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GENERATION OF SPATIAL PRODUCTS USING THE WISE DATABASE

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Related ISRIC Reports:

World Inventory of Soil Emissions: Report of Working Group Discussions and Recommendations. Proceedings of an international workshop organized in the framework of the Netherlands National Research Programme on Global Air Pollution and Climate Change (24-27 August 1992). WISE Report 1, ISRIC, Wageningen, ii + 20 p.

World Inventory of Soil Emission Potentials. Proceedings of an International Workshop organized in the framework of the Netherlands National Research Programme on Global Air Pollution and Climate Change (24-27 August 1992). WISE Report 2, ISRIC, Wageningen, iv + 122 p. [ISBN 90-6672-049-2].

A Review of Soil Factors and Processes that Control Fluxes of Heat, Moisture and Greenhouse Gases. Technical Paper 23/WISE Report 3, ISRIC, Wageningen, viii + 201 p. [ISBN 90-6672-048-4].

World Inventory of Soil Emission Potentials: Guidelines for Soil Profile Selection and Protocol for Completing the WISE Data Entry Sheets. Working Paper and Preprint 93/02, ISRIC, Wageningen, ii + 32 p.

World Inventory of Soil Emission Potentials: Profile Database User's Manual (Version 1.0). Working Paper and Preprint 93/04, ISRIC, Wageningen, 28 pp.

World Inventory of Soil Emission Potentials: Development of a Global Soil Database of Process Controlling Factors. Working Paper and Preprint 94/01, ISRIC, Wageningen, 19 pp.

Report of a Joint ISRIC-IRRI Questionnaire on Site Characteristics of Irrigated Rice Lands of Relevance to Methane Production and Emission. Working Paper and Preprint 94/02, ISRIC, Wageningen, 23 pp.

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1 Introduction

This paper reviews the procedures for handling profile data and generating spatial products using the global soil database which has been developed at the International Soil Reference and Information Centre (ISRIC) in the framework of a project entitled World Inventory of Soil Emissions Potentials (WISE). The emphasis in this project has been the development of a uniform soil data set for global modelling purposes (*Batjes and Bridges*, 1994).

WISE version 2.1 permits the handling of soil "point data" and "area data" using a relational database management system (*Batjes*, 1994). The "point data" consist of geo-referenced soil profiles, considered to be representative for the legend units of the 1:5 million scale Soil Map of the World, which are linked to a ½° by ½° degree grid-version of the edited, digital version of this map (*FAO-Unesco*, 1974; *FAO*, 1991). Consequently, the main soil units of each grid cell on the map can be characterized using appropriate data held in the profile database. The WISE database will provide a refinement to the 1° x 1° database which *Zobler* (1986) derived from the original printed Soil Map of the World.

2 The WISE data handling system

2.1 Implementation

The WISE database, as schematically depicted in figure 1, is comprised off: (a) a file with information on the type and extent of the component FAO soil units of each ½° x ½° grid-cell, corresponding with the "area-data"; and (b) a suite of soil profile data representative for the respective FAO soil units, to which is attached a subfile listing the analytical methods and source of the primary data. The above database files can be used to generate a set of files containing derived characteristics for the topsoil and subsoil of the respective FAO soil units. These files are to provide a uniform basis for production of thematic maps and subsequent modelling activities (see Section 3).

The WISE database development activities include:

(1) Griding the edited Soil Map of the World to a ½° x ½° grid and providing digitized information on the typology and relative extents of the component soil units within each grid cell (*Nachtergaele*, unpublished data);

(2) Elaboration of procedures for developing the database and of guidelines for coding soil attributes (*Batjes*, 1992, 1993a). The full complement of data selected for inclusion in the WISE profile database is listed in Appendix 1. These attributes are similar to those proposed for the European Soil Analytical Database (*Madsen and Jones*, 1992), and during the IGBP-DIS/GCTE workshop at Silsoe (*Ingram*, 1993);

(3) Development of a relational data management system for the profile database of WISE (*Batjes*, 1993b, 1994);

(4) An international data collection activity coordinated by ISRIC. This included: (a) transferring data held in quality-controlled pedon databases, such as available at ISRIC's Soil Information System (ISIS) and the USDA Soil Conservation Service (SCS) at Lincoln, into WISE using an automated transfer-facility (*Tempel*, 1994; *W. Zunnenberg*, unpublished data), and (b) the processing of manuscript sources. National soil survey organizations have been asked to collaborate in providing ISRIC, and by implica-

tion the wider scientific community, with regionally representative profiles for the FAO soil units occurring in their respective countries;

(5) Providing statistically reliable information on data shown within the grid cells, with reference to a gradually increasing number of regionally representative soil profiles (e.g., stratified by climate and parent material), keeping in mind the necessity for global distribution (ongoing activity);

(6) Compile an inventory of soil methane emission potentials using WISE and ancillary databases in combination with available models; and ultimately,

(7) Revision of the grid information as sections of the Soil Map of the World are being updated. The actual revision of the soil and terrain unit boundaries would be one of the tasks of the long-term World Soils and Terrain Digital Database (SOTER) project (*Oldeman and Van Engelen*, 1993). Currently, the SOTER methodology, jointly developed by the Food and Agricultural Organization (FAO), United Nations Environment Program (UNEP), International Society of Soil Science (ISSS) and ISRIC, is being used for the update of the Soil Map of the World, starting with South America.

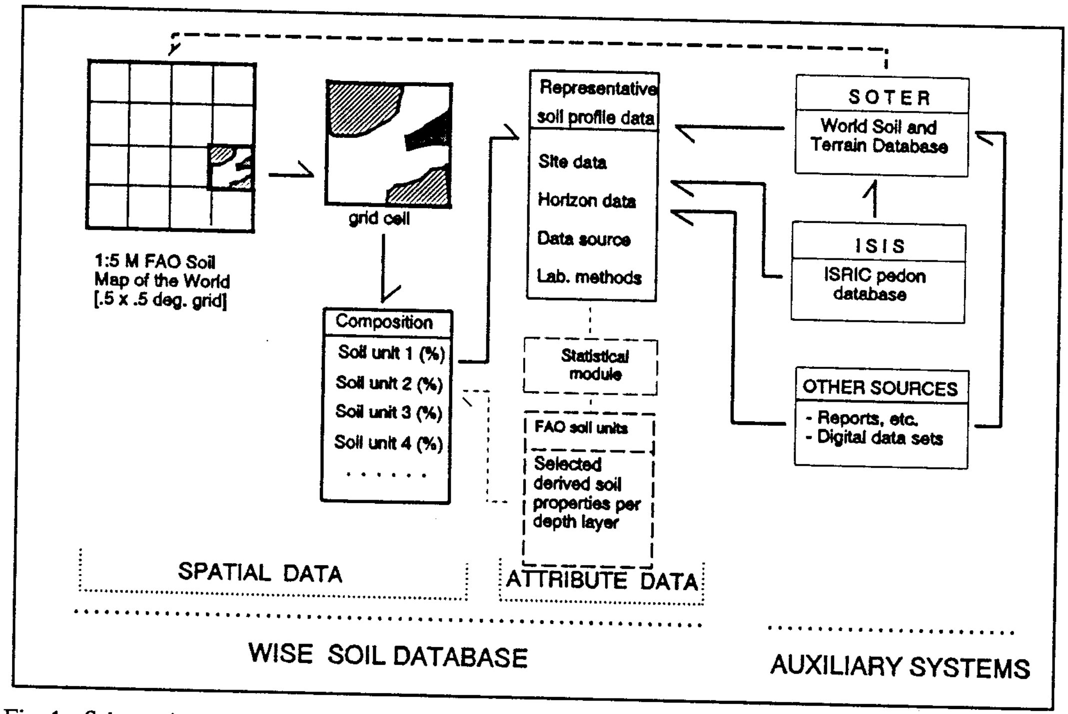

Fig. 1. Schematic representation of spatial and attribute data of the WISE database (After *Batjes*, 1992)

2.2 Soil profile data

As is shown in figure 2, the profile component of the WISE database includes information on:

(1) site and soil classification data;
(2) horizon data;
(3) source of data;
(4) the methods used for describing the analytical data; and
(5) a series of "code-definition" translation files.

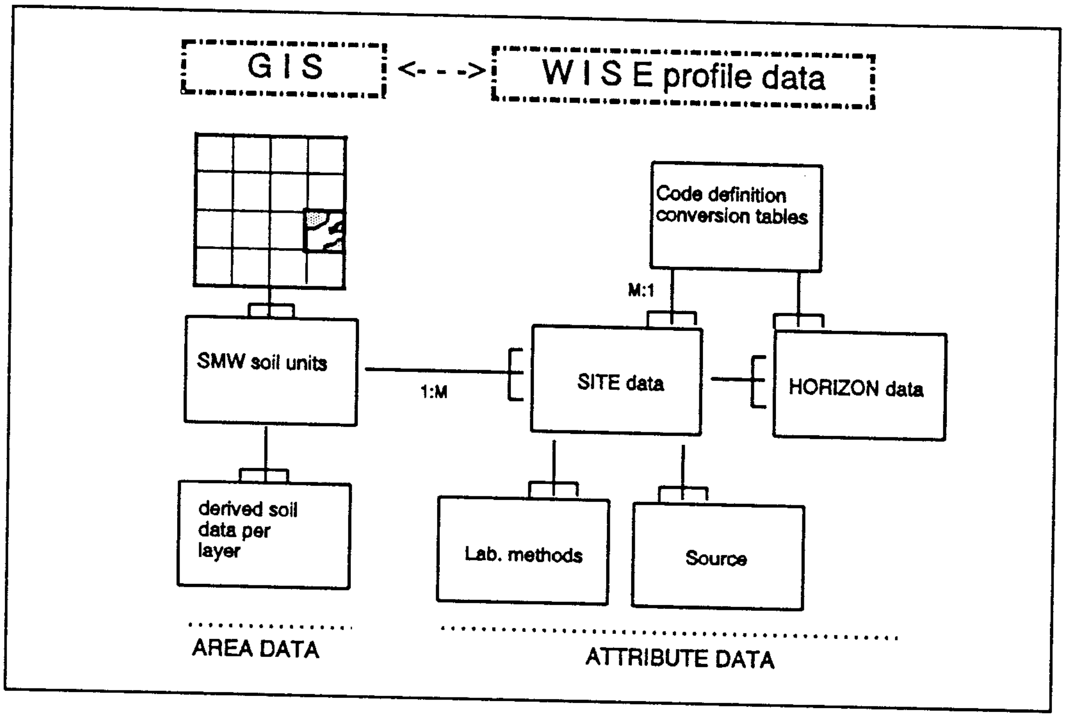

Fig. 2. Main database files of the WISE system (M:1 stands for many to one relations, and 1:M for one to many relations)

Complete physico-chemical characterizations are not a prerequisite for an accurate classification of a profile in the *FAO-Unesco* (1974) legend. This means that georeferenced profiles with incomplete data sets can still be useful for WISE, provided all missing values are flagged in the database. In all cases, the inferred quality of the data is specified in the database through the description status (see Appendix 2).

Table 1 gives an overview of the soil profiles presently available for the WISE database. Currently, about 650 profiles obtained from the USDA Soil Conservation Service (SCS) are being classified according to the FAO-Unesco (1974) and Revised FAO (1990) legend to permit inclusion in the WISE database. The number of soil profiles available in the WISE database per FAO-Unesco (1974) unit is shown in Appendix 3.

Table 1. Overview of profiles held in the WISE database (September 1994)

Source	Number
WISE (ISRIC library and int. data collection activity)	2089
ISRIC-ISIS	219
FAO-SDB	1379
USDA-SCS	677*

* The USDA-SCS profiles can first be added upon completion of their classification into the FAO-Unesco (1974) and FAO (1990) legend; an additional ≈ 300 ISIS profiles will be added upon completion of final checks by ISIS project staff.

2.3 Spatial soil data

Small scale maps encompass a marked degree of data integration, the aim being to simplify the geographical distribution of soils to a regionally representative pattern of spatially dominant soils. In the context of the WISE project, the predictive use of the digitized, 1:5 M scale Soil Map of the World becomes of significant importance. The areas of soil units depicted on this map have been used as a cartographic basis for the preparation of a ½° x ½° resolution spatial database, corresponding with ≈ 55 x 55 km at the equator. This grid size is commonly used in global change research, and has been requested by the sponsors of the WISE project.

First, the type and relative area of the component soil units of the map unit occurring at the centre of each 5' x 5' grid-cell of the digitized Soil Map of the World have been identified and characterized, using composition rules developed by FAO (1991). Next, the information for the 36 component 5' x 5' cells of a particular ½° x ½° grid have been computed, providing the definitive area-data. The algorithms for this part of the work have been prepared by staff of FAO's Land and Water Development Division (*Nachtergaele*, unpublished data), with whom WISE personnel have been closely cooperating. In the derived, spatial component of the WISE database each grid cell is characterized by the type and extent of its component soil units, up to a maximum of 10 per grid cell (Table 2). This approach reflects the natural variability in soil units within each ½° x ½° cell.

Table 2. Format of the spatial data file of the WISE database (for selected grid cells)

Record#	LON	LAT	S1	AREA1	S2	AREA2	S3	AREA3	S4	AREA4	S5	AREA5	S6	AREA6	S7	AREA7	S8	AREA8	S9	AREA9	S10	AREA10
160060	-70.5	-21.0	WT	75.0	Yh	10.1	I	6.4	So	4.6	Zo	3.9	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160061	-70.0	-21.0	Zo	46.7	Yh	23.7	ST	22.2	I	3.8	So	3.7	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160062	-69.5	-21.0	Yh	67.3	Zo	25.8	I	6.9	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160063	-69.0	-21.0	I	37.2	Kl	36.4	Yh	18.1	Tv	6.9	Hl	1.4	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160064	-68.5	-21.0	Yh	33.0	Tv	17.5	Zo	14.2	I	11.4	ST	11.1	Xh	6.7	Kl	3.1	Hl	3.1	-	0.0	-	0.0
160065	-68.0	-21.0	I	32.8	Tv	32.8	Yh	11.7	ST	11.1	Xh	6.7	Re	5.0	-	0.0	-	0.0	-	0.0	-	0.0
160066	-67.5	-21.0	Yh	50.5	Re	21.7	I	11.4	Tv	11.4	Xh	5.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160067	-67.0	-21.0	Xh	40.0	Yh	23.3	I	13.3	Tv	13.3	Re	10.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160068	-66.5	-21.0	I	45.0	Tv	45.0	Xh	10.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0
160069	-66.0	-21.0	I	66.7	Tv	33.3	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0

3 Examples of WISE applications

In the context of this paper, three types of products derived form the WISE database are presented. In the first example, the spatial database of WISE was used to map the global, relative extent of Histosols (Fig. 3). Similar thematic maps can easily be generated from ASCII-output generated using the WISE data handling system, in combination with *IDRISI* (1993) and Arc/Info software (see Batjes, 1994). The raster GIS image files and documentation files have the same format as has been adopted for the Global Ecosystems Database (Kineman, 1993).

The second example, in Table 3, uses data held in the WISE soil profile database. It gives statistics on soil carbon densities, for selected depth ranges, of Humic Ferralsols. In this example, an average bulk density of 1.4 g cm^{-3} has been assumed.

Table 3. Average soil organic carbon densities over selected soil depths
(Humic Ferralsols, bulk density assumed to be 1.4 g cm^{-3})

```
layer: 0- 25 cm
------------------------------
N:                17.00
Mean:             10.47
Median:           10.01
Minimum:           4.76
Maximum:          16.70
CV%:              27.74
------------------------------
99%-fiducial limits: 8.41 to 12.52 kg m-2

layer: 25-50 cm
------------------------------
N:                16.00
Mean:              6.32
Median:            6.20
Minimum:           4.30
Maximum:           8.54
CV%:              21.40
------------------------------
99%-fiducial limits: 5.33 to 7.32 kg m-2

layer: 50-100 cm
------------------------------
N:                14.00
Mean:              6.51
Median:            5.88
Minimum:           3.51
Maximum:          11.13
CV%:              29.30
------------------------------
99%-fiducial limits: 4.97 to 8.04 kg m-2
```

```
layer: 0- 50 cm
------------------------------
N:                16.00
Mean:             16.78
Median:           17.36
Minimum:           9.06
Maximum:          27.65
CV%:              25.84
------------------------------
99%-fiducial limits: 13.59 to 19.97 kg m-2

layer: 0-100 cm
------------------------------
N:                14.00
Mean:             22.80
Median:           21.45
Minimum:          16.99
Maximum:          30.17
CV%:              18.06
------------------------------
99%-fiducial limits: 19.49 to 26.12 kg m-2
```

CV is the coefficient of variation.

In more detailed follow up studies, however, regression functions will be used for calculating bulk densities in the case where these data are missing for a particular horizon (For our Humic Ferralsols: BULKDENS (g cm^{-3}) = 1.5077 - 0.0990*ORGC(%) - 0.0058*CLAY(%) + 0.0029*SILT(%); r^2= 0.775^{***} (F= 19.59); n= 20). In these follow up studies it will also be assessed if data for a particular soil unit can be stratified using, for example, the Köppen climate or parent material. Once statistics for a particular attribute have been computed for each soil unit (in a particular region), the outcome can readily be combined with the area database file to prepare a global inventory of, for example, soil organic carbon pools:

$$\text{Organic-C pool} = \sum_{1}^{n}(A_{ij} * R_{ik})$$

where:

- A_{ij}= extent of soil $unit_i$ in grid $cell_j$
- R_{ik}= average carbon density for soil $unit_i$ (evt., in $region_k$)
- n= number of the ½° x ½° grid cell in the spatial database

Finally, an inventory of soils with high methane emission potentials was made. In figure 4, only the soil properties have been considered, using simple algorithms. Emission of methane by natural and agricultural wetlands, however, is a direct result of soil bacterial activity, influenced by temperature, floodwater regime, organic amendments, root exudates, plant physiology, cultural practices and soil physical, chemical and biological properties (see reviews by *Bouwman*, 1990; *Neue and Sass*, 1994b). It is the net result of competing bacterial processes of production and consumption or oxidation, and also of two opposing plant-biophysical processes, transport of oxygen to the rhizosphere and transport of methane from the rhizosphere to the plant. These processes may well show independent responses to the same environmental forcing functions (*Neue and Sass*, 1994a). Only further integration of mechanistic modelling of methane fluxes with GIS-layers of factors controlling these processes will improve global estimates and predictions (*Neue and Sass*, 1994b). Many of the necessary auxiliary databases, however, are not yet available at scale ½° x ½°(see *Batjes et al.*, 1994). Furthermore, additional research is needed to fully understand the non-linear processes controlling the production and absorption of methane, and ultimately its emission to the atmosphere. This remains an important task of the IGAC Rice Group (*Neue and Sass*, 1994a).

4 Discussion

Given WISE's dependence upon existing soil data sources, the accuracy of the spatial and attribute data will be largely predetermined and will vary according to the quality of the "source materials" (*Van Reeuwijk*, 1983; *Pleijsier*, 1989). It will not always be possible to obtain complete data sets for each profile (*Msanya*, 1987). Certain physical soil attributes are seldom collected on a routine basis, particularly water retention versus tension relationships, and the unsaturated hydraulic conductivity. The solution then is to estimate these relationships from available soil data, such as particle-size distribution, organic-C content, and bulk density, through pedotransfer functions. Accuracy of the prediction of individual pedotransfer functions varies strongly with the functions used (*Tietje and Tapkenhinrichs*, 1993). Comparison of results of analytical results obtained with different analytical procedures often remains problematic (*Vogel*, 1994), highlighting the importance of specifying the analytical procedures in a global soil database. The question that arises is what variance in soil analytical data is acceptable for applications at a particular scale. At the macro-scale, this may well not be the largest source of errors, an aspect that deserves further research.

The initial use of a limited number of representative soil profiles in a 1:5 M mapping exercise implies a simplification of the natural variability observed in soil characteristics. The uncertainties associated with spatial and temporal variability of soil properties at different scales (*Bouma and Bregt*, 1989; *Mausbach and Wilding*, 1991; *Bregt*, 1992) and the development and parameterization of procedures for "scaling-up" site gas flux data to the macro-level in a geographical information system are still inadequately understood (*Rosswall et al.*, 1988; *Walker and Graetz*, 1988; *Burrough*, 1989).

Also important is the regional accuracy and reliability of the geographic base map from which the spatial data are derived. Spatial data for global maps typically are collected from a variety of sources, creating a source of heterogeneity. Because of cartographic generalization, a map only reflects a representation of reality at the considered scale. Assessing map accuracy and the accuracy of results, derived from the overlay of various maps and other spatial data types of either known or unknown accuracy, remains an important topic of research (*Estes et al.*, 1992; *Smith et al.*, 1987). In the WISE project it is recognized that parts of the Soil Map of the World are out of date (*FAO*, 1991), yet this global map holds the best spatial data available today. Had global coverage by SOTER been available, the WISE database development activities would have benefitted from it greatly! In using physiographically defined terrain and soil components, as opposed to essentially taxonomically defined soil mapping units, the SOTER approach will provide a better geographical basis for studies of environmental change than has been possible so far.

The WISE database is being developed for a suite of studies at the global level, such as an assessment of soil emission potentials for biotic greenhouse gases, a refined estimate of soil carbon pools, as well as studies of the vulnerability of soils to pollution. These studies will be based on a more extensive and uniform soil data set than has been available so far. Auxiliary databases on climate, land use and vegetation cover are needed also for these studies, yet not always available at a compatible resolution.

5 Conclusions

Although attempts have been made in the past to use the FAO-Unesco Soil Map of the World as a basis for determining the nature of the soil cover for modelling purposes, the resolution used was coarse and the potential of the map as a source of information was only partially exploited (e.g., *Zobler*, 1986). The griding procedure developed by FAO staff as part of the WISE project has greatly increased the amount of information about the world soil pattern which can be derived from the FAO-Unesco Soil Map of the World at a scale of 1:5 M, and ½° x ½° resolution. The WISE database has assembled, in a uniform manner, over 3600 soil profiles with their site, morphological, chemical and physical attributes in a single user-friendly data base. This represents a major achievement in soil science and it should provide a useful international soil profile data set for global modelling purposes.

As the WISE project nears completion, requests for data held in the database are already being received (e.g., *Scholes et al.*, 1994). Some immediate applications are being investigated in the context of the WISE project, but many of the opportunities provided by the existence of such a database remain to be exploited in the future. In collaboration with modellers of the IMAGE group (e.g., *Leemans and van den Born*, 1994), a proposal for follow up studies has been formulated for implementation under the second phase of the Netherlands National Research Programme on Global Change and Air Pollution (NOP).

Through the development of databases such as ISIS, SOTER and WISE and database applications, the International Soil Reference and Information Centre is strengthening its user-servicing capability as ICSU World Data Centre on Soil Geography and Classification.

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Appendix 1. List of Attributes of the WISE Profile Database

Site Data

- WISE_ID (unique identifier of profile)

- Soil classification and source
  - FAO-Unesco classification (1974 legend)
    - phase
    - topsoil texture class
  - FAO classification (1990 revised legend)
    - phase
  - USDA subgroup level classification
    - edition (year) of USDA Soil Taxonomy
  - local classification
  - source of data
  - name of laboratory where analyses were made
  - soil profile description status
  - date of description

- Location
  - country
  - location of soil profile, descriptive
  - latitude (deg/min/s)
  - longitude (deg/min/s)
  - altitude

- General site data
  - major landform
  - landscape position
  - aspect
  - slope
  - drainage class
  - groundwater depth
  - effective soil depth
  - parent material
  - Köppen climate classification
  - land use
  - natural vegetation

Horizon Data

- WISE_ID + horizon_NO (unique reference number for horizon within a profile)

- General attributes
  - horizon designation
  - depth, top
  - depth, bottom
  - matrix color (dry and moist)
  - mottling
  - presence of roots

- Chemical attributes*
  - organic carbon
  - total N
  - available P
  - pH-H_2O
  - pH-KCl
  - pH-$CaCl_2$
  - electrical conductivity (EC)
  - free $CaCO_3$
  - $CaSO_4$
  - exchangeable Ca^{2+}
  - exchangeable Mg^{2+}
  - exchangeable Na^+
  - exchangeable K^+
  - exchangeable Al^{3+} + H^+ (exchangeable acidity)
  - exchangeable Al^{3+} (exchangeable aluminum)
  - cation exchange capacity (CEC)
  - effective CEC (at field pH)
  - base saturation (as percent of CEC)

- Physical attributes*
  - structure type
  - particle size distribution:
    - weight % sand
    - weight % silt
    - weight % clay
  - stone and gravel content
  - bulk density
  - volume per cent water held at specified suctions
  - hydraulic conductivity at specified suctions

---

* Analytical methods are specified in a separate key-attribute file.

Appendix 2. Example of WISE Listing

```
ID022                         W I S E   S O I L   P R O F I L E   D A T A   S H E E T                         02/08/94
                              ===================================================

SOIL CLASSIFICATION:
  FAO-Unesco Legend (1974):        Gleyic Acrisol (Ag)       Phase: -- (-)              Topsoil texture: medium (M)
  FAO-Unesco Legend (1988):        Gleyic Alisol (ALg)       Phase: -- (-)
  USDA Soil Taxonomy (1987):       Aquic Paleudult
  Local Classification System:     --

SOURCES:
  Source_ID:          AS4/65       Ref. page:     Annex 2, p 43, profile 22.
  Lab_ID:             ID01         Descr. status: reference pedon (1)
  Desc. (MM/YY):      06/88

SITE DATA:
  Location:           25 km N.W. Balikpapan, East Kalimantan (Indonesia)
  Coordinates:        Lat.: S  00 deg. 42 min. 15 sec.        Lon.: E 116 deg. 42 min. 45 sec.
  Altitude:           115 m
  Landform:           valley floor (slope 0-8 %; relief int. < 100 m/km) (LV)
  Position:           intermediate part (IN)
  Aspect:             NE
  Slope:              5 %
  Drainage class:     somewhat poorly drained (I)
  Groundwater:        -1 to  -1 (cm)
  Eff. soil depth >   150 (cm)
  Parent material:    sandstone, greywacke, arkose (SC2)    (Remarks: Sandstone)
  Köppen climate:     Equatorial humid with no dry season (driest month > 60 mm; Tcm > 18C) (Af)
  Land use (LU):      selective felling (FN1)
  Main crop:          -- (-)
  Vegetation (VE):    evergreen forest (FE)
  Remarks on LU/VE:   Tropical rainforest - logged.

HORIZON DATA:
------------------------------------------------------------------------------------------------------------------------
Horiz.  Depth    Org.   Tot.  Av.        pH          ECx    CACO  GYPS          Exch. bases and acidity        CEC    ECEC  BS
                  C      N     P   --------------            3     UM   -------------------------------     ---------
Desig.  (cm)     (%)    (%)        H2O  KCl CaCl2           (%)   (%)   Ca    Mg    K     Na    Ac    Al   (meq/100g)  (%)
------------------------------------------------------------------------------------------------------------------------
Ah        0-  5  4.60   0.34  26.3  5.5  4.6 -1.0  -1.00   -1.0  -1.0   2.6   1.6   0.4   0.1   0.4   0.3  14.8   5.0  32
E         5- 38  0.70   0.09   4.5  4.4  3.6 -1.0  -1.00   -1.0  -1.0   0.4   0.3   0.2   0.1   6.8   6.4  11.4   7.4   8
Btg1     38- 68  0.37   0.07   3.4  4.6  3.7 -1.0  -1.00   -1.0  -1.0   0.4   0.3   0.2   0.1   6.4   5.8  11.4   6.8   8
Btg2     68-150  0.27   0.05   3.2  4.6  3.7 -1.0  -1.00   -1.0  -1.0   0.4   0.3   0.2   0.1   6.8   6.3  12.0   7.3   8
------------------------------------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------------------------------
Horiz.      Colour        M  R ST Sand Silt Clay  GR    Bd      % vol/vol moisture held at a pF of          AWC    HCs   HCu
        --------------            (%)  (%)  (%)  (%)        ------------------------------------------- (%v/v)  (cm/hr)
Desig.  Dry     Moist                                     0.0 1.0 1.5 1.7 2.0 2.3 2.5 2.7 3.4 3.7 4.2
------------------------------------------------------------------------------------------------------------------------
Ah       -     10YR3/3   C MX GR  34   41   25   -1  1.03  61  -1  -1  47  -1  -1  46  -1  -1  -1   7    39    -1.0  -1.0
E        -     10YR5/4   N CX AB  33   35   32   -1  1.40  47  -1  -1  41  -1  -1  40  -1  -1  -1  12    28    -1.0  -1.0
Btg1     -     10YR5/6   C FX AB  38   27   35   -1  1.47  46  -1  -1  41  -1  -1  40  -1  -1  -1  21    19    -1.0  -1.0
Btg2     -     10YR5/8   C FM AB  47   23   30   -1  1.50  44  -1  -1  39  -1  -1  39  -1  -1  -1  20    19    -1.0  -1.0
------------------------------------------------------------------------------------------------------------------------
  * Abbr.: Available P as mg P2O5/kg soil; ECx= electrical conductivity in dS/m; Ac= exchangeable (H + Al) in meq/100g;
           BS= base saturation as % of CEC; M= mottles; R= roots; ST= structure; GR = % > 2mm size; Bd= bulk density
           (g/cm3); HC= hydr. conduct., saturated (HCs) resp. unsaturated (HCu) in cm/hr; AWC = av. moisture in % v/v;
           -1 stands for missing numeric values and - for missing alphanumeric values.

REMARKS:
    Acid; argic; mottling in surface and below 38cm depth.
```

REFERENCES:

(Cont. for ID020)

a) Source of profile data [AS4/65]:
Van Bremen, H., Iriansyah, M. and Andriesse, W. 1990. Detailed Soil Survey and Site Characteristics in 12 permanent plots in East Kalimantan. Tropenbos Foundation, Ede.

b) Laboratory name and methods [ID01]:
Centre for Soil Research, Bogor, Indonesia.

Analytical method	Code and description
Organic Carbon:	OC01: Method of Walkley-Black (Org. matter = Org. C x 1.72)
Total Nitrogen:	TN01: Method of Kjeldahl
Available P:	TP02: Method of Bray I (dilute HCl/NH4F)
pH-H_2O:	PH02: pH 1:2.5 soil/water solution
pH-KCl:	PK02: pH in 1:2.5 soil/ M KCl solution
pH-CaCl2:	PC--: Not measured
Electr. conductivity:	EL--: Not measured
CaCO3 content:	CA--: Not measured
Gypsum content:	GY--: Not measured
Exch. Ca, Mg, Na and K:	EX01: Various methods with no apparent differences in results
Exch. acidity and aluminum:	EA01: Exchangeable acidity (H+Al) in 1 M KCl
CEC soil:	CS01: CEC in 1M NH4OAc buffered at pH 7
Effective CEC:	CE01: Sum of exch. Ca, Mg, K and Na, plus exchangeable aluminium (in 1M KCl)
Base saturation:	BS01: Sum of bases as percentage of CEC (method specified above)
Particle size analysis:	TE01: Pipette method, with appropriate dispersion treatment (c< 0.002 <si< 0.05 <sa< 2mm)
Bulk density:	BD01: Core sampling (pF rings)
Soil moisture content:	MC01: sand/silt baths and porous plates, undisturbed samples (pF rings)
Hydraulic conductivity:	HC--: Not measured

Appendix 3. Overview of Soil Profiles Held in WISE per FAO-Unesco Soil Unit
(Total of 3673 per September 1994).

A: ACRISOLS
Af= 74 Ag= 12 Ah= 42 Ao= 55 Ap= 23 [206]

B: CAMBISOLS
Bc= 20 Bd= 65 Be= 112 Bf= 17 Bg= 43 Bh= 36 Bk= 90 Bv= 39 Bx= 14 [436]

C: CHERNOZEMS
Cg= 0 Ch= 23 Ck= 32 Cl= 14 [69]

D: PODZOLUVISOLS
Dd= 4 De= 3 Dg= 1 [8]

E: RENDZINAS
E = 33 [33]

F: FERRALSOLS
Fa= 17 Fh= 21 Fo= 67 Fp= 5 Fr= 33 Fx= 35 [178]

G: GLEYSOLS
Gc= 14 Gd= 51 Ge= 74 Gh= 31 Gm= 37 Gp= 3 Gx= 3 [213]

H: PHAEOZEMS
Hc= 16 Hg= 12 Hh= 30 Hl= 72 [130]

I: LITHOSOLS
I = 8 [8]

J: FLUVISOLS
Jc= 134 Jd= 26 Je= 156 Jt= 20 [336]

K: KASTANOZEMS
Kh= 13 Kk= 14 Kl= 1 [28]

L: LUVISOLS
La= 25 Lc= 84 Lf= 78 Lg= 96 Lk= 144 Lo= 115 Lp= 9 Lv= 14 [565]

M: GREYZEMS
Mg= 1 Mo= 1 [2]

N: NITOSOLS
Nd= 21 Ne= 35 Nh= 11 [67]

O: HISTOSOLS
Od= 34 Oe= 13 Ox= 3 [50]

P: PODZOLS
Pf= 2 Pg= 14 Ph= 16 Pl= 9 Po= 26 Pp= 10 [77]

Q: ARENOSOLS
Qa= 11 Qc= 178 Qf= 88 Ql= 35 [312]

R: REGOSOLS
Rc= 24 Rd= 31 Re= 39 Rx= 1 [95]

S: SOLONETZES
Sg= 14 Sm= 5 So= 25 [44]

T: ANDOSOLS
Th= 61 Tm= 19 To= 15 Tv= 13 [108]

U: RANKERS
U = 8 [8]

V: VERTISOLS
Vc= 108 Vp= 119 [227]

W: PLANOSOLS
Wd= 10 We= 21 Wh= 1 Wm= 8 Ws= 19 Wx= 0 [59]

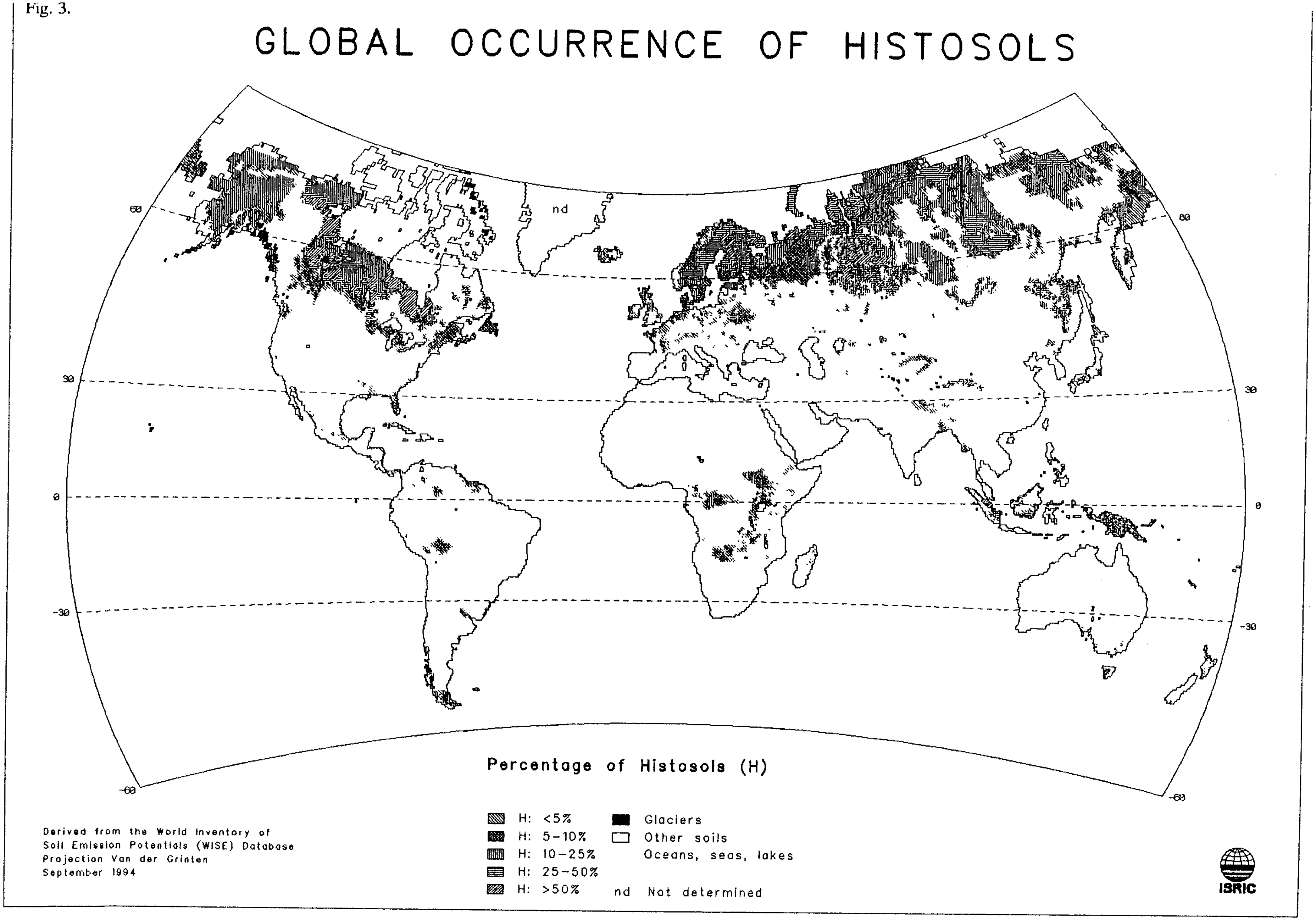
X: XEROSOLS
Xh= 15 Xk= 11 Xl= 78 Xy= 3 [107]

Y: YERMOSOLS
Yh= 6 Yk= 11 Yl= 9 Yt= 1 Yy= 11 [38]

Z: SOLONCHAKS
Zg= 21 Zm= 2 Zo= 37 Zt= 2 [62]

For abbreviations of FAO-Unesco soil units see FAO-Unesco (1974); Excluding the ≈ 650 USDA-SCS profiles.

Fig. 3.



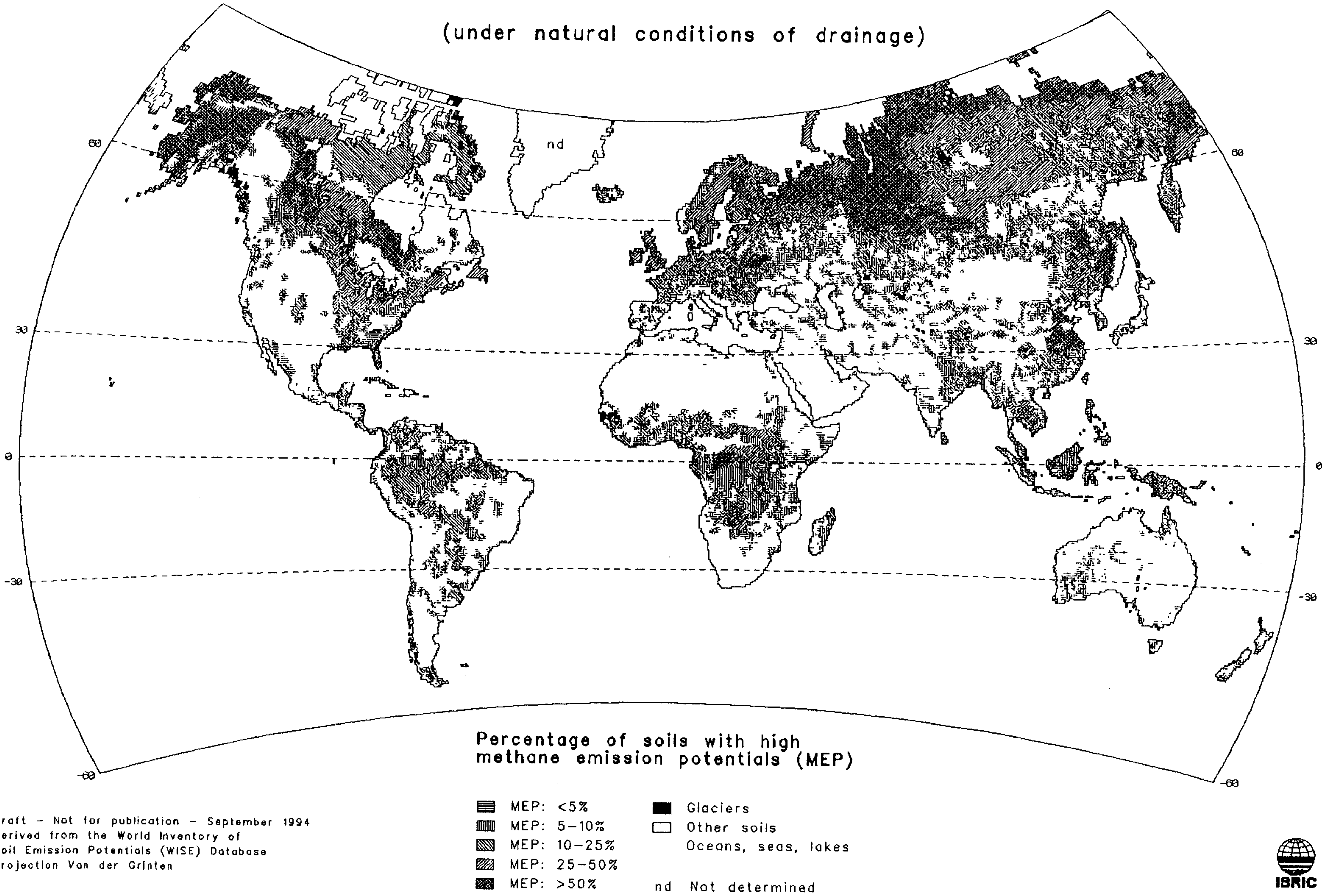
GLOBAL OCCURRENCE OF HISTOSOLS

Derived from the World Inventory of
Soil Emission Potentials (WISE) Database
Projection Van der Grinten
September 1994

Fig. 4.

INVENTORY OF SOILS WITH HIGH METHANE EMISSION POTENTIALS

(under natural conditions of drainage)



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