PRECISION FARMING

FIELDWORK SUITS

NIRS down to the ground!

Thanks to near-infrared spectroscopy technology, farmers can now assess their produce's characteristics, such as the protein content of their wheat, while it is still in the field.

Up to now, near-infrared spectroscopy (or NIRS) was the domain of laboratories; however, it is now used in fields and helps to instantly assess the quality of a crop or a soil. The instruments have become smaller and relatively cheap, while being reasonably precise.

Nowadays, near-infrared spectroscopy (insert) forms an integral part of agricultural raw material characterisation in a laboratory context, and is used by storage organisations and primary food processors. For example, this method is used to measure the grain's protein content, on which the farmer's remuneration is based.

The ongoing development of digital equipment and technology has helped to reduce analysis time from a few minutes to a few milliseconds.

The equipment has become much lighter and therefore portable, and considerably cheaper. It can now be used in fields, which widens the scope of application. It is no longer just a case of analysing grain, but also the soil, livestock effluent, silage composition; and it can be used to characterise plants very quickly, cheaply and with minimal logistical requirements.

So that near-infrared spectroscopy can become a precision farming tool, Arvalis is developing "calibrations" on devices currently on the market, i.e. models forecasting the biochemical composition of a sample based on the measurements taken by those devices. The aim here is to assess new sensors, some of them being marketed at very attractive prices, or claiming very low error margins, or even offering a new type of service.

A near-infrared sensor such as the PSS can be fitted to a tractor to analyse in real time the quality of grain or of silage as it is being cut.

Continuous grain and forage analysis at harvest

Two types of equipment are currently available on the market: onboard systems, and portable sensors.

Many plant breeders and seed companies have equipped their own experimental combine harvesters with continuous flow analysers such as Polytec's PSS, Zeiss's Corona or Perten Instruments' DA 7200; some manufacturers such as Haldrup also offer this type of sensor to private individuals. Those systems assess the quality of the harvest in real time, field by field. The criteria that are most often analysed are moisture content, protein content, oil content, glucosinolate content for grain (wheat, barley, oil seed rape, sunflowers, etc.) and criteria used to calculate silage digestibility.

The sensor (or its contact probe) is placed on the combine header, in contact with the grain or above the conveyor belt, at a set distance from the harvested product. Integrating this type of sensor often involves carrying out some mechanical adjustments (like creating a hole in the header) as well as electrical ones (power and result transmission cables).

The analysis process starts automatically as soon as the harvested grain passes through. The computer that controls the instrument is in the cab. The data acquisition software can be linked to a GPS type georeferencing tool. The user can then instantly view the measurements and retrieve all the data necessary to map the field. This type of instrument can also be used in silos, to build uniform batches, carry out transfers between silos, or to assess drying quality, for example.

The physico-chemical properties of a sample are deduced by analysing the near-infrared spectrum measured by a sensor.

Arvalis's trials found that such sensors provide equally good performances as FOSS's Infratec 1241, popular among storage operators, and that the precision of their measurements is comparable. The other benefit is that multiple samples can be used in order to get as close to reality in the field as possible. The protein content of grain from 50 bread and durum wheat samples harvested between 2002 and 2015 was measured with ± 0.5% accuracy, either with an onboard sensor (Polytec's PSS) or with an Infratec 1241.

Arvalis developed calibrations for the portable LabSpec system in order to measure some of the physico-chemical properties of soil, based on simple soil auger sampling.

Soil analysis in the field

Arvalis is studying another field tool for its versatility and its light weight: ASD Inc's LabSpec can be transported on a quad bike, in a wheel barrow or in a backpack and includes several accessories. The optical signal is transmitted through optical fibre from the spectrometer and a measuring probe placed in direct contact with the soil sample. The sensor is controlled via a computer or a tablet. Arvalis is developing calibrations in order to offer a tool measuring agricultural soil composition through a spectroscope. There are numerous potential applications: field characterisation, field mapping, checking variations within a field, or optimising fertiliser or plant protection product inputs. The need for such a system became apparent with the advent of more stringent environmentally focussed regulations, the increase in input costs, and the price of traditional soil analysis.

The measurement is taken directly from a traditional core sample obtained with an Edelman type auger introduced into the soil to a depth of 0 cm to 20 cm (ploughing depth). The target parameters are physical (clay, silt, sand and lime rock), chemical (pH and CEC), organic (organic carbon content and total nitrogen content), or nutritional (phosphorus, potassium, magnesium, calcium, boron, zinc, copper and iron). The results of the analysis carried out directly in the field will be less precise than those obtained in a laboratory using chemical methods, but it is accurate enough for agronomic advice purposes or to determine the relative variability of a parcel.

Over 1000 samples and spectra from the LabSpec device were collected over several seasons from a wide variety of soils with very different moisture levels on farmland all over France. To date, eight calibrations have been developed in order to assess the percentage of clay, silt, sand, total lime rock, total nitrogen and organic matter in the soil, as well as its available phosphorus (Olsen method) and exchangeable potassium contents.

To ascertain the impact of the NIRS's measurement accuracy, P and K advice maps were drawn up for a 7.3ha field in Boigneville (near Paris) with a clayey-silty stony soil, using the results obtained with near-infrared spectroscopy in the field, and, in parallel, using the measurements obtained in a laboratory. The phosphorus rate advised for bread wheat was underestimated for one out of 33 sites (advice: 52 units vs. 68 using the control method) and overestimated for one site (52 units instead of 42). The potassium rate was underestimated for one site (none instead of 40). Those preliminary results are quite promising but will need to be consolidated using other species and other soil types.

Ever smaller sensors

Other, more recent, portable instruments such as Thermo Scientific's PHAZIR, JDSU's MicroNIR, Consumer Physics' SCIO and Spectral Engines' NIRONE Sensor fit in the palm of the hand; their price varies between €500 and €25,000. Their small size means that they offer even more field applications and their price makes them more affordable for farmers. Arvalis is currently assessing the cheapest two of those small sensors (€500 and €2,500 respectively) to measure the protein content and the moisture content of wheat and barley.

In spite of such a promising outlook, it is crucial to keep in mind the fact that any change modifies the detected signal, be it the nature of the sample being analysed (genotype, agricultural and meteorological conditions, inputs, wet rather than dry product, etc.), the measurement protocol (crumbed soil or original core sample, smaller leaf, etc.) or even the sensor. The golden rules to ensure reliable results are: adhering to the system's operating conditions and checking calibrations regularly.

Arvalis is currently assessing the very compact SCIO (above) and NIRONE Sensor to measure protein and moisture contents of wheat and barley.

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How does it work?

Near infrared spectroscopy is an indirect method based on the interaction between a chemical element and near-infrared radiation. The signal that reaches the sensor represents the amount of light energy absorbed by the sample, which is proportional to the number of chemical bonds. A correlation then needs to be established between this signal and a physico-chemical property – moisture, nitrogen, starch content, etc. analysed through conventional laboratory methods – using a mathematical equation called "calibration". The easiest properties to forecast are those based on chemical bonds including a hydrogen atom (O-H, N-H, C-H bonds...).

This method of analysis has numerous benefits: it requires very little or even no preparation work on the sample, no chemicals, it is non-destructive, easy to implement, but most of all it is quick, reliable and cheap.