A Globally Distributed Soil Spectral Library Visible Near Infrared Diffuse Reflectance Spectra

World Agroforestry Centre (ICRAF)

ISRIC - World Soil Information

Preface

The need to maintain the health of the soil resource base as an imperative for sustainable development is increasingly being recognized. Science and technological developments in remote sensing are providing new opportunities for low cost and efficient applications for characterizing and monitoring the health of the soil resource base. We are pleased to introduce this spectral library of world soils, which will provide a valuable resource for research and applications for sensing soil quality both in the laboratory and from space. This product is a result of collaboration between ICRAF and ISRIC scientists and we encourage further development of this area of research.

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Introduction

This spectral library consists of visible near infrared spectra of 785 soil profiles (4,437 samples) selected from the Soil Information System (ISIS) of the International Soil Reference and Information Centre (ISRIC). The samples consist of all physically archived samples at ISRIC for which soil attribute data was available in 2004. The spectra were measured at the World Agroforestry Center's (ICRAF) Soil and Plant Spectral Diagnostic Laboratory. The samples are from 58 countries spanning Africa, Asia, Europe, North America, and South America. Associated attribute data, such as geographical coordinates, horizon, and physical and chemical properties, are provided in a single relational database.

Methods

Soil diffuse reflectance spectra were recorded for each library sample using a FieldSpec FR spectroradiometer (Analytical Spectral Devices, Boulder, CO) at wavelengths from 0.35 to 2.5 μm with a spectral sampling interval of 1 nm. The instrument had been calibrated by the manufacturer on an annual basis. The optical setup was as reported in Shepherd et al. (2003). Samples were illuminated from below using a high-intensity source probe (Analytical Spectral Devices, Boulder, CO). The probe illuminates the sample (4.5 W halogen lamp giving a correlated color temperature of 3000 K; WelchAllynSkaneatles Falls, NY, USA) and collects the reflected light from a 3.5-cm-diameter sapphire window through a fiber-optic-cable (Fig. 1).

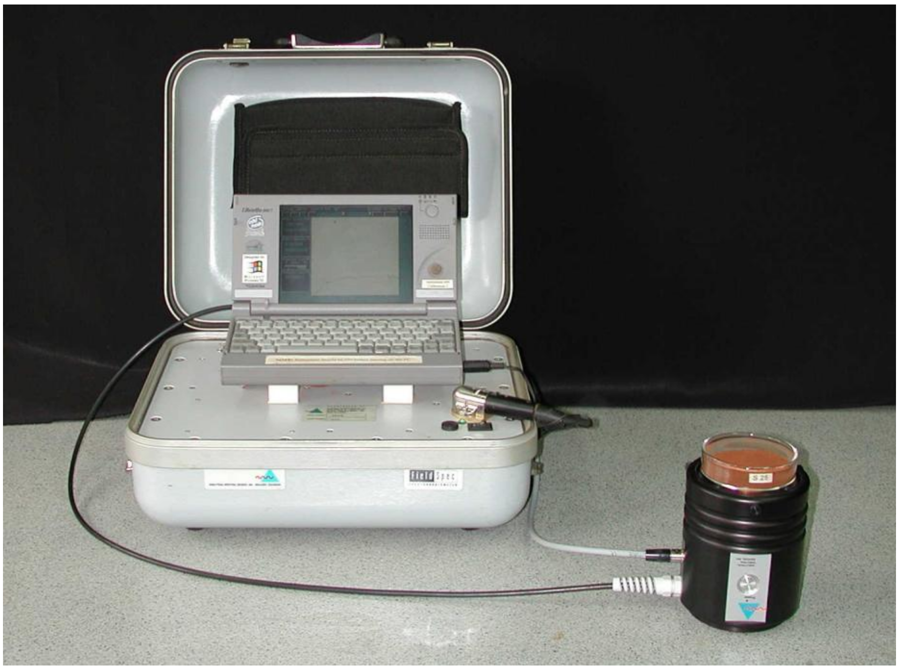

Fig. 1. Field portable spectrometer showing the optical set up.

About 20 g of air-dried soil ground to pass through a 2-mm sieve were placed into 7.4 cm diameter Duran glass Petri dishes to give a sample height of about 1 cm. To sample within-dish variation, reflectance spectra were recorded at two positions, successively rotating the sample dish through 90° between readings and an average of 25 spectra (the manufacturer's default value) was recorded at each position to minimize instrument noise. Before reading each sample 10 white reference spectra were recorded using calibrated spectralon (Labsphere, Sutton, NH, USA) placed in a glass petri dish. The certified white reference reflectance factors are given in Table 1. Reflectance readings for each wavelength band were expressed relative to the average of the white reference readings. The 1 nm interval spectra was resampled by selecting every tenth-nanometer value from 0.35 to 2.5 µm to give a total of 216 data points for each spectrum.

Soil property attributes were provided by ISRIC and had been analysed according to the ISRIC "Procedures for soil analysis" (Van Reeuwijk, 2002). Soil samples were air-dried, clods crushed and the resulting sample material sieved through a 2 mm sieve prior to further analysis. Soil pH was determined by shaking soil together with deionized water for two hours in a soil:liquid ratio of 1:2.5. Organic carbon content was determined using the Walkley-

Black procedure. This involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulfuric acid at about 125°C. Cation exchange capacity and exchangeable Ca and Mg were determined using the ammonium acetate method, which included usage of sodium acetate instead of ammonium acetate for samples with a pH value above 7. Exchangeable Ca and Mg were measured by flame atomic absorption spectrophotometry and CEC by flame emission spectrophotometry. Removal of soil organic matter and carbonates prior to soil texture analysis was done using H_2O_2 and HCl, respectively. The sand fraction was separated first by wet sieving. Clay fractions were determined by the pipette method.

Table 1. 8º/hemispherical spectral reflectance factor for the white reference used (Labsphere SRT-99-020).

Wavelength (nm)	**Reflectance factor**
350	0.981
400	0.986
450	0.988
500	0.989
550	0.989
600	0.990
650	0.989
700	0.989
750	0.989
800	0.989
850	0.988
900	0.991
950	0.989
1000	0.990
1050	0.990
1100	0.989
1150	0.990
1200	0.989
1250	0.989
1300	0.988
1350	0.988
1400	0.986
1450	0.986
1500	0.987
1550	0.987
1600	0.987
1650	0.986
1700	0.984
1750	0.984
1800	0.986
1850	0.981
1900	0.979
1950	0.978

2000	0.973
2050	0.963
2100	0.956
2150	0.951
2200	0.967
2250	0.969
2300	0.963
2350	0.951
2400	0.947
2450	0.945
2500	0.941

Linked database

The relational database combines the ISRIC Soil Information System (ISIS) data with the ICRAF VNIR spectral data in MS-Access®. ISIS includes data on chemical and physical soil properties, site details, and soil classification. The ISIS data tables are linked to the spectra table ("ASD Spectra") by using four fields: (a) Horizon; (b) BBOT; (c) BTOP; and (d) Sampleno. The ISIS and spectral table are linked using the "Chemical properties" table (Fig. 2).

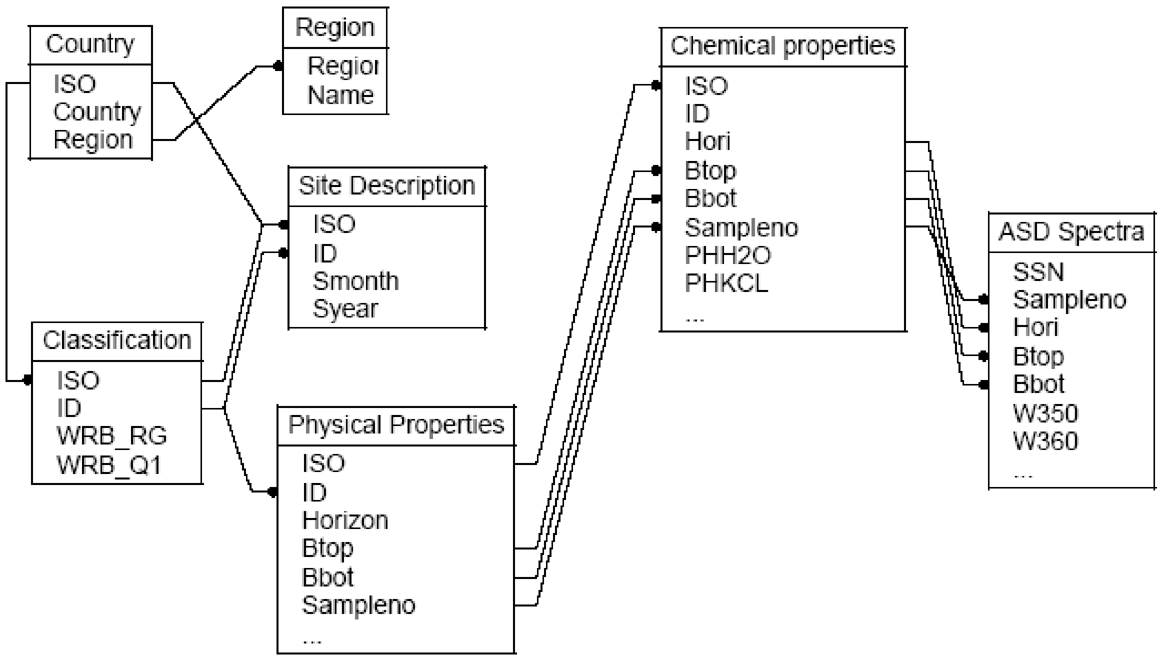

Fig. 2. Structure of the relational database.

Variable descriptions

The table “Key” contains the descriptions of the variables and abbreviations used in the ISRIC database tables. The field names in the spectra table are:

Field names	Description
SSN	Unique identification number for each spectrum
Sampleno	Sample number as in the ISRIC database; can be used to match spectra table to the other tables
Hori	Soil sampling horizon name
Btop	Start point of sampling depth (cm)
Bbot	End point of sampling depth (cm)
W350…W2500	Wavebands in nanometers at which reflectance values are given in the database.

Instructions for downloading spectra

The complete merged database containing both soil and spectral data can be accessed from www.africasoils.net under the filename “ICRAF-ISRIC VNIR Soil Database“; also through a link from www.isric.org.

With the database file open, users can view data by either tables or queries. This is easily done using the standard navigation of Microsoft Access objects.

A query named “ISRIC-ICRAF data” has been created as shown in Fig. 2 and the user can remove or add the fields required from the different tables. It is recommended to retain this query without modification for future use and save any changes made under a different query name. New queries can be created depending on the users needs using the query wizard or design in the query mode.

The numbers of profiles and samples per country are given in Table 2, and spectral plots for the entire 4,437 sample set organized by regions are shown in Fig. 3.

Table 2. Number of profiles and soil samples per region with spectral data.

Region	Profiles	Samples
Central_America	50	249
East_Asia	49	263
Eastern_Africa	70	356
Eastern_Europe	48	304
Japan	6	36
Middle_East	19	77
Oceania	28	222
OECD_Europe	133	770
South_America	103	640
South_Asia	26	111
South_East_Asia	84	414
Southern_Africa	72	422
USA	23	145
Western_Africa	74	428

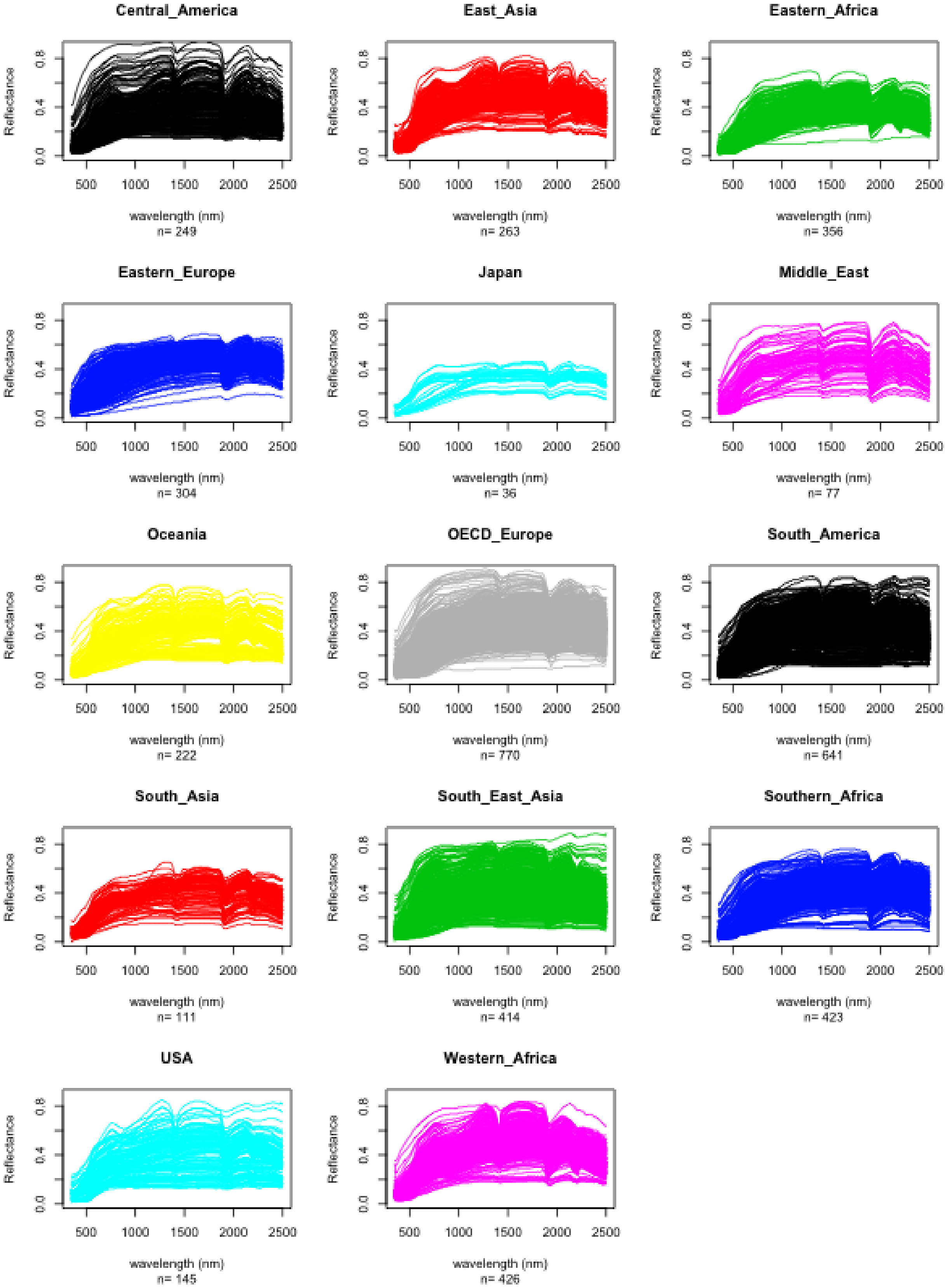

Figure 3. Visible near infrared spectra for the ICRAF-ISRIC spectral library by region.

References

1) Shepherd KD, Palm CA, Gachengo CN and Vanlauwe B. 2003. Rapid characterization of organic resource quality for soil and livestock management in tropical agroecosystems using near infrared spectroscopy. *Agronomy Journal* 95:1314-1322.

2) Van Reeuwijk LP 2002 (ed.). *Procedures for Soil Analysis*. (6th ed). Tech. Pap. 9, ISRIC, Wageningen. Available at: http://www.isric.org/Isric/Webdocs/Docs/ISRIC_TechPap09_2002.pdf.

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