GLOBAL SOIL MANAGEMENT WITH SCIAPS HANDHELD LIBS

LIBS Emerges as a New Tool for Measuring Soil Parameters

Over the past four years, Dr. Daniel Riebe from the University of Potsdam, Germany, has been working in a scientific field far from his background in physical chemistry. Riebe is part of a long-term, government-funded project which will help shape the future of food and farming: working with LIBS to analyze soil as a sustainable resource for the bioeconomy.

Handheld LIBS makes it possible to analyze every square meter of soil, in place and in real time. Courtesy bonares/i4s.

Traditional soil analysis consists of farmers taking soil samples from different parts of their fields, mixing them together, and then getting one lab result per field. However, it is common for soil to have different elemental compositions in the same field. Riebe's project is unique in that it aims to measure the heterogenous distribution of nutrients on site, in every part of the field, including challenging key indicators like carbon and phosphorus.

The key to this new approach is moving laser induced breakdown spectroscopy out of the lab and to the work site. Their first choice of instrument was the SciAps LIBS, which is the only handheld LIBS with enough laser power to produce a full spectrum from soil.

"We don't have to use such a small system, but using a handheld was an interesting idea for me," says Riebe. He could walk through a field carrying the analyzer and test areas with relatively no prep work.

Creating this soil management system has not been easy, but Riebe's team is making significant progress toward their final goal of building a platform with sensors that can connect to a tractor that drives across a field, analyzing the soil in place and in real time.

BonaRes: Soil as a sustainable resource

BonaRes is an initiative funded by the German Federal Ministry for Education and Research, to extend the scientific understanding of soil ecosystems and to improve the productivity of soils and other soil functions, while developing new strategies for a sustainable use and management of soils.

Riebe works with one of ten BonaRes projects, Integrated System for Site-Specific Soil Fertility Management (I4S). His team's focus is soil sensing, and they're hoping to design a system for fertilizer recommendations and improvement of soil functions regarding nearly every square meter of soil.

Developing a procedure that assesses individual fields more precisely and in real time will conserve resources and create an improved soil management system. Farmers will save on fertilizer, while also protecting nearby ground water from excess nitrogen pollution and other runoff.

Sampling with handheld LIBS

One of the I4S team's first steps was to analyze soil in the field. Testing with LIBS was a must because laser induced breakdown spectroscopy can measure every element. But finding a portable, handheld LIBS that could do the job in soil was key.

"We specifically picked the SciAps LIBS because it had the highest laser energy. With other handheld LIBS, we wouldn't get a spectrum from a soil sample. They are strictly for metal alloys," says Riebe.

Walking the field with a handheld analyzer was a game-changer. Until now, the standard has been taking many samples throughout the field and then bringing them to the lab to verify with ICP-OES. Sample preparation itself takes an hour or two just to dissolve the soil in the acid.

"You can only do so many samples in a day. It is really slow compared to LIBS because we can test soil with almost no sample preparation," Riebe says.

The I4S team made use of the LIBS capability to measure non-elemental parameters like pH and humus content. The humus content is all the organic material in the soils—everything that used to be plants and the material the microbes in the soil have already transformed. Organic carbon is the carbon plants can access from the soil. Inorganic carbon is the carbon plants can't access from the soils. The two together is the total carbon.

To the plants, the total carbon is irrelevant. Plants depend on the organic carbon and the humus content.

"The only reason why we could measure organic carbon is because of the machine learning algorithms. The LIBS spectra contain information about the entire elemental composition of the samples, which is a lot of information, so it can be used for a lot of things," says Riebe.

The whole range of elements, including the light elements, is accessible by LIBS—like phosphorus, an essential element for plant growth.

"Phosphorus content is one of the hardest elements to measure with LIBS because the peaks are really small, but in our study, we could measure the plant-available phosphorus with better accuracy than the total phosphorus. Usually the opposite is true. It was a success that we could measure phosphorus, which is the most important element after nitrogen for the farmers, and find the correlation for that," says Riebe.

(continues on reverse)

GLOBAL SOIL MANAGEMENT WITH SCIAPS HANDHELD LIBS *(continued from reverse)*

The future of global soil management, in a handheld

Riebe's discoveries so far have given him a global perspective on the importance of soil.

"Soil is not really an organism but an ecosystem that is alive with complex processes. I always knew there were microbes living in the soil, but I wasn't aware of how important the interaction between plants and soil was for plants to grow," says Riebe.

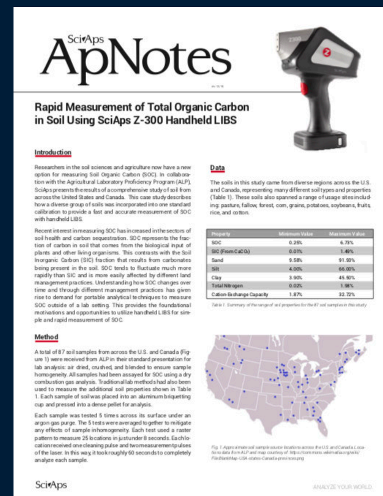
A prototype of the platform that will integrate the LIBS sensor in the future. Courtesy bonares/i4s.

In-field testing would solve several pressing problems for soil managers. One is nitrogen overload. "It's important for plants but a big problem for ground water and other ecosystems. The EU is making stricter rules for the amount of nitrogen farmers use to fertilize their fields," says Riebe. If the rulings get stricter, farmers, at some point, will be forced to limit their fertilizer use. Because of this project, the I4S team would have a method in place to help them analyze their fields, which will allow them to fertilize only where necessary.

Another benefit is the potential for LIBS to measure trace nutrients. "Trace nutrients are not brought onto the fields today. It's not because the fields don't need it, but because it's difficult to say if it is needed or not. The information that is missing about these elements is how important they are for the plants. It is unknown because there is no data about trace elements in specific soils. However, LIBS can measure all elements. In the future we could learn more about other nutrients, which could help us create more specific fertilizers to improve the agricultural processes," says Riebe.

Looking into the future, Riebe sees the difference this project will make, not only for farmers, but for all of us. In the global environmental discussion, carbon is the key element. The I4S team's project may be pivotal research for future endeavors.

"There is so much carbon stored in the soil. This could be a solution to some of the global warming issues. Carbon capture has to be done in some way if we are going to avoid further global warming. Soil is one of the biggest chances we have to make this happen," says Riebe.



SciAps ApNotes

Rapid Measurement of Total Organic Carbon in Soil Using SciAps Z-300 Handheld LIBS

Introduction

Researchers in the soil sciences and agriculture now have a new option for measuring Soil Organic Carbon (SOC). In collaboration with the Agricultural Laboratory Proficiency Program (ALP), SciAps presents the results of a comprehensive study of soil from across the United States and Canada. This case study describes how a diverse group of soils was incorporated into one standard calibration to provide a fast and accurate measurement of SOC with handheld LIBS.

Recent interest in measuring SOC has increased in the sectors of soil health and carbon sequestration. SOC represents the fraction of carbon in soil that comes from the biological input of plants and other living organisms. This contrasts with the Soil Inorganic Carbon (SIC) fraction that results from carbonates being present in the soil. SOC tends to fluctuate much more rapidly than SIC and is more easily affected by different land management practices. Understanding how SOC changes over time and through different management practices has given rise to demand for portable analytical techniques to measure SOC outside of a lab setting. This provides the foundational motivations and opportunities to utilize handheld LIBS for simple and rapid measurement of SOC.

Method

A total of 87 soil samples from across the U.S. and Canada (Figure 1) were received from ALP in their standard presentation for lab analysis: air dried, crushed, and blended to ensure sample homogeneity. All samples had been assayed for SOC using a dry combustion gas analysis. Traditional lab methods had also been used to measure the additional soil properties shown in Table 1. Each sample of soil was placed into an aluminum briquetting cup and pressed into a dense pellet for analysis.

Each sample was tested 5 times across its surface under an argon gas purge. The 5 tests were averaged together to mitigate any effects of sample inhomogeneity. Each test used a raster pattern to measure 25 locations in just under 8 seconds. Each location received one cleaning pulse and two measurement pulses of the laser. In this way, it took roughly 60 seconds to completely analyze each sample.

Data

The soils in this study came from diverse regions across the U.S. and Canada, representing many different soil types and properties (Table 1). These soils also spanned a range of usage sites including: pasture, fallow, forest, corn, grains, potatoes, soybeans, fruits, rice, and cotton.

Property	Minimum Value	Maximum Value
SOC	0.25%	6.73%
SIC (From $CaCO_3$)	0.01%	1.49%
Sand	9.58%	91.93%
Silt	4.00%	66.00%
Clay	3.90%	45.50%
Total Nitrogen	0.02%	1.98%
Cation Exchange Capacity	1.87%	32.72%

Table 1. Summary of the range of soil properties for the 87 soil samples in this study

Fig. 1. Approximate soil sample source locations across the U.S. and Canada. Locations data from ALP and map courtesy of: https://commons.wikimedia.org/wiki/File:BlankMap-USA-states-Canada-provinces.png

SciAps ANALYZE YOUR WORLD

To learn more about soil applications, see Soil Nutrient Detection for Precision Agriculture Using Handheld Laser-Induced Breakdown Spectroscopy (LIBS) and Multivariate Regression Methods (PLSR, Lasso and GPR) in the journal *Sensors*, published Jan. 11, 2020. Also see *SciAps ApNote on Rapid Measurement of Total Carbon in Soil Using SciAps Z-300.*

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