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Soil Data Derived from WISE for use in Global and Regional AEZ Studies
(Version 1.0)

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

ISRIC **INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE**

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FOR USE IN
GLOBAL AND REGIONAL AEZ STUDIES
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N.H. Batjes[1], G. Fischer[2], F.O. Nachtergaele[3], V.S. Stolbovoy[2], and H.T. van Velthuizen[2]

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CONTENTS

ABSTRACT

During discussions at the International Institute for Applied Systems Analysis (IIASA), the need was identified for refinement of the agro-edaphic element in the revision of FAO's *Agro-Ecological Zones* (AEZ) methodology carried out by IIASA and FAO and in the IIASA’s *Modeling Land Use and Land Cover Change in Europe and Northern Eurasia* (LUC) project. To this avail, the 4350 soil profile descriptions held in ISRIC's World Inventory of Soil Emission Potential (WISE) database were stratified by soil unit, topsoil textural class and depth zone (0-30 cm and 30-100 cm). Upon a screening on analytical methods used and application of an outlier rejection scheme, derived statistics were generated for 20 soil chemical and physical attributes identified as being important for AEZ studies and analyses of global environmental change. Selected results for Acrisols, classified according to the 1974 version of FAO-Unesco Soil Map of the World Legend, are presented as examples in the Appendices. Special attention was paid to the assessment of Total Available Water Capacity (TAWC), an important parameter in calculation of the length of growing period. Data have been compiled for all the considered combinations of soil unit, topsoil textural class, attribute and depth zone, both for the 1974 and 1990 Legend. Simple taxotransfer rules are introduced to fill some of the gaps that remained in the derived data, notably where sufficient measured data were lacking for particular attributes.

As a sequel to the current study, the taxotransfer rules should be fine-tuned and the results should be supplemented with data extracted from the FAO’s CD-ROM of the *Digital Soil Map of the World and Derived Soil Properties*. This combined database will be revised by a group of soil experts. The recommended level-of-detail for presenting the various results should also be determined at that stage. This follow-up activity is necessary to arrive at a mutually agreed upon set of derived soil properties for land evaluation and environmental studies at the continental and global level, for subsequent release as a unified product to the global modeling community.

1 INTRODUCTION

1.1 Rationale

The availability of geographic databases of bio-physical and of relevant socio-economic factors largely determines extrapolation and modeling capabilities at the global level (Prentice *et al.*, 1992; Hagen *et al.*, 1993; Zuidema *et al.*, 1995; Neave *et al.*, 1995; Wessman, 1992). Nonetheless, despite the importance of proper selection and quantification of soil factors for use in global models there are only few published studies on this topic. Many of the soil data sets currently available were based on limited profile data (Zobler, 1986; Webb *et al.*, 1992). The continuing need for updated and uniformly described soil and terrain data for studies at the continental level and global level is well recognized (Oldeman & Van Engelen, 1993; Arnold, 1995; Madsen & Jones, 1995; FAO, 1995; Scholes *et al*., 1995), notably in relation to data reliability and risk assessment in soil interpretations (Nettleton *et al.*, 1996).

Assessment of agro-edaphic suitability in the Agro-Ecological Zones (AEZ) project (FAO, 1978-1981), of necessity, was based on interpretation of the diagnostic and differentiating criteria of the various units considered in the legend of the Soil Map of the World (FAO-Unesco, 1971-1981). With the completion of the Digital Soil Map of the World (SMW) by FAO (1995), and the World Inventory of Soil Emission Potentials (WISE) database at ISRIC (Batjes *et al*., 1995), it became possible to update statistics for a number of soil characteristics; this was done by using a combination of calculations (when measured data are available) and expert-rules (when measured data are lacking). Nonetheless, the need remained for a uniform and agreed upon data set of derived soil properties (FAO, 1995; Batjes, 1997).

1.2 Objectives

Based on a request by and subsequent discussions at IIASA (November 1996), a number of activities have been identified as being necessary for further refinement of the AEZ and Land Use and Land Cover Change (LUC) studies. They are summarized below:

1) Assessment of Available Water Capacity (AWC) by soil unit, a measure for soil moisture retention, which is an important parameter in determining the length of growing period in AEZ (FAO, 1978-1981, 1988).
2) Assessment of soil properties considered in relation to the requirements of specific crops (at defined management levels).

This paper presents statistics for 20 soil attributes identified as being important for land evaluation in the context of AEZ studies. An important criterion in developing the data set is that the results must allow linkage with the digital Soil Map of the World (FAO, 1995) or with more recent regional maps that are based on the Revised Legend (FAO-Unesco, 1990/1994).

Topsoil textural class is an important criterion in the SMW for further characterization of the dominant soil of a (soil association) mapping unit (FAO, 1995). Topsoil texture classes of associated soils and inclusions, and for dominant soils when these are not indicated in the mapping unit, are derived from composition rules. The soil association composition rules used for the SMW (FAO-Unesco, 1971-81) have been established in the context of the Agro-ecological Zones Project (FAO, 1978-81). Soil units within a soil association are indicated as dominant soil, associated soils (more than 20% of the area), or as inclusions (more than 5% of total area of the mapping unit). Soil phases, topsoil texture and slope indicators as they occur on the map reflect properties of dominant soil units only. For associated and included soils, rules were developed that specify topsoil texture and slope based on the most common occurrence of each soil unit. Further, in case only the dominant soil group is indicated in a mapping unit, it is assumed that this represents the most common soil unit of this group. A full explanation of the composition rules can be found in FAO (1978-81, 1995).

A clustering of profiles by soil unit, topsoil textural class and depth zone (topsoil versus subsoil) is used in the current analyses. The topsoil textural class is considered as a differentiating criterion for the properties of the entire profile (*cf* FAO, 1995). An important issue, in this respect, concerns the level-of-detail that can be considered justifiable in presenting results, keeping in mind the size and representativity of the current WISE profile data set, the attributes considered, and the generalizations (composition rules) applied.

1.3 Structure of report

The methodology is discussed in Chapter 2, which includes a description of the data sources (2.1); a listing of the soil attributes (2.2); procedures for screening the various data sets (2.3); statistical procedures applied (2.4); and, procedures for calculating Total Available Water Capacity (2.5).

Results of the various analyses — in tabular form by soil unit, topsoil textural class, and depth zone (i.e. topsoil and subsoil) — for the 20 selected attributes are discussed in Chapter 3. In view of the size of the files, which include also the derived statistical parameters, and due to the need for further evaluation by experts, only summary tables are presented in this report (App. 2 and 3). The complete data files for all soils units, classified according to the FAO 1974 Legend and the Revised 1990 Legend, are available in electronic form and will be released to the global change research community after review by a panel of soil experts. The structure of the various data files is explained in Appendix 4. Procedures for filling gaps that remain in the derived data sets are proposed in section 3.4, while results of the gap-filling for the various attributes are presented in section 3.5. Summary files, in ASCII format, are also presented on the diskette. These files, and some overall summary tables, should facilitate the evaluation and final gap-filling by a panel of soil experts. Appendix 5 provides an inventory of the occurrence of FAO 1974 soil units and topsoil textural classes in the SMW. Finally, possible uses of the derived data in AEZ and LUC, as well as other global environmental studies, are discussed and future developments are outlined in Chapter 4.

2 METHODOLOGY

2.1 Source of soil data

The WISE soil profile database was developed to be linked to a 0.5 x 0.5 degree version of the digital Soil Map of the World (Batjes *et al.*, 1995). The soil profile data in WISE were compiled from five sources: (a) ISRIC's Soil Information System; (b) FAO's Soil Database; (c) the digital data set of the National Soil Conservation Service of the United States of America (NRCS); (d) profile descriptions chosen by national soil survey organizations to be representative for the units of the Soil Map of the World present in their countries; and, (e) data gathered from survey monographs held in ISRIC's library. In the systematic compilation of the soil profile data, special attention was given to the compatibility of laboratory methods by which the various analytical results were obtained (Batjes & Bridges, 1994).

The 1974 and 1990 FAO-Unesco classification of the 4,353 profile descriptions currently held in WISE is shown in Appendix 1, and their geographic distribution in Figure 1. The profiles originate from: Africa (1799); South West and North Asia (522); South East Asia (553); Australia and the Pacific Islands (122); Europe (492); North America (266); and South America and the Caribbean (599). As Figure 1 shows, there still are only few profiles for some regions of the world, notably the former Soviet Union, Mongolia, and Northern Territories of Canada.

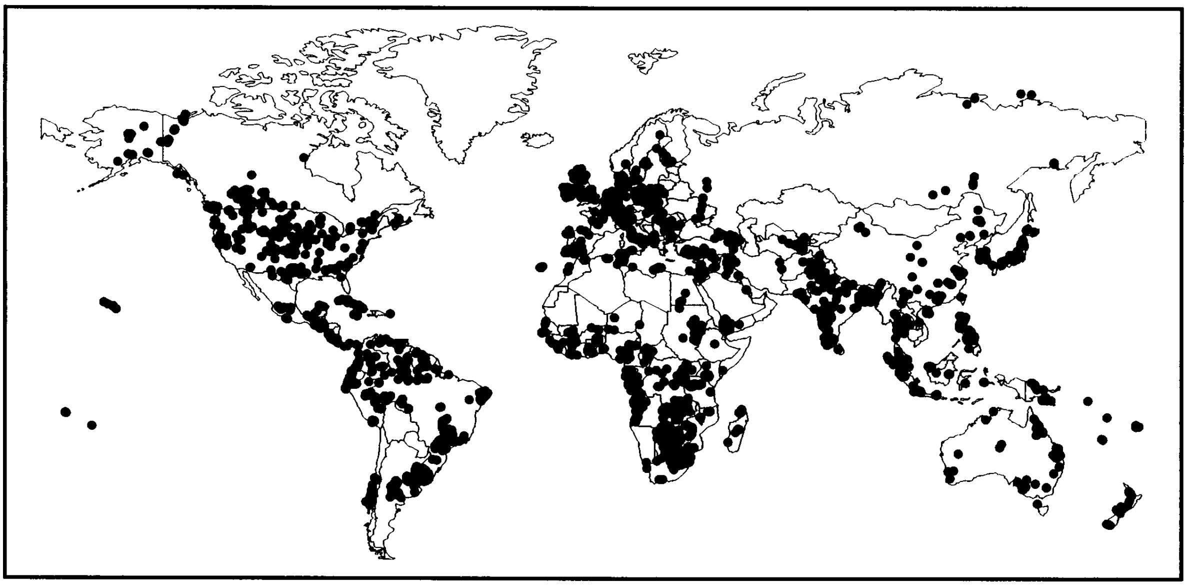

Fig. 1 Geographic distribution of soil profiles held in WISE

Complete data sets are not always available for each sample or horizon for the soil attributes selected. Consequently, the number of samples for each of these attributes varies between soil units and with the depth range considered. In addition, the profiles have been analyzed according to various analytical methods, necessitating a screening by analytical procedures (e.g. Driessen, 1986; Pleijsier, 1989; Vogel, 1994). The criteria applied for the selection of soil profiles for inclusion in WISE are presented in Batjes (1995b).

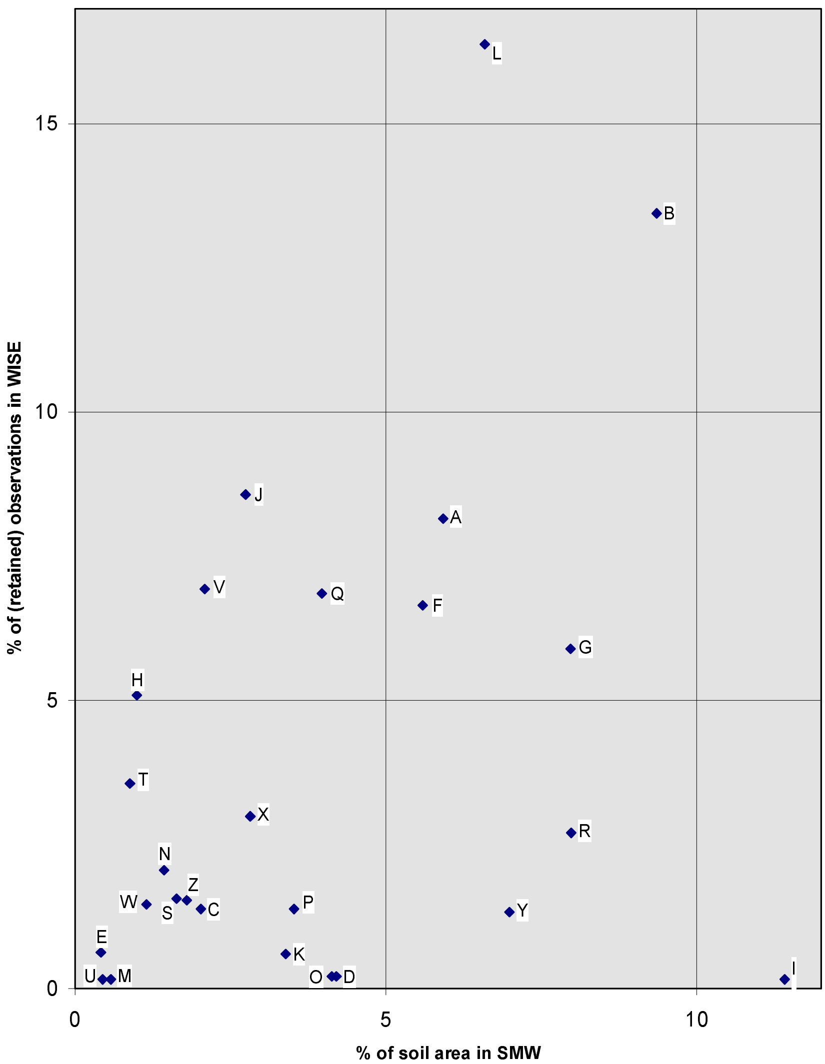

Fig. 2 Representation of Major Soil Groups in WISE relative to their extents in the SMW

Figure 2 shows a comparison between the relative extent of individual major soil groups in the Digital Soil Map of the World, and the occurrence of WISE soil profiles in the same individual major soil groups[1].

For instance, Regosols (R) account for about eight percent of the total extent of soils in the SMW, but for less than three percent of soil profiles in WISE. On the other hand, Vertisols (V) represent some two percent of the soils in the SMW but almost seven percent of the soil profiles in WISE.

Appendix 5 presents the percentage occurrence of FAO'74 soil units in the SMW. It shows the distribution of dominant soils by three topsoil textural classes and also indicates relative extents of dominant and non-dominant (NonDS) soil units (i.e., co-dominant soils, associated soils, and

[1] Percentages were calculated after screening for internationally accepted and commonly applied particle size class limits as well as for comparability of analytical methods.

inclusions). Representation of soil unit/topsoil textural class combinations by soil profiles in WISE, retained after screening for internationally accepted and commonly applied particle size limits as well as for comparability of analytical methods, is visualized in three shades, namely: more than five profiles – no shading; one to five profiles – marked light gray; and zero soil profiles – marked dark gray. Note that several of the combinations marked in dark gray do not occur in the SMW.

2.2 Soil attributes

A range of qualitative and quantitative attributes was identified as being required for the ongoing AEZ and LUC studies. Table 1 shows those attributes for which quantitative data are desirable; these are to be derived from the soil profile database. In addition, information on several other attributes will be inferred directly from the Soil Map of the World. These are: soil drainage, soil depth, gravel content, electrical conductivity, exchangeable sodium percentage, calcium carbonate content and gypsum content. These attributes are only partially available from the WISE database. Linkage of results obtained by statistical analysis of soil profiles in WISE with the Digital SMW database will be dealt with in a follow-up study. Procedures for deriving a number of these attributes are contained on FAO's CD-ROM (FAO, 1995).

Table 1 List of soil attributes derived from WISE profile data

Profile identifier
FAO-Unesco soil unit (in 1974 and 1990 Legend, respectively)
Topsoil textural class
Measured data to be analyzed *(for topsoil and subsoil, respectively)*
Organic carbon
$pH(H_2O)$
Sum of exchangeable Ca, Mg, Na and K (TEB) ◊
Ratio of exchangeable Ca/Mg ◊
Ratio of exchangeable (Ca+Mg)/K ◊
Effective CEC †
CEC_{soil}
CEC_{clay} ◊
Base saturation (as % of CEC_{soil}) ◊
$CaCO_3$ content
Gypsum content
Exch. sodium percentage (ESP) ◊
Bulk density
Total porosity (as derived from bulk density) ◊
%sand
%silt
%clay
Available Water Capacity (AWC_1; from pF 2.0 to pF 4.2)
Available Water Capacity (AWC_2; from pF 2.5 to pF 4.2)

◊ Calculated from other measured soil properties.
† ECEC is defined as sum of exchangeable[Ca+Mg+K+Na]+ exchangeable[H+Al], after Van Reeuwijk (1993).

2.3 Data screening

Data screening prior to the analyses by soil unit (section 2.4) involved six stages: (1) screening by profile on methods used for the particle size analysis; (2) allocation of individual samples of a profile to the topsoil resp. subsoil; (3) allocation of each profile to Coarse, Medium or Fine topsoil textural class; (4) screening on missing values; (5) screening on analytical methods, by attribute; and finally (6) statistical outlier-rejection analysis.

2.3.1 Screening on particle size analyses

The internationally accepted and commonly applied particle size class limits of USDA are used, viz.: clay < 2 µm < silt < 50 µm < sand < 2000 µm (Soil Survey Staff, 1993). This means that all samples for which different particle size class limits and analytical methods were used, had to be excluded from the current study.

2.3.2 Allocation to a depth zone

All horizon or sample data were assigned to either the *topsoil* (0 to 30 cm) or *subsoil* (30 to 100 cm) based on their depth of occurrence in a profile. This stratification was done by taking into account the upper (*topdep*) and lower depth (*botdep*) of each layer, using uniform criteria:

Topsoil: (*botdep* - *topdep*)*1/2 ≤ (30 - *topdep*) AND *botdep* ≤ 40 cm
Subsoil: (*botdep* - *topdep*)*1/2 ≤ (100 - *topdep*) AND *botdep* ≤ 120 cm

2.3.3 Stratification by topsoil textural class

Topsoil textural class was determined according to the definitions of the SMW Legend (FAO-Unesco, 1974) and Revised Legend (FAO-Unesco, 1990).

In the current study, the symbol "#" is used when analytical data are analyzed by soil unit, attribute and depth zone only, i.e. without further stratification by textural class. In the case of Arenosols, for example, the category "#" will correspond with coarse topsoil textures only.

2.3.4 Screening on missing values (by attribute)

In order to provide linkage to the digital SMW, all profile data were aggregated on a soil unit plus topsoil textural class basis (e.g. Ao2 stands for an orthic Acrisol with a medium textured topsoil), and this by attribute. In accordance with FAO (1995), the code for the topsoil textural class was used as a *flag* (i.e. a clustering criterion) for the corresponding subsoil.

Prior to the statistical analyses a weighted value was calculated for each profile, by depth zone, for each of the attributes considered in Table 1. All horizons in a profile for which there were no measured data for the attribute and depth zone under consideration were flagged and removed from the ‘working-file’.

2.3.5 Screening on analytical methods (by attribute)

During a subsequent screening, the analytical methods were checked by attribute for their comparability:

- Soil pH(H_2O) was measured in a soil:water solution varying from 1:1 to 1:5 (see Batjes, 1995a).
- Organic carbon (OC) content was determined largely according to Walkley/Black (see Nelson & Sommers, 1982).
- Cation exchange capacity (CEC_{soil}) for the fine earth fraction was measured in a 1 *M* NH_4OAc solution buffered at pH 7.
- Exchangeable sodium percentage (ESP) is given as percent of CEC_{soil}.
- The CEC of the clay size minerals (CEC_{clay}) was calculated from CEC_{soil} by assuming a mean contribution of 2.4 cmol(+) kg^{-1} OC, the common range being from 1.8 to 3.0 cmol(+) kg^{-1} OC (Scheffer & Schachtschabel, 1984, p. 93).
- Effective CEC is determined as the sum of exchangeable Ca, Mg, K and Na, plus 1 *M* KCL extractable acidity (Van Reeuwijk, 1993).
- Apparent bulk density was determined according to the core-method.
- Total porosity was calculated from bulk density, assuming an average particle density of 2.65 g cm^{-3}.
- The soil moisture range considered in determining Available Water Capacity is from pF 2.0 to pF 4.2 (≈ 10 to 1500 kPa; AWC_1) and pF 2.5 to pF 4.2 (≈ 33 to 1500 kPa; AWC_2) respectively. The suction limits for AWC_2, conform with USDA standards (Soil Survey Staff, 1993). AWC_1 is used in AEZ (Doorenbos & Kassam, 1978; FAO, 1988).

Screening of the profile data for comparability of analytical methods (on an attribute basis) lead to the primary sample population of weighted topsoil and subsoil data for the subsequent outlier-rejection analyses.

2.3.6 Outlier rejection analysis

Although all profile descriptions, and corresponding soil classifications, have been subjected to an intensive screening prior to their entry into the WISE database (see Batjes, 1995b), a number of outliers have been found to remain. In order to reduce the influence of such outliers, use of the median is generally preferred to the average (Snedecor & Cochran, 1983). Values of each attribute were tested for departure from the median at the 95% level-of-confidence according to Pleijsier (1989). The remaining sample population was used for the statistical analyses.

2.4 Data analyses

The statistical parameters generated in this study include sample size, means, medians and 95%-confidence intervals (see App. 4). In addition, an *indicator* for the level of possible ‘confidence’ (*CONF*) in the derived medians has been introduced (Table 2). The underlying assumption is that the ‘confidence’ in the results shown should increase with size of the sample populations. Since the current analyses are based on a still relatively small and not necessarily representative selection of soil profile descriptions, consideration of *CONF* in conjunction with expert knowledge will be essential when developing taxotransfer rules[2] to fill gaps in the derived data (see Section 3.4).

[2] A *taxotransfer* function is the estimation of soil parameters based on modal soil characteristics of soil units, as derived from a

Table 2 Criteria for defining 'confidence' in the derived data

CONF		NUM
V	Very high	>30
H	High	15-29
M	Moderate	5-14
L	Low	1-4
-	No data	0

* *NUM* is the sample size after the screening procedure.

2.5 Total Available Water Capacity

The medians for Available Water Capacity (AWC), by soil unit and depth zone, have been used to estimate the 'profile' or Total Available Water Capacity (TAWC), as follows:

- Shallow soils (i.e. Lithosols, Rendzinas and Rankers):
  $TAWC_i = d * AWC_{it}$
- Other soils:
  $TAWC_i = 3*AWC_{it} + 7*AWC_{ib}$

where:

i is the pF range considered for *AWC* (i.e. AWC_1 is from pF 2.0 to pF 4.2, and AWC_2 from pF 2.5 to pF 4.2).

t resp. *b* refer to the topsoil and subsoil, respectively, for the considered topsoil textural class.

d is the maximum depth range (*maxdep*, in dm).

A maximum depth of 100 cm has been adopted for all soil units, except for Lithosols (and lithic Leptosols, LPq; *maxdep*= 10 cm), Rendzinas and Rankers (*maxdep*= 30 cm).

3 RESULTS AND DISCUSSION

3.1 Data aggregation

Generalization of measured soil (profile) data by soil unit and topsoil textural class — to permit linkage with the units shown on the digital Soil Map of the World — for use in regional and global models, involves the transformation of variables that show a marked spatial and temporal variability, and that have been determined in many laboratories according to various methods. No attempt was made in this study to establish the location of individual profiles, because each profile description was assumed to be representative for a particular FAO-Unesco (1974) soil unit. As such, differences in landform, parent material, land use history, natural vegetation, and time of sampling are not considered explicitly.

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combination of their classification name or taxon (which by definition often implies a certain range for a number of properties), expert knowledge and empirical rules, and a statistical analysis of a large number of soil profiles belonging to the same taxon.

A *pedotransfer* function is a mathematical relationship between two or more soil parameters which shows a reasonable high level of statistical confidence. This relationship is used to facilitate the estimation of a non-measured soil parameter from one or more measured ones.

3.2 Derived data

Results for the various analyses have been retained as dbf-files; the structure of the various files is explained in Appendix 4. As an example, listings for the ferric Acrisols of the 1974 Legend are attached in a self-explanatory table (App. 2). Overall confidence in the results shown should be highest where the degrees of freedom are highest, when it is assumed that all the available profiles are equally representative for the considered combination of soil units and topsoil textural classes.

3.3 Summary of derived data

All 20 attributes have now been analyzed by soil unit, topsoil textural class and depth zone. A summary of the frequencies of occurrence is shown in Table 3 and 4.

Table 3 Summary of derived data for FAO-Unesco (1974) Legend

ATTRIB	DEPZONE	Freq. of occurrence					
		N	F	C	M	A	CMA
AWC1	A	40	40	19	2	0	21
AWC1	B	38	39	21	2	0	23
AWC2	A	20	33	28	14	5	47
AWC2	B	19	33	29	17	2	48
BSAT	A	8	28	23	18	24	65
BSAT	B	10	27	25	18	19	62
BULKDENS	A	11	31	28	18	11	57
BULKDENS	B	11	32	29	17	12	58
CECCLAY	A	8	16	28	15	33	76
CECCLAY	B	8	20	22	17	33	72
CECSOIL	A	8	15	29	13	35	77
CECSOIL	B	8	17	25	16	35	76
ORGC	A	6	12	25	21	36	82
ORGC	B	6	15	24	20	35	79
PHH2O	A	6	12	25	21	36	82
PHH2O	B	6	14	26	17	37	80
R_CAMG_K	A	8	20	34	16	23	73
R_CAMG_K	B	11	22	36	15	17	68
R_CA_MG	A	7	18	28	22	25	75
R_CA_MG	B	7	20	33	16	24	73
TEB	A	8	19	36	18	20	74
TEB	B	10	18	36	17	19	72
TOTPORES	A	11	32	28	17	11	56
TOTPORES	B	11	33	28	17	12	57

Note: Sample populations by attribute are stratified by soil unit and depth zone, i.e. for all available textural classes. 'A' stands for topsoil and 'B' for subsoil. Frequency of occurrence refers to the number of cases for which either **N**o (0), **F**ew (1-4), **C**ommon (5-14), **M**any (15-29) and **A**bundant (>30) observations are available for the specified attribute, and is expressed as a percentage of the total number of soil units (i.e. 106 in 1974-Legend and 153 for the 1990-Legend). CMA stands for C+M+A. Totals for N+F+C+M+A may differ from 100 in places due to rounding.

An important question that arises at this stage is: (1) for which of these combinations by attribute can one present medians with sufficient confidence based on the available profile data, and (2) is this sufficient to develop a scheme of taxotransfer rules to fill the gaps (see 3.4). To answer these questions, a sequential approach has been adopted. First, the complement of derived data has been analyzed by attribute for the situation in which the population available by soil unit and depth zone is largest. When this first analysis showed that the number of profiles/observations was generally adequate for the considered attribute at this level of aggregation, it was tested whether statistically different medians for the different textural classes based on the current set of profiles could be presented. The attributes CACO3, GYPSUM, ESP and ECEC are omitted from Table 3 and 4 because these attributes are only determined for specific soils (see Van Reeuwijk, 1993). Sand, silt and clay content are not considered in Table 3 and 4, as they were used to cluster the various data sets by topsoil textural class (see 2.3).

Table 3 shows that there generally exists an adequate basis for filling gaps in the derived data, using taxotransfer rules, although some substantial gaps remain. For AWC_1 and to a lesser degree AWC_2, the data may not allow for the use of such rules. Therefore, alternative procedures are needed for providing estimates of available water holding capacity (e.g. Landon, 1991; FAO, 1995).

The summary for the Revised Legend in Table 4 shows limited possibilities for applying taxotransfer rules due to a larger number of soil units (i.e. 153 versus 106 soil units). This applies especially to the soil physical attributes. Thus, an alternative approach must be followed for these attributes based on the current derived data, complemented with expert judgement and procedures used for the SMW's CD-ROM (FAO, 1995).

Table 4 Summary of derived data for FAO-Unesco (1990) Legend

		Freq. of occurrence					
ATTRIB	DEPZONE	N	F	C	M	A	CMA
AWC1	A	48	41	9	1	0	10
AWC1	B	48	38	13	1	0	14
AWC2	A	30	36	22	10	2	34
AWC2	B	30	38	19	12	1	32
BSAT	A	14	35	26	13	12	51
BSAT	B	18	36	22	11	12	45
BULKDENS	A	20	39	27	8	7	42
BULKDENS	B	20	39	26	7	7	40
CECCLAY	A	11	27	30	14	18	62
CECCLAY	B	14	30	24	15	16	55
CECSOIL	A	11	29	27	13	20	60
CECSOIL	B	12	30	24	16	17	57
ORGC	A	9	25	27	18	22	67
ORGC	B	11	28	25	15	21	61
PHH2O	A	10	25	24	18	24	66
PHH2O	B	11	28	23	15	22	60
R_CAMG_K	A	12	30	31	14	13	58
R_CAMG_K	B	18	37	24	9	12	45
R_CA_MG	A	11	29	27	13	20	60
R_CA_MG	B	13	31	27	14	14	55
TEB	A	13	33	27	15	12	54
TEB	B	16	33	26	12	13	51
TOTPORES	A	20	38	27	8	7	42
TOTPORES	B	20	40	26	7	7	40

See Table 3 for footnotes

3.4 Development of taxotransfer rules

As is apparent from Table 3 and 4, substantial gaps remain in the derived data sets. Generalized procedures for filling these gaps are introduced in the following paragraphs. These procedures, referred to as taxotransfer rules (TTR), will be used whenever the confidence in a certain derived attribute is low (defined as *NUM* < 5). In order to keep track of the rules adopted, they have been documented in the TTR-derived data sets together with information on the (original) confidence in the substituted-data, the number of samples considered, and the substituted median (see App. 4).

The taxotransfer rules are:

Rule 0:

If *NUM* ≥ 5 for the considered combination of soil unit, attribute, depth zone and topsoil textural class, then use the median (*MED*) for the corresponding population (i.e. remains as is).

Rule 1:

If there is only a limited number of measured data (*NUM* < 5) for a specific combination of FAO-Unesco soil unit, soil attribute and topsoil textural class but *NUM* ≥ 5 for the corresponding combination of major soil group, soil attribute and topsoil textural class, then the median for this major group, topsoil textural class, depth interval and soil attribute is substituted in the derived data set. (In case of subsoils, the code for the topsoil textural is used as a *flag*)

Rule 2:

If median pH(H_2O) for the considered combination of soil unit, attribute, depth zone and topsoil textural class is less than 5.5 and $NUM_{pH} \geq 5$, then the $CaCO_3$ content is set at 0 percent.

Rule 3:

If median pH(H_2O) for the considered combination of soil unit, attribute, depth zone and topsoil textural class is less than 7.0 and $NUM_{pH} \geq 5$, then the gypsum content is set at 0 percent.

Rule 4:

If median pH(H_2O) for the considered combination of soil unit, attribute, depth zone and topsoil textural class is less than 6.5 and $NUM_{pH} \geq 5$, then the exchangeable sodium percentage is set at 0 percent.

Rule i:

If there are no data (*NUM* = 0) for a certain combination of attribute, textural class, depth interval and soil unit, and *NUM* < 5 for the corresponding combination of major group, soil attribute and textural class, then no data substitution is made and the rule is flagged as "R?". In these cases, a group of experts must recommend the proper substitution-procedure and agree on the value obtained through this procedure. Each new taxotransfer rule will have to be coded (*i*= 5 to *n*) so that they can be traced in the 'final' data set, and readily be updated when more extensive and better profile data become available.

3.5 Application of taxotransfer rules

Above taxotransfer rules have been applied to the various attributes, with the implicit understanding that the substituted values still need to be subjected to a final check by a group of experts prior to their use. Appendix 3 illustrates the results of the substitution process for organic carbon, using the 1974 Acrisols as an example. This type of summary tables were prepared for all the considered attributes as ASCII text-files (see App. 4), which are to be used during the subsequent expertvalidation stage.

Estimates of AWC_i and $TAWC_i$ by soil unit, in the 1974 and 1990 Legend, together with a code for the inferred confidence in the TTR-derived values were also compiled from the WISE profile data (see App. 4). It is important to note that in some cases medians for $TAWC_2$ were larger than for $TAWC_1$ for a certain combination of soil unit, topsoil textural class and depth zone, especially when the number of profiles available for the analyses is small. Clearly, this is in apparent contradiction with pedological reality! The discrepancy, however, can be explained by the fact that the available AWC_1 and AWC_2 data did seldom relate to the same profiles; there are only few profiles in WISE for which volumetric water content was measured both at pF2.0 and pF2.5. Also, of necessity, the considered textural classes are fairly wide and it was not possible to account for differences in composition of the sand fraction, for example. The adopted segregation into two broad depth zones, further may not permit to account adequately for the contribution of organic matter to TAWC.

4 CONCLUSIONS

This paper presents statistics for selected properties of the soil units considered in the FAO-Unesco 1974 and FAO-Unesco 1990 Revised Legend. The analysis is based on over 4350 profile descriptions held in ISRIC's WISE database, which includes most of the 1700 profiles used in the derivation of SMW's soil properties (FAO, 1995).

The present study confirms the persisting need for additional profile data in WISE, notably for the under-represented soil units and regions. A fairly large number of the 1990 Revised Legend soil units is still lacking, and needs a systematic effort to collect specific analyzed soil profiles, particularly for gelic and gypsic units, mollic Solonchaks, humic Nitisols, luvic Kastanozems and Chernozems, plinthic Gleysols, and Podzoluvisols. Increased attention to soil results from regions such as the former Soviet Union, China and Mongolia should be paid.

Representation of soil attributes for the FAO-Unesco 1974 Legend soil units by five or more observations, after application of three specific rejection procedures, and combining all texture classes, can be summarized as follows:

- For about seventy percent of the soil units more than two-thirds of the selected soil attributes fall into the Moderate (5-14), High (15-29) and Very high (> 30) availability or 'confidence' classes.
- For the soil units Fp, Gc, Kk, Pg, Pl, Po, Pp, Qa, Sg, To, Wd, Xh, and Zg less than two-thirds (but more than zero) of the attributes fall in the same 'confidence' classes.
- For the remainder, i.e., Cg, all Podzoluvisols (Dd, De, and Dg), Gp, Gx, Kl, Mg, Oe, Ox, Pf, Rx, Sm, Wh, Wx, Yt, Zm, and Zt, all of the selected soil attributes fall in the Low (1-4) or No data categories. Of these, soil units Pf and Wx do not occur in the digital version of the SMW (see also Appendix 5).

Several soil attributes are fairly well represented in WISE, including OC, pH(H_2O), TEB, CEC_{soil}, CEC_{clay}, BS, ESP, %sand, %silt, %clay, and the ratios of exchangeable Ca/Mg and (Ca+Mg)/K. For these attributes, 90 to 95 percent of the FAO-Unesco 1974 Legend soil units are represented by at least one profile, and 65 to 85 percent by at least five profiles. Availability of profile data for ECEC, AWC_1 and AWC_2 is particularly limited[3].

The fact that a certain derived attribute currently gets a high 'confidence' rating does not necessarily imply that this derived value will be representative for the soil unit under consideration; profile selection for WISE, like for other global databases, is not probabilistic but based on available data. Also, several of the attributes considered in this study are not diagnostic in the FAO-Unesco Legend. Therefore, it is recommended that soil experts also review estimates with high 'confidence' ratings.

The availability of soil profiles poses severe limitations to statistically deriving soil attributes by the three FAO topsoil texture classes. As described in the notes of Appendix 2, the differences of estimates for soil attributes by topsoil texture classes were tested for statistical significance. At the level of FAO-Unesco 1974 Legend major soil groups, more than 44 percent of all the possible combinations could not be tested due to lack of data. In the remaining cases, i.e. 55 percent of the total, for close to 60 percent of the tests significant differences between estimates by topsoil texture classes resulted. At the soil unit level, 70 percent of the possible combinations could not be tested, and in about 50 percent of the remainder the differences turned out to be significant. Therefore, it has been concluded that presently there does not exist a sufficiently homogenous and large soil profile database to estimate all major soil properties by soil unit, depth-zone, and topsoil textural class without having to use alternative calculation procedures and expert opinion.

The study has confirmed that there is a need for additional measured pF-data in WISE to adequately estimate AWC at the soil unit level, in particular for the 1990 Revised Legend. In addition, it is possible that the clustering of data applied in this study, based on 3 textural classes and 2 depth zones, may not be the best way of deriving TAWC data. Therefore, it is recommended to apply procedures for calculating water holding capacity considering readily available soil attributes such as particle size distribution, organic matter content and inferred clay activity (*cf*. Scholes, 1994), and soil depth. Until this is tested, it is recommended to use algorithms specifically developed for the Legend of the SMW (FAO, 1995); these algorithms apply to moisture held between 10 kPa and 1500 kPa, as used in AEZ studies (Doorenbos & Kassam, 1978; FAO, 1988).

Medians rather than means should be used in defining taxotransfer rules, as this will reduce the effect of outliers. The taxotransfer rules and the results obtained through their application must now be reviewed in a collaborative activity involving soil scientists from internationally recognized institutes in order to arrive at a uniform and agreed upon set of derived soil properties, for subsequent release as a unified product to the global modeling community.

The ultimate product, a dataset with best available information of median soil properties, derived from the WISE and FAO databases and subsequently reviewed and completed by a panel of soil

[3] ECEC measurements are limited to acid soils.

experts — with additional tabular information extracted from the databases contained in FAO (1995), such as soil drainage and soil depth — will allow geographical linkage to the digital version of the Soil Map of the World through application of FAO's composition rules, the soil unit code and topsoil textural class. This comprehensive set can then be used in various GIS-based studies, e.g. of soil gaseous emission potentials, soil vulnerability to pollution, and crop productivity at the global and regional levels.

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App. 1a List of FAO-Unesco (1974) soil units represented in WISE

FAO soil unit†

A: Acrisols
Af= 124 Ag= 21 Ah= 71 Ao= 68 Ap= 36
B: Cambisols
Bc= 30 Bd= 91 Be= 140 Bf= 47 Bg= 49 Bh= 49 Bk= 115 Bv= 45 Bx= 17
C: Chernozems
Cg= 0 Ch= 24 Ck= 32 Cl= 14
D: Podzoluvisols
Dd= 5 De= 5 Dg= 1
E: Rendzinas
E = 35
F: Ferralsols
Fa= 24 Fh= 50 Fo= 85 Fp= 8 Fr= 44 Fx= 50
G: Gleysols
Gc= 15 Gd= 63 Ge= 90 Gh= 33 Gm= 47 Gp= 4 Gx= 7
H: Phaeozems
Hc= 25 Hg= 18 Hh= 73 Hl= 92
I: Lithosols
I = 8
J: Fluvisols
Jc= 141 Jd= 32 Je= 167 Jt= 26
K: Kastanozems
Kh= 13 Kk= 14 Kl= 1
L: Luvisols
La= 28 Lc= 109 Lf= 114 Lg= 101 Lk= 145 Lo= 148 Lp= 12 Lv= 17
M: Greyzems
Mg= 1 Mo= 7
N: Nitosols
Nd= 25 Ne= 43 Nh= 13
O: Histosols
Od= 35 Oe= 11 Ox= 4
P: Podzols
Pf= 2 Pg= 15 Ph= 20 Pl= 11 Po= 29 Pp= 12
Q: Arenosols
Qa= 12 Qc= 184 Qf= 89 Ql= 36
R: Regosols
Rc= 28 Rd= 35 Re= 54 Rx= 2
S: Solonetz
Sg= 17 Sm= 5 So= 42
T: Andosols
Th= 90 Tm= 28 To= 16 Tv= 31
U: Rankers
U = 8
V: Vertisols
Vc= 152 Vp= 148
W: Planosols
Wd= 10 We= 22 Wh= 1 Wm= 8 Ws= 21 Wx= 0
X: Xerosols
Xh= 20 Xk= 19 Xl= 88 Xy= 8
Y: Yermosols
Yh= 9 Yk= 13 Yl= 17 Yt= 1 Yy= 15
Z: Solonchaks
Zg= 21 Zm= 3 Zo= 47 Zt= 2

† For definitions of soil unit codes see FAO-Unesco (1974); total= 4353 profiles.

App. 1b List of FAO-Unesco (1990) soil units represented in WISE

FAO soil unit†								
AC: Acrisols								
ACf= 51	ACg= 14	ACh= 99	ACp= 28	ACu= 41				
AL: Alisols								
ALf= 6	ALg= 10	ALh= 30	ALj= 1	ALp= 3	ALu= 12			
AN: Andosols								
ANg= 8	ANh= 18	ANi= 0	ANm= 23	ANu= 64	ANz= 49			
AR: Arenosols								
ARa= 11	ARb= 18	ARc= 14	ARg= 12	ARh= 119	ARl= 66	ARo= 65		
AT: Anthrosols								
ATa= 2	ATc= 20	ATf= 1	ATu= 1					
CH: Chernozems								
CHg= 5	CHh= 14	CHk= 30	CHl= 8	CHw= 0				
CL: Calcisols								
CLh= 112	CLl= 35	CLp= 35						
CM: Cambisols								
CMc= 105	CMd= 87	CMe= 137	CMg= 48	CMi= 16	CMo= 67	CMu= 46	CMv= 45	CMx= 24
FL: Fluvisols								
FLc= 141	FLd= 25	FLe= 145	FLm= 13	FLs= 5	FLt= 25	FLu= 3		
FR: Ferralsols								
FRg= 25	FRh= 99	FRp= 6	FRr= 48	FRu= 29	FRx= 59			
GL: Gleysols								
GLa= 0	GLd= 59	GLe= 87	GLi= 7	GLk= 7	GLm= 37	GLt= 2	GLu= 22	
GR: Greyzems								
GRg= 0	GRh= 6							
GY: Gypsisols								
GYh= 5	GYk= 12	GYl= 1	GYp= 4					
HS: Histosols								
HSf= 20	HSi= 4	HSl= 1	HSs= 21	HSt= 3				
KS: Kastanozems								
KSh= 9	KSk= 17	KSl= 2	KSy= 0					
LP: Leptosols								
LPd= 11	LPe= 22	LPi= 0	LPk= 29	LPm= 7	LPq= 6	LPu= 9		
LV: Luvisols								
LVa= 20	LVf= 17	LVg= 35	LVh= 137	LVj= 44	LVk= 78	LVv= 17	LVx= 135	
LX: Lixisols								
LXa= 2	LXf= 27	LXg= 4	LXh= 66	LXj= 1	LXp= 5			
NT: Nitisols								
NTh= 29	NTr= 8	NTu= 15						
PD: Podzoluvisols								
PDd= 5	PDe= 5	PDg= 1	PDi= 0	PDj= 0				
PH: Phaeozems								
PHc= 25	PHg= 17	PHh= 61	PHj= 4	PHl= 94				
PL: Planosols								
PLd= 12	PLe= 30	PLi= 0	PLm= 12	PLu= 0				
PT: Plinthosols								
PTa= 5	PTd= 9	PTe= 5	PTu= 2					
PZ: Podzols								
PZb= 10	PZc= 14	PZf= 2	PZg= 24	PZh= 35	PZi= 3			
RG: Regosols								
RGc= 21	RGd= 24	RGe= 45	RGi= 2	RGu= 3	RGy= 1			
SC: Solonchaks								
SCg= 20	SCh= 11	SCi= 0	SCk= 11	SCm= 2	SCn= 12	SCy= 14		
SN: Solonetz								
SNg= 18	SNh= 26	SNj= 4	SNk= 11	SNm= 4	SNy= 3			
VR: Vertisols								
VRd= 2	VRe= 148	VRk= 120	VRy= 3					

† For definitions of soil unit codes see FAO-Unesco (1990/1994); Total: 4157 profiles.

App. 2 Derived soil properties for Ferric Acrisols (1974 Legend)[4]

FAO_74	ATTRIB	DEPZONE	TOPTEX	NUM	MEA	MED	CVA	MIN	MAX	LLI	ULI	FINSIG	REJ0	REJ1	REJ2	CONF
Af	AWC1	A	1	2	6.00	6.00	-1	-1.00	-1.00	-1.00	-1.00		2	2	2	L
Af	AWC1	A	2	5	13.20	15.00	46	5.00	21.00	5.73	20.67		5	5	5	M
Af	AWC1	A	3	5	11.80	11.00	57	6.00	23.00	3.41	20.19		5	5	5	M
Af	AWC1	A	#	12	11.42	10.50	53	5.00	23.00	7.57	15.26	o-o	12	12	12	M
Af	AWC1	B	1	3	7.00	6.00	65	3.00	12.00	-4.38	18.38		3	3	3	L
Af	AWC1	B	2	6	9.83	8.50	47	5.00	16.00	4.98	14.69		6	6	6	M
Af	AWC1	B	3	3	10.00	10.00	0	10.00	10.00	10.00	10.00		5	5	3	L
Af	AWC1	B	#	14	10.00	10.00	42	3.00	16.00	7.58	12.42	-oo	14	14	14	M
Af	AWC2	A	1	10	4.20	4.00	50	2.00	8.00	2.70	5.70		10	10	10	M
Af	AWC2	A	2	25	8.52	8.00	69	1.00	25.00	6.11	10.93		29	29	25	H
Af	AWC2	A	3	7	8.57	7.00	44	4.00	15.00	5.08	12.07		7	7	7	M
Af	AWC2	A	#	40	6.75	6.50	58	1.00	16.00	5.50	8.00	*-*	46	46	40	V
Af	AWC2	B	1	9	3.67	3.00	47	2.00	7.00	2.34	5.00		9	9	9	M
Af	AWC2	B	2	26	10.92	9.00	60	3.00	24.00	8.26	13.59		28	28	26	H
Af	AWC2	B	3	5	5.20	6.00	21	4.00	6.00	3.84	6.56		6	6	5	M
Af	AWC2	B	#	34	6.47	6.00	59	2.00	15.00	5.14	7.80	**-	43	43	34	V
Af	BSAT	A	1	12	67.25	70.00	24	41.00	98.00	57.00	77.50		12	12	12	M
Af	BSAT	A	2	41	36.46	32.00	64	4.00	90.00	29.14	43.79		45	42	41	V
Af	BSAT	A	3	22	28.73	26.50	71	3.00	69.00	19.63	37.83		23	22	22	H
Af	BSAT	A	#	78	37.71	33.00	63	3.00	90.00	32.37	43.04	*-*	80	80	78	V
Af	BSAT	B	1	13	44.54	47.00	33	14.00	67.00	35.63	53.44		14	14	13	M
Af	BSAT	B	2	32	20.72	15.50	62	6.00	46.00	16.14	25.30		38	35	32	V
Af	BSAT	B	3	15	21.07	21.00	59	5.00	49.00	14.13	28.01		16	15	15	H
Af	BSAT	B	#	64	25.08	21.50	62	5.00	61.00	21.18	28.98	*-*	68	68	64	V
Af	BULKDENS	A	1	14	1.59	1.59	7	1.47	1.75	1.53	1.66		14	14	14	M
Af	BULKDENS	A	2	34	1.41	1.42	15	1.08	1.87	1.33	1.48		34	34	34	V
Af	BULKDENS	A	3	10	1.38	1.38	11	1.10	1.64	1.28	1.49		11	11	10	M
Af	BULKDENS	A	#	58	1.45	1.48	14	1.08	1.87	1.39	1.50	*-*	59	59	58	V
Af	BULKDENS	B	1	14	1.57	1.58	5	1.40	1.71	1.52	1.62		14	14	14	M
Af	BULKDENS	B	2	34	1.41	1.41	7	1.19	1.60	1.37	1.44		35	35	34	V
Af	BULKDENS	B	3	12	1.35	1.30	20	1.04	1.96	1.18	1.52		12	12	12	M
Af	BULKDENS	B	#	56	1.44	1.43	9	1.19	1.71	1.41	1.48	*-*	61	61	56	V
Af	CACO3	A	1	1	0.50	0.50	-1	-1.00	-1.00	-1.00	-1.00		1	1	1	L
Af	CACO3	A	2	0	-1.00	-1.00	-1	-1.00	-1.00	-1.00	-1.00		0	0	0	-
Af	CACO3	A	3	1	0.00	0.00	-1	-1.00	-1.00	-1.00	-1.00		1	1	1	L
Af	CACO3	A	#	2	0.25	0.25	-1	-1.00	-1.00	-1.00	-1.00	ooo	2	2	2	L
Af	CACO3	B	1	1	0.60	0.60	-1	-1.00	-1.00	-1.00	-1.00		1	1	1	L
Af	CACO3	B	2	0	-1.00	-1.00	-1	-1.00	-1.00	-1.00	-1.00		0	0	0	-
Af	CACO3	B	3	1	0.00	0.00	-1	-1.00	-1.00	-1.00	-1.00		1	1	1	L
Af	CACO3	B	#	2	0.30	0.30	-1	-1.00	-1.00	-1.00	-1.00	ooo	2	2	2	L
Af	CECCLAY	A	1	27	20.62	21.30	53	3.00	45.80	16.29	24.95		29	29	27	H
Af	CECCLAY	A	2	53	16.65	17.10	50	2.00	36.20	14.34	18.95		57	54	53	V
Af	CECCLAY	A	3	33	12.75	13.50	44	2.00	25.00	10.75	14.74		36	35	33	V
Af	CECCLAY	A	#	118	16.42	16.35	53	2.00	36.20	14.84	18.00	-**	122	122	118	V
Af	CECCLAY	B	1	28	16.49	16.85	46	3.90	33.30	13.56	19.42		29	29	28	H
Af	CECCLAY	B	2	51	13.88	12.70	51	3.60	29.60	11.91	15.85		56	53	51	V
Af	CECCLAY	B	3	33	13.01	12.90	43	4.50	25.50	11.02	14.99		34	33	33	V
Af	CECCLAY	B	#	114	14.10	13.45	47	3.60	29.60	12.87	15.33	--*	119	119	114	V
Af	CECSOIL	A	1	28	3.04	2.90	40	1.10	5.40	2.57	3.52		30	30	28	H
Af	CECSOIL	A	2	52	6.66	5.80	39	3.00	12.50	5.93	7.38		57	54	52	V
Af	CECSOIL	A	3	35	10.36	10.10	41	4.30	20.70	8.89	11.82		36	35	35	V
Af	CECSOIL	A	#	113	6.20	5.50	49	1.10	13.10	5.63	6.77	***	123	123	113	V
Af	CECSOIL	B	1	30	3.71	3.35	51	0.80	7.80	3.01	4.42		30	30	30	V
Af	CECSOIL	B	2	54	6.57	6.45	45	1.70	13.50	5.76	7.37		57	54	54	V
Af	CECSOIL	B	3	32	7.54	7.60	36	2.00	12.80	6.58	8.50		35	34	32	V
Af	CECSOIL	B	#	115	5.85	5.20	47	0.80	11.90	5.34	6.35	*-*	122	122	115	V
Af	CLAY	A	1	28	8.68	9.00	32	4.00	15.00	7.59	9.77		31	31	28	H
Af	CLAY	A	2	55	25.80	26.00	21	15.00	34.00	24.35	27.25		57	57	55	V
Af	CLAY	A	3	34	48.12	48.00	16	35.00	62.00	45.51	50.72		36	36	34	V
Af	CLAY	A	#	122	27.52	26.00	57	2.00	62.00	24.74	30.29	***	124	124	122	V
Af	CLAY	B	1	24	15.54	14.50	33	6.00	26.00	13.41	17.68		31	31	24	H
Af	CLAY	B	2	56	40.14	40.00	23	21.00	60.00	37.65	42.63		57	57	56	V
Af	CLAY	B	3	31	55.16	54.00	15	40.00	71.00	52.18	58.15		35	35	31	V
Af	CLAY	B	#	119	38.92	40.00	40	7.00	71.00	36.11	41.72	***	123	123	119	V
Af	ECEC	A	1	2	4.40	4.40	-1	-1.00	-1.00	-1.00	-1.00		2	2	2	L
Af	ECEC	A	2	22	9.31	9.60	29	4.20	14.50	8.12	10.50		23	23	22	H
Af	ECEC	A	3	10	14.71	14.65	34	6.10	21.60	11.12	18.30		10	10	10	M
Af	ECEC	A	#	34	10.07	9.90	42	2.50	19.70	8.60	11.54	o*o	35	35	34	V
Af	ECEC	B	1	4	6.23	5.95	68	2.10	10.90	-0.47	12.92		4	4	4	L
Af	ECEC	B	2	16	7.93	7.55	18	5.50	10.80	7.18	8.68		19	19	16	H
Af	ECEC	B	3	6	13.25	13.50	11	11.30	14.60	11.75	14.75		6	6	6	M
Af	ECEC	B	#	28	9.49	9.10	31	3.30	14.60	8.37	10.62	-**	29	29	28	H
Af	ESP	A	1	6	3.33	3.00	31	2.00	5.00	2.25	4.42		9	9	6	M
Af	ESP	A	2	31	2.13	2.00	57	1.00	5.00	1.69	2.57		34	32	31	V
Af	ESP	A	3	10	1.00	1.00	0	1.00	1.00	1.00	1.00		16	16	10	M
Af	ESP	A	#	54	2.02	2.00	60	0.00	5.00	1.69	2.35	*oo	59	59	54	V
Af	ESP	B	1	9	3.89	3.00	49	2.00	8.00	2.43	5.35		11	11	9	M
Af	ESP	B	2	32	1.94	2.00	54	1.00	5.00	1.56	2.31		33	33	32	V
Af	ESP	B	3	8	1.00	1.00	0	1.00	1.00	1.00	1.00		14	14	8	M
Af	ESP	B	#	54	2.04	2.00	56	1.00	5.00	1.73	2.35	*oo	58	58	54	V
Af	GYPSUM	A	1	0	-1.00	-1.00	-1	-1.00	-1.00	-1.00	-1.00		0	0	0	-
Af	GYPSUM	A	2	1	0.10	0.10	-1	-1.00	-1.00	-1.00	-1.00		1	1	1	L
Af	GYPSUM	A	3	0	-1.00	-1.00	-1	-1.00	-1.00	-1.00	-1.00		0	0	0	-
Af	GYPSUM	A	#	1	0.10	0.10	-1	-1.00	-1.00	-1.00	-1.00	ooo	1	1	1	L
Af	GYPSUM	B	1	0	-1.00	-1.00	-1	-1.00	-1.00	-1.00	-1.00		0	0	0	-
Af	GYPSUM	B	2	1	0.10	0.10	-1	-1.00	-1.00	-1.00	-1.00		1	1	1	L

[4] See footnotes at end of this table.

Af	GYPSUM	B	3	0	-1.00	-1.00	-1	-1.00	-1.00	-1.00	-1.00		0	0	0	-
Af	GYPSUM	B	#	1	0.10	0.10	-1	-1.00	-1.00	-1.00	-1.00	ooo	1	1	1	L
Af	ORGC	A	1	25	0.39	0.33	47	0.20	0.79	0.31	0.47		30	30	25	H
Af	ORGC	A	2	54	1.05	0.97	42	0.16	1.95	0.93	1.17		57	57	54	V
Af	ORGC	A	3	34	1.43	1.32	45	0.25	2.78	1.21	1.65		36	36	34	V
Af	ORGC	A	#	113	0.97	0.95	54	0.16	2.29	0.88	1.07	***	123	123	113	V
Af	ORGC	B	1	26	0.19	0.19	46	0.02	0.39	0.16	0.23		30	30	26	H
Af	ORGC	B	2	53	0.38	0.36	45	0.10	0.76	0.33	0.43		56	56	53	V
Af	ORGC	B	3	33	0.44	0.42	28	0.18	0.70	0.40	0.48		34	34	33	V
Af	ORGC	B	#	117	0.36	0.34	48	0.02	0.76	0.33	0.39	*-*	120	120	117	V
Af	PHH2O	A	1	30	-1.00	5.30	-1	4.60	6.70	-1.00	-1.00		30	30	30	V
Af	PHH2O	A	2	52	-1.00	5.15	-1	3.90	6.40	-1.00	-1.00		54	54	52	V
Af	PHH2O	A	3	36	-1.00	4.90	-1	4.00	6.20	-1.00	-1.00		36	36	36	V
Af	PHH2O	A	#	116	-1.00	5.10	-1	3.90	6.40	-1.00	-1.00	*-*	120	120	116	V
Af	PHH2O	B	1	30	-1.00	5.15	-1	4.20	6.00	-1.00	-1.00		30	30	30	V
Af	PHH2O	B	2	53	-1.00	5.00	-1	4.00	6.10	-1.00	-1.00		54	54	53	V
Af	PHH2O	B	3	33	-1.00	4.80	-1	4.30	5.50	-1.00	-1.00		35	35	33	V
Af	PHH2O	B	#	109	-1.00	4.90	-1	4.20	5.80	-1.00	-1.00	-**	119	119	109	V
Af	R_CAMG_K	A	1	17	4.89	4.70	46	0.40	9.00	3.73	6.06		18	18	17	H
Af	R_CAMG_K	A	2	35	11.07	6.50	73	1.70	27.50	8.30	13.83		40	40	35	V
Af	R_CAMG_K	A	3	18	7.98	8.05	69	1.50	22.50	5.25	10.71		20	20	18	H
Af	R_CAMG_K	A	#	61	6.60	5.90	60	0.40	16.00	5.58	7.62	*-*	78	78	61	V
Af	R_CAMG_K	B	1	12	5.27	4.10	48	1.50	11.10	3.65	6.88		13	13	12	M
Af	R_CAMG_K	B	2	9	2.83	2.70	33	1.30	4.70	2.11	3.56		12	12	9	M
Af	R_CAMG_K	B	3	5	8.84	8.90	5	8.40	9.50	8.30	9.38		8	8	5	M
Af	R_CAMG_K	B	#	28	5.10	4.00	53	1.30	11.10	4.05	6.16	***	33	33	28	H
Af	R_CA_MG	A	1	26	2.43	2.35	53	0.30	5.00	1.91	2.95		27	27	26	H
Af	R_CA_MG	A	2	48	1.82	1.65	51	0.50	3.90	1.55	2.09		50	50	48	V
Af	R_CA_MG	A	3	21	1.90	1.70	63	0.40	4.90	1.35	2.44		22	22	21	H
Af	R_CA_MG	A	#	91	1.88	1.80	52	0.30	4.00	1.68	2.08	*--	99	99	91	V
Af	R_CA_MG	B	1	21	1.06	1.00	63	0.20	2.50	0.75	1.36		23	23	21	H
Af	R_CA_MG	B	2	35	1.42	1.10	64	0.10	3.60	1.11	1.73		37	37	35	V
Af	R_CA_MG	B	3	17	1.59	1.40	70	0.10	4.00	1.01	2.16		18	18	17	H
Af	R_CA_MG	B	#	68	1.21	1.00	62	0.10	2.90	1.03	1.39	---	78	78	68	V
Af	SAND	A	1	31	79.90	80.00	9	67.00	91.00	77.37	82.44		31	31	31	V
Af	SAND	A	2	50	56.44	57.50	19	31.00	77.00	53.46	59.42		57	57	50	V
Af	SAND	A	3	36	29.08	32.50	54	6.00	58.00	23.82	34.35		36	36	36	V
Af	SAND	A	#	124	52.39	56.00	44	6.00	91.00	48.30	56.47	***	124	124	124	V
Af	SAND	B	1	29	70.52	73.00	15	50.00	88.00	66.58	74.45		31	31	29	H
Af	SAND	B	2	52	40.67	41.50	26	19.00	62.00	37.68	43.66		57	57	52	V
Af	SAND	B	3	35	23.37	24.00	57	3.00	47.00	18.80	27.94		35	35	35	V
Af	SAND	B	#	120	41.39	41.00	50	3.00	82.00	37.68	45.11	***	123	123	120	V
Af	SILT	A	1	28	9.57	8.50	45	2.00	19.00	7.90	11.24		31	31	28	H
Af	SILT	A	2	54	20.57	18.50	58	4.00	47.00	17.30	23.85		57	57	54	V
Af	SILT	A	3	36	21.03	18.50	62	5.00	48.00	16.62	25.44		36	36	36	V
Af	SILT	A	#	106	14.98	13.00	56	2.00	37.00	13.37	16.59	*-*	124	124	106	V
Af	SILT	B	1	29	10.00	9.00	42	2.00	18.00	8.39	11.61		31	31	29	H
Af	SILT	B	2	54	18.76	18.00	55	3.00	44.00	15.95	21.57		57	57	54	V
Af	SILT	B	3	34	18.26	16.00	62	4.00	43.00	14.32	22.21		35	35	34	V
Af	SILT	B	#	112	15.13	13.00	56	2.00	36.00	13.54	16.73	*-*	123	123	112	V
Af	TEB	A	1	7	1.64	1.50	29	1.00	2.30	1.20	2.09		8	8	7	M
Af	TEB	A	2	25	1.92	1.60	55	0.60	4.80	1.49	2.36		32	32	25	H
Af	TEB	A	3	15	4.26	3.80	75	0.40	11.10	2.48	6.04		15	15	15	H
Af	TEB	A	#	43	2.07	1.70	60	0.40	5.20	1.69	2.44	-**	55	55	43	V
Af	TEB	B	1	9	1.49	1.60	45	0.40	2.80	0.98	2.00		10	10	9	M
Af	TEB	B	2	24	0.99	1.00	26	0.60	1.60	0.88	1.10		29	29	24	H
Af	TEB	B	3	9	2.63	2.40	41	0.60	4.10	1.80	3.47		9	9	9	M
Af	TEB	B	#	39	1.22	1.00	42	0.40	2.40	1.06	1.39	-**	48	48	39	V
Af	TOTPORES	A	1	14	40.07	40.00	11	34.00	45.00	37.61	42.54		14	14	14	M
Af	TOTPORES	A	2	34	47.00	47.00	17	29.00	60.00	44.23	49.77		34	34	34	V
Af	TOTPORES	A	3	10	47.70	48.00	12	38.00	58.00	43.74	51.66		11	11	10	M
Af	TOTPORES	A	#	58	45.45	44.50	16	29.00	60.00	43.50	47.40	*-*	59	59	58	V
Af	TOTPORES	B	1	14	40.57	40.50	8	35.00	47.00	38.71	42.43		14	14	14	M
Af	TOTPORES	B	2	30	46.90	47.00	5	41.00	51.00	45.95	47.85		35	35	30	V
Af	TOTPORES	B	3	11	51.00	51.00	15	36.00	61.00	45.89	56.11		12	12	11	M
Af	TOTPORES	B	#	54	45.83	46.00	10	37.00	55.00	44.63	47.04	*-*	61	61	54	V

Notes:

1) "A", under the heading "DEPZONE", stands for topsoil and "B" for subsoil (i.e. the 0-30 cm and 30-100 cm depth zone respectively; see text for criteria used).
2) "TOPTEX" is the abbreviation for topsoil textural class, i.e. Coarse (1), Medium (2) and Fine (3), while "#" refers to all classes combined, as appropriate. Due to the outlier rejection scheme described in section 2.3.6, the total for "C" + "M" + "F" may differ from that shown for the "#" class. In case of subsoils, TOPTEX is used as a flag to permit linkage with the corresponding topsoil textural class (see text).
3) Available Water Capacity (AWC) is given in v/v %: AWC_1 is from pF2.0 to pF4.2; AWC_2 from pF2.5 to pF4.2.
4) CECclay, is corrected for contribution of OC (using 2.4 cmol(+) kg^{-1} OC; source: Scheffer and Schachtschabel, 1984).
5) MC_stat: Student *t*-test value for difference between means (for specified attribute) for Coarse and Medium sample populations; MC_DF is the corresponding degrees of freedom; MC_sig is significance of difference at 95%, two-sided (source: Snedecor and Cochran 1980, p. 97); idem for MF_*, i.e. for Medium and Fine , and CF_* for Coarse and Fine populations. [*Note: some of these statistics are only included in the digital files, see App. 4*]
6) FINSIG stands for "final" interpretation and consists of the combined codes; in *FINSIG,* the first symbol always refers to *MC_stat*, the second to *MF_stat* and the third to *CF_stat*. If one of the differences in means is significant at 95%, in a two-sided *t*-test, this is shown by "*". The string "-" is used when there is no significant difference between the two considered sample means, while the symbol "o" is used when either one of the considered sample populations was too small *or* pedologically irrelevant for a such a comparison (e.g., a Coarse textured topsoil in case of Vertisols; see App. 5).
7) The mean (*MEA*), median (*MED*), coefficient of variation (*CVA*), minimum (*MIN*), maximum (*MAX*), and lower and upper 95% confidence limits (*LLI* and *ULI*) are shown by sample population.
8) Sample size:
REJ0: size of profile population, i.e. after screening on soil textural analysis (USDA class limits; **all** attributes).
REJ1: as above, after screening by analytical methods, as documented in WISE
REJ2: as above, after outlier-rejection based on median test at 95% confidence level (see Pleijsier,1989).
9) Confidence in results shown should increase with sample size, and be lowest where NUM is 1 (CONF: -, NUM= 0; Low, 0< NUM ≤5; Moderate, 5< NUM ≤15; High, 15< NUM ≤ 30; Very High, 30 < NUM). Note: NUM= REJ.
10) Table shows all results as "is", i.e. before the application of taxotransfer rules.
11) Similar data for the other soil units are included in the file FAO_74ST.DBF (see App.4)

App. 3 Application of taxotransfer rules for organic carbon (1974 Legend)

ATTRIB	FAO_74	DEPZONE	TOPTEX	MED	CONF	R_MED	R_CONF	RULE
ORGC	A	A	1	0.42	V	0.42	V	R0
ORGC	A	B	1	0.20	V	0.20	V	R0
ORGC	A	A	2	1.17	V	1.17	V	R0
ORGC	A	B	2	0.39	V	0.39	V	R0
ORGC	A	A	3	1.90	V	1.90	V	R0
ORGC	A	B	3	0.50	V	0.50	V	R0
ORGC	A	A	#	1.15	V	1.15	V	R0
ORGC	A	B	#	0.39	V	0.39	V	R0
ORGC	Af	A	1	0.33	H	0.33	H	R0
ORGC	Af	B	1	0.19	H	0.19	H	R0
ORGC	Af	A	2	0.97	V	0.97	V	R0
ORGC	Af	B	2	0.36	V	0.36	V	R0
ORGC	Af	A	3	1.32	V	1.32	V	R0
ORGC	Af	B	3	0.42	V	0.42	V	R0
ORGC	Af	A	#	0.95	V	0.95	V	R0
ORGC	Af	B	#	0.34	V	0.34	V	R0
ORGC	Ag	A	1	1.83	L	0.42	V	R1
ORGC	Ag	B	1	0.13	L	0.20	V	R1
ORGC	Ag	A	2	0.98	M	0.98	M	R0
ORGC	Ag	B	2	0.34	M	0.34	M	R0
ORGC	Ag	A	3	1.99	M	1.99	M	R0
ORGC	Ag	B	3	0.43	L	0.50	V	R1
ORGC	Ag	A	#	1.27	H	1.27	H	R0
ORGC	Ag	B	#	0.30	H	0.30	H	R0
ORGC	Ah	A	1	1.54	M	1.54	M	R0
ORGC	Ah	B	1	0.89	L	0.20	V	R1
ORGC	Ah	A	2	1.84	H	1.84	H	R0
ORGC	Ah	B	2	0.75	H	0.75	H	R0
ORGC	Ah	A	3	3.36	V	3.36	V	R0
ORGC	Ah	B	3	1.04	V	1.04	V	R0
ORGC	Ah	A	#	2.57	V	2.57	V	R0
ORGC	Ah	B	#	0.92	V	0.92	V	R0
ORGC	Ao	A	1	0.45	H	0.45	H	R0
ORGC	Ao	B	1	0.23	H	0.23	H	R0
ORGC	Ao	A	2	1.20	H	1.20	H	R0
ORGC	Ao	B	2	0.40	H	0.40	H	R0
ORGC	Ao	A	3	1.08	M	1.08	M	R0
ORGC	Ao	B	3	0.44	M	0.44	M	R0
ORGC	Ao	A	#	1.00	V	1.00	V	R0
ORGC	Ao	B	#	0.38	V	0.38	V	R0
ORGC	Ap	A	1	0.53	M	0.53	M	R0
ORGC	Ap	B	1	0.23	M	0.23	M	R0
ORGC	Ap	A	2	1.68	H	1.68	H	R0
ORGC	Ap	B	2	0.44	H	0.44	H	R0
ORGC	Ap	A	3	2.73	M	2.73	M	R0
ORGC	Ap	B	3	0.63	M	0.63	M	R0
ORGC	Ap	A	#	1.25	V	1.25	V	R0
ORGC	Ap	B	#	0.34	V	0.34	V	R0

Notes:
- FAO_74 is the classification according to the FAO-Unesco (1974) Legend.
- ORGC is organic carbon content.
- DEPZONE in this table refers to the topsoil (0-30 cm) resp, subsoil (30-100 cm).
- "TOPTEX" is the abbreviation for topsoil textural class, i.e. Coarse (1), Medium (2) and Fine (3), while "#" refers to all classes combined. In case of subsoils, TOPTEX is used as a flag to permit linkage with the corresponding topsoil textural class (see text).
- Confidence in results shown should increase with sample size, and be lowest where CONF is "L" (CONF: -, NUM= 0; Low, 0< NUM ≤5; Moderate, 5< NUM ≤15; High, 15< NUM ≤ 30; Very High, 30 < NUM).
- R_MED is median organic carbon content after application of the taxotransfer rules.
- R_CONF, refers to the (original) *CONF* for the data substituted with the taxotransfer rule.
- Similar data for the other soil units and attributes are presented in file FAO_74S8.DBF, while the full ASCII-table for organic carbon is attached as file 74_ORGC.S80 (see App. 3).

App. 4 Structure of digital data files

DATA FILES

The following files are attached on the accompanying diskette:

Database files

FAO_*xx*ST.DBF Initial data file with all statistics by soil unit, attribute, textural class and depth zone for 19*xx* FAO-Unesco Legend (with *xx*=74 and 90, respectively).

FAO_*xx*S7.DBF Data file with median $TAWC_i$ data by soil unit, textural class and specified depth range for 19*xx* FAO-Unesco Legend (derived from AWC_i data in FAO_*xx*ST.DBF).

FAO_*xx*S8.DBF As above for all attributes, after application of taxotransfer rules to file FAO_*xx*ST.DBF.

FAO_*xx*S9.DBF As above but for $TAWC_i$, after application of taxotransfer rules to file FAO_*xx*S7.DBF.

Summary files:

SUMTAB*xx*.DBF Overall summary file of medians, for all 17 considered attributes, derived from WISE database with information on taxotransfer rules used.

xx_attri.s80 Summary ASCII text-files by *attri*bute listing medians by soil unit, topsoil textural class and depth zone, and documenting the taxotransfer rule used (see section 3.4). Excerpt from file FAO_*xx*S8.DBF.

FAO_*xx*S9.TXT Summary ASCII text-files for $TAWC_i$. Excerpt from file FAO_*xx*S9.DBF.

FAO_*xx*.227 Summary ASCII text-files showing *FINSIG* and *CONF* by attribute, soil unit, topsoil textural class and depzone. Excerpt from file FAO_*xx*ST.DBF.

The zipped database files (≈ 1.8 Mb) require about 15.6 Mb disk space after decompresion [**pkunzip -d -o a:wise_aez c:**]. Files will be decompressed to C:\wise_aez\dbf_74 (3.8 Mb; 5 files); ...\74_txt (2.6 Mb; 25 files); ...\90_dbf (5.5 Mb; 5 files), and ...\wise_aez\90_txt (3.7 Mb; 25 files).

STRUCTURE OF DBF-FILES

The structures of the various database files are described below, using the 1974 Legend as example. The ASCII text-files use the same coding conventions as described below for the dbf-files.

File: FAO_74ST.DBF

Field Name	Type	Width	Dec	Description
FAO_74	Character	2		Classification in FAO-Unesco (1974) Legend
ATTRIB	Character	8		Code for attribute under consideration
DEPZONE	Character	3		Depth interval (A=topsoil; B= subsoil)
TOPTEX	Character	1		Topsoil textural class (or flag in case of subsoils)
NUM	Numeric	4		Number of observations after outlier rejection (= REJ2)
MEA	Numeric	6	2	Arithmetic mean (in respective units of measurement)
MED	Numeric	6	2	Median (in respective units of measurement)
CVA	Numeric	3		Coefficient of variation (in per cent)
MIN	Numeric	6	2	Minimum
MAX	Numeric	6	2	Maximum
LLI	Numeric	6	2	Confidence interval, 95%, lower limit
ULI	Numeric	6	2	Confidence interval, 95%, lower limit
SDEV	Numeric	8	3	Standard deviation
VAR	Numeric	10	3	Variance
MC_STAT	Numeric	8	2	Student-t value for difference between means for Coarse and Medium sample population
MC_DF	Numeric	4		Corresponding degrees of freedom
MC_SIG	Character	2		Significance of difference at 95%, two-sided.
MF_STAT	Numeric	8	2	Student-t value for difference between means for Medium and Fine sample population
MF_DF	Numeric	4		Corresponding degrees of freedom
MF_SIG	Character	2		Significance of difference at 95%, two-sided.
CF_STAT	Numeric	8	2	Student-t value for difference between means for Coarse and Fine sample population

CF_DF	Numeric	4		Corresponding degrees of freedom
CF_SIG	Character	2		Significance of difference at 95%, two-sided.
AL_STAT	Numeric	8	2	Not used
AL_DF	Numeric	4		Not used
AL_SIG	Character	2		Not used
FINSIG	Character	3		Combined code consisting of string MC_sig + MF_sig + CF_sig. (FINSIG is only listed where TOPTEX is coded "#"; see App. 1)
REJ0	Numeric	3		Size of sample population after first screening on soil textural analysis (USDA class limits), plus exclusion of missing values for attribute under consideration
REJ1	Numeric	3		As above, but after screening by analytical methods
REJ2	Numeric	3		As above, but after outlier rejection based on median test (at 95% confidence level; after Pleijsier, 1989)
CONF	Character	1		Indicator for confidence in results (see text)

File: FAO_74S7.DBF

Field Name	Type	Width	Dec	Description
ATTRIB	Character	8		pF range used for Available Water Capacity (v/v %): AWC_1 is from pF2.0 to pF4.2; AWC_2 from pF2.5 to pF4.2
FAO_74	Character	2		Classification in FAO-Unesco (1974) Legend
TOPTEX	Character	1		Topsoil textural class (or flag in case of subsoil)
DEPZONE	Character	3		Depth interval under consideration
TOTAWC	Numeric	6		Median $TAWC_i$ (mm), for specified depth range (see text)
CONF	Character	2		Two letter code for confidence in derived $TAWC_i$ data; first letter refers to confidence in original AWC_i data for the topsoil and the second to those for the subsoil.

Note: In this file, the symbols "A" and "B" stand for the depth range considered, i.e. 0-100cm (B), except for Lithosols (A= 0-10 cm), Rankers and Rendzinas (A= 0-30 cm).

File: FAO_74S8.DBF

Field Name	Type	Width	Dec	Description
FAO_74	Character	2		Classification in FAO-Unesco (1974) Legend
ATTRIB	Character	8		Name of attribute; for abbreviations see table at end of this Appendix.
DEPZONE	Character	3		Depth interval
TOPTEX	Character	1		Topsoil textural class (or flag in case of subsoil)
NUM	Numeric	4		Number of observ. after outlier rejection (=REJ2)
MED	Numeric	6	2	Median for specified attribute
FINSIG	Character	3		Shows significance of difference in means for MC, MF and CF (only listed where toptex is coded "#")
CONF	Character	1		Indicator for confidence in the derived data.
R_MED	Numeric	8	2	Median after use of taxotransfer rules (see text)
R_CONF	Character	2		Confidence in above
RULE	Character	2		Code for taxotransfer rule used (R_0 to R_j)

File: FAO_74S9.DBF

Field Name	Type	Width	Dec	Description
ATTRIB	Character	8		AWC_1 is from pF2.0 to pF4.2; AWC_2 from pF2.5 to pF4.2
FAO_74	Character	2		Classification in FAO-Unesco (1974) Legend
DEPZONE	Character	3		Depth range
TOPTEX	Character	1		Textural class
CONF	Character	2		Indicator for confidence in data shown (see text)
TOTAWC	Numeric	6		$TAWC_i$ (mm) for profile (for relevant depth range)
R_TAWC	Numeric	5		As above, after use of taxotransfer rules
R_CONF	Character	2		Indicator for confidence in data shown
RULE	Character	2		Code for taxotransfer rule used (R_1 to R_j)

Note: The two-letter code for *CONF* consists of the "confidence" rating for AWC_i for the topsoil and AWC_i for the subsoil. For example, a code of "LH" would imply a low "confidence" in the results for the topsoil and a high "confidence" in the results for the subsoil; thus the overall the confidence in the cumulated $TAWC_i$ will be low (as determined by the most limiting AWC_i value).

File: SUMTAB74.DBF

Field Name	Type	Width	Dec	Description
FAO_74	Character	2		Classification in FAO-Unesco (1974) Legend
TOPTEX	Character	1		Code for topsoil textural class
ORGC_TM	Numeric	6	2	Organic matter content, median for the topsoil (TM)
ORGC_TR	Character	2		Number of taxotransfer rule used for topsoil organic matter content (TR)
ORGC_BM	Numeric	6	2	Organic matter content, median for the subsoil (SM)
ORGC_BR	Character	2		Number of taxotransfer rule used for subsoil organic matter content (SR)
PHH2O_TM	Numeric	6	2	As above, but for pH(H_2O)
PHH2O_TR	Character	2		As above, but for pH(H_2O)
PHH2O_BM	Numeric	6		As above, but for pH(H_2O)
PHH2O_BR	Character	2		As above, but for pH(H_2O)
CECSOIL_TM	Numeric	6	2	As above, but for CEC_{soil}
CECSOIL_TR	Character	2		As above, but for CEC_{soil}
CECSOIL_BM	Numeric	6	2	As above, but for CEC_{soil}
CECSOIL_BR	Character	2		As above, but for CEC_{soil}
CECCLAY_TM	Numeric	6	2	As above, but for CEC_{clay}
CECCLAY_TR	Character	2		As above, but for CEC_{clay}
CECCLAY_BM	Numeric	6	2	As above, but for CEC_{clay}
CECCLAY_BR	Character	2		As above, but for CEC_{clay}
TEB_TM	Numeric	6	2	As above, but for Total Exchangeable Bases
TEB_TR	Character	2		As above, but for Total Exchangeable Bases
TEB_BM	Numeric	6	2	As above, but for Total Exchangeable Bases
TEB_BR	Character	2		As above, but for Total Exchangeable Bases
BSAT_TM	Numeric	6	2	As above, but for base saturation
BSAT_TR	Character	2		As above, but for base saturation
BSAT_BM	Numeric	6	2	As above, but for base saturation
BSAT_BR	Character	2		As above, but for base saturation
ESP_TM	Numeric	6	2	As above, but for Exchangeable Sodium Percentage
ESP_TR	Character	2		As above, but for Exchangeable Sodium Percentage
ESP_BM	Numeric	6	2	As above, but for Exchangeable Sodium Percentage
ESP_BR	Character	2		As above, but for Exchangeable Sodium Percentage
CAMG_K_TM	Numeric	6	2	As above, but for ratio of Exch.(Ca+Mg) over Exch. K
CAMG_K_TR	Character	2		As above, but for ratio of Exch.(Ca+Mg) over Exch. K
CAMG_K_BM	Numeric	6	2	As above, but for ratio of Exch.(Ca+Mg) over Exch. K
CAMG_K_BR	Character	2		As above, but for ratio of Exch.(Ca+Mg) over Exch. K
CA_MG_TM	Numeric	6	2	As above, but for ratio of Exch.(Ca) over Exch.
CA_MG_TR	Character	2		As above, but for ratio of Exch.(Ca) over Exch.
CA_MG_BM	Numeric	6	2	As above, but for ratio of Exch.(Ca) over Exch.
CA_MG_BR	Character	2		As above, but for ratio of Exch.(Ca) over Exch.
ECEC_TM	Numeric	6	2	As above, but for Effective Cation Exchange Capacity
ECEC_TR	Character	2		As above, but for Effective Cation Exchange Capacity
ECEC_BM	Numeric	6	2	As above, but for Effective Cation Exchange Capacity
ECEC_BR	Character	2		As above, but for Effective Cation Exchange Capacity
CACO3_TM	Numeric	6	2	As above, but for calcium carbonate content
CACO3_TR	Character	2		As above, but for calcium carbonate content
CACO3_BM	Numeric	6	2	As above, but for calcium carbonate content
CACO3_BR	Character	2		As above, but for calcium carbonate content
GYPSUM_TM	Numeric	6	2	As above, but for gypsum content
GYPSUM_TR	Character	2		As above, but for gypsum content
GYPSUM_BM	Numeric	6	2	As above, but for gypsum content
GYPSUM_BR	Character	2		As above, but for gypsum content
BULK_TM	Numeric	6	2	As above, but for bulkdensity
BULK_TR	Character	2		As above, but for bulkdensity
BULK_BM	Numeric	6	2	As above, but for bulkdensity
BULK_BR	Character	2		As above, but for bulkdensity
TOTPOR_TM	Numeric	6	2	As above, but for total porosity
TOTPOR_TR	Character	2		As above, but for total porosity
TOTPOR_BM	Numeric	6	2	As above, but for total porosity
TOTPOR_BR	Character	2		As above, but for total porosity
AWC1_TM	Numeric	6	2	As above, but for Available Water Capacity (AWC1)
AWC1_TR	Character	2		As above, but for Available Water Capacity (AWC1)
AWC1_BM	Numeric	6	2	As above, but for Available Water Capacity (AWC1)
AWC1_BR	Character	2		As above, but for Available Water Capacity (AWC1)
AWC2_TM	Numeric	6	2	As above, but for Available Water Capacity (AWC2)
AWC2_TR	Character	2		As above, but for Available Water Capacity (AWC2)
AWC2_BM	Numeric	6	2	As above, but for Available Water Capacity (AWC2)
AWC2_BR	Character	2		As above, but for Available Water Capacity (AWC2)
TAWC1_M	Numeric	6	2	As above, for Total Available Water Capacity (TAWC1)
TAWC1_R	Character	2		As above, for Total Available Water Capacity (TAWC1)
TAWC2_M	Numeric	6	2	As above, for Total Available Water Capacity (TAWC2)
TAWC2_R	Character	2		As above, for Total Available Water Capacity (TAWC2)
SAND_TM	Numeric	6	2	As above, but for sand
SAND_TR	Character	2		As above, but for sand

SAND_BM	Numeric	6	2	As above, but for sand
SAND_BR	Character	2		As above, but for sand
SILT_TM	Numeric	6	2	As above, but for sand
SILT_TR	Character	2		As above, but for silt
SILT_BM	Numeric	6	2	As above, but for silt
SILT_BR	Character	2		As above, but for silt
CLAY_TM	Numeric	6	2	As above, but for clay
CLAY_TR	Character	2		As above, but for clay
CLAY_BM	Numeric	6	2	As above, but for clay
CLAY_BR	Character	2		As above, but for clay

Note: This file can easily be expanded to include parameters derived from FAO's CD-ROM, such as soil drainage class, soil depth class, gravel content and electric conductivity. A "-9" in this file refers to no data.

CODES FOR PHYSICAL AND CHEMICAL ATTRIBUTE

Attribute	Explanation
AWC1	Available water capacity (for 10 to 1500 kPa; % v/v)
AWC2	Available water capacity (for 33 to 1500 kPa; % v/v)
BSAT	Base saturation (% of CECsoil)
BULKDENS	Bulkdensity (g cm^{-3})
CACO3	Calcium carbonate (% by weight)
CECCLAY	Calculated CEC of clay fraction (cmol(+) kg^{-1})
CECSOIL	Calculated CEC of soil fraction (1 *M* NH_4OAc at pH 7; cmol(+) kg^{-1})
ECEC	Effective CEC (cmol(+) kg^{-1})
ESP	Exchangeable sodium percentage (as % of CECsoil)
GYPSUM	Total gypsum, as $CaSO_4.2H_2O$ (% by weight)
ORGC	Organic carbon content (% by weight)
PHH2O	pH water
R_CAMG_K	Ratio of exchangeable Ca+Mg over K
R_CA_MG	Ratio of exchangeable Ca over Mg
TEB	Total exchangeable bases (Ca + Mg + K + Na)
TOTPORES	Total porosity (% v/v)

Note: For analytical methods see Section 2.3.

App. 5 Occurrence of FAO-Unesco (1974) soil units by topsoil textural classes in the SMW

FAO74 SOIL UNIT	Dominant Soil: Topsoil Texture (%) Coarse	Med.	Fine	Dominant Soil: % Total	NonDS % Total	Total % of SMW
A	6	53	41	58	42	5.92
Af	18	46	36	63	37	1.04
Ag	22	74	4	36	64	0.26
Ah	0	77	23	37	63	0.35
Ao	3	53	45	69	31	3.23
Ap	2	57	41	33	67	1.02
B	11	70	19	52	48	9.36
Bc	0	66	34	50	50	0.60
Bd	22	68	11	49	51	1.90
Be	25	54	21	55	45	1.65
Bf	0	81	19	31	69	0.25
Bg	36	59	5	47	53	0.27
Bh	2	65	33	36	64	0.56
Bk	2	82	15	49	51	0.59
Bv	1	25	74	36	64	0.22
Bx	3	81	17	63	37	3.09
C	2	51	47	85	15	2.02
Cg	0	0	100	96	4	0.07
Ch	4	66	30	88	12	0.77
Ck	0	37	63	67	33	0.31
Cl	1	62	37	96	4	0.60
D	17	83	0	54	46	4.20
Dd	2	98	0	23	77	2.35
De	18	82	0	97	3	1.57
Dg	45	55	0	79	21	0.27
E	0	55	45	37	63	0.42
F	6	38	56	73	27	5.59
Fa	0	36	64	96	4	0.34
Fh	0	18	82	69	31	0.19
Fo	1	35	65	76	24	2.75
Fp	0	96	4	24	76	0.45
Fr	2	12	87	65	35	0.46
Fx	19	49	32	85	15	1.36
G	9	67	25	36	64	7.97
Gc	46	0	54	37	63	0.16
Gd	23	53	24	32	68	1.84
Ge	14	33	52	49	51	1.05
Gh	5	77	18	19	81	0.72
Gm	0	38	62	42	58	0.90
Gp	28	26	47	3	97	0.34
Gx	0	99	0	47	53	2.44
H	5	67	28	70	30	0.99
Hc	25	54	21	51	49	0.03
Hg	9	58	33	41	59	0.11
Hh	9	78	13	82	18	0.35
Hl	1	61	39	78	22	0.45
I	7	90	2	69	31	11.41
J	5	57	38	54	46	2.74
Jc	10	75	15	47	53	0.76
Jd	0	73	27	55	45	0.31
Je	4	46	50	65	35	1.30
Jt	1	27	72	52	48	0.09
K	12	82	6	77	23	3.39
Kh	16	78	6	87	13	1.58
Kk	1	87	11	46	54	0.17
Kl	8	87	6	87	13	1.33
L	18	67	15	60	40	6.59
La	5	83	12	76	24	0.65
Lc	12	57	31	55	45	1.55
Lf	30	55	15	73	27	1.54
Lg	23	68	8	51	49	0.87
Lk	41	59	1	40	60	0.46
Lo	3	87	10	63	37	1.19
Lp	26	74	0	50	50	0.17
Lv	0	32	68	49	51	0.03

FAO74 SOIL UNIT	Dominant Soil: Topsoil Texture (%) Coarse	Med.	Fine	Dominant Soil: % Total	NonDS % Total	Total % of SMW
M	0	88	12	53	47	0.57
Mg	0	97	3	98	2	0.11
Mo	0	83	17	43	57	0.47
N	7	39	54	61	39	1.43
Nd	7	38	55	63	37	0.81
Ne	8	38	55	61	39	0.51
Nh	0	62	38	80	20	0.06
O	2	90	8	50	50	4.13
Od	2	90	7	47	53	2.53
Oe	0	98	2	58	42	0.75
Ox	2	81	18	55	45	0.67
P	72	28	0	69	31	3.52
Pf	n.a	n.a	n.a	n.a	n.a	0.00
Pg	41	59	0	60	40	0.54
Ph	100	0	0	54	46	0.39
Pl	82	18	0	57	43	0.12
Po	75	25	0	80	20	2.27
Pp	91	9	0	59	41	0.02
Q	95	4	0	66	34	3.97
Qa	82	18	0	25	75	0.39
Qc	92	7	1	79	21	1.32
Qf	98	2	0	65	35	1.61
Ql	99	1	0	75	25	0.56
R	54	41	5	41	59	7.98
Rc	23	59	19	36	64	1.53
Rd	89	6	5	46	54	1.25
Re	67	33	1	41	59	1.88
Rx	45	54	2	50	50	2.64
S	17	33	50	36	64	1.63
Sg	0	46	54	4	96	0.11
Sm	0	14	86	57	43	0.33
So	27	44	30	36	64	1.06
T	11	85	4	53	47	0.88
Th	0	99	0	70	30	0.13
Tm	3	92	6	70	30	0.06
To	0	88	12	58	42	0.21
Tv	24	76	0	55	45	0.39
U	4	96	0	5	95	0.44
V	0	2	98	63	37	2.09
Vc	0	2	98	71	29	1.16
Vp	1	3	97	63	37	0.76
W	22	45	33	34	66	1.15
Wd	35	53	12	11	89	0.11
We	5	46	49	61	39	0.27
Wh	15	85	0	35	65	0.00
Wm	0	39	61	44	56	0.16
Ws	52	46	2	25	75	0.57
Wx	n.a	n.a	n.a	n.a	n.a	0.00
X	18	73	9	69	31	2.82
Xh	32	54	14	78	22	0.63
Xk	18	72	10	73	27	1.26
Xl	6	93	1	83	17	0.58
Xy	0	81	19	39	61	0.05
Y	28	65	7	67	33	6.99
Yh	15	81	4	70	30	1.46
Yk	36	51	13	60	40	1.83
Yl	23	68	8	64	36	1.15
Yt	4	11	85	87	13	0.12
Yy	22	75	3	64	36	0.50
Z	2	40	57	33	67	1.80
Zg	2	21	77	37	63	0.33
Zm	0	50	50	35	65	0.08
Zo	4	46	50	34	66	0.96
Zt	0	2	98	29	71	0.09
Total	20	61	20	58	42	100.0

See notes on next page

Notes for Appendix 5

The Appendix presents the occurrence of FAO-Unesco (1974) soil units in the SMW and indicates also the availability of soil profile data from the WISE database. It shows the distribution of dominant soils by three topsoil textural classes and also the relative extents of dominant and non-dominant (NonDS) soil units (i.e., co-dominant soils, associated soils, and inclusions). Representation of soil unit/topsoil textural class combinations by soil profiles in WISE, retained after screening for internationally accepted and commonly applied particle size limits as well as for comparability of analytical methods, is visualized by shading, as follows:

- Dark gray shading indicates that there are no soil profiles available in WISE[5];
- Light gray shading indicates that there are one to five soil profiles available, and
- No shading indicates that there are five or more soil profiles available.

Note that several of the combinations marked in dark gray do not occur in the SMW.

[5] Note that several combinations marked in dark grey do not occur on the SMW, either because they are ruled out by the legend, or because they could not be mapped at a scale of 1:5 M.