Soil Analysis

On average 60 percent of crop yields depend on soil fertility. Soil degradation is a threat to all farmers. It is estimated that each year 24 billion tons of fertile soil are lost due to erosion as a result of unbalanced soil management and the consequences of overutilization. Because soil restoration is a difficult, costly and time-consuming process, effective soil management is needed before damage occurs.

Proper soil management starts with soil testing followed by the application of the appropriate fertilizers at the right time. In order to improve soil fertility, the actual soil fertility status must first be determined. While properties such as texture, color and structure are visible, it is impossible to see the chemical composition of the soil.

Current soil measurement techniques can be accurate but may take days. The process involves collecting the sample correctly, taking or sending samples to an agricultural extension lab with a knowledge of soil analysis, and waiting for the results to come back. At this point it may be too late and the wrong soil fertility management decisions may have been made.

What is needed is a cost-effective portable soil health measurement tool that can provide real-time results. In this way sampling can be performed at will in as many locations and as frequently as needed, in order to obtain a total picture of soil health.

Miniaturization of near-infrared (NIR) spectrometers has advanced to the point where handheld instruments could provide reliable and affordable means to serve this purpose. In this application note, we demonstrate the possibility of using the NeoSpectra spectral sensor for portable soil chemistry measurement.

Identification and Quantification of Soil Nutrients

In order to demonstrate the ability of the NeoSpectra spectral sensor in identification and quantification of soil nutrients, our customer AgroCares developed a portable scanning tool to determine multiple nutrients, including nitrogen, phosphorus, and potassium as key indicators. AgroCares also determines pH, organic carbon, soil temperature, and cation exchange capacity (CEC). CEC affects many aspects of soil chemistry and is used as a measure of the soil's buffer capacity, as it indicates the capacity of the soil to retain several nutrients in plant-available form.

When the AgroCares portable scanner (incorporating NeoSpectra) is put on a soil sample, the scanner relays the spectral signature and quantification data to the mobile phone, which sends it to the cloud, where the spectral signatures are compared and the data analyzed. The soil status and recommendations are sent back to the phone and displayed within the AgroCares app.

Smart Farming
Soil Analysis

Calibration Methodology

Samples have been collected so far from 22 different countries in the same, standardized way and have been measured with the portable scanner as well as in AgroCares' own "gold-standard laboratory" (GSL) with the latest wet chemistry analyses. These analyses are conducted in AgroCares' own facilities to ensure exact methodology matches.

All samples were analyzed for 93 parameters: not only chemical elements, but texture, exchange capacity, and pH. Based on the comparisons, algorithms were developed to predict the values of the GSL results.

As the algorithms were honed for each country and across multiple soil types, the number of soil samples required for calibration decreased for each new country due to the total knowledge contained in the database and the refinement of the algorithms for determining soil status.

Measurement Conditions

- Measurement mode: diffuse reflection
- Spectral range: 1300 – 2525 nm
- Scan time: (5 * 10 seconds)
- Resolution: 12 @ 1400nm up to 36 @ 2400nm
- Spot size: Ø±9mm (E-series Scanner)
- Background: ceramic tile, 80% reflection (almost flat spectral response across the NIR-range)
- Measurements are performed outdoors, temperature range: 5° - 45°C.

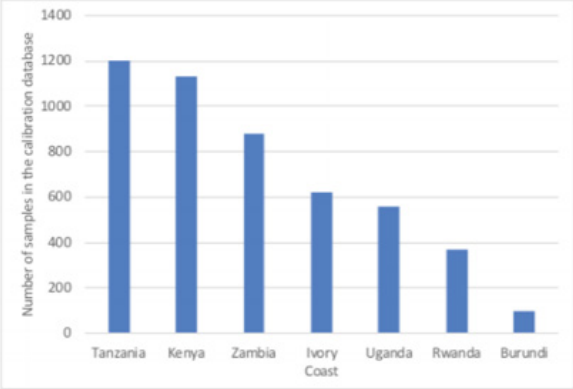

Figure 1: Number of samples per country for calibration. The number depends on the spectra diversity, size and sequence of calibration. Early calibrated countries (such as Kenya) have relatively high number of samples.

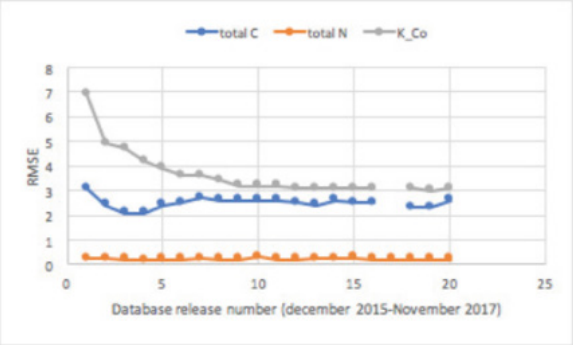

Figure 2: Development of the error for some key parameters per database update for Kenya.

Data Evaluation

In order to deal with the highly variable composition of a soil sample, Agrocares adopted a machine learning methodology called Locally Weighted Learning (LWL) to predict analytical results from the incoming spectral signature. In results modeling, technologies assuming linear relations between the spectral response and the elements of interest cannot be successful. The LWL solution processes the spectra of the calibration database to create a multi-dimensional data space. The sample spectrum to be analyzed is projected into this dataspace. Only calibration samples having similar spectral features, and therefore most likely a similar composition, will neighbor the target sample. Using only the neighboring samples, a final regression model is built to produce the outcome. This procedure of projecting and predicting is an automated process trained to deliver the best accuracy for all variables valid for the Soil Scanner application. The training process is repeated and further optimized, using a 10-fault cross validation, every time a significant number of new samples have entered the database.

To rapidly collect valuable soil fertility information on-site requires a trade-off. In this case it means the accuracy of the predicted soil variables will be slightly lower than what is expected from a traditional laboratory. However, for each element reported the accuracy range will be rated as low, adequate or high.

The Soil Scanner is able to provide predictions for Soil Texture (Clay, Sand), Soil Organic Carbon, pH, Cation Exchange Capacity, Total Nitrogen, Total Phosphorus, and Exchangeable Potassium.

Conclusions

These results clearly demonstrate that the spectra of soil samples measured with NeoSpectra spectral sensors provide suitable analytical data to accurately measure the soil chemistry in various locations around the world. The ability to obtain on-site soil analysis and soil health recommendations is critical for the success of small farmers around the world to help them boost production and save their soil in the face of challenges including climate change. NeoSpectra spectral sensors enable cost-effective, fast testing in the field without the need to spend time preparing or transporting samples for evaluation.

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