	55	2
SULPHUR	1988-1990	14 537	0,16	0	18	82	0
	1990-1993	14 211	0,17	0	11	89	0
	1993-1995	8 869	0,18	0	9	90	0
	1996-1997	5 975	0,19	1	30	69	0
	AVG (Trend)	9 337	0,17	2	30	66	1
		65 356		<12	12 – 15	15 – 25	>25
	1980-1982	1 694	18	3	27	63	7
	1983-1985	5 495	19	7	21	66	6
	1986-1988	15 260	18	10	22	59	9
ZINC	1988-1990	14 535	20	3	13	70	14
	1990-1993	14 211	18	10	23	60	6
	1993-1995	8 848	20	9	22	62	8
	1996-1997	5 967	18	7	18	66	8
	AVG (Trend)	9 430	19	7	21	64	8