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A National Soil Profile Database for Brazil Available to International Scientists

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ABSTRACT

A comprehensive digital soil profile database of Brazil was compiled and is being made available through the Internet. Most of the soil data were obtained from the Radambrasil project and other regional surveys. The database contains information from 5086 profiles distributed over the whole Brazilian territory corresponding to data from 10 034 horizons, each with 31 variables. The variables were chosen to represent different areas of soil science, embracing soil morphological, chemical, mineralogical, and physical attributes. The distribution uniformity of the data was low with sampling densities varying from one profile per 10 000 km^2 to one profile per 1370 km^2. The access to the database is free and its design allows its use not only by soil scientists but also by those working with agricultural, environmental, and land use issues.

Large-scale phenomena and impacts, discussed on a global scale under a multiperspective analysis are increasingly on society's agenda (Pearce and Warford, 1993). Examples directly related to soil science are the expansion of agriculture to areas of tropical forest; contamination of water resources with residues of pesticides, phosphate and nitrate used in agriculture; and the degradation of soils through soil erosion (Habern, 1992; Doran et al., 1996; Doran and Safley, 1997). Additionally, soil scientists are increasingly concerned about global climate changes, where soil organic C storage is a key issue (Uri and Bloodworth, 2000; Soil and Water Conservation Society, 2001).

To analyze global phenomena related to soil science we need comprehensive, consistent, georeferenced, and quantitative databases on national or continental scales. Some multi-country thematic specific databases are available such as HYPRES (Hydraulic Properties of European Soils, Wösten et al., 1999), WISE (World Inventory of Soil Emission Potentials, Batjes, 1996) and UNSODA (Unsaturated Soil Hydraulic Database, Nemes et al., 2001), but the type of information included in these databases is limited. Many countries already have soil electronic databases available such as the USA (USDA-National Resources Conservation Service, 2004), Canada (Agriculture and Agri-Food Canada, 2000), Australia (Commonwealth Scientific & Industrial Research Organization–Land and Water, 2004), and FAO (Food and Agricultural Organization, 1993, 1995), but in most countries these data are not available. This is especially true in countries of the tropics. An attempt to solve this problem in Brazil was made through the Soil Information System (Sissolos) (EMBRAPA, 1984) started in the early 1980s but not completely established until now.

The usefulness of large-scale soil databases to assess important aspects related to tropical soil science is well described in Moraes et al. (1995) and Batjes and Dijkshoorn (1999) by calculating the C and N stocks of the Brazilian Amazon basin, that was based on the digitalization of 1162 and 618 soil profile data obtained from available bibliographic sources.

This manuscript describes the creation of a quantitative georeferenced soil database similar to that described in Moraes et al. (1995), but extending it to the total Brazilian territory and increasing comprehensiveness.

DATABASE DESCRIPTION AND ORIGINS

Most of the data was obtained from the Radam project (Projeto Radambrasil, 1973–1986). The Radam project (Radar in Amazon) was created in 1970 with the objective of providing support data needed to incorporate the Brazilian Amazon region into the national economy. The Brazilian government, at that time under the coordination of a military dictatorial regime, decided to expedite surveys of soil, geology, geomorphology, land use, and forest inventory of 1 500 000 km^2 along the Transamazonian highway. The innovative technology selected for remote sensing was the Side-Looking Radar (SLRA). Because of the success obtained in the first part of Radam, the survey area was extended in 1975 to the entire Amazon region and later to the other Brazilian territories. The program was discontinued in 1986 when volume 33 of Radam (maps at the scale of 1:1 000 000 and books containing descriptions and analytical data), covering the State of Rio Grande do Sul, located at the extreme southern part of Brazil was published. These surveys, performed during 1973–1984, covered the Brazilian territory of 8 511 965 km^2 almost completely, except for some parts of the Southeast region. During fieldwork, 4600 soil profiles were described and analyzed for chemical, physical, mineralogical and morphological attributes, and published in 33 printed volumes. The areas not covered by Radam were extracted from several other regional surveys to ensure the total coverage of the Brazilian territory (Fig. 1).

Due to the large amount of data that were collected and organized, and the objective of developing the database as a multi-user tool, the basic information were compiled in a single text (ASCII format) table to allow a more flexible and user-friendly environment. In this way, any piece of data can be partially or totally added, deleted, edited, or extracted using the database system and structure of the final user's preference.

The sequence used to show the data followed the Radam volumes, or that of the institution responsible for the regional soil surveys. This main table contains

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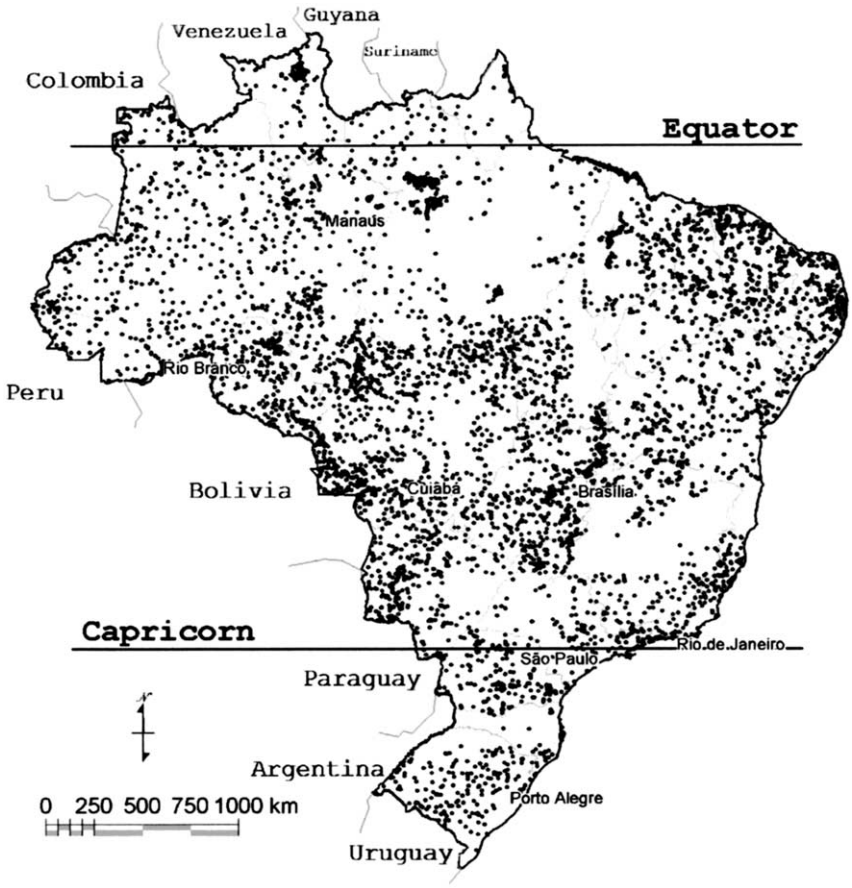

Fig. 1. Database soil profile location.

data from all of the soil profiles extracted from the abovementioned surveys. The profiles are numbered and georeferenced (latitude and longitude in geographic coordinates using decimal degrees with unspecified datum). Each profile contains data of the surface and the diagnostic subsurface horizons. The variables or soil attributes (Table 1) are listed according to a logical order that depends on the type of soil attribute (physical, chemical, or morphological).

Auditing of the database was performed to control the quality of the information. The main errors found were typing mistakes, wrong locations, and analytical or calculation errors found in the original publications. The auditing routines were based on those attributes that can be calculated using other analytically determined soil attributes such as CEC and particle-size distribution, or those that can be geographically represented (e.g., latitude and longitude). No quality control was done on analytically determined data. In all the auditing routines, when possible, corrections were made. In the case of various or difficult to correct and missing data, the profiles were eliminated from the final database.

Some profiles, especially the more recent ones, had coordinates (latitude and longitude) in their description with no indication of datum. These coordinates were used in the database after examination of their inclusion within the coordinates of the respective mapping area. Most of the older profiles description had no coordinate indication. In some cases the profile number was indicated on the printed map and in others a general location description (e.g., distance from a city traveling along a specific road) was provided. In these cases, the location was identified on the printed map and coordinates were calculated using the map's georeferenced grid, or the profile's location was found on a digital road map. This procedure allowed the inclusion of several nongeoreferenced profiles as geocoded data in the final database.

Spatial Data Distribution and Intent

A total of 5255 profiles were originally included in the database, this corresponds to a total of 10 528 horizons. After auditing 5086 profiles remained in the database. These were distributed over the whole of Brazil. This corresponds to data from 10 034 horizons, where each horizon contains information on 31 soil variables (Table 1). Each profile and/or horizon is stored in the database linked to an identification key that contains the number of the Radam volume or code of the regional soil survey and the corresponding soil profile number. The soil profile number is the same as those found in the soil survey volumes so that crosschecking and/or correction can be done.

The uniformity of the data extracted from the soil surveys was quite low. In the Radam project, many regions of Brazil, mainly the regions concerning volumes

Table 1. List of variables used in the database with their description and analytical method of determination.

Database code	Variables and soil attributes	Description	Analytical method
ClassifSolo	soil classification	soil name according to the 1970s and 1980s Brazilian soil classification system	field and analytical observations
DecVal	slope	inclination of the surface in relation to a flat reference	field observation
Drenagem	drainage	velocity at which water is removed from the soil profile	field observation
ProfSolo	soil depth	maximum soil depth indicated in the descriptions	field observation
HzSimb	horizon type	according to pedological convention	field observation
HzProf	horizon depth	depth of appearance and disappearance of the horizon	field observation
CorMunsell	color	described according to Munsell Soil Color Chart	field observation
CG	coarse gravel	material >20 mm in diameter	sieving
FG	fine gravel	material between 20–2 mm in diameter	sieving
Areia	sand	particles between 2–0.05 mm in diameter	sieving
Silte	silt	particles between 0.05–0.002 mm in diameter	(sand-clay)
Argila	total clay	particles <0.002 mm in diameter	dispersion with NaOH and sodium hexametaphosphate, Bouyoucos, or pipette method for determination
ArgilaNat	natural clay	particles <0.002 mm in diameter	dispersion with H_2O, Bouyoucos, or pipette method for determination
Floc	degree of flocculation	proportion of clay that is flocculated	100 (total clay − natural clay)/total clay
BD	bulk density	mass of dry soil per unit volume	volumetric ring method
SIO2	SiO_2	amount of silicon dioxide in soils	sulfuric attack
Al2O3	Al_2O_3	amount of aluminum oxide in soils	sulfuric attack
Fe2O3	Fe_2O_3	amount of ferric oxide in soils	sulfuric attack
pHH2O	pH H_2O	pH at a specified soil/water ratio	soil-water suspension, potentiometer
pHKCl	pH KCl	pH at a specified soil KCl ratio	soil-KCl suspension, potentiometer
C	C	soil organic C content	oxidation with 0.067 *M* $K_2Cr_2O_7$, Tiurim method
N	N	soil total N content	Kjeldahl digestion
Ca	Ca^{++}	exchangeable Ca	extracted with 1 *M* KCl
Mg	Mg^{++}	exchangeable Mg	extracted with 1 *M* KCl
K	K^{+}	exchangeable K	extracted with 0.05 *M* HCl
Na	Na^{+}	exchangeable Na	extracted with 0.05 *M* HCl
Al	Al^{+++}	exchangeable Al	extracted with 1 *M* KCl
H	H^{+}	exchangeable H	(total acidity-Al^{+++})
Tac	total acidity	total acidity including residual and exchangeable acidity	extracted with 1 *M* KCl
CEC	CEC	cation exchange capacity	bases extracted with ammonium acetate at pH 7
EC	EC	electrical conductivity	conductivity meter in a saturated paste of soil and water

1 to 14, were mapped with very few sampling points (<100 per volume). The lowest sampling intensities are in volumes 1 to 6 where the number of profiles was <45. In the case of volumes 1 to 6, the sampling density was one profile for every 10 000 km^2 and for volumes 7 to 14, one profile for every 3800 km^2. For volumes 14 to 33 where the mean number of soil profile per volume is 183, a sampling density of one profile for every 1370 km^2 is found. The lack of uniformity in the Radam database can be explained by the changing financial and political situation during the 11-yr span of the project. The regional soil surveys, used to complement the database, also presented very low uniformity concerning the profile distribution. This can be partly explained by the different scales and sampling densities used in the different surveys. In these surveys, scales ranging from 1:10 000 to 1:1 000 000 and sampling densities varying from one profile every 19 km^2 to one profile every 2878 km^2, were found.

One objective for assembling this database was to make available the most comprehensive soil profiles information as possible while using as sources only published data. In this way, information that was restricted to personal or public libraries is being made available through the Internet for noncommercial use. Several variables reflecting soil chemical, physical, mineralogical, morphological, and pedogenetic features were included, useful for a wide range of topics related to soil science. Of the 31 chosen variables (Table 1), six correspond to soil morphological attributes, eight correspond to soil physical attributes, and 16 correspond to soil chemical attributes. To these soil attributes, soil classification of each profile is also included, using the original terminology, completing the 31 variables contained in the database.

The database is useful to soil scientists, and other professionals working with agronomy, land-use planning, environmental management, soil process modeling or any other area in which basic soil data is necessary. Use of this database for noncommercial purpose is free, preserving the reference to its authorship. User-defined searches are allowed, as well as modifications to the structure or contents of all or part of the database. Importation into other database management systems and use with GIS or other interpolating systems is also possible. The database is available for free download at http://www.esalq.usp.br/gerd/ (verified 21 Dec. 2004).

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REFERENCES

Agriculture and Agri-Food Canada. 2000. Canadian Soil Information System. Available at http://sis.agr.gc.ca/cansis/(verified 21 Dec. 2004). CanSIS, Ottawa, Ontario.

Batjes, N.H. 1996. Development of a world data set of soil water retention properties using pedotransfer rules. Geoderma 71:31–52.

Batjes, N.H., and J.A. Dijkshoorn. 1999. Carbon and nitrogen stocks in the soils of the Amazon region. Geoderma 89:273–286.

Commonwealth Scientific & Industrial Research Organization–Land and Water. 2004. Australian Soil Resource Information System. Available at http://www.clw.csiro.au/aclep/ASRIS2004.htm (verified 21 Dec. 2004). CSIRO-Land and Water, Glen Osmond, Australia.

Doran, J.W., M. Sarrantonio, and M. Liebig. 1996. Soil health and sustainability. Adv. Agron. 56:1–54.

Doran, J.W., and M. Safley. 1997. Defining and assessing soil health and sustainable productivity. p. 1–28. *In* C.E. Pankhurst et al (ed.) Biological Indicators of Soil Health. CAB International, UK.

EMBRAPA. 1984. SISSOLOS–Guia de Entrada. Documentos SNLCS No9 (In Portuguese.). EMBRAPA, Rio de Janeiro.

Food and Agricultural Organization. 1993. Global and national soils and terrain digital database (SOTER). Procedures manual. FAO World Soil Resource Rep., 74. FAO, Rome.

Food and Agricultural Organization. 1995. Digital soil map of the world and derived soil properties. Version 3.5. FAO, Rome.

Habern, J. 1992. Viewpoint: A soil health index. J. Soil Water Conserv. 47:6.

Moraes, J.L., C.C. Cerri, J.M. Melillo, D. Kicklighter, C. Neill, D.L. Skole, and P.A. Steudler. 1995. Soil carbon stocks of the Brazilian Amazon Basin. Soil Sci. Soc. Am. J. 59:244–247.

Nemes, A., M.G. Schaap, F.J. Leij, and J.H.M. Wösten. 2001. Description of the unsaturated soil hydraulic database UNSODA version 2.0. J. Hydrol. (Amsterdam) 251:151–162.

Pearce, D., and J. Warford. 1993. World Without End. World Bank, Washington, DC.

Projeto, Radambrasil. 1973–1986. Levantamento de Recursos Naturais. Vol. 1–33 (In Portuguese). Departamento Nacional de Produção Mineral, Rio de Janeiro.

Soil and Water Conservation Society. 2001. Growing carbon: A new crop that helps agricultural producers and the climate too. Soil and Water Conservation Society, Ankeny.

Uri, N.D., and H. Bloodworth. 2000. Global climate change and the effect of conservation practices in US agriculture. Global Environ. Change 10:197–209.

USDA-National Resources Conservation Service. 2004. Online soil surveys. Available at http://soils.usda.gov/(verified 21 Dec. 2004). USDA-NRCS, Washington, DC.

Wösten, J.H.M., A. Lilly, A. Nemes, and C. Le Bas. 1999. Development and use of hydraulic properties of European soils. Geoderma 90:169–185.