Ethiopia
research evidence for policy
Regional edition Horn of Africa No. 7 August 2013
NCCR north south

Many parts of Ethiopia are intensively farmed, and their soils need efficient monitoring.
Photo: Birru Yitaferu

Measuring and monitoring the quality of soils using spectroscopy

Case studies featured here were conducted in Ethiopia.

Policy message

- Land-management policies must be based on reliable information about soils. Spectroscopy can provide the required baseline data.
- Soil spectroscopy is a novel technology that can quantify the carbon in the soil, along with many other soil properties.
- Compared to convention alanalysis methods, soil spectroscopy is non-destructive, inexpensive, and fast.
- Soil spectroscopy is an ideal tool for large-scale monitoring and surveillance, which are required to ensure food and livelihood security.
- The technology is versatile and can be applied both in the laboratory and the field, with less costly infrastructure.
- In conjunction with remote-sensing imagery, soil spectroscopy can be used for area-wide monitoring of surface soils.

How much carbon is in the soil? How much nitrogen? How much will there be if the land is ploughed, or planted with trees? Answering these questions is increasingly important for initiatives promoting payments for ecosystem services and carbon sequestration, which depend heavily on the accurate assessment and monitoring of soils, vegetation, and water.

In Ethiopia, many soils are depleted because of poor land management. New approaches and efficient ways to implement them are needed. Spectroscopy is an ideal tool for providing the required baseline and monitoring data for planning such approaches. It is as accurate as conventional methods, and in combination with global positioning systems and satellite remote sensing, it allows the fertility of large areas to be monitored at an affordable cost.

Improving agricultural productivity through evidence-based policymaking

Agriculture in Ethiopia suffers from low soil fertility, mainly as a result of inappropriate land-management practices over many years (Hurni 1993). Poor land management degrades the soil and lowers its fertility, forcing farmers to use the soil even more intensively to grow their crops. To break out of this vicious circle, policies need to support and guide agricultural extension work and other initiatives. Reliable, up-to-date data on soils and land resources are necessary to inform these policies. Advances in soil spectroscopy now make it possible to generate such data at an affordable cost.

Need for assessment and surveillance tools

Soils have many important functions, some of which compete with each other: the production of food and fibre, carbon

Featured case studies

NCCR North-South research in Ethiopia conducted within the **Research Project 11 on Land Resource Potentials** is assessing the effects of sustainable land management on soil carbon accumulation in the Ethiopian Highlands. Knowledge and experiences gained from this project also inspired activities of the national EthioSIS project.

The **Water and Land Resource Project in Ethiopia** is collecting, archiving, and analysing long-term data on soil and water (1982–2012) in order to support natural resource monitoring. This will be an important repository for legacy data in Ethiopia.

Ethiopian Soil Information System (EthioSIS). This recent initiative managed by the Ethiopian Agricultural Transformation Agency aims to provide reliable soil fertility data by generating specific and detailed soil information for all of the Highlands. A soil fertility map of the country will be a major project output.

African Soil Information Service (AfSIS). Since knowledge about trends and conditions of African soils is poor, this project is developing accurate, up-to-date, and spatially referenced soil information to support agricultural and environmental developments for the continent (ICRAF).

sequestration, water-quality protection, and waste disposal. There is an increasing need to understand, assess and monitor soils and the nutrients they contain in order to manage them better.

The soils of the Ethiopian Highlands are subject to severe erosion and other forms of degradation. Their fertility and productivity have declined, seriously threatening people's livelihoods and the national economy. Concerted action is required to reverse this trend. For this, it is vital to assess the status of degradation and to establish observatories to monitor soil health. But conventional soil analysis methods are prohibitive both financially and technically: Ethiopia has many different soils, agro-ecological zones, geologies, and landscapes, which require large numbers of samples to be analysed. That makes it impossible to measure and monitor soils over large areas using conventional methods at a reasonable cost.

Cutting costs and improving monitoring

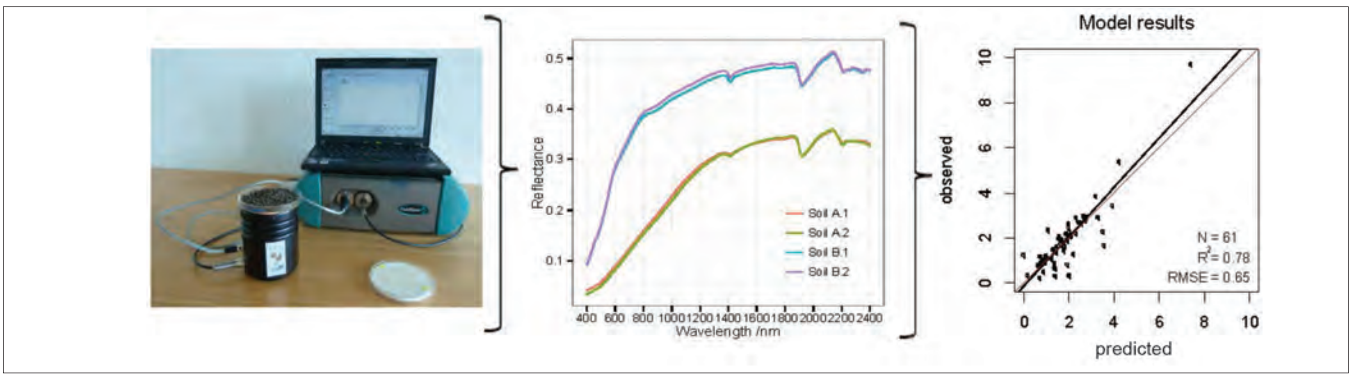
How to reduce costs while intensifying and improving the monitoring of soils? The most promising approach is to combine remote sensing imagery and soil spectroscopy. The use of soil spectroscopy alone can reduce costs by around 70% compared to conventional "wet" chemical analysis (Stenberg et al 1995), and savings are expected to be even higher in countries like Ethiopia that have to import chemicals for the conventional analysis. Plus, the costs of spectroscopy can be expected to fall further in the future.

How does soil spectroscopy work?

Major advances in applied science are linked to progress in basic sciences. This is also true for soil spectroscopy, which was originally developed by physicists to study the behaviour of electrons.

A soil spectroscope works much like a digital camera. 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 detector, where it is registered, quantified, and recorded. This reflected light has a very specific "spectral fingerprint" in the form of a spectrum that is characteristic for the soil under investigation. From it, many soil properties can be inferred, such as the iron content, 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, but only to develop the basic soil parameters and spectral data for a given environment; afterwards only spectral readings



The measured reflectance can be calibrated against the results of the chemical analysis to build a calibration model. This makes it possible to predict the composition of other samples just by measuring their spectra.

are needed for regular monitoring (Shepherd and Walsh 2007).

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

Building a spectral library of soils

The Highlands of Ethiopia have very varied soils. That makes it important to collect enough samples from the different soils to cover the full variation. The spectra of the collected samples 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 compare the spectrum from a new soil sample with this library to determine the sample's properties.

A global initiative by the Soil Spectroscopy Group (Viscarra Rossel 2009) 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 global soil spectral library.

Reaching from point to space

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

Modern spectrometers can be operated by one person in the field as well as in the lab.
Photo: Christian Hergarten

Introducing soil spectroscopy in Ethiopia: A success story with challenges

Its many advantages over conventional wet-chemistry-based analysis make soil spectroscopy an ideal candidate technology for developing countries like Ethiopia. The Ethiopian Soil Information System (EthioSIS) is currently collecting a multitude of soil information throughout the country and is analysing it using up-to-date techniques, including soil spectroscopy.

The introduction of a new technology of this type faces various challenges. The most important are capacity development and laboratory equipment.

Most conventionally trained soil scientists lack the skills required by soil spectroscopy, such as statistics and quantitative techniques. Universities and training institutions need to ensure that future soil scientists have a sound understanding of these methods.

New technologies require continued education and training of staff.
Photo: Bettina Wolfgramm

Research institutions need the staff and equipment for soil spectroscopy. Government institutions tend to have better equipment, but find it hard to retain trained staff. Private-sector enterprises are poorly developed in the field of analytical soil science, but could benefit considerably from partnerships with the public sector.

Storing soil samples is important for long-term monitoring and may be a valuable source for legacy data.
Photo: Tadele Amare

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 takes time.

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Policy implications of NCCR North-South research

- **Use new technologies to support policymaking**
  Properly applied, quantitative, and accurate methods like soil spectroscopy have the potential to improve the policymaking process by supplying reliable baseline data.
- **Integrate new technologies**
  New analysis technologies like soil spectroscopy need to be introduced carefully and in response to real requirements. Adaptations to the local institutional environment are often required. At the same time, such technologies can foster collaboration among different stakeholders and feed into public–private partnerships.
- **Take advantage of existing soil collections**
  The National Soil Testing Centre in Ethiopia has accumulated an impressive amount of chemically analysed soil samples from all over the country. Such legacy data provide a good starting point for mid- and long-term soil-monitoring activities.
- **Foster knowledge and technology transfer**
  For countries like Ethiopia to benefit from technological advances like soil spectroscopy, qualified skills development and training programmes are very important and must be strengthened.
- **Update the institutional setup**
  A soil spectroscopy laboratory has different requirements from a conventional laboratory. Fewer trained chemists are needed in the field, but reliance increases on highly accurate reference analysis laboratories.
- **Update equipment and instruments**
  The hardware requirements for soil spectroscopy are moderate; nevertheless it is important to equip institutions with adequate and up-to-date tools and instruments.

Further reading

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The NCCR North-South is a worldwide research network including six partner institutions in Switzerland and some 140 universities, research institutions and development organisations in Africa, Asia, Latin America and Europe. Approximately 350 researchers worldwide contribute to the activities of the NCCR North-South.

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This issue
Series editor: Berhanu Debele
Editor: Paul Mundy
Design: Simone Kummer
Layout: Bersabel Alemayehu
Printed by: Master Printing Press

The NCCR North-South is co-financed by the Swiss National Science Foundation (SNSF), the Swiss Agency for Development and Cooperation (SDC) and the participating institutions. The views expressed in *evidence for policy* belong to the authors concerned and do not necessarily reflect the opinions of the funding agencies, the overall NCCR North-South network, or other institutions.

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Fonds national suisse
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Citation: Hergarten C, Tadele Amare, Birru Yitaferu, Hurni H. 2013. *Measuring and monitoring the quality of soils using spectroscopy*. Evidence for Policy Series, Regional edition Horn of Africa, No. 7, ed. Berhanu Debele. Addis Abeba, Ethiopia: NCCR North-South.