Soil Analysis Systems and Data Presentation

H. I. SVENSSON

The Agricultural-Chemical Laboratory of Kristianstad /SWEDEN/

The organization of soil analysis work in Sweden

Soil analysis leading to soil maps has been performed in Sweden since the thirties. Mostly the object has been to get tools for the planning of the fertilization of crops. The decision of taking the samples and to get them analyzed is in general taken by the farmer himself. Of course, in many cases an advisor or an advisory organization has taken the original initiative. But still, soil mapping - including the analytical work - is something that is ordered by a farmer. Accordingly, in most cases, soil mapping of this kind is not organized systematically over larger areas in Sweden. Every map covers a single farm not a larger area. The farmer pays for the costs.

The results of the soil sample analyses are however treated statistically in the different counties. From time to time this gives a view of the situation in different regions of Sweden. Work has also been done on compiling soil classification data from this soil mapping work. From another point of view the Swedish Geological Survey makes maps of the soils in their natural condition. Remote sensing methods have also been tried.

The samples for the soil mapping, that we are involved in, might be taken by persons from the county agricultural societies, from the governmental county farm authorities, by the farmers themselves or by persons employed by a laboratory.

For the laboratory work there is a governmental laboratory, three laboratories are owned by agricultural societies, one is owned by a coppera-tive company and a few by private companies.

This means that there is a rather free competition in soil sampling as well as soil analysis in Sweden. Principally it also means that each farmer is free to order or to perform any strategy of sampling that he might prefer, and also that any laboratory in principle is free to market any kind of analytical system that is supposed to be usable.

Of course we have rules that have been set up by the involved authorities together with research workers, advisors and analysts. In general these rules are followed. Initiatives to try new ways can, of course, still be very valuable. New sampling strategies and new soil extraction methods and determination methods have actually been developed by such work. To coordi-

nate the development work there is a special "Cooperation Committee for Plant Nutrition Control".

A changing situation

Up to now the main reason for collecting and analyzing soil samples and for preparing a soil map, where the results are represented, has been to have a tool for planning fertilization in order to receive the best economical result out of the crops.

At present, however, leakage of plant nutrients from the fields to rivers, lakes and to the sea is attracting more and more attention in Sweden. This also means that other parts of the Swedish society are paying great attention to the use of plant nutrients in Swedish agriculture. A regulatory system for minimizing this leakage is being built up. Special regulations are set up for the use of manure. A special tax is put on fertilizers. The official advisory service concerned in the use of plant nutrients has been enlarged.

Evidently, this situation gives a new perspective on the use of soil and plant analysis as a tool in the planning of manuring and fertilization. Governmental authorities presumably will now start coordinating soil mapping over larger areas to control the leakage. In doing so, they might also pay the costs or at least part of them. Presumably, this will result in more soil mapping and more plant nutrient analyses than before. The strategies of field sampling, the analytical work, the way of presenting the results and the routines for using the results might all change to some extent to meet the new needs.

In short: we are probably facing a developing period and the systems that will be described now might be somewhat different in the forthcoming years.

Sampling strategies

The name of the most widely used sampling method in Sweden can be translated as "point sampling". From a certain point of the field about 7-8 subsamples are taken over a minor area. The subsamples are brought together. The number of these "point samples" in general vary from less than 1/2 to 2 per hectare.

"Area sampling", where a sample consists of a number of subsamples that are taken at random from all parts of a field or a part of a field is in general not used in Sweden.

At the sampling time a "raw map" is also produced, showing the shapes of the fields and where the sampling points are situated. A map from a previous sampling or from other available map material can be used to produced the raw map.

The "point sampling" described gives samples that can be used for all kinds of plant nutrient determinations, except for mineral nitrogen. The samplings should, in general, be renewed every 5-8 years.

In order to follow the changes in the plant nutrient situation of the fields better, a so-called "line sampling method" was developed several years ago. The method implies taking a sample consisting of 20 subsamples in a very reproducible way on a fix line across a field. "Line samples" are taken yearly from the same line or at least with very short intervals.

A special problem is taking samples for mineral nitrogen determination. The periods of the year when such samples give meaningful analytical results are evidently restricted. The analysis results must be ready within a very short period. The sampling has to cover both the topsoil and the subsoil, and the samples must be kept cool or frozen until analysis.

For further aspects on sampling problems and sampling equipment, I wish to refer to I. STEEN's lecture.

For glasshouses special sampling routines are used.

Sample preparation

The samples arrive at the laboratory in small boxes. The volume of ordinary "point samples" is 1/2 litre. "Line samples" contain 1 1/2 litres. These samples are dried at 35 °C and ground to pass a 2 mm sieve.

Samples used for mineral nitrogen determination are frozen and ground in a special grinder in a frozen condition.

Extraction

pH determination is made in a slurry with deionized water after mixing, soaking over-night and another mixing.

For ordinary soil mapping analysis, 5 g of the soil sample is extracted by 100 ml of AL-solution. This extracting solution is 0.1 molar in ammonium lactate and 0.4 molar in acetic acid. It was developed in the fifties by EGNÉR in Sweden and RIEHM in Germany in a wide cooperation with other soil analysts. In this extract phophorus and potassium are determined and, if ordered, also magnesium and calcium. The results are expressed as mg/100 g and called "AL-number" /P-AL, K-AL, Mg-AL, etc./.

Extraction on a volume basis or recalculation of result to volume basis is normally not performed in regular soil mapping in Sweden.

Other extracting solutions are hot 2-molar HCl, which is used for extracting the "reserves" of potassium and copper and sometimes phosphorus. The K-HCl- and P-HCl-numbers are also expressed in mg/100 g, while Cu-HCl like other minor elements is expressed in ppm.

Boron is extracted with hot water in a modification of TROUGS method. The boiling is prolonged to 15 minutes in order to get a better reproducibility than could be reached with the original TROUG method.

Zinc and molybdenum are determined comparatively seldom. In such cases zinc is extracted with EDTA and molybdenum with a formiat buffer /TAMM's solution/.

Mineral nitrogen is extracted by 2-molar KCl. The high potassium concentration in this solution is due to the need of eluting the ammonium ions from the soil matrix.

Soil analysis in glasshouse growth substrates does not belong to the soil mapping analysis system but might still be mentioned. A quite different extraction method is used for these samples. It is the old American Spurway method. Extraction solution is a very weak acetic acid solution /0.018 molar/ and the extraction is made on a volume basis. The method is used in glasshouses and also by some field vegetable growers. These often also have glasshouses. They therefore are used to this method.

Analysis of the extracts

In soil analysis the extraction methods are critical for the results and they have always to be performed in the same way when using a special soil analysis system. The chemical determinations of the elements in the extracts, however, can be made with different methods as long as good, reproducible and specific methods are used in a responsible way.

Until recently the determination methods used at our laboratory have been the following. Generally other laboratories also use the same:

Phosphorus: Colorimetric determination as "molybdenum blue";

Potassium: Flame photometry with a propane-air flame;

Magnesium, calcium, copper, zinc, molybdenum: Atomic absorption.
Boron: Colorimetric with "Azomethine-H".

About a year ago we bought an Inductively coupled plasma emission spectrometer /called an ICP/ equipped for parallel determination of a number of elements. The instrument is intended for a range of different kinds of samples, not only for soils. That is the reason why we haven't started to use it yet for soil analysis in general. However, for boron it has already replaced the somewhat difficult colorimetric method.

We might face some problems, if we are going to replace the colorimetric phosphorus determination by ICP. The colorimetry measures just inorganic phosphorus. The ICP also measures organic phosphorus that apparently might exist in minor amounts in the extract.

We think however, that the analysis systems will develop against determination of a wider range of elements also for practical farming. This will favor the use of instruments as ICP. This also leads to a need of further development of extraction systems as the advantage of the instrument is its ability to determine many elements simultaneously in the same solution.

Mineral nitrogen, nitrate- and ammonium-nitrogen, are determined colorimetrically in an automatic setup.

In the "Spurway extracts" from glasshouses and some field growing of vegetables the elements are in general analyzed with the same methods as described above, with one important exception. Nitrate in these samples is in general at such a high level that a nitrate electrode can be used.

Soil classification and texture analysis

Soil classification is probably easier in Sweden than in Mid-Europe. All Swedish mineral soils were formed at the end of the Glacial Age. This means that the Swedish soils can be rather well classified by just taking the texture and the humus content into consideration.

Classification of the soil is still, to a great extent, made manually by the persons who are taking the soil samples. This is however, considered rather time-consuming, a lot of time is also needed for training and still mistakes can be made very easily.

These are the reasons why we have sought for a good simplified laboratory texture analysis method to use as a foundation for the classification.

A hygroscopicity method has been used to some extent since about ten years ago. It gives a rough measure of the clay fraction and together with wet sieving and loss of incineration it can be used for soil classification.

Under certain circumstances, hygroscopicity is not a good indicator of the clay content. That is why we have tried to develop other methods for this purpose.

We now have a method that can be described as a miniaturized sedimentation technique. A small amount of soil is treated in a test tube with hydrogen peroxide, washed with hydrochloric acid and dispersed in sodium pyrophosphate. After two hours of sedimentation, while thermostated at 23 °C, the limit of the clay fraction has reached 28 mm below surface.

The density of the suspension on this level can be measured by bringing a small sample of it into a Paar densitometer /ANTON PAAR KG, Graz, Austria/. The clay content is calculated from this density. The rest of the test tube content can be used for wet sieving to get the fraction of material with a diameter bigger than 0.06 mm /sand/. The silt fraction is calculated as a difference. The humus content is calculated from the loss of ignition with a correction made due to the clay content. It is then possible to classify the soil according to the system that is used in Sweden.

With this method soil samples easily can be treated in a rather large scale. We are confident that it will be a standard procedure in soil mapping in Swedish agriculture in the future.

Data treatment in the laboratory

Most of the laboratory instruments that are used for the determinations at our laboratory in Kristianstad are connected with a computer system that was built up in the laboratory in about 1980.

The laboratory has a system of different series of fixed numbered flasks that are used for the extractions, for the extracts, for dilution and for color development at colorimetry. After these numbers are registered on the samples in the computer, it is possible to identify the sample when a flask reaches an analysis instrument. The results then can go directly from the instrument into the computer system.

When all the results for a certain farm are ready, and when a certain check work has been made, the results can be written out. The system had worked very well, but we are now at a point when it should be renewed.

Data presentation

The results of the phosphorus and potassium determinations are not only presented as "numbers". They are also classified into five classes, class 5 indicating the highest level. These phosphorus and potassium classes are then used in the planning of the fertilization. Other elements and pH are just presented as their numbers without further classification.

The results are then presented on soil maps. According to the system that is generally used in Sweden one "phosphorus map" and a "potassium map" is produced with the help of the raw map that was made at sampling. The different classes are then presented with color marks at the points on the maps, where the samples had been taken. The pH is also written out on the map and so is the sample number. The rest of the results are presented on a list from the computer with references to the numbers of the samples that are shown on the map.

Further development

Some development lines have already been mentioned. Both the need of the users and the possibilities given by the new instruments indicate that more determinations will be carried out on each sample.

Another important development will be the better use of computers in different phases of the chain. This involves sample handling and the analytical work in the laboratory. It also deals with presenting the data in a more "taylor made" way for different customers and in general improving the service to the customers. As customers we then regard farmers, advisors, organizations and authorities who all will need our services in the future. All these customers might need different data handling services in connection with analysis and mapping work. The maps will be drawn by computers. Other kinds of data presentations, storing of results for further treatment in the future, and using the results in different calculations for a better description of the plant nutrient status are other examples.

In general, we have a feeling that soil analysis and soil mapping in connection with this analytical work will play an even more important part in Swedish agriculture and Swedish society in the future.