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Harmonized soil profile data for applications at global and continental scales: updates to the WISE database

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Abstract

Version 3.1 of the ISRIC-WISE database holds selected site and horizon data for some 10 250 soil profiles from 149 countries. Profile data were extracted from a wide range of sources and harmonized with respect to the original (1974) and revised (1988) Legend of the FAO-Unesco Soil Map of the World. Profiles have been described, sampled, and analysed according to methods and standards in use in the originating countries; analytical results for the same property cannot always be compared directly; as a result the amount of measured data available for modelling is sometimes much less than expected. WISE was specifically developed for land-related applications at continental and global scales.

Keywords: Legacy data, soil profiles, soil properties, global data set, modelling, WISE

Introduction

Large-scale data sets of the world's resources, based on well-documented procedures and standards, are necessary for many assessments at global and continental scales. Staff at ISRIC have developed a uniform methodology for a global soil database known as the ISRIC-WISE database (Batjes & Bridges, 1994). Original profile descriptions have been (re)classified according to the original and revised legend of the soil map of the world (FAO-Unesco, 1974; FAO, 1988). As a consequence the WISE data can be linked using GIS to the mapping units of digitized as well as digital soil maps that use either of these Legends (Batjes, 2000; Batjes *et al.*, 2007; FAO/IIASA/ISRIC/ISSCAS/JRC, 2008); harmonized legacy soil data that arise from traditional soil survey can also facilitate new digital soil mapping activities (Hartemink *et al.*, 2008).

Earlier releases of WISE have provided input for a wide range of studies, including pedotransfer function development, global agro-ecological zoning, assessments of crop production potential, soil vulnerability to pollution, and soil gaseous emission potentials (see ISRIC-WISE, 2008 for references). A new version, release 3.1 of the ISRIC-WISE database (hereafter referred to as WISE3), is now available online at http://www.isric.org.

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Methods

Strict criteria have been set for accepting profiles: (a) completeness and *apparent* reliability of data; (b) traceability of source of data; and (c) classifiable in the FAO-Unesco (1974) Legend and Revised Legend (FAO, 1988). Where possible, profiles are geo-referenced within defined limits. To facilitate querying and exporting, data in WISE are handled using a relational database management system. Input is screened for possible inconsistencies using automated and visual procedures; these include, for example, checks to assess whether pH values and C/N ratios are within the normal range reported for most soils. Methodological details and coding conventions for WISE3 may be found in a technical report (Batjes, 2008).

Contents

There are 10 253 profiles in WISE3, with some 47 800 horizons, compared with some 4380 profiles for the earlier public domain version and some 9600 profiles in an interim, in-house version (Batjes, 2002a). Data were obtained from 260 different sources, covering some 149 countries.

The profiles were collected between 1925 and 2005; about two-thirds of the descriptions originate from the period 1955 to 1995. Most profiles are from Africa (41%), followed by Asia (18%) and South America (18%, Table 1); approximate locations are shown in Figure 1. There is no consistent set of

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Table 1 Number of soil profiles in WISE3, by continent with their description status

Continent	Profile description status[a] 1	2	3	4	Total
Africa	421	1337	2392	23	4173
Asia	441	970	426	10	1847
Antarctica	4	6	0	0	10
Europe	225	712	359	20	1316
North America	495	222	127	11	855
Oceania	50	49	106	4	209
South America	149	1380	313	1	1843
Total	1785	4676	3723	69	10253

[a]The description status provides a *coarse* indicator for the inferred quality of the soil description and the analytical data; it is indicative of the reliability of soil profile information entered into a database (FAO, 2006). Values range from 1 for so-called 'reference profile descriptions' to 4 for 'other descriptions' in which essential elements are missing in the description. Code 4 type data are generally not accepted for inclusion in WISE, unless the corresponding FAO soil unit is grossly under-represented; such profiles may be purged from subsequent releases of WISE once new status 1 or 2 profiles have been found for the relevant soil units.

properties for which all profiles have analytical data, generally because only selected measurements were planned during the original surveys.

Each profile has been rated according to its *description status*, a coarse indicator for the completeness and quality of source data required to classify the soil according to the FAO soil legends. Analytical data for profiles having a high description status may be considered as most reliable (Table 1). Some 25 site and 30 horizon-related variables can be handled in WISE3 (Table 2). Typically, there are fewer data for soil physical as opposed to soil chemical attributes and there are fewer measurements for deeper than for superficial horizons. Secondary attributes, such as exchangeable sodium percentage, CEC of the clay-size fraction and profile available water capacity, are not included in WISE3 as these may be derived from the primary data.

Discussion

Attribute data in WISE3 reflect the state of the source materials at the time they were incorporated in the database. When given, FAO classifications were taken at face value, having been assigned by pedologists familiar with the source materials/regions, unless inconsistencies were observed in the original classifications; even experienced taxonomists may have different perceptions about how a particular soil profile should be classified, especially when data are incomplete.

There are differences in procedures for soil profile description and chemical and physical analyses as carried out in over 150 laboratories worldwide; analytical procedures are described concisely in the dataset with a flag to the data source. Methods typically vary from one laboratory to

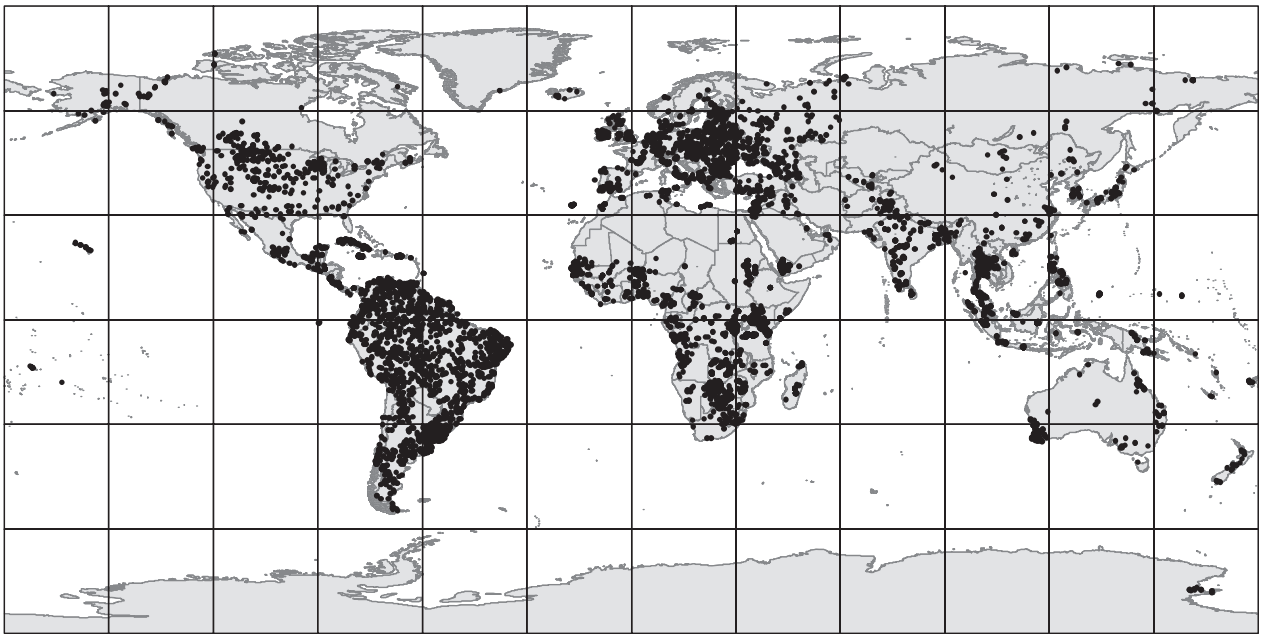

Figure 1 Global distribution of geo-referenced soil profiles in WISE3 (rasters are 30 by 30 degrees).

Table 2 Variables considered in WISE3 and proportion of filled records

Site data		Horizon data	
WISE3_ID[a] (n = 10 253)	(% filled)	WISE3_ID + horizon_No[b] (n = 47 833)	(% filled)
General[c]		General	
Soil profile description status	100	Horizon number	100
Description, year of	65	Depth, top	100
Description, month of	54	Depth, bottom	100
Depth of soil (described/sampled)	100	Horizon designation	87
Number of horizons	100	Matrix Munsell colour, moist	62
		Matrix Munsell colour, dry	22
Soil classification		Chemical attributes	
FAO-Unesco 1974 legend	100	Organic carbon	87
Phase (1974)	8	Total N	54
FAO-Unesco 1988 legend	100	Electrical conductivity	68
Phase (1988)	7	Free $CaCO_3$	71
Reference soil group (WRB, 2006)	100	$CaSO_4$	55
USDA soil taxonomy	37	pH-H_2O	91
Edition (year) of USDA soil taxonomy	22	pH-KCl	43
National soil classification	37	pH-$CaCl_2$	24
		Exchangeable Ca^{2+}	74
Location		Exchangeable Mg^{2+}	73
Country (ISO code)	100	Exchangeable Na^{+}	61
Latitude (degrees/min/s)	80/80/54	Exchangeable K^{+}	69
Longitude (degrees/min/s)	80/80/79	Exchangeable Al^{3+} + H^{+} (exchangeable acidity)	49
Location (descriptive)	47	Exchangeable Al^{3+}(exchangeable aluminium)	54
		Cation exchange capacity (CEC)	89
General site data		Base saturation (as per cent of CEC)	52
Climate	46		
Altitude	67	Physical attributes	
Major landform	39	Weight % sand	92
Landscape position	28	Weight % silt	92
Slope	30	Weight % clay	92
Parent material	33	Volume % >2 mm	22
Drainage class	100	Bulk density	32
Land use	39	Volume per cent water held at −10 kPa	4
		Volume per cent water held at −33 kPa	13
		Volume per cent water held at −1500 kPa	15

[a]Unique identifier (primary key) for profile. [b]Unique reference number for horizon within a profile. [c]Coding conventions and keys to the analytical methods are detailed in Batjes (2008).

another and may change over time within a single laboratory. This complicates worldwide comparison of soil analytical data; available options for data harmonization will vary with the analytical methods and soil attributes under consideration (Vogel, 1994; Hollis *et al.*, 2006). A certain minimum level of variation will always occur even when analytical methods are standardized (Pleijsier, 1989; Landon, 1991).

For a given soil unit, the number of measured data for each property varies between profiles and with depth. As a result, the number of data for pedotransfer function development and modelling is sometimes much less than expected, particularly when differences in analytical procedures are considered in detail; for a discussion see Vogel (1994) and Batjes (2002b).

Defining too stringent rules on data collection and data comparability would preclude the compilation of a global soil data set. Conversely, uncertainties associated with differences in measurement of, for example, particle size distribution and bulk density will be reflected in the accuracy of pedotransfer functions derived from the primary data. Cross-correlations between uncertain variables determine how uncertainties will propagate in a modelling study (Heuvelink & Brown, 2006). Accuracy levels considered to be acceptable will vary with the scale and type of questions being asked (Finke, 2006). WISE was specifically developed

for applications at continental and global scales (1:500 000 or broader).

Being based on diverse data, WISE3 inevitably has geographic, soil taxonomic and soil analytical gaps; for example, there are still few soil profiles from boreal and cold temperate regions; details are given in Batjes (2008). However, adroit use of the data will permit a wide range of agricultural and environmental applications at global and continental scales (for examples see ISRIC-WISE, 2008). Consolidation and expansion of online depositories of soil survey data (e.g. Hallet *et al*., 2006; ISRIC, 2007; USDA-NRCS, 2008) remain essential to provide new source materials for a possible expansion of WISE.

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