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Using the WISE database to parameterize soil inputs for crop simulation models

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Abstract

During the 1990s, a soils database was developed by the International Soil Reference and Information Centre in The Netherlands for the project "World Inventory of Soil Emission Potentials" (WISE). Using this database, we converted 1125 soil profiles from around the world into a format that can be used as input data to some commonly used biophysical computer models, such as the crop simulation models within the Decision Support System for Agrotechnology Transfer (DSSAT). Soil data are often unavailable, particularly for many locations in the tropical and subtropical regions. If little or nothing is known about the soil profile for a particular location, a soil database can be used to estimate some of its parameters, based on a comparison with other soils from the same region. The WISE database is one of the most comprehensive soil databases, with samples well distributed in the World. The resulting soil profile can then be used as input parameters for a model to simulate growth, development and yield for one or more crops for this location. With multiple profiles available for many soil classes, it is possible to obtain an indication about the range of values for each soil parameter and then conduct an uncertainty analysis with respect to the model's response to this range. All soil profiles have been geo-referenced, and can thus be linked to the digital version of the FAO-UNESCO soil map of the world. We describe the methods used to convert the soil profile database, discuss the variability of key soil variables by soil class, illustrate how the database can be used, and conclude with recommendations for further work to improve the database for biophysical modeling applications.

Keywords: Database; Crop simulation model; Decision Support System; SoilProfile; Crop production; Resource management

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1. Introduction

Soil data are essential inputs for many different types of biophysical simulation models, ranging from the (relatively simple) LPJ (Lund–Postdam–Jena) Dynamic Global Vegetation Model (Sitch et al., 2003) to comprehensive ecosystem

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Abbreviations: APSIM, Agricultural Production Systems sIMulator; CSM, Cropping System Model; DSSAT, Decision Support System for Agrotechnology Transfer; EPIC, Environmental Policy Integrated Climate Model; FAO, Food and Agriculture Organization of the United Nations; ISRIC, International Soil Reference and Information Centre; PTF, pedotransfer function; UNESCO, United Nations Educational, Scientific and Cultural Organization; WISE, World Inventory of Soil Emission Potentials

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models such as Savanna (Ellis and Coughenour, 1998) and detailed crop simulation models such as those associated with the DSSAT (Decision Support System for Agrotechnology Transfer; Jones et al., 2003; Hoogenboom et al., 2004), APSIM (Agricultural Production Systems sIMulator; McCown et al., 1996; Keating et al., 2003) and EPIC (Environmental Policy Integrated Climate model; Williams et al., 1989; Guerra et al., 2004). Soil data requirements obviously vary, depending on the processes that are simulated within a particular model, but for many management-orientated models, there are considerable overlaps. For both the DSSAT and the APSIM crop simulation models, for example, a considerable amount of information is required, on either a horizon-by-horizon or layer-by-layer basis, which has to be obtained through extensive soil sampling and analysis. The work of Batjes (1996, 1997, 2002) is of great use for this. Typical soil data model requirements are listed in Table 1.

There are many situations in which model users simply do not have access to such soil data. In developing countries, this is probably the rule rather than the exception. In such cases, there are only limited options, all of which may involve rough estimates and plain guesses. One is to use generic data that are typical of soils of a particular texture; for example, there are several such profiles in the DSSAT soils database, such as “deep silty clay” and “shallow sandy loam”. A second option is to use a soils map. With sufficient spatial resolution, it is possible to identify the soil class for a particular location, but relatively few of the variables needed (Table 1) are included in soil map information. It would be very helpful to have good examples of soil input files for a particular profile that is of a similar type to the profile that is to be used for a simulation. As one step towards providing such a tool, we converted a public-domain soils database that includes many profiles from around the world into a format that contains the information typically needed as input to biophysical and ecosystem models (Table 1) and is suitable for operating and running the DSSAT crop simulation models. In this paper, we describe the methods used to accomplish this. The resulting soil profiles can be used in various ways, but in general, the profiles are not meant to be used as ready-to-run model input files, but rather as a starting point for investigating the plausible values for key variables that may be exhibited by a particular class of soils. We illustrate some of this variability for certain soil classes within the database, and show how the data may be used. Hiederer et al. (2006) highlight some of the problems that one faces when using existing international soil databases. This paper concludes with a summary of the strengths and weaknesses of the approaches used, and we discuss what could be done in the future to improve the utility of such a soils database.

2. Methods

The WISE database was developed by the International Soil Reference and Information Centre (ISRIC) in Wageningen, The Netherlands, as part of a project on “World Inventory of Soil Emission Potentials” (WISE), which was a contribution to the activities of the Global Soils Data Task Group of IGBP-DIS (Batjes, 1995). A subset of the database consists of 665 profiles of the Natural Resources Conservations Service (NRCS, Lincoln, Nebraska, USA), 250 profiles obtained from the Food and Agriculture Organization (FAO, Rome, Italy) and 210 profiles from ISRIC to provide a basis for the Global Pedon Database (GPDB) with 1125 globally distributed profiles. All profiles are georeferenced and classified according to the FAO system, and they can thus be linked to the digital version of FAOs soils map of the world (FAO, 1995). For the soil type correlation at continental and global scale, the WISE database also links with the World Reference Base for Soil Resources (WRB, 1998, 2006).

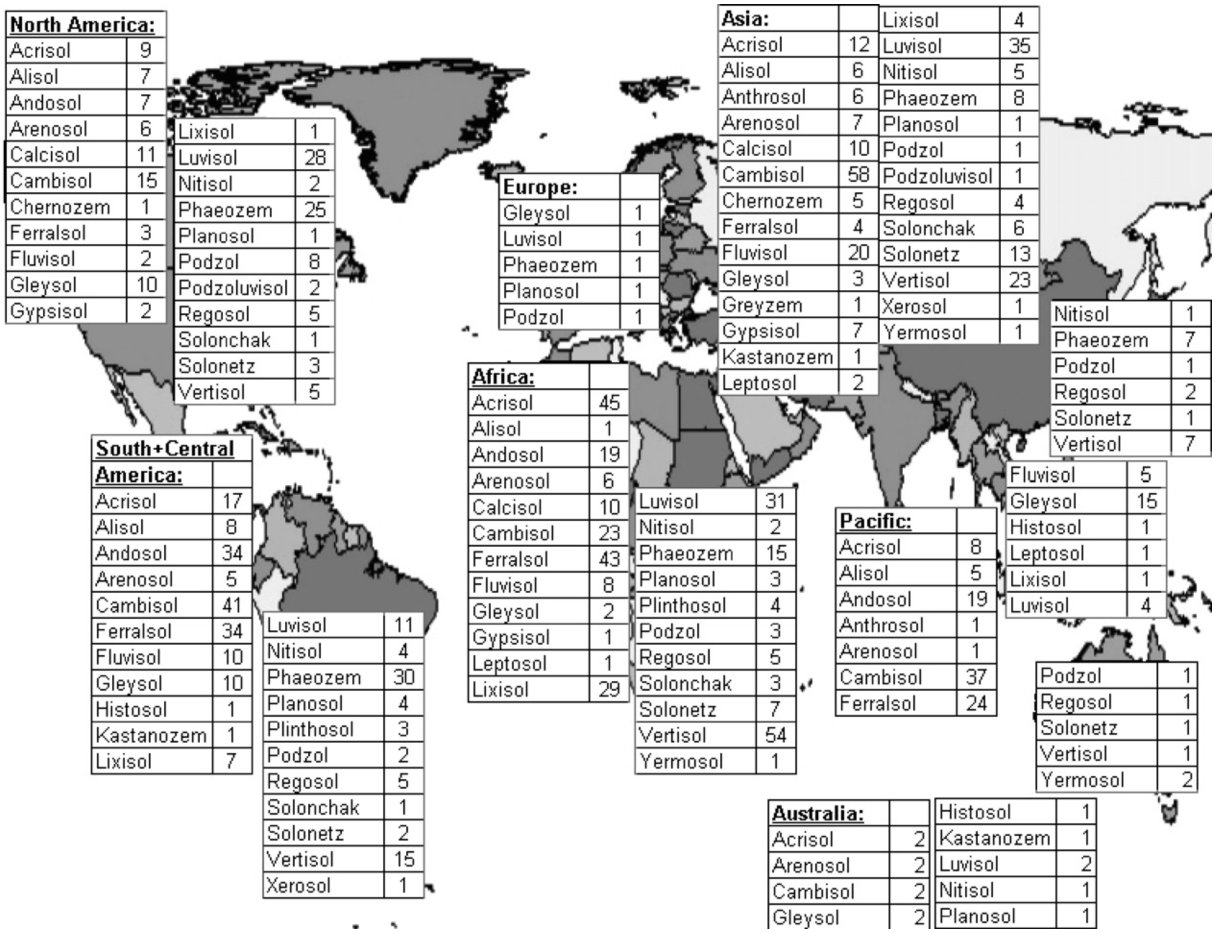
The distribution of the WISE profiles across the world is shown in Fig. 1 to demonstrate the extensiveness of this soils database and its potential for modeling and decision support applications for many different locations.

The WISE database can be downloaded from ISRIC (2005). It includes several tables, of which WISEHOR contains the data of 1125 profiles by soil horizon for a total of 6837 soil layers and WISESITE contains the precise sampling location of the soil profile, including longitude, latitude, elevation, location description and slope, and the soil classification according to FAO-UNESCO (1974), FAO (1990) and/or USDA (1999). Both of these tables are organized alphabetically by country, from Argentina to Zimbabwe. The sampling depth in WISEHOR varies widely, sometimes to a depth of 8.50 m. WISESITE provides information about the soil profile, all soil layers from a certain profile being from the same location.

The WISE database consists of independent *.dbf files that contain most of the data needed for defining a soil data input file for a biophysical model: soil layer distribution and classification, soil color, organic-carbon and total-nitrogen content, pH in water and in KCl, CEC, sand, silt, clay, coarse fraction and bulk density. However, many parameters first required some type of interpretation, for which we used the approach presented by Ritchie et al. (1990).

Table 1
Soil data input requirements for a daily time-step crop simulation model, such as the Cropping System Model (CSM) (Ritchie et al., 1990; Jones et al., 2003)

Parameter name	Meaning	Units
General data		
SLTX	Texture code of surface layer	–
SLDP	Soil depth	cm
SLDESCRIP	Soil description or local classification	–
COUNTRY	Country	–
LAT	Latitude	–
LONG	Longitude	–
SCSC FAMILY	Soil class	–
SCOM	Soil color according to the Munsell color system	–
Apply to entire profile		
SALB	Albedo	–
SLU1	Evaporation limit	cm
SLDR	Drainage rate	fraction day^{-1}
SLRO	Runoff curve number	–
SLNF	Mineralization factor	0–1 scale
SLPF	Photosynthesis factor	0–1 scale
SMHB	pH in buffer determination method	–
SMPX	Extractable phosphorus detemination code	–
SMKE	Potassium determination method	–
First tier		
SLB	Depth till base of layer	cm
SLMH	Master horizon	–
SLLL	Lower limit of plant extractable soil water	cm^3 cm^{-3}
SDUL	Drained upper limit	cm^3 cm^{-3}
SSAT	Saturated upper limit	cm^3 cm^{-3}
SRGF	Root growth factor	0–1 scale
SSKS	Saturated hydraulic conductivity	cm h^{-1}
SBDM	Bulk density (moist)	g cm^{-3}
SLOC	Soil organic carbon concentration	%
SLCL	Clay (<0.002 mm)	%
SLSI	Silt (0.002 mm–0.05)	%
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 capacity)	0–1 scale
Second tier		
SLPX	Extractable soil phosphorus concentration	mg kg^{-1}
SLPT	Total soil phosphorus as P (not P2O5) concentration	mg kg^{-1}
SLPO	Soil organic phosphorus concentration	mg kg^{-1}
CACO3	Soil CaCO3 concentration	%
SLAL	Soil aluminium concentration	cmol(+) kg^{-1}
SLFE	Soil iron concentration	cmol(+) kg^{-1}
SLMN	Soil manganese concentration	cmol(+) 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	Soil magnesium concentration	cmol(+) kg^{-1}
SLNA	Soil sodium concentration	cmol(+) kg^{-1}
SLSU	Soil sulfur concentration	cmol kg^{-1}
SLEC	Soil electric conductivity	dS m^{-1}
SLCA	Soil calcium concentration	cmol(+) kg^{-1}



North America:	
Acrisol	9
Alisol	7
Andosol	7
Arenosol	6
Calcisol	11
Cambisol	15
Chernozem	1
Ferralsol	3
Fluvisol	2
Gleysol	10
Gypsisol	2
Lixisol	1
Luvisol	28
Nitisol	2
Phaeozem	25
Planosol	1
Podzol	8
Podzoluvisol	2
Regosol	5
Solonchak	1
Solonetz	3
Vertisol	5

Europe:	
Gleysol	1
Luvisol	1
Phaeozem	1
Planosol	1
Podzol	1

Asia:	
Acrisol	12
Alisol	6
Anthrosol	6
Arenosol	7
Calcisol	10
Cambisol	58
Chernozem	5
Ferralsol	4
Fluvisol	20
Gleysol	3
Greyzem	1
Gypsisol	7
Kastanozem	1
Leptosol	2
Lixisol	4
Luvisol	35
Nitisol	5
Phaeozem	8
Planosol	1
Podzol	1
Podzoluvisol	1
Regosol	4
Solonchak	6
Solonetz	13
Vertisol	23
Xerosol	1
Yermosol	1

South+Central America:	
Acrisol	17
Alisol	8
Andosol	34
Arenosol	5
Cambisol	41
Ferralsol	34
Fluvisol	10
Gleysol	10
Histosol	1
Kastanozem	1
Lixisol	7
Luvisol	11
Nitisol	4
Phaeozem	30
Planosol	4
Plinthosol	3
Podzol	2
Regosol	5
Solonchak	1
Solonetz	2
Vertisol	15
Xerosol	1

Africa:	
Acrisol	45
Alisol	1
Andosol	19
Arenosol	6
Calcisol	10
Cambisol	23
Ferralsol	43
Fluvisol	8
Gleysol	2
Gypsisol	1
Leptosol	1
Lixisol	29
Luvisol	31
Nitisol	2
Phaeozem	15
Planosol	3
Plinthosol	4
Podzol	3
Regosol	5
Solonchak	3
Solonetz	7
Vertisol	54
Yermosol	1

Pacific:	
Acrisol	8
Alisol	5
Andosol	19
Anthrosol	1
Arenosol	1
Cambisol	37
Ferralsol	24
Fluvisol	5
Gleysol	15
Histosol	1
Leptosol	1
Lixisol	1
Luvisol	4
Nitisol	1
Phaeozem	7
Podzol	1
Regosol	2
Solonetz	1
Vertisol	7

Australia:	
Acrisol	2
Arenosol	2
Cambisol	2
Gleysol	2
Histosol	1
Kastanozem	1
Luvisol	2
Nitisol	1
Planosol	1
Podzol	1
Regosol	1
Solonetz	1
Vertisol	1
Yermosol	2

Fig. 1. World map with the soil classes (equivalent to order) summarized by continent or region, e.g., the Pacific. The soil classes are according to FAO (1990) and if missing according to FAO-UNESCO (1974). The numbers indicate the number of profiles in the WISE database.

2.1. Parameters that hold for the complete profile

The soil files that are used for the DSSAT crop simulation models include parameters that hold for the complete profile, such as country, longitude, latitude, evaporation limit, drainage rate, runoff curve number and soil classification according to FAO (1990). For WISE, the equivalent parameters are defined in the table WISESITE.

2.1.1. Soil naming convention

The set of soil profiles was called WI.SOL to indicate that they originated from the WISE database; individual profiles were assigned a unique name by taking first the abbreviation ‘WI_’, followed by the first two (uppercase) letters of the FAO (1990) soil class to which each profile belongs (Table 2), two characters for the country, and the profile number of the samples in that country. For example, profile name WI_RGAR042 consists of soil class RG (a Regosol) from Argentina (AR) and profile number 042. In WISE this is identified as soil AR042. If no soil class was given in WISE, it was set to XX (for example, WI_XXAR044).

If no data exist for a profile based on the FAO (1990) classification, we used the FAO-UNESCO (1974) classification. The classification according to FAO-UNESCO (1974) has one uppercase and one lowercase letter (Table 2), which in WI.SOL results in profile names such as WI_AoAU033 or WI_NeBR056 (see Section 2.1.6).

The soil characteristics that follow are based on the descriptions and definitions of Tsuji et al. (1994b, pp. 45 and 46).

Table 2
Key to soil classes in the FAO (1990) soil classification related to the FAO-UNESCO (1974) classification

FAO90		FAO74		FAO90		FAO74	
Unit	Soil class	Unit	Soil class	Unit	Soil class	Unit	Soil class
ACg	Gleyic Acrisol	Ag	Gleyic Acrisol	LXf	Ferric Lixisol		
ACh	Haplic Acrisol			LXg	Gleyic Lixisol		
ACp	Plinthic Acrisol	Ap	Plinthic Acrisol	LXh	Haplic Lixisol		
ACu	Humic Acrisol	Ah	Humic Acrisol	LXj	Stagnic Lixisol		
AL	Alisols			LXp	Plinthic Lixisol		
ALf	Ferric Alisol			NT	Nitisols		
ALg	Gleyic Alisol			NTh	Haplic Nitisol		
ALh	Haplic Alisol			NTr	Rhodic Nitisol		
ALj	Stagnic Alisol			NTu	Humic Nitisol		
ALp	Plinthic Alisol			PD	Podzoluvisols	D	Podzoluvisols
ALu	Humic Alisol			PDd	Dystric Podzoluvisol	Dd	Dystric Podzoluvisol
AN	Andosols	T	Andosols	PDe	Eutric Podzoluvisol	De	Eutric Podzoluvisol
ANg	Gleyic Andosol			PDg	Gleyic Podzoluvisol	Dg	Gleyic Podzoluvisol
ANh	Haplic Andosol			PDi	Gelic Podzoluvisol		
ANi	Gelic Andosol			PDj	Stagnic Podzoluvisol		
ANm	Mollic Andosol	Tm	Mollic Andosol	PH	Phaeozems	H	Phaeozems
ANu	Umbric Andosol			PHc	Calcaric Phaeozem	Hc	Calcaric Phaeozem
ANz	Vitric Andosol	Tv	Vitric Andosol	PHg	Gleyic Phaeozem	Hg	Gleyic Phaeozem
AR	Arenosols	Q	Arenosols	PHh	Haplic Phaeozem	Hh	Haplic Phaeozem
ARa	Albic Arenosol	Qa	Albic Arenosol	PHj	Stagnic Phaeozem		
ARb	Cambic Arenosol	Qc	Cambic Arenosol	PHl	Luvic Phaeozem	Hl	Luvic Phaeozem
ARc	Calcaric Arenosol			PL	Planosols	W	Planosols
ARg	Gleyic Arenosol			PLd	Dystric Planosol	Wd	Dystric Planosol
ARh	Haplic Arenosol			PLe	Eutric Planosol	We	Eutric Planosol
ARl	Luvic Arenosol	Ql	Luvic Arenosol	PLi	Gelic Planosol	Wx	Gelic Planosol
ARo	Ferralic Arenosol	Qf	Ferralic Arenosol	PLm	Mollic Planosol	Wm	Mollic Planosol
AT	Anthrosols			PLu	Umbric Planosol		
ATa	Aric Anthrosol			PT	Plinthosols		
ATc	Cumulic Anthrosol			PTa	Albic Plinthosol		
ATf	Fimic Anthrosol			PTd	Dystric Plinthosol		
ATu	Urbic Anthrosol			PTe	Eutric Plinthosol		
CH	Chernozems	C	Chernozems	PTu	Humic Plinthosol		
CHg	Gleyic Chernozem			PZ	Podzols	P	Podzols
CHh	Haplic Chernozem	Ch	Haplic Chernozem	PZb	Cambic Podzol		
CHk	Calcic Chernozem	Ck	Calcic Chernozem	PZc	Carbic Podzol		
CHl	Luvic Chernozem	Cl	Luvic Chernozem	PZf	Ferric Podzol	Pf	Ferric Podzol
CHw	Glossic Chernozem	Cg	Glossic Chernozem	PZg	Gleyic Podzol	Pg	Gleyic Podzol
CL	Calcisols			PZh	Haplic Podzol		
CLh	Haplic Calcisol			PZi	Gelic Podzol		
CLl	Luvic Calcisol			RG	Regosols	R	Regosols
CLp	Petric Calcisol			RGc	Calcaric Regosol	Rc	Calcaric Regosol
CM	Cambisols	B	Cambisols	RGd	Dystric Regosol	Rd	Dystric Regosol
CMc	Calcaric Cambisol			RGe	Eutric Regosol	Re	Eutric Regosol
CMd	Dystric Cambisol	Bd	Dystric Cambisol	RGi	Gelic Regosol	Rx	Gelic Regosol
CMe	Eutric Cambisol	Be	Eutric Cambisol	RGu	Umbric Regosol		
CMg	Gleyic Cambisol	Bg	Gleyic Cambisol	RGy	Gypsic Regosol		
CMi	Gelic Cambisol	Bx	Gelic Cambisol	SC	Solonchaks	Z	Solonchaks
CMo	Ferralic Cambisol	Bf	Ferralic Cambisol	SCg	Gleyic Solonchak	Zg	Gleyic Solonchak
CMu	Humic Cambisol	Bh	Humic Cambisol	SCh	Haplic Solonchak		
CMv	Vertic Cambisol	Bv	Vertic Cambisol	SCi	Gelic Solonchak		
CMx	Chromic Cambisol	Bc	Chromic Cambisol	SCk	Calcic Solonchak		
FL	Fluvisols	J	Fluvisols	SCm	Mollic Solonchak	Zm	Mollic Solonchak
FLc	Calcaric Fluvisol	Jc	Calcaric Fluvisol	SCn	Sodic Solonchak		
FLd	Dystric Fluvisol	Jd	Dystric Fluvisol	SCy	Gypsic Solonchak		
FLe	Eutric Fluvisol	Je	Eutric Fluvisol	SN	Solonetzes	S	Solonetzes
FLm	Mollic Fluvisol			SNg	Gleyic Solonetz	Sg	Gleyic Solonetz

Table 2 (*Continued*)

FAO90		FAO74		FAO90		FAO74	
Unit	Soil class	Unit	Soil class	Unit	Soil class	Unit	Soil class
FLs	Salic Fluvisol			SNh	Haplic Solonetz		
FLt	Thionic Fluvisol	Jt	Thionic Fluvisol	SNj	Stagnic Solonetz		
FLu	Umbric Fluvisol			SNk	Calcic Solonetz		
FR	Ferralsols	F	Ferralsols	SNm	Mollic Solonetz	Sm	Mollic Solonetz
FRg	Geric Ferralsol			SNy	Gypsic Solonetz		
FRh	Haplic Ferralsol			VR	Vertisols	V	Vertisols
FRp	Plinthic Ferralsol	Fp	Plinthic Ferralsol	VRd	Dystric Vertisol		
FRr	Rhodic Ferralsol	Fr	Rhodic Ferralsol	VRe	Eutric Vertisol		
FRu	Humic Ferralsol	Fh	Humic Ferralsol	VRk	Calcic Vertisol		
FRx	Xanthic Ferralsol	Fx	Xanthic Ferralsol	VRy	Gypsic Vertisol		
GL	Gleysols	G	Gleysols			Ao	Orthic Acrisol
GLa	Andic Gleysol			XX[a]	Unknown	Bk	Calcic Cambisol
GLd	Dystric Gleysol	Gd	Dystric Gleysol			E	Rendzinas
GLe	Eutric Gleysol	Ge	Eutric Gleysol			Fa	Acric Ferralsol
GLi	Gelic Gleysol	Gx	Gelic Gleysol			Fo	Orthic Ferralsol
GLk	Calcic Gleysol					Gc	Calcaric Gleysol
GLm	Mollic Gleysol	Gm	Mollic Gleysol			Gh	Humic Gleysol
GLt	Thionic Gleysol					Gp	Plinthic Gleysol
GLu	Umbric Gleysol					I	Lithosols
GR	Greyzems	M	Greyzems			Kk	Calcic Kastanozem
GRg	Gleyic Greyzem	Mg	Gleyic Greyzem			Lo	Orthic Luvisol
GRh	Haplic Greyzem					Lp	Plinthic Luvisol
GY	Gypsisols					Mo	Orthic Greyzem
GYh	Haplic Gypsisol					N	Nitosols
GYk	Calcic Gypsisol					Nd	Dystric Nitosol
GYl	Luvic Gypsisol					Ne	Eutric Nitosol
GYp	Petric Gypsisol					Nh	Humic Nitosol
HS	Histosols	O	Histosols			Od	Dystric Histosol
HSf	Fibric Histosol					Oe	Eutric Histosol
HSi	Gelic Histosol	Ox	Gelic Histosol			Ph	Humic Podzol
HSl	Folic Histosol					Pl	Leptic Podzol
HSs	Terric Histosol					Po	Orthic Podzol
HSt	Thionic Histosol					Pp	Placic Podzol
KS	Kastanozems	K	Kastanozems			So	Orthic Solonetz
KSh	Haplic Kastanozem	Kh	Haplic Kastanozem			Th	Humic Andosol
KSk	Calcic Kastanozem					To	Ochric Andosol
KSl	Luvic Kastanozem	Kl	Luvic Kastanozem			U	Rankers
KSy	Gypsic Kastanozem					Vc	Chromic Vertisol
LP	Leptosols					Vp	Pellic Vertisol
LPd	Dystric Leptosol					Wh	Humic Planosol
LPe	Eutric Leptosol					Ws	Solodic Planosol
LPi	Gelic Leptosol					X	Xerosols
LPk	Rendzic Leptosol					Xh	Haplic Xerosol
LPm	Mollic Leptosol					Xk	Calcic Xerosol
LPq	Lithic Leptosol					Xl	Luvic Xerosol
LPu	Umbric Leptosol					Xy	Gypsic Xerosol
LV	Luvisols	L	Luvisols			Y	Yermosols
LVa	Albic Luvisol	La	Albic Luvisol			Yh	Haplic Yermosol
LVf	Ferric Luvisol	Lf	Ferric Luvisol			Yk	Calcic Yermosol
LVg	Gleyic Luvisol	Lg	Gleyic Luvisol			Yl	Luvic Yermosol
LVh	Haplic Luvisol					Yt	Takyric Yermosol
LVj	Stagnic Luvisol					Yy	Gypsic Yermosol
LVk	Calcic Luvisol	Lk	Calcic Luvisol			Zo	Orthic Solonchak
LVv	Vertic Luvisol	Lv	Vertic Luvisol			Zt	Takyric Solonchak
LVx	Chromic Luvisol	Lc	Chromic Luvisol				

[a] The key ‘XX’ is not from the FAO soil classification, but is used here for an unknown soil class.

2.1.2. Site name (variable in DSSAT soil file: SITE)

The DSSAT soil file allows 11 characters for the site name, while in WISE the LOCAT field has up to 50 characters, with a detailed description of where the sampling was conducted. Because of the length of the WISE descriptions of the sampling location, this variable was defined as '-99' for all soils in the DSSAT soil file.

2.1.3. Country (variable in DSSAT soil file: COUNTRY)

The country where the profile was sampled is indicated in the file WISESITE.DAT as parameter COUN with a two-character abbreviation that is explained in KEYCOUN.DBF (one of the *.dbf files in the WISE database).

2.1.4. Source (variable in DSSAT soil file: SLSOURCE)

As the data originated from the WISE database, this field was defined as 'WISE'.

2.1.5. Soil surface texture (variable in DSSAT soil file: SLTX)

This parameter refers to the texture of the surface layer and a texture code, such as SCL for sandy clay loam and SIC for silty clay, was used here.

2.1.6. Soil classification (variable in DSSAT soil file: SLDESCRIP)

The soil classification is defined in the file KEYFAO.DBF and has names such as "Ferric Acrisol", "Gleyic Acrisol", "Haplic Acrisol", "Plinthic Acrisol", and "Humic Alisol". The two capital letters indicate the main soil class (Acrisol, Alisol, Andosol, Arenosol, etc) and the third lower case letter indicates the subclass (Ferric, Gleyic, Haplic, Humic, Plinthic, etc.). The file KEYFAO.dbf provides all 181 names.

For the SLDESCRIP field, both main class and subclass are indicated, with the abbreviation in brackets, such as "Haplic Acrisol (ACh)".

If the soil class of FAO (1990) is missing from WISESITE, the soil class according to FAO-UNESCO (1974) is given. In such cases, this older classification as described in KEYFAO.DBF is used. FAO-UNESCO (1974) has two letters, one uppercase and one lowercase, so these were used to name a profile (see also Table 2). It should be noted that while in KEYFAO.DBF some soils of FAO-UNESCO (1974) are included with only one character, e.g., A, B, C, E and F, there are no occurrences of profiles for which FAO90 does not exist and FAO74 with one character is used.

2.1.7. Soil family, SCS system (variable in DSSAT soil file: SCSFAMILY)

This field was set to "WISE DATABASE, SOIL #" followed by the name of the profile in the WISE database, such as "WISE DATABASE, SOIL AR042" for the profile WI_RGAR042.

2.1.8. Soil color (variable in DSSAT soil file: SCOM)

The soil color is recorded in WISE according to the Munsell color system (Munsell, 1971), which is the international standard for soil colors. The Munsell Display Calculator is a tool for studying and comparing the perceptual uniformity of color spaces. It is based on the Munsell Renotation System (Wyszecki and Stiles, 1982), which is derived from three reference parameters: hue, value and chroma that are perceptually evenly spaced. Thus, all colors having the same notation for hue, such as 5.0 YR, will appear to the eye to have the same hue regardless of their value and chroma.

The Munsell system uses codes such as 10YR2/1, 7.5YR5/4, 2.5YR3/6, etc., with names such as dusky red, dark grayish brown, light brownish gray, etc. However, DSSAT just uses Brown, Red, Black, Gray, Yellow, and Yellow-Red (see Tsuji et al., 1994a, p. 65). The Munsell color codes were thus simplified to the six DSSAT soil colors: dusky red became Red, dark grayish brown became Brown, light brownish gray became Gray, and so on.

Some soils in WISE had been classified with a color code that seemed erroneous (such as 56YR/3) or at least were different from the common color codes. This could be because of interpolation or extrapolation with respect to the default color codes, but it could also be an error. Given the difficulty of determining exactly what it should be, the code was modified by comparing it with the code of other layers in the same profile. Also, some layers had apparently been interpolated between two color hue values, resulting in a color code that is not in the Munsell color chart of 1971; an example is 9YR, supposedly an interpolation between 7.5YR and 10YR. These were reclassified to the nearest color hue, e.g., 9YR became 10YR. These interpretations may not be strictly correct, however.

Table 3
Relation between (moist) soil color of the topsoil and soil albedo

Soil color	Albedo
Black	0.09
Brown	0.13
Grey	0.13
Red	0.14
Yellow	0.17

Soils that did not have a color code were classified as 5YR3/2 in the Munsell classification, which in the DSSAT soil-color naming system is ‘brown’.

2.1.9. Soil albedo (variable in DSSAT soil file: SALB)

Soil albedo is the reflectance of solar radiation by the soil surface. It varies with surface roughness, soil wetness and soil color. Following Ritchie et al. (1990), the albedo was estimated from the moist soil color (MCOLOR) of the topsoil layer in WISEHOR (see Table 3).

2.1.10. Drainage rate (variable in DSSAT soil file: SLDR)

For the drainage classification, WISE has seven classes, e.g., P = poorly drained (see file KEYDRAIN.DBF), plus 12 subclasses, e.g., PI = poorly to somewhat poorly drained, while Ritchie et al. (1990) indicate seven permeability classes. The main classes of WISE were equated as indicated in Table 4. Soils that did not fit any of these categories were classified as moderately well drained.

2.1.11. Runoff curve number (variable in DSSAT soil file: SLRO)

For the runoff curve number, Ritchie et al. (1990) classify the soils by slope and by Hydrologic Group. Slope is given in WISESITE, and Ritchie et al. (1990) provide a description of the types of soil that fit in each Hydrologic Group:

- For Group A (“lowest runoff potential”), Ritchie et al. (1990) suggest deep sands and other rapidly permeable soils. For the DSSAT soil file based on WISE, this was done by including [i] soils that were at least 150 cm deep and were classified as ‘sand’ for all layers; and [ii] soils with a drainage rate SLDR ≥ 0.75.
- Group B (“moderately-low runoff potential”) has sandy soils that are less deep than the soils of Group A and other soils with above-average infiltration. This included [i] soils that were less than 150 cm deep and were classified as ‘sand’ for all layers; and [ii] soils with SLDR ≥ 0.60 and < 0.75.
- Group C (“moderately high runoff potential”) was used for soils that were less than 80 cm deep and which were classified as ‘clay’, ‘silty clay’, ‘silty clay loam’ or ‘clay loam’ for all layers and had SLDR < 0.30.
- Group D (“high runoff potential”) was used for [i] soils that were classified as ‘clay’ for all layers and had a SLDR < 0.30, or [ii] soils that were less than 80 cm deep and with SLDR < 0.25.
- Soils that did not fit any of these categories were classified as Group B.

The resulting curve numbers are shown in Table 5.

Table 4
Drainage classes in the WISE database equated with the permeability classes of DSSAT in agreement with Ritchie et al. (1990)

WISE	Ritchie	Permeability (fraction day^{-1})
Very poorly drained	Very slow	0.01
Poorly drained	Slow	0.05
Somewhat poorly (imperfectly) drained	Moderately slow	0.25
Moderately well drained	Moderate	0.40
Well drained	Moderately rapid	0.60
Somewhat excessively drained	Rapid	0.75
Excessively drained	Very rapid	0.85

Table 5
Runoff curve numbers (Ritchie et al., 1990)

% Slope	Hydrological conditions			
	A	B	C	D
0–2	61	73	81	84
2–5	64	76	84	87
5–10	68	80	88	91
>10	71	83	91	94

2.1.12. Mineralization factor (SLNF) and soil fertility factor (SLPF)

The mineralization factor SLNF and the soil fertility factor SLPF were always set to 1.00, because these vary with local soil conditions.

2.2. Individual soil horizon and layer parameters

Other than the parameters that hold for the complete profile or only the topsoil (such as soil color), the DSSAT soil file has many parameters that may vary by soil horizon or soil layer. The conversion to the DSSAT format was conducted according to Ritchie et al. (1990), some of which was also published by Ritchie and Crum (1989).

2.2.1. Horizon boundaries (variable in DSSAT soil file: SLB)

For all soil horizons, the WISE database defines the horizon boundaries TOPDEP and BOTDEP. However, the soil file only includes the lower limit of a soil layer or horizon (variable SLB). We thus used BOTDEP to set the variable SLB.

2.2.2. Layer designation (variable in DSSAT soil file: SLMH)

WISE has the layer designation DESIG, which in the soil file becomes the master horizon (variable in DSSAT soil file: SLMH).

2.2.3. Soil water-retention parameters (variable in DSSAT soil file: LL, DUL, and SAT)

Some of the layers of a profile in the WISE database included measured data for volumetric water content ($cm^3\,cm^{-3}$) at various pF values (logarithm of the negative of the matric potential in cm), i.e. pF0.0, pF1.0, pF1.5, pF1.7, pF2.0, pF2.3, pF2.5, pF2.7, pF3.4, pF3.7, pF4.2. For other layers there were no such data. The soil input file requires data for the volumetric water content at the permanent wilting point, also referred to as the lower limit of plant extractable water (LL), at field capacity, also referred to as the drained upper limit (DUL), and at soil saturation (SAT).

The pF used for field capacity differs between authors and countries, but there is general agreement that it depends on the soil texture: for sandy soils pF2.0 (−100 kPa) is generally used, for medium textured soils pF2.3 (−200 kPa) and for heavy textured soils pF2.5 (−330 kPa). The permanent wilting point is defined, conceptually, as the suction at which plants can no longer extract water from the soil. In reality, the suction of the soil water at which plants wilt varies greatly, and is not easy to determine. The value is set arbitrarily to −1.5 MPa (=−15,000 cm H_2O) or pF4.2. The saturation point is measured at pF0.

For soil layers for which WISE does not have water-retention values, LL, DUL and SAT were estimated by using the soil texture and soil organic carbon content as input for a pedotransfer function (PTF). Many PTFs for estimating soil hydraulic properties have been published (see overviews by Rawls et al. (1991), Timlin et al. (1996) and Wösten et al. (2001)). Timlin et al. reported 49 methods and estimated that this covers only about 30% of the total. Gijsman et al. (2002) compared eight methods for all the soil classes that make up the texture triangle. They went through the triangle in steps of 1% sand, 1% silt and 1% clay and determined the estimated values of LL, DUL, SAT. Gijsman et al. (2002) concluded that none of the methods were universally good. It was clear, however, that the method of Ritchie et al. (1987), which was employed in the DSSAT v3.5 soil-input utility programme, should not be used because it included several errors. The best method in this comparison was Saxton et al. (1986), closely followed by Rawls et al. (1982). It was initially thought that Saxton et al. (1986) should be used here, but neither Saxton et al. (1986) nor

Rawls et al. (1982) applies to soils for all textures, and both methods exclude very sandy, very silty and very clayey soils. Using either of these methods alone would thus lead to several missing values in the soil file.

As a follow-up to the comparison of methods reported in Gijsman et al. (2002), Jagtap et al. (2004) developed a new approach that does not fit a mathematical equation through the data, but rather compares the soil layer for which LL, DUL and SAT have to be estimated with all layers in a database of field-measured soil–water-retention data in relation to its physical properties. The layer that is most similar in texture and organic carbon concentration is considered to be the ‘nearest neighbor’ among all the layers in the database and its soil–water-retention values are assumed to be similar to those that need to be estimated. To avoid making estimated soil–water-retention values dependent on only one soil in the database, the six ‘nearest neighbors’ are used and weighted according to their degree of similarity (Jagtap et al., 2004). This is a non-parametric procedure, in the sense that it does not assume a fixed mathematical relationship between the physical properties and the water holding properties of soils.

The data available for the nearest-neighbor database came from a dataset with 401 field-measured profiles from 15 US states (Ratliff et al., 1983; Ritchie et al., 1987). Profiles that showed an increase in LL with depth were excluded (cf. Van Bavel et al., 1968). The authors themselves had already excluded the topsoil layer (ca. 10–15 cm) from consideration, as this layer often dries out much more than the remainder of the soil profile. This left 272 pedons from the original set of 401. In addition we had access to approximately 200 field-measured data for LL and DUL from Argentina (Julio Dardanelli, Instituto Nacional de Tecnología Agropecuaria, Argentina).

The soils in the nearest-neighbor database have values only for LL and DUL, so SAT has to be estimated using other methodologies. To estimate SAT, we assumed that it was a certain percentage of the porosity (POR) and dependent on the USDA soil texture classes (Dalgliesh and Foale, 1998). For sand, loamy sand and sandy loam, we used a value of 93%; for loam, silt loam, silt, sandy clay loam, and sandy clay we used 95%; and for clay, clay loam, silty clay and silty clay loam we used 97%.

The DUL calculation is based on field-measured values, which sometimes may be excessively high (for example, because of a crack in the soil). As DUL does not use the estimated (theoretical) porosity, which is based on texture and SOM content, there were some soils where the estimated DUL resulted in larger values than those estimated for SAT. In such cases, we set $\text{DUL} \leq 0.95 * \text{SAT}$. Only if both LL and DUL (pF2.0, 2.3 or 2.5) exist in the WISE database were their values accepted for the soil file, because otherwise unbalanced results might arise if one value is taken from WISE and another derived using the nearest-neighbor method (such as LL in WISE being greater than DUL derived using the nearest neighbor approach).

2.2.4. *Saturated hydraulic conductivity (variable in DSSAT soil file: SSKS)*

The saturated hydraulic conductivity, K_{sat}, is a highly variable parameter, and different estimation methods can give very different estimates. A commonly used method is that of Rawls et al. (1982, 1998). However, this method assigns the same K_{sat} value to all soils from the same taxonomic group. Two soils of quite different texture may then be assigned the same K_{sat} value, simply because the soils are classified in the same soil class. Accordingly, we used the method developed by Suleiman and Ritchie (2001), in which K_{sat} depends on DUL and porosity. The method by which DUL is measured is important here. For laboratory-measured DUL and field-measured DUL after 10 days of drainage, K_{sat} is defined as

$$K_{\text{sat}} = 37\left(\frac{\text{POR} - \text{DUL}}{\text{DUL}}\right)^2,$$

while for field-measured DUL after 2 days of drainage,

$$K_{\text{sat}} = 75\left(\frac{\text{POR} - \text{DUL}}{\text{DUL}}\right)^2.$$

We used the method after 2 days of drainage, as this is easier to determine when no laboratory facilities are available. This gives K_{sat} in units of cm/h, as required for the DSSAT soil file.

2.2.5. *Bulk density (variable in DSSAT soil file: BD)*

Only 3580 of the 6837 profile layers in WISE have a value for bulk density (BD), and several of these are exceptionally high, with values of 1.7–2.5, or exceptionally low, with values of 0.2–0.7. The value for BD affects the porosity calculation and thus the saturation, which is taken as a fraction of POR. As LL and DUL are calculated independently of POR, this may result in an improbably low SAT, which could even be lower than DUL, which is not permissible in most biophysical models.

The theoretical value of the BD can be calculated according to the soil's texture and SOM content, as described by Rawls (1983) and Rawls and Brakensiek (1985, 1989): first the mineral bulk density BDMIN, i.e., minerals plus pores but without SOM, is taken from Fig. 1 in Rawls and Brakensiek (1985), which is then corrected for the SOM content by weighting the contributions of minerals and SOM as follows:

$$\mathrm{BD} = \frac{100}{\mathrm{SOM}/0.224 + (100 - \mathrm{SOM})/\mathrm{BDMIN}}.$$

To determine the maximum theoretical value of the BD, this method was applied to all conceivable texture combinations by stepping through the texture triangle in increments of 1%, and with a SOM concentration of 0.66%, which Rawls et al. (1982) reported as the average value for US soils. This resulted in more than 5100 texture combinations, for which the maximum theoretical BD was 1.65 g cm^{-3}.

To accommodate some increase in BD due to animal trampling or machinery use, it was decided to use the theoretical BD if the BD as given in WISE was greater than 1.80 g cm^{-3}. For instance, profile NE013 in the WISE database has a BD of 2.52 g cm^{-3} for one of its deeper layers, but with the theoretical value this decreases to 1.57 g cm^{-3}. This method was also used if the data for BD were missing in the WISE database.

For BD values that appear to be too low, the situation is more complicated. There is no clear-cut critical minimum BD value that one can take as the lower limit above which WISE data are acceptable, because BD can be changed by land management. These very low values of BD are, therefore, left to the judgment of the user of these data. In the soil file based on WISE, all BD values less than 0.5 g cm^{-3} were replaced by the theoretical bulk density.

2.2.6. Organic carbon content (variable in DSSAT soil file: OC)

There are some very high (>50%) organic-C values in WISE, which suggest that the soil sample was taken at a site with an almost peat-like soil. This may be understandable in the top layer, but finding 46.8% organic C at a depth of 1.5 m is unusual, as in WISE profile GY002. It is likely that something is wrong with the data, as this site has only 0.91% total N, resulting in a C/N ratio of 51, which is very high. These values cannot simply be changed, but considering that the BD is affected by the SOM content and that it impinges on the porosity, it means that all BD and SAT values, and perhaps also TOTN, must be regarded with suspicion, particularly if the organic C value is high (SAT being estimated in the range 0.93*POR to 0.97*POR). Many of the soils that had very high values for organic C also had missing texture data, which is understandable, as for Histosols often no texture class is determined; these soils were not included in the DSSAT soil file.

2.2.7. Total nitrogen content (variable in DSSAT soil file: SLNI)

This parameter is indicated in the WISE database as TOTN; in the soil file it is defined as SLNI. With this parameter, there is always the uncertainty as to whether total N (organic plus inorganic) has been measured, or only inorganic N. However, this cannot generally be checked and we, therefore, relied on the data in the WISE database.

2.2.8. Soil texture parameters (variable in DSSAT soil file: SLCL, SLSI, and SLCF)

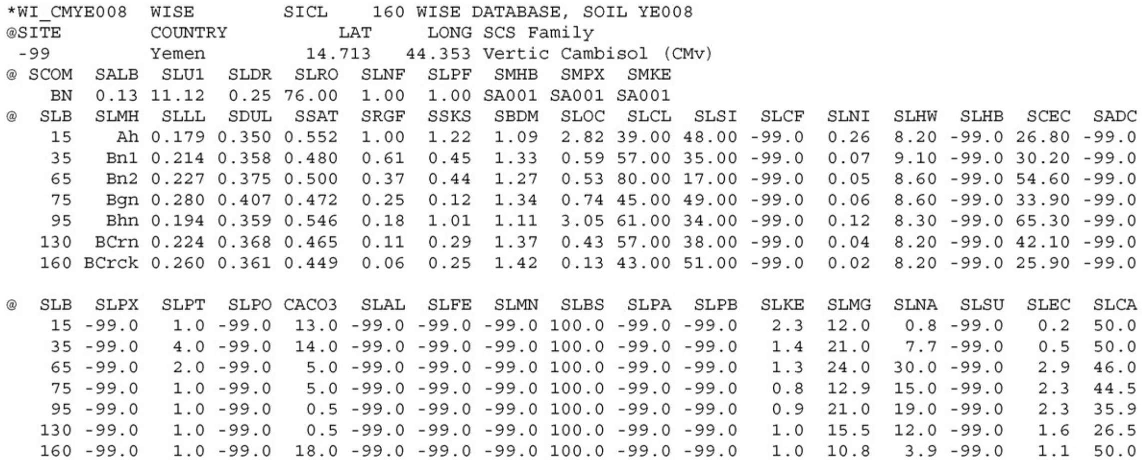
WISE provides the SAND, SILT, CLAY and GRAVEL content, which in the DSSAT soil file correspond to SLSI and SLCL for silt and clay; the sand content is not used, as it follows from the values for clay and silt. SLCF is the coarse fraction or gravel content.

2.2.9. Soil pH (variable in DSSAT soil file: SLHW and SLHB)

WISE includes the pH in water (PHH2O), pH in KCl (PHKCL) and pH in $\mathrm{CaCl_2}$ (PHCACL2). In the soil file, the pH in water is defined as SLHW and pH in buffer is defined as SLHB, for which we used pH-KCl, and not the pH-$\mathrm{CaCl_2}$.

2.2.10. Cation exchange capacity (variable in DSSAT soil file: SCEC)

The cation exchange capacity of a layer is given in WISE as CECSOIL and is defined in the soil file as SCEC.



```
*WI_CMYE008  WISE        SICL    160 WISE DATABASE, SOIL YE008
@SITE        COUNTRY          LAT     LONG SCS Family
 -99         Yemen          14.713   44.353 Vertic Cambisol (CMv)
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13 11.12  0.25 76.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    15    Ah 0.179 0.350 0.552  1.00  1.22  1.09  2.82 39.00 48.00 -99.0  0.26  8.20 -99.0 26.80 -99.0
    35   Bn1 0.214 0.358 0.480  0.61  0.45  1.33  0.59 57.00 35.00 -99.0  0.07  9.10 -99.0 30.20 -99.0
    65   Bn2 0.227 0.375 0.500  0.37  0.44  1.27  0.53 80.00 17.00 -99.0  0.05  8.60 -99.0 54.60 -99.0
    75   Bgn 0.280 0.407 0.472  0.25  0.12  1.34  0.74 45.00 49.00 -99.0  0.06  8.60 -99.0 33.90 -99.0
    95   Bhn 0.194 0.359 0.546  0.18  1.01  1.11  3.05 61.00 34.00 -99.0  0.12  8.30 -99.0 65.30 -99.0
   130  BCrn 0.224 0.368 0.465  0.11  0.29  1.37  0.43 57.00 38.00 -99.0  0.04  8.20 -99.0 42.10 -99.0
   160 BCrck 0.260 0.361 0.449  0.06  0.25  1.42  0.13 43.00 51.00 -99.0  0.02  8.20 -99.0 25.90 -99.0

@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    15 -99.0   1.0 -99.0  13.0 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   2.3  12.0   0.8 -99.0   0.2  50.0
    35 -99.0   4.0 -99.0  14.0 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   1.4  21.0   7.7 -99.0   0.5  50.0
    65 -99.0   2.0 -99.0   5.0 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   1.3  24.0  30.0 -99.0   2.9  46.0
    75 -99.0   1.0 -99.0   5.0 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   0.8  12.9  15.0 -99.0   2.3  44.5
    95 -99.0   1.0 -99.0   0.5 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   0.9  21.0  19.0 -99.0   2.3  35.9
   130 -99.0   1.0 -99.0   0.5 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   1.0  15.5  12.0 -99.0   1.6  26.5
   160 -99.0   1.0 -99.0  18.0 -99.0 -99.0 -99.0 100.0 -99.0 -99.0   1.0  10.8   3.9 -99.0   1.1  50.0
```

Fig. 2. An example of a silty clay loam soil profile (Vertic Cambisol) from a site located approximately 1 km north of Risabah in Yemen and parameterized for use by the Cropping System Model.

2.2.11. The second tier of the DSSAT soil file

In the DSSAT soil file, there is an option for a second tier that includes many soil chemical parameters (see Tsuji et al., 1994b, pp. 44–46). These parameters relate to the soil phosphorus balance (e.g., Fairhurst et al., 1999), with total, extractable and organic P (mg kg^{-1}) and various soil cations (Ca, Al, Fe, Mg, Mn, K, Mg, Na; cmol(+) kg^{-1}). The cations are combined in the base saturation (%); additional parameters include $CaCO_3$ (%), sulfur concentration (mg kg^{-1}), and electrical conductivity (dS m^{-1}). Where these data exist in the WISE database, they were added to the appropriate field in the second tier of the DSSAT soil file.

3. Results

The conversion of the WISE database has resulted in various soil profile data files. The soils in the WISE database that do not have missing data or obvious errors in the data are located in the soil file WI.SOL. This file includes 836 profiles, out of a total of 1125 profiles in the WISE database. They can be used directly to run any of the DSSAT crop simulation models. An example of a complete soil profile from Yemen is shown in Fig. 2.

If some profiles have missing data or errors, they may still be of use to modelers who need data for a specific soil class or from a specific country; or it may be that only the data of one layer are missing. In such cases, missing parameters may be estimated based on the information in other profiles depending on what the user wants to do. Rather than eliminating profiles with missing data, these profiles, together with the complete profiles in file WI.SOL, are located in the soil file WI_EXTENDED.SOL.There are 289 profiles that include incomplete data. In general, if there is no value for a certain parameter in the WISE database, this is translated into the DSSAT soil files as '-99' (missing data). For some of these incomplete profiles, it does not necessarily mean that they cannot be used for running the DSSAT models. It depends on the information that is missing, as some parameters are not essential for certain types of simulation runs; for instance, the coarse fraction (SLCF), pH in buffer (SLHB), and CEC (SCEC) are in most cases not required input data. Again, if the texture data are incomplete, the organic carbon, bulk density or hydraulic conductivity data may still be of use.

If a value is given for a particular parameter, but it is highly likely to be incorrect (for example, if TOPDEP < 0, or percent sand, silt and clay do not add up to 100%), then a comment line is included in the DSSAT soil file, such as, "ERROR: TEXTURE DOES NOT ADD UP TO 100". While such profiles cannot be used directly to run a crop simulation model, they may have other uses.

3.1. Example application

As an example of the use of the soils database, we ran some simple simulations with the CSM-CERES-Maize model (Ritchie et al., 1998; Jones et al., 2003). For these runs we used the 47 Haplic Acrisol profiles (ACh) in the

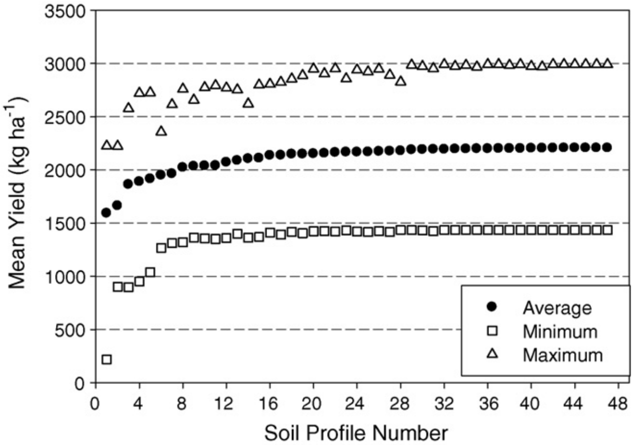


Fig. 3. Simulated maize yield for the 47 Haplic Acrisols in the WISE database, sorted by mean yield, with 30 weather-year replications for Mutha, Kenya.

database. Acrisols are acid soils of the tropics and subtropics, with a clay-enriched lower horizon, a low CEC, and low saturation of bases. The 47 profiles came from Burundi, Brazil, China, Colombia, Costa Rica, Indonesia, Kenya, Lesotho, Mali, Niger, Panama, Philippines, Thailand, Uganda, USA, Venezuela, Zambia and Zimbabwe. We generated 30 years of daily weather data using MarkSim (Jones and Thornton, 2000) for the location of the one Kenyan ACh profile (1.87°S, 38.37°E). Rainfall at this location, near the village of Mutha, Eastern Province, is bimodal, with a short wet season in March–April and a longer wet season from October to December. Average rainfall is 695 mm, elevation is 701 m above sea level, and average temperature is 23.9 °C. The simulation experiment consisted of 47 treatments – the 47 ACh profiles – and to match the climate at the site, planting took place on day-of-year 280 (7 October), at 3.7 plants m^{-2}, using the variety Katumani Composite B, a fairly short-season Kenyan variety developed for drier areas. Each simulation started on day-of-year 1 (January 1), and 50 kg N were added to the soil at planting. Fig. 3 shows the mean, maximum and minimum for each yield distribution. About half of the ACh profiles resulted in a similar yield distribution for these conditions.

We then ran exactly the same experiment, but used weather data from a wetter site near the town of Embu (0.99°S, 37.00°E), again with a bimodal rainfall distribution and a total of 971 mm of rain per year, an average temperature of 19.4 °C and an elevation of 1567 m above sea level. The resulting yield distributions are shown in Fig. 4, and the two simulation experiments are compared in Fig. 5, showing the yield distribution means plotted against the standard

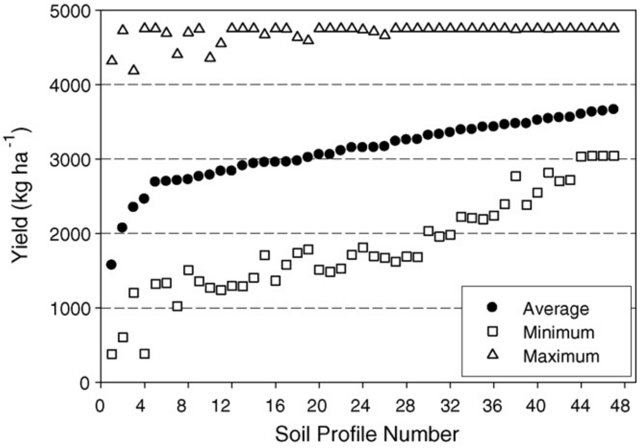


Fig. 4. Simulated maize yield for the 47 Haplic Acrisols in the WISE database, sorted by mean yield, with 30 weather-year replications for Embu, Kenya.

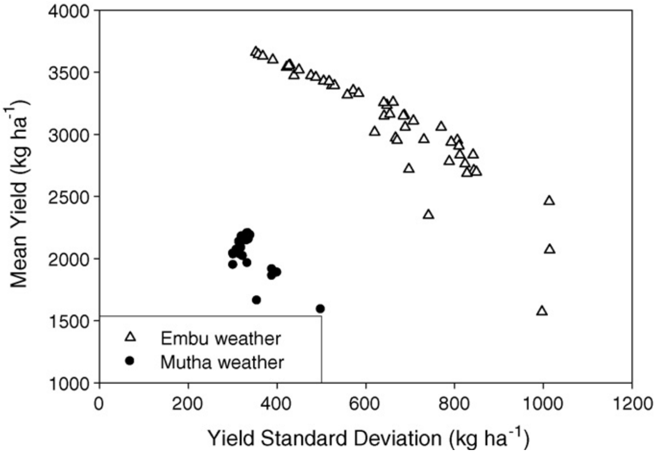


Fig. 5. Simulated maize yield for the 47 Haplic Acrisols in the WISE database: means plotted against standard deviation.

deviation. The interaction of weather and soil class is marked; even for the drier and hotter site, choice of soil profile from within the Haplic Acrisols is a critical issue, as simulated maize yields may vary by more than 40%. For the cooler, wetter site, mean yields vary by a factor of more than two. Given the variability in simulated maize yields that may arise from utilizing soils of the same class, some care may be needed in selecting a soil profile that matches as well as possible the soil under investigation, even within the same class.

4. Discussion and conclusions

We envisage that the soil file based on the WISE database will be of use to biophysical modelers, particularly for applications concerned with areas in Africa, Asia and South America where soils data are not generally available. The value of the file resides in the fact that there are example profiles for most of the FAO soil classes. It is, therefore, possible to find common or typical values of particular variables for different soil classes. The data contained in the file were either measured in the field or the laboratory, or are the result of careful interpretation, and can probably be viewed as “best-bet” estimates of the relevant soil parameters. As noted above, the file can be used not only as a ready-to-run model input file, but also (and more realistically) as a starting point for determining which values may be valid for particular soil classes.

Users of the DSSAT models can use the file WI.SOL without modification. For users of APSIM, EPIC or other similar models, the data first have to be converted into the appropriate model-specific format, but many of the parameters are the same or similar, such as albedo, drainage rate, runoff, water-retention data (LL, DUL, SAT), saturated hydraulic conductivity, bulk density, organic carbon concentration, pH, and CEC.

A database such as WISE, to which many scientists have contributed, is unlikely to be free of errors. In addition, the parameters in WI.SOL were estimated using several WISE parameters, each of which may have a high level of uncertainty, or by using a purely theoretical approach. There is bound to be a certain accumulation of uncertainties and errors, and this inevitably leads to the conclusion that WI.SOL is only providing an educated guess as to which values to expect for a certain soil class. In all cases, the user needs to check these data carefully, and where possible, replace them with measured data.

In terms of future work, one useful activity would be to expand the number of soil profiles, so that where there are currently few profiles from agriculturally suitable soils (Table 2), the number can be increased, allowing rigorous comparison of distributions of key soil parameters within and between different soil classes. For example, there are more than 4000 soil profiles in the complete WISE database Version 1.1.

Another useful activity would be a comprehensive sensitivity analysis of crop model performance in relation to the different soil classes within the soils database. The outputs of such an analysis could be of considerable value in prioritizing future model-related soil profile data collection. Such outputs could also be used for defining meaningful parameter envelopes for specific soil classes, to assist in assembling appropriate input data in situations where little is known about the soils being used in simulation experiments.

5. Database availability

There are two DSSAT soil files based on WISE, i.e. WI.SOL that has been corrected for potential errors; and the complete soil file WI_EXTENDED.SOL that includes samples with missing data as well.Both data files are available and can be downloaded as ZIP files from the ICASA web page http://www.icasa.net/ WI.SOL has a size of 258 kB and WI_Extended.SOL of 330 kB, If problems are experienced in downloading these files, or if any errors are found, users are asked to please contact one of the authors.

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