CO-ORDINATION OF SOIL ANALYSIS SERVICES IN SOUTH AFRICA

A J Buys, FSSA

Introduction

Since, upon chemical analysis of plant material and soil, it was first realised that soil contained many of the nutrients essential for plant growth, soil analysis became a respected tool in the hands of soil and plant scientists. To this day, however, it remains a tool to be used with circumspection and it still often baffles the scientists.

Fertilization advisory services rely heavily on analyses of soil samples taken from crop lands. At present (1982) some 170 000 soil samples are analysed annually for this purpose in South Africa, involving some 35 laboratories.

The mere magnitude of these figures makes soil analysis an important activity. They do not necessarily, however, ensure a satisfactory service. Such a service is indeed fraught with limitations and problems, making soil analysis a difficult operation.

The problems are encountered at the very first stage of the advisory service, even before analysis, viz when sampling the soil. While an analysis can only be as good as the sample, it is unfortunately true that in South Africa soil sampling leaves much to be desired.

The next problem is to find a suitable method of extracting plant nutrients from the soil in such a way as to simulate what a growing plant's roots will do during the growing season. There is no clearcut answer to this problem and arbitrarily chosen methods must be correlated with plant responses and fertilization in extensive experimentation. Scientists have unfortunately come up with several different answers to the problem.

Further problems are encountered during the actual analysis of the extracted nutrients. Concentrations to be determined are low, down to less than 0,0001% (ie 1 ppm). This makes the contamination hazzard an ominous one. It calls also for very sensitive methods and equipment. Insensitive methods, ie non-specific, will yield biased results. Over-sensitive methods on the other hand will yield variable results, calling for repeat analyses to obtain a realistic mean analysis.

On top of all this comes the human element and management.

Given a number of laboratories using different methods and with differing levels of overall performance, an undesirable situation could develop. And indeed, to a certain extent this is true of South Africa. It is cause for concern not only to the laboratories or their owners but especially to the farmer for whose benefit the soil analysis service is provided. On the basis of the analyses of a few soil samples he will have to make decisions about the purchase of materials, especially fertilizer, to the tune of maybe tens of thousands of rands.

Historical back-ground

Let it be said at the outset that the organisations rendering soil analysis services in South Africa have acted responsibly and have since the late 1950's been aware of the problems and have been seeking solutions. Several attempts have been made at rationalising the situation with only limited success.

In the fifties the laboratories of the Department of Agriculture — ie its regional and research institutions — very much called the tune although the number of samples from farmers were few. Fertilizer companies ran soil analysis laboratories as an extension to their production quality control laboratories. In most of these laboratories the methodology and instrumentation of the nearest Departmental laboratory was followed. This, however, meant that different methods were used in different areas. The various laboratories of the Department each used its own perferred method and all calibration work was coupled to the respective methods used. A situation of diverging results developed. The actual quality of analytical work performed by the laboratories was also not known since it could not very well be checked by an external (independent) monitoring system. The situation was appreciated as an unsatisfactory one, but its extent could not be quantified.

Early moves

The first record, in the annals of the FSSA, of the concern about the limitations of the soil analysis service is to be found in the minutes of the third meeting of the Agronomic Subcommittee, held in 1959, the year of the Society's inauguration.

Indeed it was in the form of a plea for the FSSA, as one of its first concerted efforts as an association, to rationalise soil analysis within the fertilizer industry. The need for the standardisation of methods of analysis was emphasised by Mr J Moerdyk of the then Windmill Fertilizers. The desirability of a centralised service was advocated at the same meeting. These motions were carried and marked the beginning of a series of deliberations and developments, which to this day, 23 years later, are still continuing.

Standardisation of methods

(i) In 1963 it was decided that methods of soil analysis should be standardised in the fertilizer industry. This was implemented in 1964.

The methods of extraction agreed upon were:

P: Bray no 2 (0,1 mol/ℓ HCl plus 0,025 mol/ℓ NH_4F).
Cations (K, Ca, Mg and Na): Ammonium acetate (1,0 mol/ℓ at pH 7; soil leached at a ratio of 1:25 mass/volume, later 1:10 extraction).

pH: Measured in water and also in 1 mol/ℓKC1 (both at a suspension ratio of 1:2,5 mass/volume).

(ii) The details of the methods were revised in 1970 and again in 1974, when they were first published (Soil Analysis Methods. FSSA Publication No 37). A further revised edition was published in 1980/81. (Soil Analysis: Manual of Methods. FSSA Publication No 74).

(iii) Reconsidering the phosphate extraction method, it was decided in 1979 to accept the ISFEI method, proposed by the Department of Agriculture, as a reference method. It did not replace the Bray 2 standard method, but samples from research plots were to be analysed also by ISFEI. Provided certain practical problems could be eliminated the method would be considered as standard for phosphate and cations.

(iv) In 1981 the phosphate extraction method was changed from Bray 2 to Bray 1.

(v) A Soil Analysis Subcommittee of the FSSA was formed in 1967. All laboratories of fertilizer companies were represented on this committee.

(vi) The standard methods of the FSSA were accepted by virtually all laboratories other than those of the Department of Agriculture.

(vii) For certain non-routine analyses standardisation could not be achieved. These include the determination of lime requirements, cation exchange capacity, mechanical analysis and zinc.

(viii) In many cases where methods have been standardised, laboratories do not necessarily follow identical procedures although extraction methods are the same. These deviations are nevertheless a cause for concern, since they may cause variations in results. Standardisation to the finest detail will, however, never be possible under present conditions. There is no authoritative body which can enforce precise conformance by independent laboratories.

(ix) The norms for evaluating test sample results were initially based on pure statistical concepts and linked with precision and bias, but later only precision. It was subsequently decided that a more realistic approach would be to obtain an arbitrary estimate of standard deviation based on the knowledge, experience and requirements of a number of senior practicing agronomists actively engaged in fertilization recommendation work. Such standard deviations are in no way linked to the adventitious analytical precision and/or bias, but relate to agronomic considerations, however analytical capabilities had to be taken into account. This method of evaluation was found necessary because despite standardisation, the biases between laboratories, were fairly great and far exceeded the analytical precision of individual laboratories. A different system of rejecting outliers had therefore also to be devised, again an arbitrary one.

(x) Despite standardisation of methods within the group under the guidance of the FSSA, some seven methods of determining phosphate are still being used in South Africa.

Monitoring scheme

With the formation of the Soil Analysis Subcommittee in 1967 a scheme of interlaboratory sample exchange commenced. Since 1974 other laboratories joined the scheme, the latest in 1982. At present there are 20 participating laboratories, only five of which belong to fertilizer companies.

In 1975 the running of the FSSA Soil Analysis Check and Control Scheme was taken over by the FSSA. The Soil Analysis Working Committee represents all participating laboratories and replaced the previous committee.

This committee considers the standard methods of analysis to be used by the group. Through its members it performs laboratory tests to investigate problems that may arise. It is also responsible for maintaining the external monitoring scheme.

The scheme essentially consists of the following:

(i) Fortnightly check samples submitted to participating laboratories. Analysis results are collated and analysed statistically with report-back to participants. Included in the report is an evaluation of laboratory performance.

(ii) Standard samples are sent out approximately every six weeks. The samples are accompanied by specified, agreed analyses to serve as a means of calibrating the laboratories against one another.

General Soil Analysis Laboratory

From the outset (1960) the principle of a centralised soil analysis service was accepted by the FSSA. This was confirmed on several occasions until 1976.

The form of this suggested centralised facility varied from a purely soil analysis laboratory to a fully-fledged fertilizer institute including fertilization recommendations. Instead of one, two or three facilities were considered.

Various kinds of organisations were considered, including an organisation functioning under the auspices of the FSSA, a private company jointly owned by members of the FSSA, organisations involving the fertilizer industry and the Government, and an independant private company contracting for the analysis of samples submitted by member companies.

In 1968 and again in 1970 the Leaf Analysis Service of the S A Co-operative Citrus Exchange quoted for the soil analyses required by the fertilizer industry. The earlier quote was eventually withdrawn and the latter not considered. V H Whitlock and Serfontein in 1970 and R F Loxton, Hunting & Associates in 1976 also quoted, but neither was accepted.

Eventually, in 1976, the FSSA Management Committee decided that a centralised soil analysis service was not feasible.

After further efforts at rationalisation in 1977 it was decided that member companies and any other laboratory owners could voluntarily close down their soil analysis laboratories and have their client's samples analysed by some central laboratory. In this way the change-over to a central facility or facilities would be gradual and more practical. It was agreed that the Leaf Analysis Service's soil laboratory be recommended as a central laboratory. This was actually implemented, but only to a very small degree. Only a few laboratories closed down and samples were diverted to Leaf Analysis Service, while certain companies and bodies who did not have thier own laboratories made use of the same facility.

One attempt at having a centralised facility for the Cape was seriously considered in 1976 but later abandoned.

In the mean time the number of practising laboratories has increased to 33, with a further 7 being considered.

Liaison and co-operation with the Department of Agriculture

From the early days of soil analysis services rendered by members of the fertilizer industry the co-operation and guidance of the Department of Agriculture was sought. Officials at all levels from both sides liaised officially in meetings and symposia, and privately in open discussions on many matters pertaining to soil analysis. Noteworthy were the following events:

(i) September 1968: A meeting on soil analysis with the Department, represented by Dr S J du Plessis.

(ii) May 1969: A meeting on the 'Utilization of Soil Analysis' with the Department under the chairmanship of Dr J W C Geyer. The basis for fertilization recommendations and soil analysis norms were discussed with a view to uniformity of approach. The idea of a central soil analysis laboratory was discussed. That was to be preceded by standardisation of methods and later followed by a Soil Analysis Institute also catering for fertilizer advisory work.

(iii) September 1969: A meeting on standardisation of soil analysis under the chairmanship of Dr C P Naude. Methods of sampling, extraction and determination were discussed. Reference was made also to fertilization advice based on soil analysis.

(iv) November 1969: A meeting on the centralisation of soil analysis services under the chairmanship of Dr C P Naude. An initial central laboratory for the northern areas was envisaged after standardisation of methods had first been achieved. This could later be extended to Natal and the Cape.

(v) 1970: The FSSA planned a symposium on soil analysis but this was abandoned pending an investigation by the Department.

(vi) 1971: A Departmental Committee for the Co-ordination of Soil Analysis Services was formed and commenced work. FSSA members contributed to the investigation. The committee brought out a confidential report.

(vii) Mid seventies to date: Apart from the liaison mentioned, Dr A J van der Merwe, who had been appointed to co-ordinate soil analysis services in the Department, presented a number of papers and gave several talks, also to meetings of the FSSA. After extensive experimentation, he put forth various recommendations which included a recommendation that a modified ISFEI extract be adopted as a standard and universal method for the extraction of phosphate and cations (including micro elements). This method was accepted in 1979 as a reference method for phosphate, but not necessarily as a routine method for samples from farmers' lands. The ideal was to eventually adopt it once technical problems could be eliminated.

(viii) **Sample exchange:** Recently a limited number of samples from the monitoring system of the FSSA and the Department were exchanged. A national monitoring scheme embracing all soil analysis laboratories was thought not yet feasible, because of the different methods being used. Such a scheme had, however, been set as an ideal by both parties.

(ix) In a few special cases samples from experiments were analysed by Departmental laboratories for the FSSA and vice versa. This pertained especially to P by Bray 1 (done by fertilizer companies for the Department) and P by ISFEI (by Departmental laboratories for the FSSA).

Other matters

(i) An attempt was made by FSSA members to standardise interpretation of soil analysis. Wide norms for the evaluation of soil fertility were agreed upon. It was not, however, used as a guideline for fertilization recommendations.

(ii) A standard soil analysis report form for fertilizer companies was devised.

(iii) A standard method for the sampling of topsoil was agreed upon (1976).

(iv) A fee for soil analysis was instituted in 1977. The fee was a nominal R5,00 per sample based on actual total cost at the time. Laboratories of fertilizer companies accepted this, but other laboratories charged approximately R6,50 for the analysis package. Some continued to render a free service. In 1982 an increase to R7,50 was suggested on the basis that costs had gone up since 1976 (basis for 1977 fee), although this could not be accurately quantified.

(v) Some attempts had been made to analyse soil analysis cost, but this proved difficult because of different costing systems being used by different companies and because in most cases the soil analysis service is cost and management wise entangled with other analytical services. (Existing information is given in Table 7.)

Present situation

Soil analysis for fertilizer advisory work is gaining in importance, judged by the increase in the number of samples analysed. in 1981 over 150 000 samples were analysed by 30 laboratories. Most of these samples (about 82%) were analysed by the 18 laboratories outside the Department of Agriculture. This compares with 60 000 samples 15 years earlier. See Table 1 and Figures 1 and 2.

The fact that there are at present 33 practicing laboratories and seven more considered, confirms not only the value attached to soil analysis but also suggests that the service rendered by existing laboratories is probably not regarded as adequate — adequate in the sense of reliability, speed of service and capacity.

Soil analysis services

The existing soil analysis laboratory organisations may be subdivided into six groups according to ownership and purpose of analysis. See Table 2.

It is interesting to compare this with the situation in some other countries. Table 3 gives an indication of soil analysis services in the United Kingdom, Holland, France and Israel. All these services seem to operate satisfactorily. On the face of it the system used in Holland appears to be closest to the ideal, at least for the geographically compact area in which it operates. Such a single laboratory system is probably not feasible in South Africa; but it certainly has many commendable features that should be considered.

The French system is quite different and appears rather similar to the present South African system with many laboratories under different kinds of ownership. The most commendable features are that methods of analysis are standardised, that a

TABLE 1 Number of soil samples analysed for fertilizer advisory services in South Africa (rounded to nearest 500) x 1000.

Laboratories	1966	1970	1976	1977	1978	1979	1980	1981
Department of Agriculture*	4,0 (7%)	7,0 (9%)	18,5 (17%)	21,5 (27½%)	23,5 (23%)	25,0 (22%)	25,5 (20%)	27,0 (18%)
Fertilizer Companies	48,0 (79%)	56,5 (77%)	72,0 (65%)	30,0** (38%)	44,5 (44%)	51,5 (48%)	60,5 (47%)	66,0 (43½%)
Other labs (incl. co-ops)	8,5 (14%)	10,5 (14%)	20,5 (18%)	27,0 (34½%)	34,0 (33%)	36,0 (32%)	41,5 (33%)	58,5 (38½%)
Total	60,5	74,0	111,0	78,5	102,0	112,5	127,5	151,5
Index, 1976 = 100	55	67	100	71	92	101	115	136
Number of labs	22	24						30
Average Samples /lab (x 1000) per annum	2,8	3,1						5,1 ***

* Estimates based on personal enquiries.

** Analysis fees were introduced by fertilizer companies.

*** • The number of samples/lab per annum ranged between 200 and 19100

• About two-thirds of the samples were analysed by a quarter of the laboratories:

— Number of labs that analysed less than 2000 samples: 15
2 000 - 10 000: 9
10 000 - 15 000: 2
15 000 - 20 000: 4
30

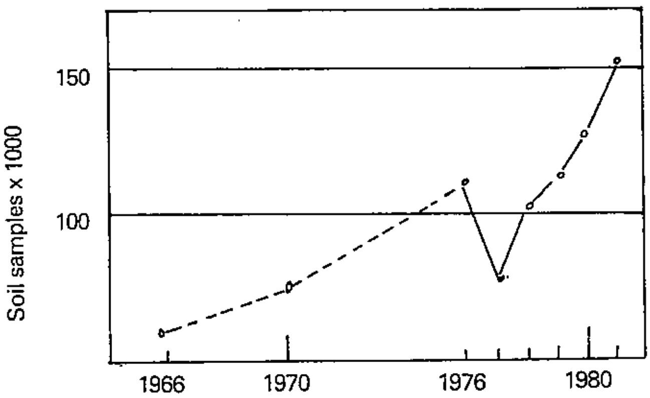


FIG 1: Total number of soils analysed in South Africa for advisory services

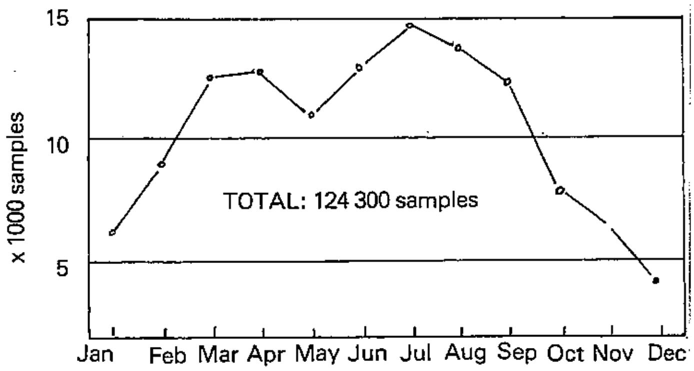


FIG 2: Soil samples analysed during 1981 by 18 laboratories (FSSA Soil Analysis Check and Control Scheme; excluding Dept of Agriculture) for advisory services

central methodology research facility is available, that there exists a co-ordinating body for most (84%) of the laboratories, and that a monitoring scheme is in operation. Much is to be learned from the way the French rationalised their soil analysis services.

The systems in both the United Kingdom and Israel are not quite comparable to that in South Africa. It is, however, important to note that methods are standardised and that monitoring schemes are in operation.

Problem areas

Many problems are preventing soil analysis services in South Africa from being really good. None of the problems, is however insurmountable. In the past it was believed that all problems would be resolved by first standardising the methods of analysis and then centralising the service at one or two suitable localities. This is still true, but both measures have proved difficult to execute and only partial success was achieved with the former. It is therefore now once more opportune to consider the nature of the problems and to try and seek alternative viable and acceptable solutions.

(i) **Laboratory management and organisation**

From an organisational point of view the soil analysis services in the United Kingdom, Israel and Holland are comparatively simple, making possible satisfactory management. Analysis is done in a soil laboratory headed by a soil scientist assisted by chemist/s and trained analysts.

This is not true of all laboratories in South Africa. Table 4 shows in broad terms the basis of management of the soil analysis laboratories. In many cases a soil analysis service was added to an existing laboratory, eg to the feed analysis laboratories (for production control) of the co-ops, or to leaf analysis laboratories, or to fertilizer

TABLE 2: *Soil Analysis Laboratories, 1982*

(Analyses of samples from farm lands for advisory service)

State Departments 16 (+2)	Fertilizer Companies* 5	Agricultural Co-Operatives* 4 (+2)	Other Companies 4	Independant Labs* (Consulting) 3 (+2)	Associations, etc* 1 (+1)
RSA: • Agriculture (12): Transvaal Rgn Highveld Rgn Free State Rgn Natal Rgn Eastern Cape Rgn Karoo Rgn Winter Rainfall Rgn Summer Grain Centre Citrus § Subtr. R I Tobacco & Cotton R I Fruit & Fruit Tech. R I Oenol. & Viti. R I • Transport (1)* • Railways (1)* • Forestry (1)* **Venda:** • Agriculture (1)*	• Fedmis, Milnerton • Fedmis, Sasolburg • Omnia • Triomf, Potchefstroom • Triomf, Somerset West	• NTK • OTK • Sentraalwes • Suidwes-Tvl	• Rhodes Fruit Farms • Sapekoe* • Stellenbosch Farmer's Winery* • Zebediela Estates*	• Gardiner Labs • Labserve • Leaf Analysis Service (Citrus Exchange)	• S A Sugar Assoc. Experiment Station
Considered: • (Transkei) (Agric) • (Bophuthatswana) (Agric)		**Considered:** • (Noordwes) • (Vrystaat)	(Soil analyses for own use mainly)	**Considered:** • (Hoogenboesem) • (Engelbrecht)	**Considered:** • (University of the North)

* Participates in FSSA Soil Analysis Check and Control Scheme (monitoring service)

TABLE 3: Comparison of soil analysis services for advisory work in different countries (Most figures of samples are estimates based on information obtained privately, except for France and South Africa, other than governmental)

Laboratory organisations	FRANCE 1979			SOUTH AFRICA 1979			SOUTH AFRICA 1981			HOLLAND 1981		UK 1981	ISRAEL 1981		
	Labs	Samples x 1000		Labs	Samples x 1000		Labs	Samples x 1000		Labs	Samples x 1000	labs	Samples x 1000		
		Total	per lab		Total	per lab		Total	per lab		Total		Labs	Total	per lab
Governmental	18	96,0	5,3	13	25,2	1,9	15	27,9	1,9			12	15	85	5,7
Fertilizer companies	5	24,5	4,9	5	51,6	10,3	5	66,1	13,2						
Agricultural Co-ops	4	10,3	2,6	2	12,7	6,4	4	25,3	6,3						
Other companies	14	60,2	4,3	3(+3)	0,8	0,3	3(+1)	2,6	0,9						
Societies, etc				1	16,5	16,5	1	17,1	17,1	1(+1)	300				
Independant companies	4	22,5	5,6	(+2)	5,9	5,9	2(+1)	12,2	6,1						
TOTAL	45	213,5	4,7	25(+5)	112,8	4,5	30(+2)	151,3	5,0	1(+1)	300	12	15	85	5,7

Notes:

(1) France
- Standard methods: pH (H_2O), N, organic matter, P (citric acid, or ammonium oxalate extractable), K, Ca, Mg (exchangeable cations with ammonium acetate).
- 1974: 17 labs (8 governmental + 9 other) started a sample exchange scheme.
- 1978: 26 labs formed an organisation to study methodology and subscribed to the Interprofessional Bureau of Analytical Studies which conducts an independant analysis monitoring scheme.
- 1979: 38 out of the 45 laboratories participated in the scheme.

(2) South Africa
- Standard methods for 18 labs (excluding Dep of Agriculture) (20 in 1982):: pH(H_2O), pH (KC1), P (Bray 2, changed to Bray 1 in 1981), K, Ca, Mg, (Na), (extracted with ammonium acetate), (Texture).
- 1964: Standard methods for labs of fertilizer companies.
- 1966: Sample exchange scheme between labs of fertilizer companies.
- 1975: Soil analysis monitoring by FSSA for most labs (excluding Department of Agriculture).
- 1982: 20 labs participate in scheme. Seven more labs being considered.

(3) Holland
- Practically only one lab owned by a farmers' organisation, ie a completely centralised service.
- Soil sampling done by lab.
- Fertilization recommendations done by lab (it is therefore a complete soil analysis service).

(4) UK
- Standardised methods prescribed by ADAS: pH (H_2), P (Olsen), K, Mg, and other.
- Soil analysis monitoring scheme run by ADAS for the 12 laboratories.
- Advisory work done by ADAS.

(5) Israel
- Standard methods: pH (H_2O), P (Olsen), K ($CaC1_2z$), Na (ammonium acetate), (Cl). Labs air-conditioned.
- Management: Soil scientist, with a chemist. — Also leaf analysis and moisture capacity (for irrigation).
- Central lab for co-ordiantion, methodology research and monitoring service. — Advisory work included.

TABLE 4: Laboratory ownership, management and associated activities (responsibilities)

	Ownership	Management	Associated* activities
State departments (16)**	State	(State institution)	Various to none
Agricultural co-operatives (4)	Co-op	Advisory service/Extention	Feed analysis
Fertilizer companies (5)	Company	Fetilizer production	Fertilizer analysis
Other companies (4) (analyses for own use)			
• Rhodes Fruit Farms	RFF	Self (Production)	
• Sapekoe	Sapekoe	Self (production & Research)	Leaf analysis, Tea testing
• Stellenbosch Farmers Winery	SWF	Self (Production & Research)	Wine testing
• Zebediela Estates	Zebediela	Self (Production & Research)	leaf analysis
Independant labs (consultancy) (3):			
• Gardiner Labs	Gardiner	Owner	None
• Labserve	Auerswald	Owner	Leaf analysis Soil analysis
• Leaf Analysis Service	Citrus Exchange	Self	Leaf analysis, etc.
Other (1)			
• S A Sugar Assn Expt Station	SASA	Advisory Service (Extension)	Leaf analysis

* Activities performed in the same laboratory, sharing facilities, staff and equipment to a greater or lesser degree.

** State Departments include RSA Dep of Agriculture and Fisheries, Dep of Transport, Dep of Railways, Dep of Forestry, as well as Venda Dep of Agriculture and Forestry.

analysis laboratories (for production control) for the fertilizer companies, or to research laboratories. The rationale was that facilities, equipment and staff could be shared and idle capacity taken up. This is valid for a relatively small laboratory with a management that is sympathetic towards the requirements and idiosyncrasies of such a service.

Very often the soils side of a dual-purpose laboratory is neglected because of the overruling priorities of the other side or due to a lack of appreciation of the requirements and priorities of a soil analysis service. In larger laboratories, fortunate enough to operate under sympathetic management, it soon becomes evident that separate facilities with appropriate seperate management is essential.

Top management for many of South Africa's largest soil analysis laboratories is not concerned with the main objective of the analysis, eg a fertilizer production manager is not involved in fertilizer advisory service. Soils are nevertheless analysed to aid such an advisory service.

A problem ensuing from a 'non-soil' senior management, eg in the fertilizer industry, is that decisions regarding methodology, taken by the Fertilizer Society of South Africa and hence supported by member companies' advisory service officials (extension, marketing), will not necessarily be implemented by laboratories since they operate under fertilizer production management.

Another disconcerting aspect in laboratory management is found in cases where technical supervision and indeed technical depth is lacking. Fortunately such a state of affairs is not frequently encountered, but there is some cause for concern as may be seen in Table 5. The total complement under the headings 'Chemist' and 'Management' (referring to senior management in the technical field) should at least be one body, even for a very small laboratory.

A certain degree of autonomy in running its own affairs as efficiently as it knows how is essential for a soil analysis laboratory. Very often laboratory routine is upset when staff are pressurised into preferential analysis or even unnecessary analyses to appease certain people.

(ii) **Analytical reliability**

Table 6 is an example of the performances of laboratories participating in the FSSA Soil Analysis Check and Control Scheme. Three alternative/complementary assessments are given, viz in terms of % 'Good Results', or 'Net Good Results', or 'Combined Evaluation'. All are arbitrary and based on agreed rules.

Despite the arbitrary nature of the assessments it is quite clear that laboratories A to F were performing well when the assessment was made and that laboratories L to R performed poorly to unacceptably poorly. It is not a satisfactory state of affairs if one-third of the laboratories falls in this low category.

TABLE 5: Soil analysis laboratories: Personnel complement and efficiency (Some values are estimates only)

Personnel									
Non-technical				Technical					
Laboratory	Samples (1981)	Labourers	Typists, clerks	Supervi-sors	Analysts*	Chemists*	Management*	Total* (Analyst)	Samples/ Analyst per day** (average)
	x 1000				(x1)	(x½)	(x¼)		
1	19,1	1	0,3	1	9	1	1	9,75	7,8
2	17,6	3	1	1	3	1	0,1	3,53	19,9
3	17,3	2	0,5	0	4,3	1	0,2	4,85	14,3
4	17,1	1	0,5	1	8	1	0,5	8,63	7,9
5	12,5	(–)	0,5	1	10	1	0,1	10,53	4,7
6	10,5	3	1	0	5	1	0,3	5,58	7,5
7	9,1	1,5	1	0,5	2,5	0,5	0,5	2,88	12,6
8	6,8	2	0,5	0	2	0,5	0	2,20	12,4
9	5,2	1	0,2	0	1	0	0,3	1,08	19,3
10	3,2	1	0,2	0	1	0	0,3	1,08	11,9
11	2,0	0,5	0,1	0	1,3	0,2	0,1	1,43	5,6
12	1,1	1	0,2	0	1	0,5	0,5	1,38	3,2
13	1,0	0,5	0,2	0	1	0,5	0,5	1,38	2,9
14	0,6	0,1	0	0	0,4	(–)	(–)	0,40	6,0
15	0,5	0,5	0,1	0	1	0,5	0	1,25	1,6
16	0,4	0,3	0	0	0,3	0,3	0,1	0,48	3,3
17	0,3	1	0,1	0	2	0	0	2,00	0,6
18	0,2	0,2	0	0	0,2	0,2	0,1	0,33	2,4
Total	124,3	18,1	6,2	4,5	53,0	9,0	4,8	58,76	8,5
Mean	6,9								

* Total operating analysists are taken as 'Analyst' x 1 plus 'Chemists' x ½ plus Management x ¼.

** 250 effective working days assumed.

Laboratories must find their own ways and means of improving the situation, but the FSSA is doing what it can to aid them.

When different methods of analysis are used, such as the different phosphate extraction methods used by laboratories of the Department of Agriculture, it is of course difficult to assess the performance levels of the laboratories. Each laboratory is a rule unto itself.

(iii) Analyst efficiency

The efficiency of analysts can only be assessed in individual laboratories. It is not at this stage possible to set general norms for analyst efficiency, but both the volume and quality of work have to be considered. An indication of the varying apparent efficiencies for 18 laboratories participating in the FSSA Soil Analysis Check and Control Scheme during 1981 is given in Table 5. The average number of samples analysed per day by one analyst is shown in the last column. It would be more opportune to use actual determinations rather than samples, but on average and considering samples analysed for normal fertilizer advisory purposes, the pattern will not change significantly if samples are used. (See also Figure 3.)

It would appear that analysts at low-volume laboratories doing, say, less than 2 000 samples a year, are less efficient than larger laboratories. The average number of samples/analyst/day for the former being less than one and for the latter about nine, with an overall average of 8,5 samples per analyst per day. This compares with approximately 6 in Israel (figure adapted for the same number of determinations per sample, their actual average figure being about 10).

The variability of the figures in Table 6 may at least partly be due to varying quality of work and/or instrumentation. Analyst efficiency has cost implications.

(iv) Cost of analysis

Table 7 shows the cost history of soil analysis for a few laboratories. These values are estimates only, but do give some indication of cost efficiency when the figures for 1977 are compared — costs range from R2,70 to R9,00 per sample. Again, cost is greatly influenced by analyst efficiency since analysts' salaries contribute a substantial amount to the fixed cost. It could well be imagined that at some small laboratories present actual

TABLE 6: Performances of Soil Analysis Laboratories

(participants to FSSA Soil Analysis Check and Control Scheme — assessment for Feb - March 1982)

Average overall performance judged on pH, P, K, Ca and Mg for four consequtive fortnightly check samples, using different arbitrary criteria (all expressed as percentage of times either participated, or good results achieved, or analyses rejected).

LAB	PARTICI-PATION	GOOD RESULTS		NET GOOD RESULTS		COMBINED EVALUATION*	
	%	%	RANK	%	RANK	%	RANK
A	100	98	1	98	1	98	1
B	100	85	2	85	2	85	2
C	75	83	3	80	3	60	5
D	100	83	3	78	4	78	3
E	75	80	5	73	5	55	6
F	100	78	6	73	5	73	4
G	75	70	7	67	7	50	7
H	75	67	9	63	8	47	9
I	75	70	7	63	8	47	9
J	75	67	9	60	10	45	11
K	30	67	9	58	11	17	17
L	100	63	12	50	12	50	7
M	50	55	14	45	13	23	15
N	50	55	14	45	13	23	15
O	75	53	17	37	15	28	14
P	100	55	14	35	16	35	12
Q	100	60	13	33	17	33	13
R	100	43	18	3	18	3	18
MEAN	81	68	–	58	–	47	–

* Net good results = Good results — Rejected results
* Combined evaluation = Net x participation ÷ 100

(Good results are those within 1,25 standard deviation of the agreed group mean of an analysis. The standard deviations are arbitrary values according to the judgement of experienced agronomists).

costs run as high as R30 or more a sample, while it may in other cases be as low as R5.

If a low quality of analysis is coupled with a high cost the result is entirely unacceptable. There is unfortunately evidence that this is the case for a few laboratories. Fortunately the opposite is true for other laboratories: low cost, high quality and large volume.

(v) **Methodology research**

Except for the Department of Agriculture, hardly any research on methods of analysis is possible. In Holland, Israel and France special institutions or sections of the routine laboratories (Holland) exist for this purpose. The facility provided by the Department of Agriculture in South Africa is naturally geared to its own needs and not necessarily to those of the other laboratories which are jointly responsible for more than 80% of the analyses.

Most laboratories do not possess the facilities and capacity to carry out necessary development and investigations for adaptation of analytical techniques. Our laboratories are poorly equiped to deal with cases where 'special' analyses are required.

(vi) **Standardisation**

There are two main groups of soil analysis laboratories catering for advisory services, viz that of the Department of Agriculture and the bulk of the remaining laboratories grouped under the FSSA Soil Analysis Working Committee. This is not a satisfactory state of affairs.

Yet a further problem being encountered where standardisation has been affected is the phenomenon of the obstinate non-conformance by laboratories to the details of standard methods. While it must be agreed that complete standardisation down to the minutest technical detail is not feasible, major divergencies cannot be tolerated. There is, however, a case for valid 'alternatives' with respect to certain techniques and equipment, but in many cases the validity is not apparent and a certain amount of research may be required to resolve the matter.

(vii) **Soil sampling**

Soil sampling is a sore point. It is fairly certain that many, if not most of the samples analysed for advisory services in South Africa are not truly representative of the lands from which they were taken. There are

TABLE 7: Soil analysis cost (approximately)
(based on quotations and cost estimates)

Year/Company	Number of samples x 1000	Cost, R x 1000, p.a.			Fee charged or quoted (R/sample)
		Fixed	Variable	Total	
1968 Leaf Analysis Services (est)	72	72,15	17,85	90,0	1,50 (1,25)
1968 Leaf Analysis Services (est)	36	54,12	11,88	66,0	1,50 (1,83)
1970 Leaf Analysis Services (est	50	49	8,5	57,5	1,20 (1,15)
1970 Whitlock (adapted) (est)	60	40	4,8	44,8	0,70 (0,75)
1970 FSSA (estimate)	50/60				1,50
1976 Loxton, Hunting of Associates	40				4,50 - 5,00
1976 Agrilab					11,00
1977 FSSA members					5,00
1977 Leaf Analysis Service					6,50
1977 Fedmis, Milnerton (est)	10	23,9	3,1	27,0	(2,70)
1977 NTK (est) (building excluded)	0,7	4,7	1,6	6,3	6,50 (±) (9,00)
1982 Leaf Analysis Service (budget)	6,4	61,5	3,0	64,5	9,00 (±) (10,08)
1982 Certain FSSA members					7,50/10,00
1982 Gardiner Labs					15,00

() Figures in brackets are 'actual' costs.

laudible exceptions, but that is not sufficient. It is suspected that even the minimum requirements laid down in several guidelines are not met. it will probably not be possible to go to the ideal extreme of intensive sampling done in Holland, but an improvement is urgently needed.

(viii) **Interpretation of analysis**

At the other end of the scale is the interpretation of soil analysis values in order to assess the soil fertility status and the subsequent conversion to a fertilization recommendation. To say that all is well in this regard will be overstatement. The problem hails from the very choice of a suitable method of analysis. In a quest to understand the values obtained in an analysis the soil scientist and agronomist must do research. They must therefore be able to rely completely on the quality of the analysis. A wrong value cannot be interpreted.

Requirements

Interested bodies

In the South African context the initiating responsibility for rationalising and co-ordinating soil analysis services rests mainly with the following bodies:

(i) **Department of Agriculture**

Because of its research and extension function, its facilities and its traditional involvement in soil analysis, the Department must feature in a nationwide soil analysis service.

(ii) **The Fertilizer Society of South Africa**

The FSSA has played a role in standardising methods of analysis and co-ordinating soil analysis activities, and runs a soil analysis monitoring service for laboratories analysing more than 80% of the samples for advisory services.

(iii) **Organised agriculture**

The farmer appears both at the beginning and the end of the chain of events surrounding soil analysis. The service is provided for his benefit and he must therefore be represented in such a service. His interests could be handled by agricultural co-operatives, agricultural unions and other farmer organisations, associations and committees.

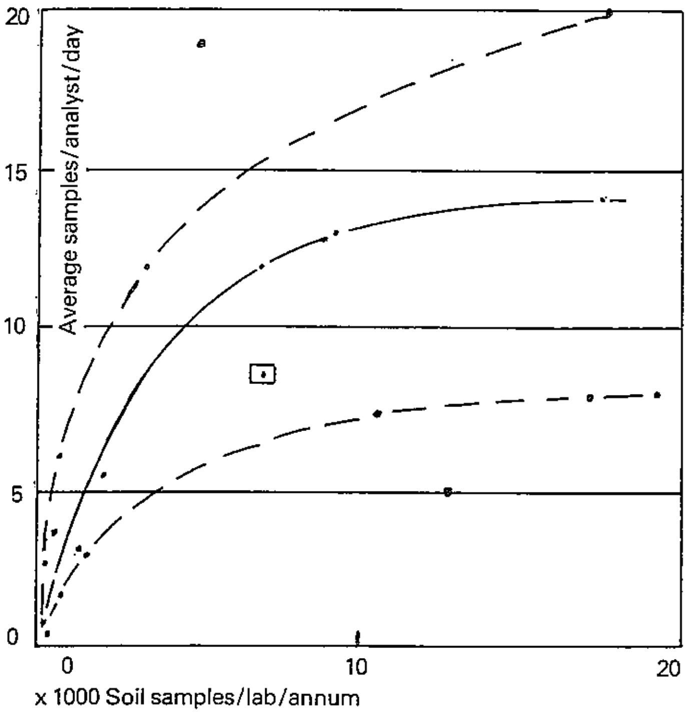


FIG 3: Average number of samples analysed per Analyst per day by 18 laboratories (FSSA Soil Analysis Check and Control Scheme) during 1981 related to the volume of work.

(iv) **Laboratory owners**

The owners of soil analysis laboratories and their technical managements must be represented in any concerted effort at regulating soil analysis services.

Appropriate samples

(i) No soil analysis service can be successful without the guarantee of representative samples from correctly selected lands. While this requires some technical skill and a sense of responsibility from the sampling organisation, the farmer has the responsibility of insisting on correctly taken samples.

(ii) Sampling procedure must be standardised.

Suitable methods

(i) It goes without saying that methods of extraction and determination must be capable of meaningful interpretation, adaptable to routine analysis and not be too costly. Methods must be standardised or valid alternatives provided.

(ii) Methodology must be continually investigated and techniques developed and adapted to routine procedures.

(iii) Facilities for small scale investigation must exist at every laboratory. This should include facilities for trouble shooting and for special analysis.

Reliability

The credibility of soil analysis and of the laboratories performing the analysis must be above question. There is no room for competitive advantage — 'better' methods, 'better' laboratories — when it comes to soil analysis for advisory services. There is equally no room for confusion and uncertainty, created by an unco-ordinated effort, in the minds of the farmers who are the end-users of the service.

(i) Analytical expertise comprising equipment, facilities, knowledge and experience is essential in all laboratories, irrespective of size. Suitably trained and qualified personnel are a prime requirement in this regard.

(ii) Norms for analytical quality (accuracy) must be set in terms of required precision and allowable bias.

(iii) Suitable internal quality control measures for analytical work must be instituted by all laboratories.

(iv) Laboratory performances must be monitored by an independent and impartial external body, checking them regularly against the set norms.

(v) Laboratories must be able to achieve a certain speed of work at the specified quality level.

Management

(i) Top management as well as management at laboratory level must be soil/technically orientated.

(ii) A soil laboratory must be seen as a separate entity and only operations associated with soil fertility and plant nutrition (including tissue analysis) should be housed in a soils laboratory. In the case of a tissue testing or similar service this should nevertheless be placed in a distinctly seperate section with separate sub-management.

(iii) Where a laboratory is part of a larger organisation its management must be accountable to the appropriate section of that organisation, ie the section for whose benefit the work is done and which is directly concerned with fertilizer advisory work.

Siting

Apart from the obvious advantage of siting a laboratory in the area from which most of the soil samples are obtained, ie where the need for the service is greatest, choice of terrain is also of some importance. The main consideration is that the area be contamination free with respect to the determinations done on soil samples. These include especially N, P, K, Ca and to a lesser extent Mg, Na, Cl, acid/alkali and some of the micro elements such as Zn, B, Mo.

Cost

A soil analysis laboratory unit (routine analysis) must be regarded as a cost centre in its own right to make proper costing possible. Cost analysis should include itemised fixed costs and variable costs, cost per analysis per element, cost efficiencies of major instruments, of methods and of analysts.

Priorities and Possibilities

Quality, reliability and credibility are of prime importance, while cost is of secondary importance. Competitive advantage is not applicable in a soil analysis service; it must be above question and not linked to a competitive sales effort.

With 33 operating laboratories and seven more being contemplated, some of them very small, the question may be asked whether soil analysis services in South Africa are not over-provided for. Furthermore, it has been shown that some of these laboratories are not performing satisfactorily, both from the point of view of quality of work and analyst efficiency and/or cost efficiency. There is also a shortage of suitably qualified and experienced personnel to man a large number of laboratories and technical management in many cases is not satisfactory.

In addition to this the demand for soil analysis is increasing, not only in terms of numbers of samples, but also because of the realisation that it forms part of a sound basis for decision-making regarding important crop production inputs.

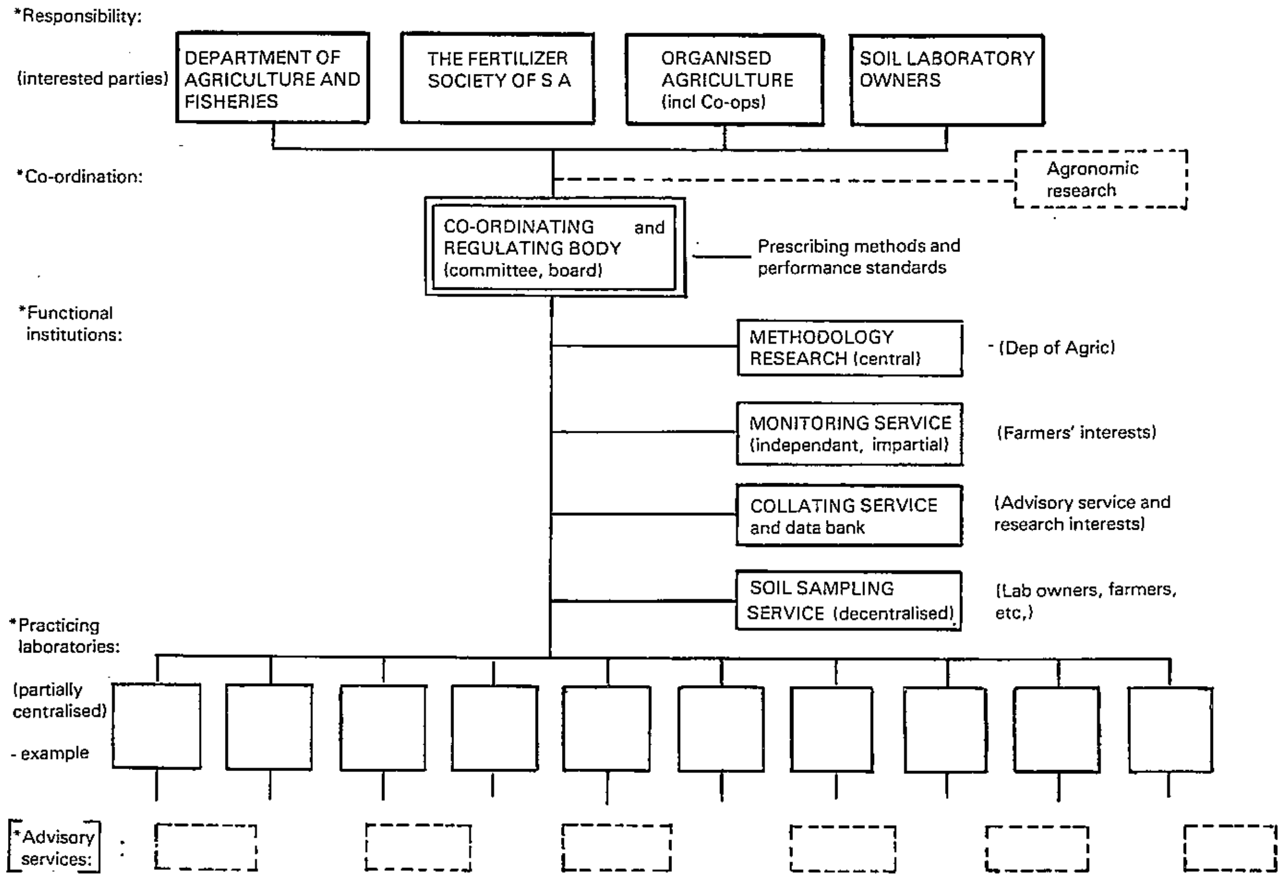
The importance of a reliable and credible soil analysis service has thus been established. At the same time it has become urgent to meet the requirements as soon as possible in order to avoid further floundering and to establish a firm basis for plant nutrition and crop production in as far as it is related to an understanding of soil fertility. After 23 years of considering and 13 years of intermittant deliberations and negotiations we should now be in a position to give this matter a high priority.

Rational system

The following scheme, diagrammatically shown in Figure 4 is offered as a framework for the co-ordination and rationalisation of soil analysis services for advisory purposes in South Africa. It is offered as an alternative to the present situation.

The scheme is not intended to upset matters, but rather attempts to make use of elements in the present situation and adapt them in such a way as to achieve a decidedly more satisfactory situation.

FIG 5: Structure for a National soil analysis service (for advisory work).



(i) **Initiative and responsibility**

The initiative and responsibility for setting this in motion lies with the main interested bodies viz the Department of Agriculture, the Fertilizer Society of South Africa, Organised Agriculture and the owners of existing soil analysis laboratories. These organisations are to a greater or lesser extent involved in agronomic research which has a bearing on or relies on soil analysis.

(ii) **Co-ordination**

The initiating and responsible parties must form a permanent co-ordinating and regulating body to control soil analysis services on a national basis. They must all be represented on such a co-ordinating board. This board should prescribe methods of analysis and standards of performance. It must also regulate the activities of functional institutions operating in the scheme.

(iii) **Functional institutions**

In order to effectively regulate a national soil analysis scheme the co-ordinating body requires the expert services of certain functional institutions, viz one each for

(a) Methodology research — preferably an existing central institute with adequate facilities. This is available in the form of the research laboratories of the Department's Soil and Irrigation Research Institute at Pretoria. No less than this is required.

(b) A monitoring service — an independent body to monitor quality of analysis of the particing laboratories. This institution must at least also represent the farmers' intersts.

(c) A collating service — to collate soil analysis figures from all laboratories and keep it in a data bank for the benefit of follow-up work by the advisory services and for soil fertility surveys.

(d) Soil sampling — a rational and reliable national soil analysis service deserves meaningful samples. So does the farmer. It is now opportune to institute a service — decentralised into regional units — that can regulate soil sampling.

(iv) **Practising laboratories**

The present 33 plus a possible 7 laboratories would appear excessive and a reduction in this number should perhaps be considered. This would; ensure that practicing laboratories are economically viable and not heavily subsidised by other sections of the respective organisations; ensure a high standard of work; ensure better utilisation of the existing limited supply of competent analysts and chemists, and ensure better utilisation of very expensive analysis systems.

Conclusion

It is both important and urgent that soil analysis services in South Africa be improved. This applies in general to the average level of reliability by all laboratories and more specifically to those performing poorly at present. As this is a matter of high priority there is no justification for postponing action. If the matter can be appropriately resolved then rationalising soil sampling becomes critical. The means of achieving a satisfactory service exists, but implementation will have to be phased in over a period. It is therefore an opportune time now to set the process in motion.

Summary

Although an extensive soil analysis service for advisory work is provided in South Africa there is need for improvement. Soil analysis is important as is evidenced by the fact that 151 500 samples were analysed during 1981 by 30 laboratories.
Laboratories are subdivided into two main groups, viz those of the Department of Agriculture (12) and those that participate in the FSSA quality monitoring service (20), including fertilizer companies, co-operatives, independent laboratories, other state departments and other laboratories. The latter group is responsible for about 82% of all the soil analysis for advisory work. In 1964 the FSSA standardised methods of soil analysis for the fertilizer industry and the 20 said laboratories follow these methods. Standardised methods are a prerequisite for the assessment and control of quality in a group of soil analysis laboratories. Unfortunately some of these laboratories do not perform satisfactorily. The quality position in the Department of Agriculture is not known and it is difficult to assess because their laboratories do not use standardised methods as a routine procedure. Other problems encountered by soil analysis laboratories concern the type of management, analyst efficiency and methodology research, siting of laboratories and lack research and technique development facilities.

An improvement in the soil analysis services is essential, not only for the sake of good order, but especially for the sake of the farmer.

In order to materially improve the present state of affairs it is suggested that a national co-ordinating and regulating body be formed by the main interested parties, viz the Department of Agriculture, the FSSA, Organised Agriculture and the laboratory owners. This body would prescribe methods of analysis and set standards of performance. It should be assisted by a number of functional institutions, viz a central research laboratory for methodology research, a monitoring service, a collating service and analysis data bank and a soil sampling service. The operating laboratories would be accountable to the co-ordinating body, for conformance to the system, but it would otherwise operate under its own management, which must be soil-technically orientated and linked to advisory services. The number of laboratories could be reduced.