Agricultural Systems 139 (2015) 93–99

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Short communication

Representative soil profiles for the Harmonized World Soil Database at different spatial resolutions for agricultural modelling applications

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ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form 30 June 2015
Accepted 1 July 2015
Available online 20 July 2015

Keywords:
WISE 3.1
Soil profile
DSSAT
Cluster
MarkSimGCM
CMIP5

ABSTRACT

Agricultural modellers often need detailed soil profile data with which to run their models. We combine an extensive soil profile database with the Harmonized World Soil Database, a 30 arcsecond raster database of soil information worldwide, and describe a statistical process to identify representative soil profiles for each of its 188 distinct soil types at different spatial resolutions. We then outline a method to cluster the soils in the Harmonized World Soil Database to produce soil maps at coarser resolution, and we describe derived global soil maps at spatial resolutions of 5 and 10 arcmin, which may be more practical for some large-scale modelling studies. The derived data files allow a user to select any point or area on land and then to access the set of soil profiles pertaining to the mapping unit selected, which are available in a format suitable for use in modelling applications. In situations where the user has little or no other information about the soils in the region of study, the methods described can be used to produce plausible soil profile information based on the most up-to-date global soil map currently available.

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1. Introduction

The availability of suitable input data continues to be a serious constraint to undertaking many applied research activities in the realm of agriculture, particularly in developing countries. Previously, we described a tool, MarkSimGCM, which allows the stochastic generation of daily weather data that are characteristic of current climatologies and, to some extent characteristic, of future climatologies (Jones and Thornton, 2013). These data can then be used to drive any agricultural model that requires daily (or otherwise aggregated) weather data. In addition to weather, another primary determinant of agricultural production is the soil. As for weather data, accessibility to and availability of appropriate soil data for agricultural modelling may pose serious constraints. Furthermore, the format in which soil data are available may constrain their widespread use, added to which is the problem of different soil classification schemes, which may or may not be translatable one to another.

Here we utilise the Harmonized World Soil Database (HWSD), the most up-to-date world soil map (FAO, 2012). It incorporates a data table of 48,148 soil profile descriptions related to the various soils associated with each mapping unit, at a spatial resolution of 30 arcsec (approximately 1 km at the equator). The data have been derived from a variety of sources, and are quite comprehensive. Unfortunately for many users, the data are grouped into broad topsoil and subsoil categories. For some purposes such as crop modelling, however, a soil profile is required with a full set of horizon data.

Below we describe an analysis that uses soil profile data from a large database and identifies the most statistically representative soil profile for each soil type in the HWSD. We then outline a method to cluster the soils in the HWSD to produce soil maps at coarser resolutions. We describe modifications to an existing tool, MarkSimGCM, that provide the user with soil profile data for any location, along with daily weather data for current and future climatologies. We have also updated MarkSimGCM with more recent climate model output; we also describe this. The weather and soil data can be used directly for a wide range of purposes. We briefly illustrate the use of the soil data set, and comment on its limitations.

2. Materials and methods

2.1. Using the WISE database to define representative soil profiles

The WISE databases contain soil profile data from many places around the world (Batjes, 2008, 2009). These data have been converted for use with the DSSAT (Decision Support System for Agrotechnology Transfer) crop modelling system (Jones et al., 2003; Gijsman et al., 2007; Chaves and Hoogenboom, 2014). From the most recent version, WISE 3.1, Chaves and Hoogenboom (2014) constructed a data file with 9618 soil profiles in DSSAT format. All soil profiles were classified according to both the original and the most recent legends of FAO's

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http://dx.doi.org/10.1016/j.agsy.2015.07.003
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soil map of the world (FAO, 1974, 1988). From this set of soil profiles, one question of interest is, which profile is the most representative of each soil type? If we can define representative profiles for each soil type, we can assign appropriate profiles to each mapping unit.

We proceeded as follows. Each soil profile contains both character and numeric data (Table 1, from Chaves and Hoogenboom, 2014). Tier 1 and tier 2 variables were available for each horizon within the profile. The varying number of horizons made direct comparisons difficult between profiles. Three horizons were therefore chosen: the top, bottom and the one closest to the middle. Some soil types such as Lithosols\ had only one profile and some had only two. In the first case the algorithm triplicated the horizon and in the second case the second horizon was duplicated. This ensured consistency of the distance measure across profiles and simplified programming.

Taking all available numeric values and eliminating those with missing values and those that did not vary across the sample of profiles gave a minimum of 37 values for profile comparison; some soil types had more than 37. All variables were normalised by dividing by the range and the average of each set of profiles for each soil type was calculated. Then for each profile the Euclidean distance (in 37-dimensional space) from the average was calculated. The most representative profile was chosen as the profile with the minimum distance from the mean.

In most cases, the full binomial key to the soil type was available and so the set of profiles applies to a specific soil (e.g., Eutric Cambisol). In some cases the modifier is not given, just the major soil type (e.g., Cambisol). In such cases all profiles classified as Cambisols were used for finding the typical profile. Typical profiles were found for both the FAO (1974) and the FAO (1988) legend keys.

Several soil types are not present in Chaves and Hoogenboom (2014) but do exist in the HWSD data (FAO, 2012): Folic Histosols, Luvic Gypsisols, Gypsic Kastanozems, Glosic Chernozems, Albic Lixisols, Urbic Anthrosols, Gelic Andosols, Aric Anthrosols, Stagnic Lixisols, Gelic Podzoluvisols, Gelic Planosols, and Andic Gleysols. Of these, the Gelic and Aric modifiers relate more to climate than to the actual soil profile, and are unlikely to be good arable land. The others are more problematic as they could potentially be used for cropping. It was decided to provide a reference profile for all of them for completeness, based on the representative profile of the appropriate major soil type.

Two further soils, Takyric Solonchaks and Takyric Yermosols, deserve mention. There are two profiles of the first and one of the second present in the Chaves and Hoogenboom (2014) dataset, but it was judged that these represented too few profiles from which to draw a representative profile. In the case of the Solonchaks the profiles were quite different, one being a heavy clay soil and the other a silty clay. Takyric soils are unlikely to be good agricultural soils and these have been assigned the representative profile of the major soil type.

The representative soil profile identifiers are stored in the file "HWSD_consolidated_class.txt", which contains 48,148 records and corresponds one-to-one with the HWSD database (see Table 2). The 188 reference profiles in DSSAT format are stored in the file "Consolidated.sol" (all distribution files are listed in Table 3).

Table 1
Soil data input for a daily time step crop simulation model (Chaves and Hoogenboom, 2014).

Characteristic	Definition	Units
General data		
SLTX	Texture code of surface layer	
SLDP	Soil depth	cm
SLDESCRIP	Soil description or local classification	
COUNTRY	Country name	
LAT[a]	Latitude	
LONG[a]	Longitude	
SCSC FAMILY	Soil class	
Profile data		
SCOM[a]	Soil colour (Munsell colour system)	
SALB[a]	Albedo	
SLU1[a]	Evaporation limit	cm
SLDR[a]	Drainage rate	Fraction day^{-1}
SLRO[a]	Runoff curve number	
SLNF	Mineralization factor	0–1 scale
SLPF	Soil fertility factor	0–1 scale
SMHB	pH in buffer determination method	
SMPX	Extractable phosphorus determination code	
SMKE	Potassium determination code	
First tier		
SLB	Depth until base of layer	cm
SLMH	Master horizon	
SLLL[a]	Lower limit of plant extractable soil water	$cm^3\ cm^{-3}$
SDUL[a]	Drained upper limit	$cm^3\ cm^{-3}$
SSAT[a]	Saturated upper limit	$cm^3\ cm^{-3}$
SRGF[a]	Root growth factor	0–1 scale
SSKS[a]	Saturated hydraulic conductivity	cm h^{-1}
SBDM[a]	Bulk density (moist)	g cm^{-3}
SLOC	Soil organic carbon concentration	%
SLCL	Clay (<0.002 mm)	%
SLSI	Silt (0.002 to 0.05 mm)	%
SLCF	Coarse fraction (>2 mm)	%
SLNI	Total nitrogen concentration	%
SLHW	pH in water	
SLHB	pH in buffer	
SCEC	Soil cation exchange capacity	Cmol(+) kg^{-1}
SADC	Soil adsorption coefficient (anion exchange cap.)	0–1 scale
Second tier		
SLPX	Extractable soil phosphorus concentration	mg kg^{-1}
SLPT	Total soil phosphorus concentration	mg kg^{-1}
SLPO	Soil organic phosphorus concentration	mg kg^{-1}
CACO3	Soil $CaCO_3$ concentration	%
SLAL	Soil aluminum concentration	mg kg^{-1}
SLFE	Soil iron concentration	mg kg^{-1}
SLMN	Soil manganese concentration	mg kg^{-1}
SLBS	Soil base saturation	%
SLPA	Soil phosphorus isotherm A	mmol kg^{-1}
SLPB	Soil phosphorus isotherm B	mmol kg^{-1}
SLKE	Exchangeable potassium soil concentration	cmol(+) kg^{-1}
SLMG	Exchangeable magnesium concentration	cmol(+) kg^{-1}
SLNA	Exchangeable sodium concentration	cmol(+) kg^{-1}
SLSU	Soil sulphur concentration	cmol(+) kg^{-1}
SLEC	Soil electric conductivity	dS m^{-1}
SLCA	Soil calcium concentration	cmol(+) kg^{-1}

[a] Calculated variables.

2.2. Processing the HWSD to produce 10- and 5-minute grids

In Section 2.1, we described how a DSSAT-formatted profile was assigned to each of the soil types in each mapping unit of the HWSD

Table 2
Contents of file "HWSD_consolidated_class.txt". The file contains 48,148 records and corresponds one-to-one with the HWSD database (FAO, 2012).

Variable	Meaning
ID	HWSD record ID
MU_GLOBAL	HWSD mapping unit number
SHARE	HWSD share % of the mapping unit for this profile
SEQ	HWSD sequence number of profile in mapping unit
SU_SYM74	HWSD FAO soil symbol 1974
SU_SYM90	HWSD FAO soil symbol 1988
WISE_PROFILE	10-Character WISE profile identifier
WISE_KEY	Numeric key to wise profile
SOIL_NAME	Soil name, according to either FAO (1974) or FAO (1988)
FLAG	Soil profile origin
	0 Not a soil. This includes water bodies and rock outcrops.
	1 Missing soil type with the profile of the major soil class provided.
	2 Profile obtained from the complete group of profile for the major soil type.
	3 Profile obtained from the set of appropriate profiles.

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