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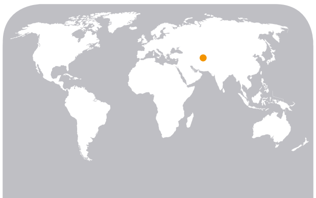
research evidence for policy


Soil spectroscopy is a highly versatile technology that can be used both in the laboratory and in the field.
Photo (Tajikistan): Bettina Wolfgramm

NCCR north south

Measuring soil quality using spectroscopy


Case studies featured here were conducted in Tajikistan

Policy Message

- Soil spectroscopy is a novel technology that can be used to accurately quantify the amount of organic carbon in the soil, along with many other soil properties.
- Compared to conventional analysis methods, soil spectroscopy is non-destructive, inexpensive, and fast.
- Soil spectroscopy is an ideal tool for large-scale monitoring and surveillance, which is required to ensure food and livelihood security as well as for controlling soil degradation.
- The technology is highly versatile and can be applied both in the laboratory and in the field, and unlike conventional soil analysis it does not need costly infrastructure.
- In conjunction with remote-sensing imagery, soil spectroscopy can be used for area-wide monitoring of surface soils.

There is an increasing demand for monitoring and evaluating our environment. Initiatives promoting payments for environmental services and carbon sequestration, for example, depend heavily on accurate assessment and monitoring of the soil, vegetation and water. That in turn calls for efficient methods. Soil, one of the most critical resources, requires special attention and regular auditing. Soil spectroscopy is an ideal tool for this task. Laboratory tests show that it is as accurate as conventional methods, which rely on wet chemistry. If used in combination with global positioning systems and satellite remote sensing, large areas can be monitored at an affordable cost.

Need for intensified monitoring and assessment tools

Concerns about the environment and attempts to use natural resources sustainably point to the need to monitor and assess the environment. Central Asia is an example of a region where soils are subject to erosion and other forms of degradation. The fertility status and productivity of the soils there have declined, damaging people's livelihoods and the national economies. Concerted action is needed to reverse this situation, including assessing the status of degradation and establishing observatories to monitor the soil. But monitoring and assessment using conventional methods of soil analysis are prohibitive both financially and technically: Central Asia is big and has many different soils, agro-ecological zones, geologies and landscapes, which require large numbers of samples. That makes it a challenge to measure and monitor soils over large areas at a reasonable cost.

Cutting costs and improving monitoring

How can we reduce costs while intensifying and improving the monitoring of soils? The most promising solution to this problem is to use innovative and efficient monitoring techniques

Featured case studies

NCCR North-South research in Tajikistan is assessing the effects of land degradation and sustainable land management on soil organic carbon contents and soil productivity in agricultural systems. Soil spectroscopy and remote sensing are the most prominent technologies used in this research work. (http://www.north-south.unibe.ch/content.php/page/id/287)

NCCR North-South research is also working on the establishment of a national soil spectral library to allow the rapid and inexpensive assessment and monitoring of soil health in Tajikistan.

The World Overview on Conservation Approaches and Technologies (WOCAT) has documented many case studies in Tajikistan highlighting the role of sustainable land management for soil organic carbon accumulation and soil health (www.wocat.net).

For an example see: Shokirov Q. 2011. Comparative study of two different soil conservation practices from the vineyard mulching treatment in Faizabad region of Tajikistan. Master's project, Dept of Environmental Studies, Antioch Univ New England. (https://www.wocat.net/fileadmin/user_upload/documents/Theses/Shokirov2011.pdf)

Modern field spectrometers are portable and can be operated by one person. Photo (Tajikistan): Christian Hergarten

such as soil spectroscopy. This can reduce costs by around 70% compared to conventional chemical analysis (Stenberg et al 1995), and the savings are expected to be even higher in developing countries that depend on imported chemicals. Plus, the costs of spectroscopy can be expected to fall further in the future. Such fully functional soil spectroscopy labs have been successfully set up in Africa (see http://tinyurl.com/bluh6ks).

We might compare soil spectroscopy with the introduction of mobile phones, which have revolutionised telecommunications throughout the world. Conventional soil analysis is complicated and costly: it relies on wet chemistry, which requires specialised labs with expensive equipment and chemicals, and numerous physical soil samples. Soil spectroscopy is much simpler: it uses infrared photographs of the soil (rather than physical samples), and the analysis is done using a computer rather than in a test tube. That means it is possible to collect and analyse a lot more samples, more quickly and cheaply. A revolution in monitoring and managing the soil beckons.

How does soil spectroscopy work?

Spectroscopy is a new approach of soil analysis, which has been used commonly in the chemical and pharmaceutical industries. It works much like a digital camera: reflected light is collected from an illuminated soil sample across wavelengths in the infrared part of the spectrum. The result is a very specific "spectral fingerprint" in the form of a spectral reflectance curve, based on which many soil properties can be predicted.

Light energy in the infrared range – usually from the visible, near- or mid-infrared part of the spectrum – hits the surface of the dried soil sample. Some of the light is absorbed by the soil sample, but the rest is reflected back to the spectrometer, where it is registered, quantified, and recorded. The resulting reflectance spectrum is characteristic for the soil under investigation: specific spectral signatures can be observed, e.g., for iron, organic matter, and other typical components of soils. The properties of unknown soils can be predicted by calibrating the spectral data with properties of selected soil samples that are known from chemical analysis. Conventional analysis is still needed only to develop the basic soil parameters and spectral data for a given environment; afterwards only spectral readings are needed for regular monitoring.

Compared to conventional lab analysis, soil spectroscopy is very efficient: in a day, the visible and near-infrared spectra of 300 samples can be measured comfortably. This makes the technology fast and comparatively inexpensive.

Building a spectral library of soils

Soils tend to be highly variable in a mountainous environment like Tajikistan, where topography and climate may vary from one valley to another. That means it is important to collect enough samples from the different soils to cover the full range of variation. The spectra of the collected samples then have to be measured and related to each soil's properties. The spectra and the calibrated properties are then stored in a spectral library. The soil analyst can then compare the spectrum from a new soil sample with this library to determine the sample's properties.

A global initiative, the Soil Spectroscopy Group (http://groups.google.com/group/soil-spectroscopy), seeks to establish a global spectral library, holding soil samples from a multitude of soils from many places. One of the aims of this initiative is to harmonise and standardise the sample and data processing steps while building a soil spectral library.

Reaching from point to space

While conventional soil surveys rely very much on ground-based sampling and analysis, the soil spectroscopy opens up new horizons. The ground-based measurements of soil properties can be used in conjunction with remotely sensed data from satellites or planes and geographical positioning system data in order to produce precise geo-referenced maps. That will make it possible to quickly identify abnormalities such as hotspots of soil degradation or surface contamination over large areas.

Introducing soil spectroscopy in Tajikistan

Initial studies in Tajikistan have shown that soil spectroscopy works well (Wolfgramm et al 2007, Shokirov 2010). Soil spectral libraries for specific areas (Fayzobod and Shughnon districts) have been calibrated and are operational. Tajik soil specialists have been given initial training in soil spectroscopy in collaboration with IAEA/FAO Technical Cooperation and the Tajik Soil Institute.

However, from an institutional point of view, introducing this technology in Central Asia faces various challenges. Research institutions dating back to Soviet times often suffer from out-dated equipment and lack adequately trained staff. This is particularly true for Tajikistan, where a civil war in the 1990s brought an abrupt halt to technological and institutional development. The poor state of academic education, which suffers from weak institutional commitment and a lack of funds and trained staff, contributes to the lack of technically skilled personnel.

In such circumstances, fundamental changes in research institutions may be needed to develop an innovation-friendly environment.

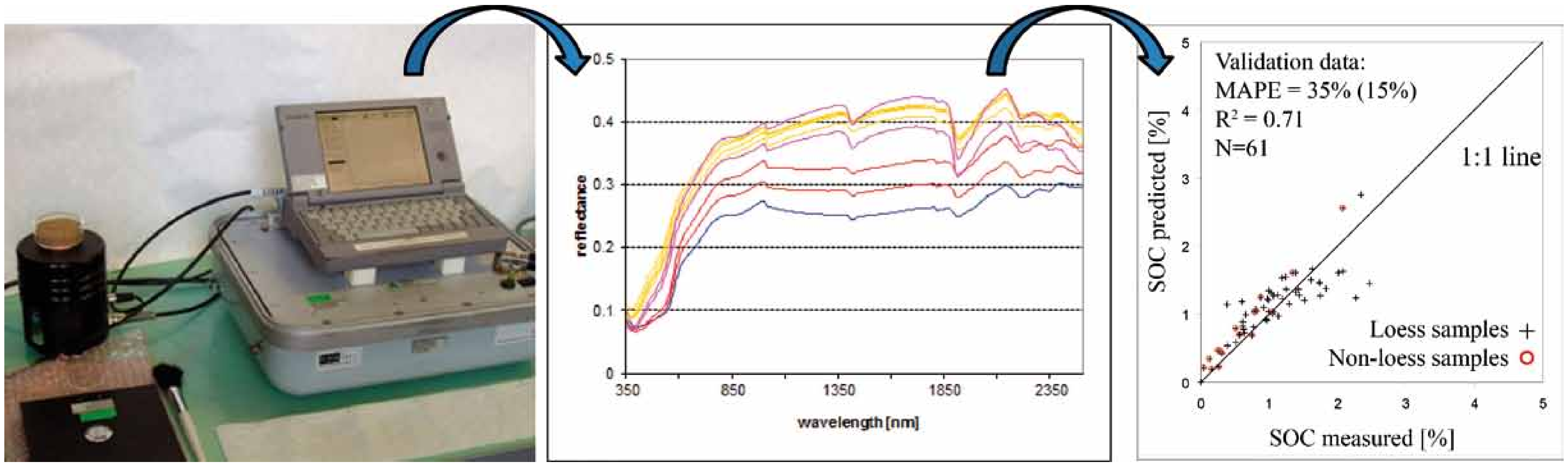
Soils in parts of Tajikistan are severely degraded. Efficient tools such as soil spectroscopy are very important to monitor the level and extent of degradation. Photo: Hanspeter Liniger

Definitions

Infrared spectroscopy is a way of measuring the interaction between radiated energy and matter, using infrared light.

Reflectance spectrum (plural "spectra") refers to the data obtained from a spectral measurement and is the specific distribution of electromagnetic radiation reflected or absorbed by a particular object.

Conventional soil analysis – also called wet chemistry – is the commonly used method for determining the chemical properties of soils. It relies on chemicals, skilled laboratory staff and well-equipped laboratories, and is relatively time-consuming.



The measured reflectance spectra can be calibrated with the results of chemical analysis to build a prediction model. That makes it possible to use just the spectra to analyse other samples. Graph: Bettina Wolfgramm

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Policy implications of North-South research

Integrate and embed new technologies in the institutional environment

Introducing new analysis technologies like soil spectroscopy requires commitment to integrate these in existing institutional structures, workflows, procedures, and capacity-development strategies. Long-term planning is required to implement the necessary changes.

Foster knowledge and technology transfer through close, long-term collaboration

For countries like Tajikistan to benefit from technological advances such as soil spectroscopy, skills development and long-term on-the-job training are very important and have to be strengthened.

Update institutional set-up and introduction of business approaches

While wet-chemistry laboratories often work with out-dated equipment and lack of good chemicals, soil spectral laboratories provide potentially cheap, accurate and fast soil-property analysis. Thus, soil spectroscopy has a clear potential for developing business approaches for government institutions that need to raise additional funds. Suitably designed services and close collaboration with agricultural projects will help create these new institutional set-ups.

Update equipment

The hardware requirements for soil spectroscopy are moderate; nevertheless it is important to equip institutions with adequate and up-to-date tools and instruments, both for spectral measurements and analysis and accurate wet-chemistry reference.

Further reading

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evidence for policy

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