GUIDELINES FOR
SOIL DESCRIPTION

FAO
FIAT PANIS

Guidelines for **soil description**

Fourth edition

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List of acronyms

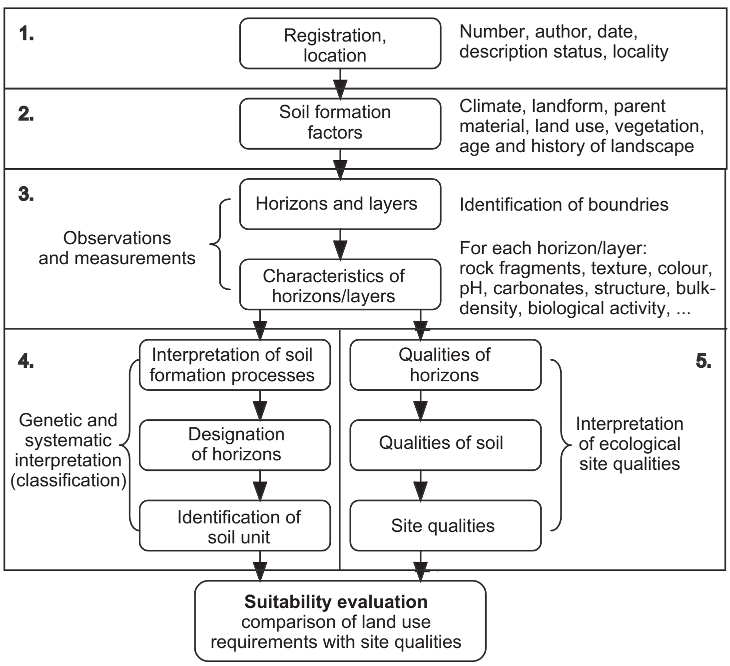
EC	Electrical conductivity
GPS	Global Positioning System
HDPE	High-density polyethylene
HTM	Human-transported material
ISO	International Organization for Standardization
PVC	Polyvinyl chloride
RSG	Reference Soil Group
USDA	United States Department of Agriculture
UTM	Universal Transverse Mercator
WRB	World Reference Base for Soil Resources

Chapter 1
Introduction

The main objective of research in soil science is the understanding of the nature, properties, dynamics and functions of the soil as part of landscapes and ecosystems. A basic requirement for attaining that objective is the availability of reliable information on soil morphology and other characteristics obtained through examination and description of the soil in the field.

It is important that soil description be done thoroughly; it serves as the basis for soil classification and site evaluation as well as interpretations on the genesis and environmental functions of the soil. A good soil description and the derived knowledge on the genesis of the soil are also powerful tools to guide, help explain and regulate costly laboratory work. It can also prevent errors in soil sampling. Figure 1 shows the role of soil description as an early step to classification, soil and site assessment, and suitability evaluation.

FIGURE 1
The process of soil description, classification, site quality and suitability evaluation



Soils are affected by human activities, such as industrial, municipal and agriculture, that often result in soil degradation and loss or reduction in soil functions. In order to prevent soil degradation and to rehabilitate the potentials of degraded soils, reliable soil data are the most important prerequisite for the design of appropriate land-use systems and soil management practices as well as for a better understanding of the environment.

With the present internationalization, the use of a common language is of prime importance, also in soil science. The increasing need for internationally accepted rules and systems of soil description and soil classification led to the development of various soil classification concepts, e.g. the FAO–UNESCO *Legend for the Soil Map of the World* (FAO–UNESCO, 1974, 1988) and *Soil Taxonomy* (USDA Soil Survey Staff 1975, 1999), and soil maps, e.g. the *Soil Map of the World* (FAO–UNESCO, 1970–1981; FAO, 2002), *Soil Map of the European Communities* (ECSC–EEC–EAEC, 1985), and *Soil Atlas of Europe* (EC, 2005).

These guidelines are based on the internationally accepted *Guidelines for Soil Description* (FAO, 1990). Some new international developments in soil information systems and soil classification, such as the *Field Book for Describing and Sampling Soils* (Schoeneberger *et al.*, 2002) and *Keys to Soil Taxonomy* (USDA Soil Survey Staff, 2003), *Updated Global and National Soils and Terrain Digital Databases* (ISRIC, 2005) and the second edition of the *World Reference Base for Soil Resources* (IUSS Working Group WRB, 2006) are taken into consideration. For practical reasons, the contents of the major sources were modified, shortened and rearranged.

Specifically, the various chapters of this field guide were based on the following sources:

- Chapter 2 on general site description – *Guidelines for Soil Description* (FAO, 1990).
- Chapter 3 on the description of soil forming factors – *Guidelines for Soil Description* (FAO, 1990); updated SOTER (ISRIC, 2005); *Field Book for Describing and Sampling Soils* (Schoeneberger *et al.*, 2002); and *Keys to Soil Taxonomy* (USDA Soil Survey Staff, 2003).
- Chapter 4 on soil description – *Guidelines for Soil Description* (FAO, 1990) and partly the German Mapping Guide 5 (Kartieranleitung 5; Ad-hoc-AG-Boden, 2005), the material of DVWK (1995), *Field Book for Describing and Sampling Soils* (Schoeneberger *et al.*, 2002), as well as the personal experiences of the authors.
- Chapter 5 on horizon designation and soil classification – *Guidelines for Soil Description* (FAO, 1990), *Field Book for Describing and Sampling Soils* (Schoeneberger *et al.*, 2002), *Keys to Soil Taxonomy* (USDA Soil Survey Staff, 2003) and the second edition of the *World Reference Base for Soil Resources* (IUSS Working Group WRB, 2006).

To help beginners, some explanatory notes are included as well as keys based on simple tests and observations for the determination of soil characteristics.

The guidelines provide a complete procedure for soil description and for collecting field data necessary for classification according to second edition of the

World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB, 2006). Notes for classification purposes are added to each chapter and explain the relevance of the described feature for classification according to the WRB. In order to avoid being excessively lengthy, it is not stated whether the described feature is a required one or is one of two or more options.

Chapter 2

General site information, registration and location

Before any actual soil description should be done, it is necessary to take note of some relevant information related to the registration and identification of the soil to be described, such as profile number, description status, date of description, author, location, elevation, map sheet number, and grid reference. This information is necessary for easy referencing and retrieval of the soil description from data storage systems.

PROFILE NUMBER

The profile number or profile identification code should be constructed in such a way that it meets local needs and also allows easy and simple retrieval of profile descriptions from computerized data storage systems. The profile identification code should be constructed from a combination of a location letter code and a profile number code. The letter code should consist of a practical selection of codes referring to a country, preferably the internationally accepted International Organization for Standardization (ISO) code, a topographic map reference or any other defined area or town. Example: DE/ST/HAL -0381 = Halle in Saxony-Anhalt in Germany, profile 381.

SOIL PROFILE DESCRIPTION STATUS

The status of the soil profile description refers to the quality of the soil description and the analytical data. The status is allocated after completion of the analyses and is indicative of the reliability of soil profile information entered into a database. Table 1 lists the possible descriptions.

DATE OF DESCRIPTION

It is important to always indicate the date of description in order to inform future users of the soil data as to how old the data are. The date of description is given as: yymmdd (six digits). For example, 8 January 2006 would be coded 060108.

AUTHORS

The persons who perform the description need to be acknowledged properly in future uses of the soil data. In addition, they hold responsibility for the quality of the data. The names or initials of the authors are given.

TABLE 1
Soil profile description status

	Status	
1	Reference profile description	No essential elements or details are missing from the description, sampling or analysis. The accuracy and reliability of the description and analytical results permit the full characterization of all soil horizons to a depth of 125 cm, or more if required for classification, or down to a C or R horizon or layer, which may be shallower.
1.1		If soil description is done without sampling.
2	Routine profile description	No essential elements are missing from the description, sampling or analysis. The number of samples collected is sufficient to characterize all major soil horizons, but may not allow precise definition of all subhorizons, especially in the deeper soil. The profile depth is 80 cm or more, or down to a C or R horizon or layer, which may be shallower. Additional augering and sampling may be required for lower level classification.
2.1		If soil description is done without sampling.
3	Incomplete description	Certain relevant elements are missing from the description, an insufficient number of samples was collected, or the reliability of the analytical data does not permit a complete characterization of the soil. However, the description is useful for specific purposes and provides a satisfactory indication of the nature of the soil at high levels of soil taxonomic classification.
3.1		If soil description is done without sampling.
4	Soil augering description	Soil augerings do no permit a comprehensive soil profile description. Augerings are made for routine soil observation and identification in soil mapping, and for that purpose normally provide a satisfactory indication of the soil characteristics. Soil samples may be collected from augerings.
4.1		If soil description is done without sampling.
5	Other descriptions	Essential elements are missing from the description, preventing a satisfactory soil characterization and classification.

Note: Descriptions from soil augerings or from other observations made for routine soil mapping are either kept on ordinary field data sheets or included in the database, with an appropriate indication of status.

LOCATION

A description of the soil location should be given. It should be as precise as possible in terms of the distance (in metres or kilometres) and direction to the site from permanent features that are recognizable in the field and on the topographic map. Distances along roads or traverses relate to a marked reference point (0.0 km). The description of the location should be such that readers who are unfamiliar with the area are able to locate the approximate position of the site. The administrative units, such as region, province, district, country or locality, are given in the profile number section (above). Example: Agricultural research station Bad Lauchstädt, Sachsen-Anhalt.

ELEVATION

The elevation of the site relative to sea level should be obtained as accurately as possible, preferably from detailed contour or topographic maps. Where such information is not available, the best possible estimate is made from general maps or by altimeter readings. At present, determination of elevation by the Global Positioning System (GPS) unit is inaccurate and unacceptable. Elevation is given in metres (1 foot = 0.3048 m).

MAP SHEET NUMBER AND GRID REFERENCE (COORDINATES)

The number of the topographic map sheet, preferably at 1:25 000 or 1:50 000 scale, on which the soil observation occurs is given. Example: TK50 L4536 Halle (Saale) = Topographic map 1:50 000 Number L4536 of Halle.

The grid reference number, Universal Transverse Mercator (UTM) or the established local system, can be read directly from the topographic map. The latitude and longitude of the site are given as accurately as possible (in degrees, minutes, seconds and decimal seconds); they can be derived directly from topographic maps or a GPS unit. Example: H: 56.95.250 or latitude: 51° 23´ 30.84´´ N; R: 44.91.600 or longitude: 11° 52´ 40.16´´ E.

Some countries use their own zero longitude, e.g. Italian topographic maps show the Monte Mario meridian at Rome as zero. For international use, these should be converted to the zero meridian of the Greenwich system.

Chapter 3
Soil formation factors

This chapter provides the guidelines for the description of factors that define the kind and intensity of soil formation processes. These factors are also part of the important site qualities.

The information may be derived from a combination of field measurements, climate records, field observations and evaluation of climate, topographical, geological and geomorphological maps and documents. For land use and vegetation, the present conditions are reported.

ATMOSPHERIC CLIMATE AND WEATHER CONDITIONS

The climate conditions of a site are important site properties that influence plant growth and soil formation. As minimum climate data, the monthly mean temperature (in degrees Celsius) and the monthly mean precipitation (in millimetres) can be taken from the nearest meteorological station.

Where available, the length of the growing period (in days) should be specified. The length of the growing period is defined as the period with humid conditions (excess of precipitation over potential evapotranspiration) during the time with temperature ≥ 5 °C (FAO, 1978).

The present as well as the weather conditions days or weeks before the description influence soil moisture and structure, hence these should be noted. In addition, the prevailing general weather conditions and the air temperature at the time of observation as well as that of the near past should be documented (Table 2).

TABLE 2
Codes for weather conditions

Present weather conditions (Schoeneberger *et al.*, 2002)	
SU	sunny/clear
PC	partly cloudy
OV	overcast
RA	rain
SL	sleet
SN	snow
Former weather conditions (Ad-hoc-AG-Boden, 2005)	
WC 1	no rain in the last month
WC 2	no rain in the last week
WC 3	no rain in the last 24 hours
WC 4	rainy without heavy rain in the last 24 hours
WC 5	heavier rain for some days or rainstorm in the last 24 hours
WC 6	extremely rainy time or snow melting

Note: For example: SU, 25 °C; WC 2 (= sunny, temperature 25 °C, no rain in the last week).

SOIL CLIMATE

Where applicable, the soil climate classification should be indicated. The soil moisture and temperature regimes according to *Keys to Soil Taxonomy* (USDA Soil Survey Staff, 2003) may be mentioned (Table 3; explanations in Annexes 1 and 2). Where such information is not available or cannot be derived from representative climate data with confidence, it is preferable to

TABLE 3
Soil temperature and moisture regime codes

Soil temperature regime				Soil moisture regime			
PG	= Pergelic			AQ	= Aquic	PQ	= Peraquic
CR	= Cryic			DU	= Udic	PU	= Perudic
FR	= Frigid	IF	= Isofrigid	US	= Ustic		
ME	= Mesic	IM	= Isomesic	XE	= Xeric		
TH	= Thermic	IT	= Isothermic	AR	= Aridic and	TO	= Torric
HT	= Hyperthermic	IH	= Isohyperthermic				

leave the space blank. Other agroclimate parameters worth mentioning would be a local climate class, the agroclimate zone, length of growing period, etc.

Note for classification purposes

✓ Soil temperature < 0 °C (pergelic soil temperature regime) → cryic horizon and Gelic qualifier.

LANDFORM AND TOPOGRAPHY (RELIEF)

Landform refers to any physical feature on the earth's surface that has been formed by natural processes and has a distinct shape. Topography refers to the configuration of the land surface described in four categories:

- the major landform, which refers to the morphology of the whole landscape;
- the position of the site within the landscape;
- the slope form;
- the slope angle.

Major landform

Landforms are described foremost by their morphology and not by their genetic origin or processes responsible for their shape. The dominant slope is the most important differentiating criterion, followed by the relief intensity (Table 4). The relief intensity is the median difference between the highest and lowest point within the terrain per specified distance. The specified distance can be variable. The relief intensity is normally given in metres per kilometre.

With complex landforms, the protruding landform should be at least 25 m high (if not it is to be considered mesorelief) except for terraced land, where the main terraces should have elevation differences of at least 10 m. In areas, the major terraces may be very close to each other – particularly towards the lower part of the plain. Finally, the older levels may become buried by down wash. For complex landforms, subdivisions can be used (Table 5). These subdivisions are mainly applicable to level landforms, to some extent to sloping landforms and, in the case of mountains, to intermontane plains.

Position

The relative position of the site within the land should be indicated. The position affects the hydrological conditions of the site (external and internal drainage, e.g.

TABLE 4
Hierarchy of major landforms

1st level	2nd level	Gradient (%)	Relief intensity (m km^{-1})	Potential drainage density
L level land	LP plain	< 10	< 50	0–25
	LL plateau	< 10	< 50	0–25
	LD depression	< 10	< 50	16–25
	LV valley floor	< 10	< 50	6–15
S sloping land	SE medium-gradient escarpment zone	10–30	50–100	< 6
	SH medium-gradient hill	10–30	100–150	0–15
	SM medium-gradient mountain	15–30	150–300	0–15
	SP dissected plain	10–30	50–100	0–15
	SV medium-gradient valley	10–30	100–150	6–15
T steep land	TE high-gradient escarpment zone	> 30	150–300	< 6
	TH high-gradient hill	> 30	150–300	0–15
	TM high-gradient mountain	> 30	> 300	0–15
	TV high-gradient valley	> 30	> 150	6–15

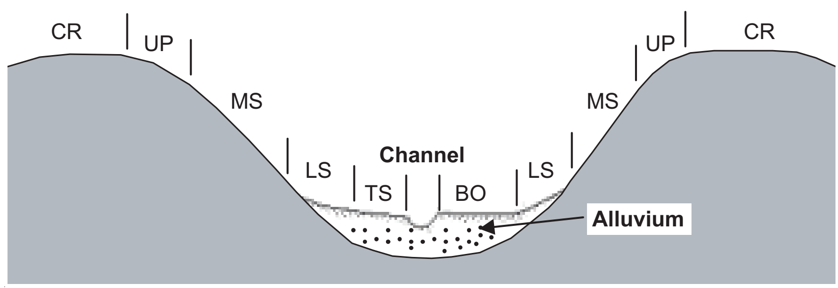
Notes:
Changes proposed at the SOTER meeting at Ispra, October 2004.
Potential drainage density is given in number of "receiving" pixels within a 10 × 10 pixels window.
Source: Updated SOTER, ISRIC, 2005.

TABLE 5
Subdivisions for complex landforms

CU	= Cuesta-shaped	DO	= Dome-shaped
RI	= Ridged	TE	= Terraced
IN	= Inselberg covered (occupying > 1% of level land)	DU	= Dune-shaped
IM	= With intermontane plains (occupying > 15%)	KA	= Strong karst
WE	= With wetlands (occupying > 15%)		

Source: Updated SOTER, ISRIC, 2005.

FIGURE 2
Slope positions in undulating and mountainous terrain



Note:

Position in undulating to mountainous terrain
CR = Crest (summit)
UP = Upper slope (shoulder)
MS = Middle slope (back slope)
LS = Lower slope (foot slope)
TS = Toe slope
BO = Bottom (flat)

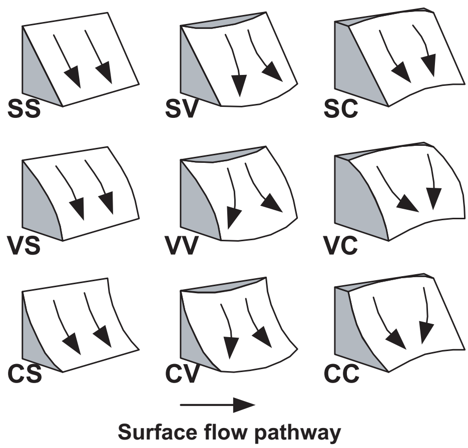
Position in flat or almost flat terrain
HI = Higher part (rise)
IN = Intermediate part (talf)
LO = Lower part (and dip)
BO = Bottom (drainage line)

Source: Redrawn from Schoeneberger *et al.*, 2002.

TABLE 6
Classification of slope forms

S	straight
C	concave
V	convex
T	terraced
X	complex (irregular)

FIGURE 3
Slope forms and surface pathways



Source: Redrawn from Schoeneberger *et al.*, 2002.

TABLE 7
Slope gradient classes

Class	Description	%
01	Flat	0–0.2
02	Level	0.2–0.5
03	Nearly level	0.5–1.0
04	Very gently sloping	1.0–2.0
05	Gently sloping	2–5
06	Sloping	5–10
07	Strongly sloping	10–15
08	Moderately steep	15–30
09	Steep	30–60
10	Very steep	> 60

subsurface runoff), which may be interpreted as being predominantly water receiving, water shedding or neither of these.

Slope form

The slope form refers to the general shape of the slope in both the vertical and horizontal directions (Figure 3). Table 6 lists the slope form classes.

Slope gradient and orientation

The slope gradient refers to the slope of the land immediately surrounding the site. It is measured using a clinometer aimed in the direction of the steepest slope. Where clinometer readings are not possible, field estimates of slope gradient should be matched against calculated gradients from contour maps.

Slope gradients in almost flat terrain are often overestimated. In open plains, slope gradients of 0.2 percent are usually clearly visible. The proper recording of minor slope-gradient variations is important, especially for erosion, irrigation and drainage.

The slope gradient is recorded in two ways. The first and most important is by means of the actual, measured value, and the second by entering in one of the following classes; they may need to be modified to fit the local topography (Table 7).

In addition to the attributes of slope in Table 7, both the slope length (particularly above the site) and aspect (orientation) should be recorded. The orientation influences, for example, the precipitation input, the temperature regime, the risk for wind impact and the character of humus formed in higher latitudes.

The orientation that a slope is facing is coded N for north, E for east, S for south and W for west; for example, SSW means south-southwest.

LAND USE AND VEGETATION

Land use

Land use applies to the current use of the land, whether agricultural or non-agricultural, in which the soil is located. Land use has a major influence on the direction and rate of soil formation; its recording enhances the interpretative value of the soil data considerably (Table 8).

For arable land use, the dominant crops grown should be mentioned (section on crops [below]), and as much information as possible given on soil management, use of fertilizers, duration of fallow period, rotation systems and yields.

Crops

Crops are plants that are cultivated for their economic value. Information on crops is important because it gives an idea of the nature of soil disturbance as a result of crop management practices as well as the nutrient and soil management requirements of the crop. Information on crops can be given in a general or detailed way as required. Examples for the most common crops with their recommended codes are given in Table 9.

Human influence

This item refers to any evidence of human activity that is likely to have affected the landscape or the physical and chemical properties of the soil. Erosion is dealt with separately in Chapter 4. For various environments, it is useful to indicate the degree of disturbance of the natural vegetation. The existing vegetation is described in the section on vegetation (below).

Examples of human influences with their recommended codes are given in Table 10.

Note for classification purposes

- ✓ Constructed terraces → Escalic qualifier.
- ✓ Raised land surfaces → plaggic and terric horizons.
- ✓ Ploughing → anthraquic and anthric horizons and Aric qualifier.
- ✓ Special depth limits if plough layers are present → Fluvisols, Chernozems and Cambisols.
- ✓ Special requirements if an eluvial horizon is part of a plough layer → argic and natric horizons.
- ✓ Does not form part of a plough layer → cambic horizon.
- ✓ Mixing or soil layers or lumps of applied lime → anthric horizon.
- ✓ Spade marks → plaggic horizon.

TABLE 8
Land-use classification

A	**= Crop agriculture (cropping)**		
	AA	= Annual field cropping	
		AA1	= Shifting cultivation
		AA2	= Fallow system cultivation
		AA3	= Ley system cultivation
		AA4	= Rainfed arable cultivation
		AA5	= Wet rice cultivation
		AA6	= Irrigated cultivation
	AP	= Perennial field cropping	
		AP1	= Non-irrigated cultivation
		AP2	= Irrigated cultivation
	AT	= Tree and shrub cropping	
		AT1	= Non-irrigated tree crop cultivation
		AT2	= Irrigated tree crop cultivation
		AT3	= Non-irrigated shrub crop cultivation
		AT4	= Irrigated shrub crop cultivation
Additional codes may be used to further specify the land-use type. For example:			
		AA4	= Rainfed arable cultivation
		AA4T	= Traditional
		AA4I	= Improved traditional
		AA4M	= Mechanized traditional
		AA4C	= Commercial
		AA4U	= Unspecified
M	**= Mixed farming**		
	MF	= Agroforestry	
	MP	= Agropastoralism	
H	**= Animal husbandry**		
	HE	= Extensive grazing	
		HE1	= Nomadism
		HE2	= Semi-nomadism
		HE3	= Ranching
	HI	= Intensive grazing	
		HI1	= Animal production
		HI2	= Dairying
F	**= Forestry**		
	FN	= Natural forest and woodland	
		FN1	= Selective felling
		FN2	= Clear felling
	FP	= Plantation forestry	
P	**= Nature protection**		
	PN	= Nature and game preservation	
		PN1	= Reserves
		PN2	= Parks
		PN3	= Wildlife management
	PD	= Degradation control	
		PD1	= Without interference
		PD2	= With interference
S	**= Settlement, industry**		
	SR	= Residential use	
	SI	= Industrial use	
	ST	= Transport	
	SC	= Recreational use	
	SX	= Excavations	
	SD	= Disposal sites	
Y	**= Military area**		
O	**= Other land uses**		
U	**= Not used and not managed**		

TABLE 9
Crop codes

Ce = Cereals		**Fo = Fodder plants**		**Fi = Fibre crops**	
CeBa	= Barley	FoAl	= Alfalfa	FiCo	= Cotton
CeMa	= Maize	FoCl	= Clover	FiJu	= Jute
CeMi	= Millet	FoGr	= Grasses	**Ve = Vegetables**	
CeOa	= Oats	FoHa	= Hay	**Pu = Pulses**	
CePa	= Rice, paddy	FoLe	= Leguminous	PuBe	= Beans
CeRi	= Rice, dry	FoMa	= Maize	PuLe	= Lentils
CeRy	= Rye	FoPu	= Pumpkins	PuPe	= Peas
CeSo	= Sorghum	**Ro = Roots and tubers**		**Lu = Semi-luxury foods and tobacco**	
CeWh	= Wheat	RoCa	= Cassava	LuCc	= Cocoa
Oi = Oilcrops		RoPo	= Potatoes	LuCo	= Coffee
OiCc	= Coconuts	RoSu	= Sugar beets	LuTe	= Tea
OiGr	= Groundnuts	RoYa	= Yams	LuTo	= Tobacco
OiLi	= Linseed	**Fr = Fruits and melons**		**Ot = Other crops**	
OiOl	= Olives	FrAp	= Apples	OtSc	= Sugar cane
OiOp	= Oil-palm	FrBa	= Bananas	OtRu	= Rubber
OiRa	= Rape	FrCi	= Citrus	OtPa	= Palm (fibres, kernels)
OiSe	= Sesame	FrGr	= Grapes, Wine, Raisins		
OiSo	= Soybeans	FrMa	= Mangoes		
OiSu	= Sunflower	FrMe	= Melons		

TABLE 10
Recommended codes for human influence

N	= No influence	BU	= Bunding
NK	= Not known	BR	= Burning
VS	= Vegetation slightly disturbed	TE	= Terracing
VM	= Vegetation moderately disturbed	PL	= Ploughing
VE	= Vegetation strongly disturbed	MP	= Plaggen
VU	= Vegetation disturbed (not specified)	MR	= Raised beds (agricultural purposes)
IS	= Sprinkler irrigation	ME	= Raised beds (engineering purposes)
IF	= Furrow irrigation	MS	= Sand additions
ID	= Drip irrigation	MU	= Mineral additions (not specified)
IP	= Flood irrigation	MO	= Organic additions (not specified)
IB	= Border irrigation	PO	= Pollution
IU	= Irrigation (not specified)	CL	= Clearing
AD	= Artificial drainage	SC	= Surface compaction
FE	= Application of fertilizers	SA	= Scalped area
LF	= Landfill (also sanitary)	BP	= Borrow pit
LV	= Levelling	DU	= Dump (not specified)
AC	= Archaeological (burial mound, midden)	MI	= Mine (surface, including openpit, gravel and quarries)
CR	= Impact crater		

TABLE 11
Vegetation classification

F = Closed forest [1]		D = Dwarf shrub	
FE	= Evergreen broad-leaved forest	DE	= Evergreen dwarf shrub
FC	= Coniferous forest	DS	= Semi-deciduous dwarf shrub
FS	= Semi-deciduous forest	DD	= Deciduous dwarf shrub
FD	= Deciduous forest	DX	= Xermomorphic dwarf shrub
FX	= Xeromorphic forest	DT	= Tundra
W = Woodland [2]		H = Herbaceous	
WE	= Evergreen woodland	HT	= Tall grassland
WS	= Semi-deciduous woodland	HM	= Medium grassland
WD	= Deciduous woodland	HS	= Short grassland
WX	= Xeromorphic woodland	HF	= Forb
S = Shrub		M = Rainwater-fed moor peat	
SE	= Evergreen shrub	B = Groundwater-fed bog peat	
SS	= Semi-deciduous shrub		
SD	= Deciduous shrub		
SX	= Xeromorphic shrub		

[1] Continuous tree layer, crowns overlapping, large number of tree and shrub species in distinct layers.
[2] Continuous tree layer, crowns usually not touching, understorey may be present.

Vegetation

Vegetation is a dominant factor in soil formation as it is the primary source of organic matter and because of its major role in the nutrient cycling and hydrology of a site. There is no uniform acceptance of a system for the description of the natural or semi-natural vegetation. The kind of vegetation can be described using a local, regional or international system. A common example is the vegetation classification according to UNESCO (1973, see updated SOTER; ISRIC, 2005), presented in Table 11 with codes added.

In addition, other characteristics of the vegetation, such as height of trees or canopy cover, may be recorded.

PARENT MATERIAL

The parent material is the material from which the soil has presumably been derived. The parent material should be described as accurately as possible, indicating its origin and nature. There are basically two groups of parent material on which the soil has formed: unconsolidated materials (mostly sediments); and weathering materials overlying the hard rock from which they originate. There are transitional cases, such as partly consolidated materials and weathering materials that have been transported, either by water, called alluvium (fluvial if transported by stream), or by gravity, called colluvium. There are also restored natural soil materials or sediments as well as technogenic materials. The reliability of the geological information and the knowledge of the local lithology will determine whether a general or a specific definition of the parent material can be given.

For weathered rock, the code WE is first entered, followed by the rock-type code. The code SA for saprolite is recommended where the *in situ* weathered material is thoroughly decomposed, clay-rich but still showing rock structure. Alluvial deposits and colluvium derived from a single rock type may be further specified by that rock type. Where one parent material overlies another, both are indicated.

The parent material is coded according to updated SOTER (ISRIC, 2005) at the lowest level of hierarchy as possible. As SOTER was developed to work with maps on a scale of 1:1 000 000, it was a requirement to have not too many rock types. In order to be able to work in smaller scales, some additional natural and anthropogenic parent materials are included in Table 12. For identification in the field, a key to the most important rock types is provided below the extended hierarchical SOTER list.

Note for classification purposes

✓ Remains intact when a specimen of 25–30 mm is submerged in water for 1 hour; roots cannot penetrate except along vertical cracks that have an average horizontal spacing of ≥ 10 cm and that occupy < 20 percent (by volume); no significant displacement has taken place → continuous rock.

✓Differences in lithology → lithological discontinuity.

✓Recent sediments above the soil that is classified at the Reference Soil Group (RSG) level → Novic qualifier.

✓Sedimentation through human-induced erosion → colluvic material.

✓Coprogenous earth or sedimentary peat, diatomaceous earth, marl or gyttja → limnic material.

✓Remnants of birds or bird activity → ornithogenic material.

✓Organic material consisting of ≥ 75 percent of moss fibres → greater thickness of organic material required for Histosols.

✓Moor peat saturated predominantly with rainwater → Ombric qualifier.

✓Bog peat saturated predominantly with groundwater or flowing surface water → Rheic qualifier.

AGE OF THE LAND SURFACE

The age of the landscape is important information from which the possible duration of the occurrence of soil formation processes can be derived. Because many soils are formed from preweathered or moved materials, or may have been derived from an assemblage of autochthonous, fluvial and eolian materials, it is often difficult to obtain precise information. However, an estimate will help to interpret soil data and interaction between different soil forming processes. It may also indicate possible climate changes during soil formation.

Table 13 provides a provisional coding.

TABLE 12
Hierarchy of lithology

Major class		Group		Type	
I	igneous rock	IA	acid igneous	IA1	diorite
				IA2	grano-diorite
				IA3	quartz-diorite
				IA4	rhyolite
		II	intermediate igneous	II1	andesite, trachyte, phonolite
				II2	diorite-syenite
		IB	basic igneous	IB1	gabbro
				IB2	basalt
				IB3	dolerite
		IU	ultrabasic igneous	IU1	peridotite
				IU2	pyroxenite
				IU3	ilmenite, magnetite, ironstone, serpentine
		IP	pyroclastic	IP1	tuff, tuffite
				IP2	volcanic scoria/breccia
				IP3	volcanic ash
				IP4	ignimbrite
M	metamorphic rock	MA	acid metamorphic	MA1	quartzite
				MA2	gneiss, migmatite
				MA3	slate, phyllite (pelitic rocks)
				MA4	schist
		MB	basic metamorphic	MB1	slate, phyllite (pelitic rocks)
				MB2	(green)schist
				MB3	gneiss rich in Fe–Mg minerals
				MB4	metamorphic limestone (marble)
				MB5	amphibolite
				MB6	eclogite
		MU	ultrabasic metamorphic	MU1	serpentinite, greenstone
S	sedimentary rock (consolidated)	SC	clastic sediments	SC1	conglomerate, breccia
				SC2	sandstone, greywacke, arkose
				SC3	silt-, mud-, claystone
				SC4	shale
				SC5	ironstone
		SO	carbonatic, organic	SO1	limestone, other carbonate rock
				SO2	marl and other mixtures
				SO3	coals, bitumen and related rocks
		SE	evaporites	SE1	anhydrite, gypsum
				SE2	halite
U	sedimentary rock (unconsolidated)	UR	weathered residuum	UR1	bauxite, laterite
		UF	fluvial	UF1	sand and gravel
				UF2	clay, silt and loam
		UL	lacustrine	UL1	sand
				UL2	silt and clay
		UM	marine, estuarine	UM1	sand
				UM2	clay and silt
		UC	colluvial	UC1	slope deposits
				UC2	lahar
		UE	eolian	UE1	loess
				UE2	sand
		UG	glacial	UG1	moraine
				UG2	glacio-fluvial sand
				UG3	glacio-fluvial gravel
		UK	* kryogenic	UK1	periglacial rock debris
				UK2	periglacial solifluction layer

TABLE 12

Hierarchy of lithology (Continued)

Major class	Group		Type	
	UO	organic	UO1	rainwater-fed moor peat
			UO2	groundwater-fed bog peat
	UA	anthropogenic/ technogenic	UA1	redeposited natural material
			UA2	industrial/artisanal deposits
	UU	* unspecified deposits	UU1	clay
			UU2	loam and silt
			UU3	sand
			UU4	gravelly sand
			UU5	gravel, broken rock

* Extended.
Source: Updated SOTER; ISRIC, 2005.

Materials (natural and anthropogenic/technogenic) deposited by humans are coded:

- d... = dumped,
- s... = spoiled.

Chapter 4 provides more details on human-made materials.

TABLE 13

Provisional coding for age of land surface

vYn	Very young (1–10 years) natural: with loss by erosion or deposition of materials such as on tidal flats, of coastal dunes, in river valleys, landslides or desert areas.
vYa	Very young (1–10 years) anthropogeomorphic: with complete disturbance of natural surfaces (and soils) such as in urban, industrial and mining areas with very early soil development from fresh natural or technogenic or mixed materials.
Yn	Young (10–100 years) natural: with loss by erosion or deposition of materials such as on tidal flats, of coastal dunes, river valleys, landslides or desert areas.
Ya	Young (10–100 years) anthropogeomorphic: with complete disturbance of any natural surfaces (and soils) such as in urban, industrial and mining areas with early soil development from fresh natural, technogenic or a mixture of materials, or restriction of flooding by dykes.
Hn	Holocene (100–10 000 years) natural: with loss by erosion or deposition of materials such as on tidal flats, of coastal dunes, in river valleys, landslides or desert areas.
Ha	Holocene (100–10 000 years) anthropogeomorphic: human-made relief modifications, such as terracing of forming hills or walls by early civilizations or during the Middle Ages or earlier, restriction of flooding by dykes, or surface raising.
lPi	Late Pleistocene, ice covered, commonly recent soil formation on fresh materials.
lPp	Late Pleistocene, periglacial, commonly recent soil formation on preweathered materials.
lPf	Late Pleistocene, without periglacial influence.
oPi	Older Pleistocene, ice covered, commonly the recent soil formation on younger over older, preweathered materials.
oPp	Older Pleistocene, with periglacial influence, commonly the recent soil formation on younger over older, preweathered materials.
oPf	Older Pleistocene, without periglacial influence.
T	Tertiary land surfaces, commonly high planes, terraces or peneplains, except incised valleys, frequent occurrence of palaeosoils.
O	Older, pre-Tertiary land surfaces, commonly high planes, terraces or peneplains, except incised valleys, frequent occurrence of palaeosoils.

Chapter 4
Soil description

This chapter presents the procedure to describe the different morphological and other characteristics of the soil. This is best done using a recently dug pit large enough to allow sufficient examination and description of the different horizons. Old exposures such as road cuts and ditches may be used, but only after scraping off sufficient material to expose the fresh soil. First, the surface characteristics are recorded. Then, the soil description is done horizon by horizon, starting with the uppermost one.

The rules of soil description and the coding of attributes are generally based on the guidelines for soil description according to FAO (1990). Additions have a citation.

SURFACE CHARACTERISTICS

Where present, surface characteristics, such as rock outcrops, coarse rock fragments, human-induced erosion, surface sealing and surface cracks, should be recorded. A number of other surface characteristics, such as the occurrence of salts, bleached sands, litter, worm casts, ant paths, claddiness, and puddling, may be also be recorded.

Rock outcrops

Exposures of bedrock may limit the use of modern mechanized agricultural equipment. Rock outcrops should be described in terms of percentage surface cover, together with additional relevant information on the size, spacing and hardness of the individual outcrops.

Table 14 lists the recommended classes of percentage of surface cover and of average distance between rock outcrops (single or clusters).

Coarse surface fragments

Coarse surface fragments, including those partially exposed, should be described in terms of percentage of surface coverage and of size of the fragments. Classes of occurrence of coarse surface fragments are correlated with the ones for rock outcrop, as per Table 15.

TABLE 14
Recommended classification of rock outcrops

Surface cover		(%)	Distance between rock outcrops	
				(m)
N	None	0		
V	Very few	0–2	1	> 50
F	Few	2–5	2	20–50
C	Common	5–15	3	5–20
M	Many	15–40	4	2–5
A	Abundant	40–80	5	< 2
D	Dominant	> 80		

TABLE 15
Classification of coarse surface fragments

Surface cover		(%)	Size classes (indicating the greatest dimension)		(cm)
N	None	0	F	Fine gravel	0.2–0.6
V	Very few	0–2	M	Medium gravel	0.6–2.0
F	Few	2–5	C	Coarse gravel	2–6
C	Common	5–15	S	Stones	6–20
M	Many	15–40	B	Boulders	20–60
A	Abundant	40–80	L	Large boulders	60–200
D	Dominant	> 80			

TABLE 16
Classification of erosion, by category

N	No evidence of erosion		
W	Water erosion or deposition	A	Wind (aeolian) erosion or deposition
	WS Sheet erosion		AD Wind deposition
	WR Rill erosion		AM Wind erosion and deposition
	WG Gully erosion		AS Shifting sands
	WT Tunnel erosion		AZ Salt deposition
	WD Deposition by water		
WA	Water and wind erosion		
M	Mass movement (landslides and similar phenomena)		
NK	Not known		

TABLE 17
Classification of total area affected by erosion and deposition

	%
0	0
1	0–5
2	5–10
3	10–25
4	25–50
5	> 50

TABLE 18
Classification of erosion, by degree

S	Slight	Some evidence of damage to surface horizons. Original biotic functions largely intact.
M	Moderate	Clear evidence of removal of surface horizons. Original biotic functions partly destroyed.
V	Severe	Surface horizons completely removed and subsurface horizons exposed. Original biotic functions largely destroyed.
E	Extreme	Substantial removal of deeper subsurface horizons (badlands). Original biotic functions fully destroyed.

Note for classification purposes

✓ Pavement (consisting of rock outcrops or surface coarse fragments) that is varnished or includes wind-shaped gravel or stones or is associated with a vesicular layer → yermic horizon.

Erosion

In describing soil erosion, emphasis should be given to accelerated or human-induced erosion. It is not always easy to distinguish between natural and accelerated erosion as they are often closely related. Human-induced erosion is the result of irrational use and poor management, such as inappropriate agricultural practices, overgrazing and removal or overexploitation of the natural vegetation.

Main categories

Erosion can be classified as water or wind erosion (Table 16), and include off-site effects such as deposition; a third major category is mass movements (landslides and related phenomena).

Area affected

The total area affected by erosion and deposition is estimated following the classes defined by SOTER (FAO, 1995) as per Table 17.

Degree

It is difficult to define classes of the degree of erosion that would be equally appropriate for all soils and environments and that would also fit the various types of water and wind erosion. Four classes are recommended (Table 18), which may have to be further defined for each type or combination of erosion and deposition and specific environment. For example, in the case of gully and rill erosion, the depth and spacing may need to be recorded; for sheet erosion, the loss of topsoil; for dunes, the height; and for deposition, the thickness of the layer.

TABLE 19
Classification of erosion, by activity

A	Active at present
R	Active in recent past (previous 50–100 years)
H	Active in historical times
N	Period of activity not known
X	Accelerated and natural erosion not distinguished

Activity

The period of activity of accelerated erosion or deposition is described using the recommended classes in Table 19.

Note for classification purposes

✓ Evidence of aeolian activity: rounded or subangular sand particles showing a matt surface; wind-shaped rock fragments; aeroturbation; wind erosion or sedimentation → aridic properties.

Surface sealing

Surface sealing is used to describe crusts that develop at the soil surface after the topsoil dries out. These crusts may inhibit seed germination, reduce water infiltration and increase runoff. The attributes of surface sealing are the consistence, when dry, and thickness of the crust as per Table 20.

Note for classification purposes

✓ Surface crust that does not curl entirely upon drying → takyric horizon.
✓ Surface crust → Hyperochric qualifier.

Surface cracks

Surface cracks develop in shrink–swell clay-rich soils after they dry out. The width (average, or average width and maximum width) of the cracks at the surface is indicated in centimetres. The average distance between cracks may also be indicated in centimetres. Table 21 lists the suggested classes.

Note for classification purposes

✓ Cracks that open and close periodically → Vertisols.
✓ Cracks that open and close periodically, ≥ 1 cm wide → vertic properties.
✓ Polygonal cracks extending ≥ 2 cm deep when the soil is dry → takyric horizon.

TABLE 20
Classification of attributes of surface sealing

Thickness		(mm)	Consistence	
N	None		S	Slightly hard
F	Thin	< 2	H	Hard
M	Medium	2–5	V	Very hard
C	Thick	5–20	E	Extremely hard
V	Very thick	> 20		

TABLE 21
Classification of surface cracks

Width		(cm)	Distance between cracks		(m)
F	Fine	< 1	C	Very closely spaced	< 0.2
M	Medium	1–2	D	Closely spaced	0.2–0.5
W	Wide	2–5	M	Moderately widely spaced	0.5–2
V	Very wide	5–10	W	Widely spaced	2–5
E	Extremely wide	> 10	V	Very widely spaced	> 5
Depth					
S	Surface	< 2			
M	Medium	2–10			
D	Deep	10–20			
V	Very deep	> 20			

TABLE 22
Classification of salt characteristics

Cover		(%)	Thickness		(mm)
0	None	0–2	N	None	
1	Low	2–15	F	Thin	< 2
2	Moderate	15–40	M	Medium	2–5
3	High	40–80	C	Thick	5–20
4	Dominant	> 80	V	Very thick	> 20

TABLE 23
Classification of bleached sand characteristics

		%
0	None	0–2
1	Low	2–15
2	Moderate	15–40
3	High	40–80
4	Dominant	> 80

Other surface characteristics

A number of other surface characteristics, such as the occurrence of salts, bleached sands, litter, worm casts, ant paths, cloddiness and puddling, may be recorded.

Salt

The occurrence of salt at the surface may be described in terms of cover, appearance and type of salt. Table 22 lists the classes for the percentage of surface cover and thickness.

Note for classification purposes

✓ Crust pushed up by salt crystals → Puffic qualifier.

Bleached sand

The presence of bleached, loose sand grains on the surface is typical for certain soils and influences the reflection characteristics of the area and, hence, the image obtained through remote sensing. Table 23 lists the classes based on the percentage of surface covered.

HORIZON BOUNDARY

Horizon boundaries provide information on the dominant soil-forming processes that have formed the soil. In certain cases, they reflect past anthropogenic impacts on the landscape. Horizon boundaries are described in terms of depth, distinctness and topography.

Depth

Most soil boundaries are zones of transition rather than sharp lines of division. The depth of the upper and lower boundaries of each horizon is given in centimetres, measured from the surface (including organic and mineral covers) of the soil downwards.

Precise notations in centimetres are used where boundaries are abrupt or clear. Rounded-off figures (to the nearest 5 cm) are entered where the boundaries are gradual or diffuse, avoiding the suggestion of spurious levels of accuracy.

However, if boundary depths are near diagnostic limits, rounded-off figures should not be used. In this case, the depth is indicated as a medium value for the transitional zone (if it starts at 16 cm and terminates at 23 cm, the depth should be 19.5 cm).

Most horizons do not have a constant depth. The variation or irregularity of the surface of the boundary is described by the topography in terms of smooth, wavy, irregular and broken. If required, ranges in depth should be given in addition to the average depth, for example 28 (25–31) cm to 45 (39–51) cm.

TABLE 24
Classification of horizon boundaries, by distinctness and topography

Distinctness		(cm)	Topography		
A	Abrupt	0–2	S	Smooth	Nearly plane surface
C	Clear	2–5	W	Wavy	Pockets less deep than wide
G	Gradual	5–15	I	Irregular	Pockets more deep than wide
D	Diffuse	> 15	B	Broken	Discontinuous

Note for classification purposes

✓ Many diagnostic horizons and properties are found at a certain depth. Important boundary depths are 10, 20, 25, 40, 50, 100 and 120 cm.

Distinctness and topography

The distinctness of the boundary refers to the thickness of the zone in which the horizon boundary can be located without being in one of the adjacent horizons (Table 24).

The topography of the boundary indicates the smoothness of depth variation of the boundary.

Note for classification purposes

✓ Cryoturbation → cryic horizon, Cryosols and Turbic qualifier.
✓ Tonguing of a mollic or umbric horizon into an underlying layer → Glossic qualifier.
✓ Tonguing of an eluvial albic horizon into an argic horizon → albeluvic tonguing and Glossalbic qualifier.
✓ Diffuse horizon boundaries → Nitisols.

PRIMARY CONSTITUENTS

This section presents the procedure on the description of soil texture and the nature of the primary rock and mineral fragments, which are subdivided into: (i) the fine earth fraction; and (ii) the coarse fragments fraction.

Texture of the fine earth fraction

Soil texture refers to the proportion of the various particle-size classes (or soil separates, or fractions) in a given soil volume and is described as soil textural class (Figure 4). The names for the particle-size classes correspond closely with commonly used standard terminology, including that of the system used by the

United States Department of Agriculture (USDA). However, many national systems describing particle-size and textural classes use more or less the same names but different grain fractions of sand, silt and clay, and textural classes. This publication uses the 2000–63–2-µm system for particle-size fractions.

Soil textural classes

The names of the textural classes (which describe combined particle-size classes) of the described soil material are coded as in Figure 4.

In addition to the textural class, a field estimate of the percentage of clay is given. This estimate is useful for indicating increases or decreases in clay content within textural classes, and for comparing field estimates with analytical results. The relationship between the basic textural classes and the percentages of clay, silt and sand is indicated in a triangular form in Figure 4.

Subdivision of the sand fraction

Sands, loamy sands and sandy loams are subdivided according to the proportions of very coarse to coarse, medium, fine and very fine sands in the sand fraction. The proportions are calculated from the particle-size distribution, taking the total of the sand fraction as being 100 percent (Figure 4).

Field estimation of textural classes

The textural class can be estimated in the field by simple field tests and feeling the constituents of the soil (Table 25). For this, the soil sample must be in a moist to weak wet state. Gravel and other constituents > 2 mm must be removed.

The constituents have the following feel:

- Clay: soils fingers, is cohesive (sticky), is formable, has a high plasticity and has a shiny surface after squeezing between fingers.
- Silt: soils fingers, is non-sticky, only weakly formable, has a rough and ripped surface after squeezing between fingers and feels very floury (like talcum powder).
- Sand: cannot be formed, does not soil fingers and feels very grainy.

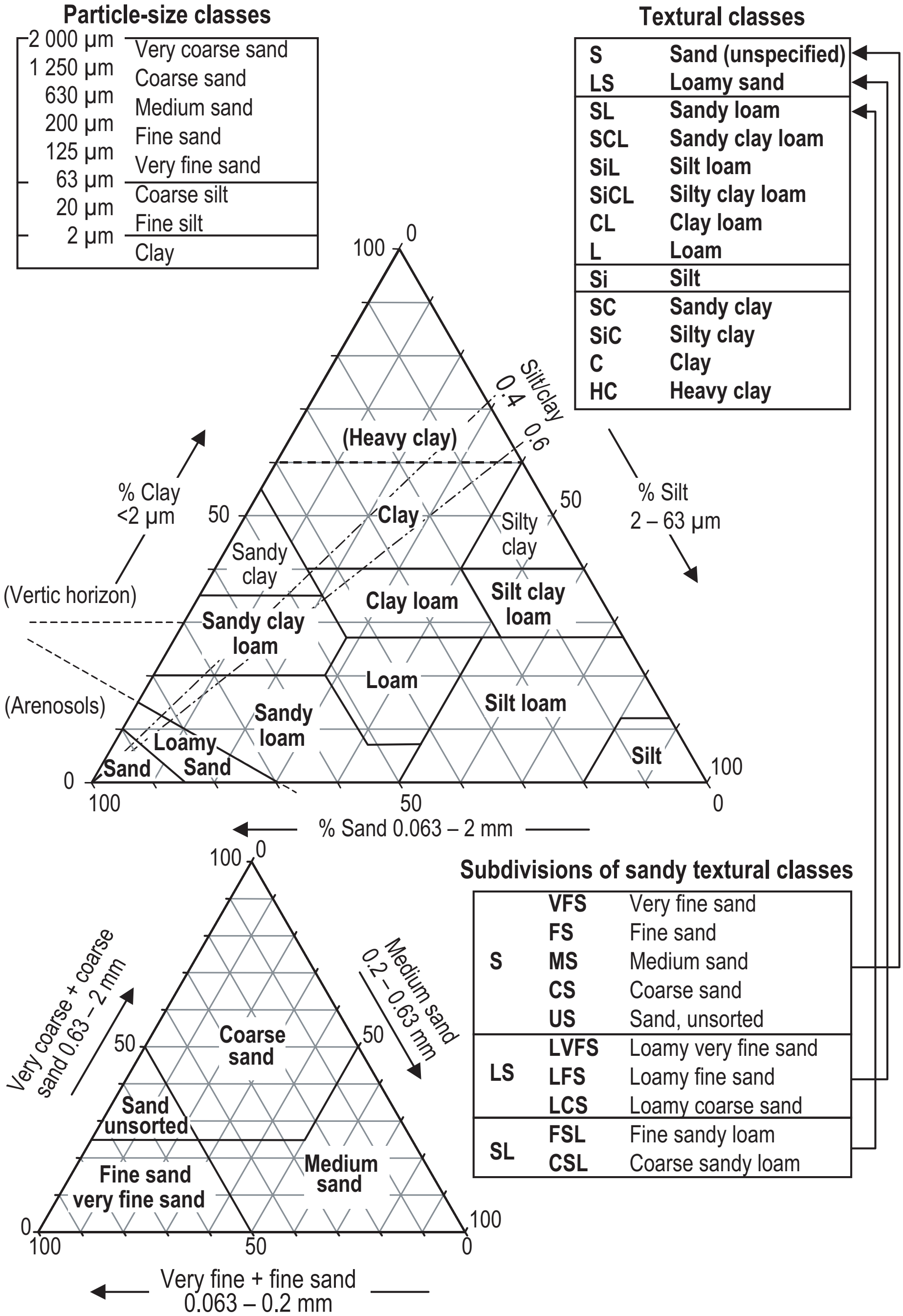
Note for classification purposes

Important diagnostic characteristics derived from the textural class are:

- ✓ A texture that is loamy sand or coarser to a depth of ≥ 100 cm → Arenosol.
- ✓ A texture of loamy fine sand or coarser in a layer ≥ 30 cm thick within 100 cm of the soil surface → Arenic qualifier.
- ✓ A texture of silt, silt loam, silty clay loam or silty clay in a layer ≥ 30 cm thick, within 100 cm of the soil surface → Siltic qualifier.
- ✓ A texture of clay in a layer ≥ 30 cm thick within 100 cm of the soil surface → Clayic qualifier.
- ✓ ≥ 30 percent clay throughout a thickness of 25 cm → vertic horizon.
- ✓ ≥ 30 percent clay throughout a thickness of 15 cm → vertic properties.
- ✓ ≥ 30 percent clay between the soil surface and a vertic horizon → Vertisol.

FIGURE 4

Relation of constituents of fine earth by size, defining textural classes and sand subclasses



Source: According to FAO (1990)

TABLE 25
Key to the soil textural classes

				~% clay
1	Not possible to roll a wire of about 7 mm in diameter (about the diameter of a pencil)			
1.1	not dirty, not floury, no fine material in the finger rills:	sand	S	< 5
	• if grain sizes are mixed:	unsorted sand	US	< 5
	• if most grains are very coarse (> 0.6 mm):	very coarse and coarse sand	CS	< 5
	• if most grains are of medium size (0.2–0.6 mm):	medium sand	MS	< 5
	• if most grains are of fine size (< 0.2 mm) but still grainy:	fine sand	FS	< 5
	• if most grains are of very fine size (< 0.12 mm), tending to be floury:	very fine sand	VFS	< 5
1.2	not floury, grainy, scarcely fine material in the finger rills, weakly shapeable, adheres slightly to the fingers:	loamy sand	LS	< 12
1.3	similar to 1.2 but moderately floury:	sandy loam	SL (clay-poor)	< 10
2	Possible to roll a wire of about 3–7 mm in diameter (about half the diameter of a pencil) but breaks when trying to form the wire to a ring of about 2–3 cm in diameter, moderately cohesive, adheres to the fingers			
2.1	very floury and not cohesive			
	• some grains to feel:	silt loam	SiL (clay-poor)	< 10
	• no grains to feel:	silt	Si	< 12
2.2	moderately cohesive, adheres to the fingers, has a rough and ripped surface after squeezing between fingers and			
	• very grainy and not sticky:	sandy loam	SL (clay-rich)	10–25
	• moderate sand grains:	loam	L	8–27
	• not grainy but distinctly floury and somewhat sticky:	silt loam	SiL (clay-rich)	10–27
2.3	rough and moderate shiny surface after squeezing between fingers and is sticky and grainy to very grainy:	sandy clay loam	SCL	20–35
3	Possible to roll a wire of about 3 mm in diameter (less than half the diameter of a pencil) and to form the wire to a ring of about 2–3 cm in diameter, cohesive, sticky, gnashes between teeth, has a moderately shiny to shiny surface after squeezing between fingers			
3.1	very grainy:	sandy clay	SC	35–55
3.2	some grains to see and to feel, gnashes between teeth			
	• moderate plasticity, moderately shiny surfaces:	clay loam	CL	25–40
	• high plasticity, shiny surfaces:	clay	C	40–60
3.3	no grains to see and to feel, does not gnash between teeth			
	• low plasticity:	silty clay loam	SiCL	25–40
	• high plasticity, moderately shiny surfaces:	silty clay	SiC	40–60
	• high plasticity, shiny surfaces:	heavy clay	HC	> 60

Note: Field texture determination may depend on clay mineralogical composition. The above key works mainly for soils having illite, chlorite and/or vermiculite composition. Smectite clays are more plastic, and kaolinitic clays are stickier. Thus, clay content can be overestimated for the former, and underestimated for the latter.
Source: Adapted from Schlichting, Blume and Stahr, 1995.

- ✓ ≥ 30 percent clay, < 20 percent change (relative) in clay content over 12 cm to layers immediately above and below, a silt/clay ratio of < 0.4 → nitic horizon.
- ✓ Sandy loam or finer particle size → ferralic horizon.
- ✓ A texture in the fine earth fraction of very fine sand, loamy very fine sand, or finer → cambic horizon.
- ✓ A texture in the fine earth fraction coarser than very fine sand or loamy very fine sand → Brunic qualifier.
- ✓ A texture of loamy sand or finer and ≥ 8 percent clay → argic and natric horizons.

- ✓ A texture of sand, loamy sand, sandy loam or silt loam or a combination of them → plaggic horizon.
- ✓ A higher clay content than the underlying soil and relative differences among medium, fine and very fine sand and clay < 20 percent → irragric horizon.
- ✓ A texture of sandy clay loam, clay loam, silty clay loam or finer → takyric horizon.
- ✓ ≥ 8 percent clay in the underlying layer and within 7.5 cm either doubling of the clay content if the overlying layer has less then 20 percent or 20 percent (absolute) more clay → abrupt textural change.
- ✓ An abrupt change in particle-size distribution that is not solely associated with a change in clay content resulting from pedogenesis or a relative change of ≥ 20 percent in the ratios between coarse sand, medium sand, and fine sand → lithological discontinuity.
- ✓ The required amount of organic carbon depends on the clay content, if the layer is saturated with water for ≥ 30 consecutive days in most years → organic and mineral materials.
- ✓ The required amount of organic carbon depends on the texture → aridic properties.
- ✓ The depth where an argic horizon starts depends on the texture → Alisols, Acrisols, Luvisols and Lixisols, and Alic, Acric, Luvic and Lixic qualifiers.
- ✓ An argic horizon in which the clay content does not decrease by 20 percent of more (relative) from its maximum within 150 cm → Profondic qualifier.
- ✓ An absolute clay increase of ≥ 3 percent → Hypoluvic qualifier.
- ✓ A silt/clay ratio < 0.6 → Hyperalic qualifier.

Rock fragments and artefacts

The presence of rock fragments influences the nutrient status, water movement, use and management of the soil. It also reflects the origin and stage of development of the soil.

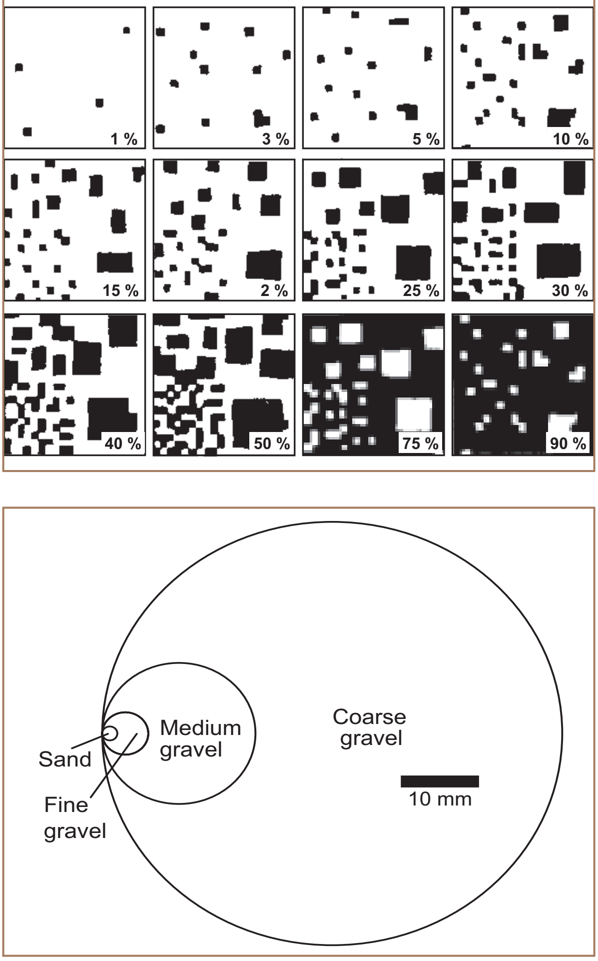
Artefacts (sections on artefacts and description of artefacts [below]) are useful for identifying colluviation, human occupation, and industrial processes.

Large rock and mineral fragments (> 2 mm) and artefacts are described according to abundance, size, shape, state of weathering, and nature of the fragments. The abundance class limits correspond with the ones for surface coarse fragments and mineral nodules, and the 40-percent boundary coincides with the requirement for the skeletic phase (Table 26 and Figure 5). Where rock fragments are not distributed regularly within a horizon but form a “stone line”, this should be indicated clearly.

TABLE 26
Abundance of rock fragments and artefacts, by volume

		%
N	None	0
V	Very few	0–2
F	Few	2–5
C	Common	5–15
M	Many	15–40
A	Abundant	40–80
D	Dominant	> 80
S	Stone line	any content, but concentrated at a distinct depth of a horizon

FIGURE 5
Charts for estimating proportions of coarse fragments and mottles



Size of rock fragments and artefacts

Table 27 indicates the classification for rock fragments and artefacts.

Note for classification purposes

Important diagnostic characteristics derived from the amount of rock fragments are:

- ✓ < 20 percent (by volume) fine earth averaged over a depth of 75 cm or to continuous rock → Leptosols and Hyperskeletic qualifier.
- ✓ ≥ 40 percent (by volume) gravel or other coarse fragments averaged over:
  - ➢ a depth of 100 cm or to continuous rock → Skeletic qualifier;
  - ➢ a depth of 50–100 cm → Endoskeletic qualifier;
  - ➢ a depth of 20– 50 cm → Episkeletic qualifier.
- ✓ ≥ 20 (by volume, by weighted average) artefacts in the upper 100 cm → Technosols.
- ✓ < 40 percent (by volume) of gravels or other coarse fragments in all layers within 100 cm or to a petroplinthic, plinthic or salic horizon → Arenosols.

TABLE 27
Classification of rock fragments and artefacts

	Rock fragments	(mm)		Artefacts	(mm)
			V	Very fine artefacts	< 2
F	Fine gravel	2–6	F	Fine artefacts	2–6
M	Medium gravel	6–20	M	Medium artefacts	6–20
C	Coarse gravel	20–60			
S	Stones	60–200	C	Coarse artefacts	> 20
B	Boulders	200–600			
L	Large boulders	> 600			
Combination of classes					
FM	Fine and medium gravel/artefacts				
MC	Medium and coarse gravel/artefacts				
CS	Coarse gravel and stones				
SB	Stones and boulders				
BL	Boulders and large boulders				

✓ Fragmental materials, the interstices of which are filled with organic material → Histosols.

Shape of rock fragments
The general shape or roundness of rock fragments may be described using the terms in Table 28.

Note for classification purposes
✓ Layers with rock fragments of angular shape overlying or underlying layers with rock fragments of rounded shape or marked differences in size and shape of resistant minerals between superimposed layers → lithological discontinuity.

State of weathering of rock fragments and artefacts
The state of weathering of the coarse fragments is described as per Table 29.

TABLE 28
Classification of shape of rock fragments

F	Flat
A	Angular
S	Subrounded
R	Rounded

TABLE 29
Classification of weathering of coarse fragments

F	Fresh or slightly weathered	Fragments show little or no signs of weathering.
W	Weathered	Partial weathering is indicated by discoloration and loss of crystal form in the outer parts of the fragments while the centres remain relatively fresh and the fragments have lost little of their original strength.
S	Strongly weathered	All but the most resistant minerals are weathered, strongly discoloured and altered throughout the fragments, which tend to disintegrate under only moderate pressure.

TABLE 30
Codes for primary mineral fragments

QU	Quartz
MI	Mica
FE	Feldspar

Note for classification purposes
✓ A layer with rock fragments without weathering rinds overlying a layer with rock fragments with weathering rinds → lithological discontinuity.

Nature of rock fragments
The nature of rock fragments is described by using the same terminology as for the rock-type description (Table 12). For primary mineral fragments, other codes can be used, e.g. as per Table 30.

Fragments of individual weatherable minerals (e.g. feldspars and micas) may be smaller than 2 mm in diameter. Nevertheless, where present in appreciable quantities, such fragments should be mentioned separately in the description. For artefacts, see section on artefacts (below).

Note for classification purposes
✓ Rock fragments that do not have the same lithology as the underlying continuous rock → lithological discontinuity.

TABLE 31
Field estimation and coding of the degree of decomposition and humification of peat

	Code	Degree of decomposition/ humification	Attributes of dry peat		Attributes of wet peat		
			Colour	Visible plant tissues	Goes between the fingers by squeezing in the hand		Remnant
Fibric	D1	very low	white to light brown	only	± clear	water	not muddy
	D2	low	dark brown	most	brown to muddy		
	D3	moderate	dark brown to black	more than 2/3	muddy	mud	muddy
Hemic	D4	strong		1/3 to 2/3	1/2 to 2/3		plant structure more visible than before
	D5.1	moderately strong		1/6 to 1/3	more or less all		only heavy decompostable remnants
Sapric	D5.2	very strong		less than 1/6			no remnant

Source: Adapted from Ad-hoc-AG-Boden, 2005

Degree of decomposition and humification of peat

In most organic layers, the determination of the texture class is not possible. More valuable is an estimate of the degree of decomposition and humification of the organic material. Colour and percentage of recognizable plant tissue of dry as well as of wet organic material can be used to estimate the degree of decomposition (Table 31).

Note for classification purposes

- ✓ Histosols have more than two-thirds (by volume) recognizable plant tissues → Fibric qualifier.
- ✓ Histosols have between two-thirds and one-sixth (by volume) recognizable plant tissues → Hemic qualifier.
- ✓ Histosols have less than one-sixth (by volume) recognizable plant tissues → Sapric qualifier.

Aeromorphic organic layers on forest floors

On forest floors, especially under temperate and cool climates, organic matter is commonly accumulated in more or less decomposed organic layers under terrestrial conditions. In acidic and nutrient poor mineral soils, the nutrient stock of the organic layers is of vital interest for the vegetation cover. The three major forms, raw humus, moder and mull, are described as follows:

- ➢ Raw humus (aeromorphic mor): usually thick (5–30 cm) organic matter accumulation that is largely unaltered owing to lack of decomposers. This kind of organic matter layer develops in extremely nutrient-poor and coarse-textured soils under vegetation that produces a litter layer that is difficult to decompose. It is usually a sequence of Oi–Oe–Oa layers over a thin A horizon, easy to separate one layer from another and being very acid with a C/N ratio of > 29.

- Moder (duff mull): more decomposed than raw humus but characterized by an organic matter layer on top of the mineral soil with a diffuse boundary between the organic matter layer and A horizon. In the sequence of Oi–Oe–Oa layers, it is difficult to separate one layer from another. This develops in moderately nutrient-poor conditions, usually under a cool moist climate. It is usually acidic with a C/N ratio of 18–29.
- Mull: characterized by the periodic absence of organic matter accumulation on the surface owing to the rapid decomposition process and mixing of organic matter and the mineral soil material by bioturbation. It is usually slightly acid to neutral with a C/N ratio of 10–18.

SOIL COLOUR (MATRIX)

Soil colour reflects the composition as well as the past and present oxidation-reduction conditions of the soil. It is generally determined by coatings of very fine particles of humified organic matter (dark), iron oxides (yellow, brown, orange and red), manganese oxides (black) and others, or it may be due to the colour of the parent rock.

The colour of the soil matrix l of each horizon should be recorded in the moist condition (or both dry and moist conditions where possible) using the notations for hue, value and chroma as given in the Munsell Soil Color Charts (Munsell, 1975). Hue is the dominant spectral colour (red, yellow, green, blue or violet), value is the lightness or darkness of colour ranging from 1 (dark) to 8 (light), and chroma is the purity or strength of colour ranging from 1 (pale) to 8 (bright). Where there is no dominant soil matrix colour, the horizon is described as mottled and two or more colours are given. In addition to the colour notations, the standard Munsell colour names may be given.

For routine descriptions, soil colours should be determined out of direct sunlight and by matching a broken ped with the colour chip of the Munsell Soil Color Charts. For special purposes, such as for soil classification, additional colours from crushed or rubbed material may be required. The occurrence of contrasting colours related to the structural organization of the soil, such as ped surfaces, may be noted.

Where possible, soil colour should be determined under uniform conditions. Early morning and late evening readings are not accurate. Moreover, the determination of colour by the same or different individuals has often proved to be inconsistent. Because soil colour is significant with respect to various soil properties, including organic matter contents, coatings and state of oxidation or reduction, and for soil classification, cross-checks are recommended and should be established on a routine basis.

Note for classification purposes

Intermediate colours should be recorded where desirable for the distinction between two soil horizons and for purposes of classification and interpretation of the soil profile. Intermediate hues (important for qualifiers, such as Chromic or Rhodic, and for diagnostic horizons, such as cambic) that may be used are: 3.5, 4, 6, 6.5, 8.5 and 9 YR. For example, when 3.5 YR is noted, it means that the intermediate hue is closer to 2.5 YR than 5 YR; 4 YR means closer to 5 YR, and so on.

If values and chromas are near diagnostic limits, rounded-off figures should not be used, but accurate recordings should be made by using intermediate values, or by adding a + or a -.

Important diagnostic hues, values and chromas are:

- ✓ Abrupt changes in colour not resulting from pedogenesis → lithological discontinuity.
- ✓ Redder hue, higher value or higher chroma than the underlying or an overlying layer → cambic horizon.
- ✓ Hue redder than 10 YR or chroma ≥ 5 (moist) → ferralic properties, Hypoferralic and Rubic qualifier.
- ✓ Hue 7.5 YR or yellower and value ≥ 4 (moist) and chroma ≥ 5 (moist) → Xanthic qualifier.
- ✓ Hue redder than 7.5 YR or both hue 7.5 YR and chroma > 4 (moist) → Chromic qualifier.
- ✓ Hue redder than 5 YR, value < 3.5 (moist) → Rhodic qualifier.
- ✓ Hue 5 YR or redder, or hue 7.5 YR and value ≤ 5 and chroma ≤ 5, or hue 7.5 YR and value ≤ 5 and chroma 5 or 6, or hue 10 YR or neutral and value and chroma ≤ 2, or 10 YR 3/1 (all moist) → spodic horizon.
- ✓ Hue 7.5 YR or yellower or GY, B or BG; value ≤ 4 (moist); chroma ≤ 2 (moist) → puddled layer (anthraquic horizon).
- ✓ Hue N1 to N8 or 2.5 Y, 5 Y, 5 G or 5 B → reductimorphic colours of the gleyic colour pattern.
- ✓ Hue 5 Y, GY or G → gyttja (limnic material).
- ✓ Chroma < 2.0 (moist) and value < 2.0 (moist) and < 3.0 (dry) → voronic horizon.
- ✓ Chroma ≤ 2 (moist) → Chernozem.
- ✓ Chroma ≤3 (moist) and value ≤ 3 (moist) and ≤ 5 (dry) → mollic and umbric horizon.
- ✓ Value and chroma ≤ 3 (moist) → hortic horizon.
- ✓ Value ≤ 4 (moist) and ≤ 5 (dry) and chroma ≤ 2 (moist) → plaggic horizon.
- ✓ Value > 2 (moist) or chroma > 2 (moist) → fulvic horizon.
- ✓ Value ≤ 2 (moist) and chroma ≤ 2 (moist) → melanic horizon.
- ✓ Values 4 to 8 and chroma 4 or less (moist) and values 5–8 and chromas 2–3 (dry) → albic horizon.
- ✓ Lower value or chroma than the overlying horizon → sombric horizon.
- ✓ Value ≥ 3 (moist) and ≥ 4.5 (dry) and chroma ≥ 2 (moist) → aridic properties.
- ✓ Value ≤ 4 (moist) → coprogenous earth or sedimentary peat (limnic material).
- ✓ Value 3, 4 or 5 (moist) → diatomaceous earth (limnic material).
- ✓ Value ≥ 5 (moist) → marl (limnic material).
- ✓ Value ≤ 3.5 (moist) and chroma ≤ 1.5 (moist) → Pellic qualifier.
- ✓ Value ≥ 5.5 (dry) → Hyperochric qualifier.

MOTTLING

Mottles are spots or blotches of different colours or shades of colour interspersed with the dominant colour of the soil. They indicate that the soil has been subject to alternate wetting (reducing) and dry (oxidizing) conditions.

Mottling of the soil matrix or groundmass is described in terms of abundance, size, contrast, boundary and colour. In addition, the shape, position or any other feature may be recorded.

Note for classification purposes

✓ Mottles of oxides in the form of coatings or in platy, polygonal or reticulate patterns are diagnostic for the anthraquic (plough pan), hydragric, ferric, plinthic and petroplinthic horizons and for the gleyic colour pattern.

✓ Mottles of oxides in the form of concretions or nodules are diagnostic for the hydragric, ferric, plinthic, petroplinthic and, pisoplinthic horizons and for the stagnic colour pattern.

✓ Redox depleted zones in macropores with a value ≥ 4 and a chroma ≤ 2 are diagnostic for the hydragric horizon.

✓ Mottles or coatings of jarosite or schwertmannite are diagnostic for the thionic horizon and the Aceric qualifier.

✓ Mottles in the form of yellow concentrations are diagnostic for the thionic horizon.

Colour of mottles

It is usually sufficient to describe the colour of the mottles in general terms, corresponding to the Munsell Soil Color Charts.

Abundance of mottles

The abundance of mottles is described in terms of classes indicating the percentage of the exposed surface that the mottles occupy (Table 32). The class limits correspond to those of mineral nodules. When the abundance of mottles does not allow the distinction of a single predominant matrix or groundmass colour, the predominant colours should be determined and entered as soil matrix colours.

TABLE 32
Classification of the abundance of mottles

		%
N	None	0
V	Very few	0–2
F	Few	2–5
C	Common	5–15
M	Many	15–40
A	Abundant	> 40

Size of mottles

Table 33 lists the classes used to indicate the approximate diameters

TABLE 33
Classification of the size of mottles

		mm
V	Very fine	< 2
F	Fine	2–6
M	Medium	6–20
A	Coarse	> 20

TABLE 34
Classification of the contrast of mottles

F	Faint	The mottles are evident only on close examination. Soil colours in both the matrix and mottles have closely related hues, chromas and values.
D	Distinct	Although not striking, the mottles are readily seen. The hue, chroma and value of the matrix are easily distinguished from those of the mottles. They may vary by as much as 2.5 units of hue or several units in chroma or value.
P	Prominent	The mottles are conspicuous and mottling is one of the outstanding features of the horizon. Hue, chroma and value alone or in combination are at least several units apart.

TABLE 35
Classification of boundary between mottle and matrix

		mm
S	Sharp	< 0.5
C	Clear	0.5–2
D	Diffuse	> 2

of individual mottles. They correspond to the size classes of mineral nodules.

Contrast of mottles

The colour contrast between mottles and soil matrix can be described as per Table 34.

Boundary of mottles

The boundary between mottle and matrix is described as the thickness of the zone within which the colour transition can be located without being in either the mottle or matrix (Table 35).

SOIL REDOX POTENTIAL AND REDUCING CONDITIONS

Determination of redox potential by field method

Soil redox potential is an important physico-chemical parameter used to characterize soil aeration status and availability of some nutrients (Table 36). The redox potential is also used in the WRB classification to classify redoximorphic soils.

To measure redox potential (DIN/ISO Draft, DVWK, 1995), drive a hole into the soil using a rigid rod (stainless steel, 20–100 cm long, with a diameter that is 2 mm greater than the redox electrodes) to a depth about 1–2 cm less than the desired depth to be measured. Immediately clean the platinum surface of the redox electrode with sandpaper and insert the electrode about 1 cm deeper than the prepared hole. At least two electrodes should be installed for each depth

TABLE 36
Redoximorphic soil characteristics and their relation to rH values and soil processes

Redoximorphic characteristics	rH values and status		Processes
No redoximorphic characteristics at permanently high potentials	permanently	> 35	strongly aerated
		< 33	NO_3^- reduction
Black Mn concretions	temporary	< 29	Mn^{II} formation
Fe mottles and/or brown Fe concretions, in wet conditions	temporary	< 20	Fe^{II} formation*
Blue-green to grey colour; Fe^{2+} ions always present	permanently	13–19	formation of Fe^{II}/Fe^{III} oxides (green rust)*
Black colour due to metal sulphides, flammable methane present	permanently	< 13	sulphide formation
	permanently	< 10	methane formation

* For field test, see section on reducing conditions (below).

being measured. After at least 30 minutes, measure the redox potential with a millivoltmeter against a reference electrode (e.g. Ag/AgCl in KCl of the glass electrode of pH measurements, installed in a small hole on the topsoil that has been filled with 1-*M* KCl solution). For dry topsoil, a salt bridge (plastic tube 2 cm in diameter and with open ends, filled with 0.5 percent (M/M) agar in KCl solution) should be installed in a hole beside and at the depth of the platinum electrodes. In this tube, the reference electrode should be installed.

The measured voltage (Em) is related to the voltage of the standard hydrogen electrode by adding the potential of the reference electrode (e.g. +244 millivolt at 10 °C of Ag/AgCl in 1 *M* KCl, +287 of Calomel electrode).

For interpretation, the results should be transformed to rH values using the formula: rH = 2pH + 2Eh/59 (Eh in mV at 25 °C).

Note the rH value on the description sheet.

Reducing conditions

Reductimorphic properties of the soil matrix reflect permanently wet or at least reduced conditions (Table 37). They are expressed by neutral (white to black: Munsell N1 to N) or bluish to greenish colours (Munsell 2.5 Y, 5 Y, 5 G, 5 B). The colour pattern will often change by aeration in minutes to days owing to oxidation processes.

The presence of Fe^{II} ions can be tested by spraying the freshly exposed soil surface with a 0.2-percent (M/V) α,α dipyridyl solution in 10-percent (V/V) acetic acid solution. The test yields a striking reddish-orange colour in the presence of Fe^{2+} ions but may not give the strong red colour in soil materials with a neutral or alkaline soil reaction. Care is necessary as the chemical is slightly toxic.

Note for classification purposes

✓ An rH value of < 20 is diagnostic for reducing conditions in Gleysols, Planosols and Stagnosols, and stagnic and gleyic lower level units of other RSGs. Gaseous emissions (methane, carbon dioxide, etc.) are diagnostic for the Reductic qualifier.

TABLE 37
Reductimorphic colour pattern and occurrence of Fe compounds

Colour	Munsell colour	Formula	Mineral
Greyish green, light blue	5–GY–5–B2–3/1–3	Fe^{II}/Fe^{III}	Fe-mix compounds (blue-green rust)
White, after oxidation brown	N7–8 ⟶ 10 YR4/5	$Fe^{II}CO_3$	siderite
White, after oxidation blue	N7–8 ⟶ 5–B	$Fe^{II}_3(PO_4)_2 \cdot 8\ H_2O$	vivianite
Bluish black (with 10% HCl; H_2S- smell)	5–10–B1–2/1–3	FeS, FeS_2 (or Fe_3S_4)	Fe sulphides
White, after oxidation white	N8 ⟶ N8	- -	Complete loss of Fe compounds

Source: Schlichting *et al.*, 1995

TABLE 38
Classification of carbonate reaction in the soil matrix

	%		
N	0	Non-calcareous	No detectable visible or audible effervescence.
SL	≈ 0–2	Slightly calcareous	Audible effervescence but not visible.
MO	≈ 2–10	Moderately calcareous	Visible effervescence.
ST	≈ 10–25	Strongly calcareous	Strong visible effervescence. Bubbles form a low foam.
EX	≈ > 25	Extremely calcareous	Extremely strong reaction. Thick foam forms quickly.

TABLE 39
Classification of forms of secondary carbonates

SC	soft concretions
HC	hard concretions
HHC	hard hollow concretions
D	disperse powdery lime
PM	pseudomycelia* (carbonate infillings in pores, resembling mycelia)
M	marl layer
HL	hard cemented layer or layers of carbonates (less than 10 cm thick)

* Pseudomycelia carbonates are not regarded as "secondary carbonates" if they migrate seasonally and have no permanent depth.

CARBONATES

Content

Carbonates in soils are either residues of the parent material or the result of neo-formation (secondary carbonates). The latter are concentrated mainly in the form of soft powdery lime, coatings on peds, concretions, surface or subsoil crusts, or hard banks. The presence of calcium carbonate ($CaCO_3$) is established by adding some drops of 10-percent HCl to the soil. The degree of effervescence of carbon dioxide gas is indicative for the amount of calcium carbonate present. In many soils, it is difficult to distinguish in the field between primary and secondary carbonates. Classes for the reaction of carbonates in the soil matrix are defined as per Table 38.

The reaction to acid depends upon soil texture and is usually more vigorous in sandy material than in fine-textured material with the same carbonate content. Other materials, such as roots, may also give an audible reaction. Dolomite commonly reacts more slowly and less vigorously than calcite. Secondary carbonates should be tested separately; they normally react much more intensely with HCl.

Forms

The forms of secondary carbonates in soils are diverse and are considered to be informative for diagnostics of soil genesis. Soft carbonate concentrations are considered to be illuvial, and hard concretions are generally believed to be of hydrogenic nature. The forms of secondary carbonates should be indicated as per Table 39.

Note for classification purposes

Important carbonate contents for classification are:

✓ ≥ 2 percent calcium carbonate equivalent → calcaric material.

✓ ≥ 15 percent calcium carbonate equivalent in the fine earth, at least partly secondary → calcic horizon.

✓ Indurated layer with calcium carbonate, at least partly secondary → petrocalcic horizon.

TABLE 40
Classification of gypsum content

	%		
N	0	Non-gypsiric	EC = < 1.8 dS m-1 in 10 g soil/25 ml H_2O, EC = < 0.18 dS m-1 in 10 g soil/250 ml H_2O
SL	≈ 0–5	Slightly gypsiric	EC = < 1.8 dS m-1 in 10 g soil/250 ml H_2O
MO	≈ 5–15	Moderately gypsiric	EC = > 1.8 dS m-1 in 10 g soil/250 ml H_2O
ST	≈ 15–60	Strongly gypsiric	higher amounts may be differentiated by abundance of H_2O-soluble pseudomycelia/crystals and soil colour
EX	≈ > 60	Extremely gypsiric	

✓ 15–25 percent calcium carbonate equivalent in the fine earth, at least partly secondary → Hypocalcic qualifier.
✓ ≥ 50 percent calcium carbonate equivalent in the fine earth, at least partly secondary → Hypercalcic qualifier.
✓ Where a soil has a calcic horizon starting 50–10 cm from the soil surface, it is only a Calcisol if the soil matrix between 50 cm from the soil surface and the calcic horizon is calcareous throughout.
✓ Calcisols and Gypsisols can only have an argic horizon where the argic horizon is permeated with calcium carbonate (Calcisols) or calcium carbonate or gypsum (Gypsisols).

GYPSUM

Content of gypsum

Gypsum ($CaSO_4{\cdot}2H_2O$) may be found in the form of residues of gypsiric parent material or new formed features. The latter are pseudomycelia, coarse-sized crystals (individualized, as nests, beards or coatings, or as elongated groupings of fibrous crystals) or loose to compact powdery accumulations. The latter form gives the gypsic horizon a massive structure and a sandy texture.

Where more readily soluble salts are absent, gypsum can be estimated in the field by measurements of electrical conductivity (EC in dS m^{-1}) in soil suspensions of different soil–water relations (Table 40) after 30 minutes (in the case of fine-grained gypsum).

Forms of secondary gypsum

The forms of secondary gypsum in soils are diverse and are considered to be informative for diagnostics of soil genesis. The forms of secondary carbonates should be indicated as per Table 41.

TABLE 41
Classification of forms of secondary gypsum

SC	soft concretions
D	disperse powdery gypsum
G	"gazha" (clayey water-saturated layer with high gypsum content)
HL	hard cemented layer or layers of gypsum (less than 10 cm thick)

Note for classification purposes

Important contents of gypsum for classification are:

✓ ≥ 5 percent (by volume) gypsum → gypsiric material.

TABLE 42
Classification of salt content of soil

		EC_{SE} = dS m^{-1} (25 °C)
N	(nearly)Not salty	< 0.75
SL	Slightly salty	0.75–2
MO	Moderately salty	2–4
ST	Strongly salty	4–8
VST	Very strongly salty	8–15
EX	Extremely salty	> 15

Source: DVWK, 1995.

- ✓ ≥ 5 percent (by mass) gypsum and ≥ 1 percent (by volume) secondary gypsum → gypsic horizon.
- ✓ Indurated layer with ≥ 5 percent (by mass) gypsum and ≥ 1 percent (by volume) secondary gypsum → petrogypsic horizon.
- ✓ 15–25 percent (by mass) gypsum and ≥ 1 percent (by volume) secondary gypsum → Hypogypsic qualifier.
- ✓ ≥ 50 percent (by mass) gypsum and ≥ 1 percent (by volume) secondary gypsum → Hypergypsic qualifier.
- ✓ Gypsisols can only have an argic horizon if the argic horizon is permeated with calcium carbonate or gypsum.

READILY SOLUBLE SALTS

Coastal or desert soils can be especially enriched with water-soluble salts or salts more soluble than gypsum ($CaSO_4{\cdot}2H_2O$; log Ks = -4.85 at 25 °C). The salt content of the soil can be estimated roughly from an EC (in dS m^{-1} = mS cm^{-1}) measured in a saturated soil paste or a more diluted suspension of soil in water (Richards, 1954). Conventionally, EC is measured in the laboratory in the saturation extract (EC_{SE}). Most classification values and data about salt sensitivity of crops refer to EC_{SE}.

An easier and more comfortable method of determining EC in the field is to use a 20 g soil/50 ml H_2O (aqua dest) suspension ($EC_{2.5}$) and to calculate EC_{SE} depending on the texture and content of organic matter (Table 43).

Procedure

Use a transparent plastic cup with marks for 8 cm^3 soil (~ 10 g) and 25 ml water and mix carefully with a plastic stick. The EC is measured with a field conductometer after 30 minutes in the clear solution. Use water with an EC < 0.01 dS m^{-1}.

The salt content (NaCl equivalent) can be estimated from $EC_{2.5}$ by:

$$\text{salt}\ [\%] = EC_{2.5}\ [\text{mS cm}^{-1}] \cdot 0.067 \cdot 2.5.$$

The $EC_{2.5}$ can be converted to EC_{SE} depending on the texture and content of humus according to the formula below and Table 43.

$$EC_{SE} = \frac{250 \cdot EC_{2.5}}{WC_{sp}}$$

Note for classification purposes

- ✓ Threshold values of ≥ 8 and ≥ 15 dS m^{-1} (EC_{SE}, 25 °C) → salic horizon.
- ✓ ≥ 4 dS m^{-1} (EC_{SE}, 25°C) in at least some layer within 100 cm → Hyposalic qualifier.

TABLE 43
Dependency of water content of saturation extract on texture and content of humus for mineral soils and on decomposition for peat soils

Textural class	Water content of saturation extract WC_{SE} in g/100 g					
Mineral soils	Content of humus					
	< 0.5%	0.5–1%	1–2%	2–4%	4–8%	8–15%
Gravel, CS	5	6	8	13	21	35
MS	8	9	11	16	24	38
FS	10	11	13	18	26	40
LS, SL $_{< 10\% \text{ clay}}$	14	15	17	22	30	45
SiL $_{< 10\% \text{ clay}}$	17	18	20	25	34	49
Si	19	20	22	27	36	51
SL $_{10\text{–}20\% \text{ clay}}$	22	23	26	31	39	55
L	25	26	29	34	42	58
SiL $_{10\text{–}27\% \text{ clay}}$	28	29	32	37	46	62
SCL	32	33	36	41	50	67
CL, SiCL	44	46	48	53	63	80
SC	51	53	55	60	70	88
SiC, C $_{40\text{–}60\% \text{ clay}}$	63	65	68	73	83	102
HC $_{> 60\% \text{ clay}}$	105	107	110	116	126	147
Peat soils	**Decomposition stage (see section 3.3.3)**					
	D1 fibric	**D2 low**		**D3 moderate**	**D4 strong**	**D5 sapric**
	80	120		170	240	300

Source: Adapted from DVWK (1995), recalculated to FAO textural classes.

✓ ≥ 30 dS m^{-1} (EC_{SE}, 25°C) in at least some layer within 100 cm → Hypersalic qualifier.

FIELD SOIL PH

Soil pH expresses the activity of the hydrogen ions in the soil solution. It affects the availability of mineral nutrients to plants as well as many soil processes.

When the pH is measured in the field, the method used should be indicated on the field data sheet. The field soil pH should not be a substitute for a laboratory determination. Field soil pH measurements should be correlated with laboratory determinations where possible.

In the field, pH is either estimated using indicator papers, indicator liquids (e.g. Hellige), or measured with a portable pH meter in a soil suspension (1 part soil and 2.5 parts 1 *M* KCl or 0.1 *M* $CaCl_2$ solution). After shaking the solution and waiting for 15 minutes, the pH value can be read. For the measurement, use a transparent 50-ml plastic cup with marks for 8 cm^3 soil (~ 10 g) and 25 ml solution.

Note for classification purposes

As the pH value in many soils correlates with the base saturation, it may be used in the field for preliminary classification purposes (Table 44). However, proof in the laboratory is necessary.

TABLE 44
Classification of pH value

pH_{CaCl_2} of	< 5.1, if > 15% OM < 4.6, if 4–15% OM < 4.2, if < 4% OM	is an indication for a Dystric qualifier (= base saturation <50%), otherwise → Eutric qualifier
	< 3.6, if > 15% OM < 3.4, if 4–15% OM < 3.2, if < 4% OM	is an indication for a base saturation of less than 10% and for a high Al saturation → Hyperalic qualifier

Source: Adapted from Schlichting, Blume and Stahr, 1995.

SOIL ODOUR

Record the presence of any strong smell (Table 45), by horizon. No entry implies no odour.

TABLE 45
Classification of soil odour

	Odour – kind	Criteria
N	None	No odour detected
P	Petrochemical	Presence of gaseous or liquid gasoline, oil, creosote, etc.
S	Sulphurous	Presence of H_2S (hydrogen sulphide; "rotten eggs"); commonly associated with strongly reduced soil containing sulphur compounds.

ANDIC CHARACTERISTICS AND VOLCANIC GLASSES

Soils formed from young volcanic materials often have *andic properties*: a bulk density of 0.9 kg dm^{-3} or less, and a smeary consistence (owing to higher contents of allophane and/or ferrihydrite). Surface horizons with andic characteristics are normally black because of high humus contents. Andic characteristics may be identified in the field using the pH_{NaF} field test developed by Fieldes and Perrott (1966). A pH_{NaF} of more than 9.5 indicates the presence of abundant allophanic products and/or organo-aluminium complexes. The method depends on active aluminium sorbing fluoride ions with subsequent release of OH^+ ions. The test is indicative for most layers with andic properties, except for those very rich in organic matter. However, the same reaction occurs in spodic horizons and in certain acid clayey soils that are rich in aluminium-interlayered clay minerals; soils with free carbonates also react. Before applying a field NaF test, it is important to check soil pH (the test is not suitable for alkaline soils) and the presence of free carbonates (using HCl field test).

Procedure

Place a small amount of soil material on a filter paper previously soaked in phenolphthalein and add some drops of 1 *M* NaF (adjusted to pH 7.5). A positive reaction is indicated by a fast change to an intense red colour. Alternatively, measure the pH of a suspension of 1 g soil in 50 ml 1 *M* NaF (adjusted to pH 7.5) after 2 minutes. If the pH is more than 9.5, it is a positive indication. Note in the description sheet the sign of a + or a -.

In addition, soil material with andic characteristics may exhibit thixotropy; the soil material changes under pressure or by rubbing from a plastic solid into a liquefied stage and back into the solid condition.

Note for classification purposes

✓ Positive field test for allophanic products and/or organo-aluminium complexes → andic properties.

✓ Thixotropy → Thixotropic qualifier.

In many young volcanic materials, volcanic glasses, glassy aggregates and other glass-coated primary minerals occur. Coarser fractions may be checked by a ×10 hand-lens; finer fractions may be checked by microscope.

Note for classification purposes

✓ ≥ 5 percent (by grain count) volcanic glass, glassy aggregates and other glass-coated primary minerals, in the fraction 0.05–2 mm, **or** in the fraction 0.02–0.25 mm → vitric properties.

✓ ≥ 30 percent (by grain count) volcanic glass, glass-coated primary minerals, glassy materials, and glassy aggregates in the 0.02–2 mm particle-size fraction → tephric material.

ORGANIC MATTER CONTENT

Organic matter refers to all decomposed, partly decomposed and undecomposed organic materials of plant and animal origin. It is generally synonymous with humus although the latter is more commonly used when referring to the well-decomposed organic matter called humic substances.

The content of organic matter of mineral horizons can be estimated from the Munsell colour of a dry and/or moist soil, taking the textural class into account (Table 46). This estimation is based on the assumption that the soil colour (value) is due to a mixture of dark coloured organic substances and light coloured minerals.

This estimate does not work very well in strongly coloured subsoils. It tends to overestimate organic matter content in soils of dry regions, and to underestimate the organic matter content in some tropical soils. Therefore, the organic matter values should always be locally checked as they only provide a rough estimate.

TABLE 46
Estimation of organic matter content based on Munsell soil colour

Colour	Munsell value	Moist soil			Dry soil		
		S	LS, SL, L	SiL, Si, SiCL, CL, SCL, SC, SiC, C	S	LS, SL, L	SiL, Si, SiCL, CL, SCL, SC, SiC, C
		(%)					
Light grey	7				< 0.3	< 0.5	< 0.6
Light grey	6.5				0.3–0.6	0.5–0.8	0.6–1.2
Grey	6				0.6–1	0.8–1.2	1.2–2
Grey	5.5			< 0.3	1–1.5	1.2–2	2–3
Grey	5	< 0.3	< 0.4	0.3–0.6	1.5–2	2–4	3–4
Dark grey	4.5	0.3–0.6	0.4–0.6	0.6–0.9	2–3	4–6	4–6
Dark grey	4	0.6–0.9	0.6–1	0.9–1.5	3–5	6–9	6–9
Black grey	3.5	0.9–1.5	1–2	1.5–3	5–8	9–15	9–15
Black grey	3	1.5–3	2–4	3–5	8–12	> 15	> 15
Black	2.5	3–6	> 4	> 5	> 12		
Black	2	> 6					

Note: If chroma is 3.5–6, add 0.5 to value; if chroma is > 6, add 1.0 to value.
Source: Adapted from Schlichting, Blume and Stahr, 1995.

Note for classification purposes

- ✓ If saturated with water for ≥ 30 consecutive days in most years (unless drained): ≥ [12 + (clay percentage of the mineral fraction × 0.1)]% organic carbon or ≥ 18 percent organic carbon, else ≥ 20 percent organic carbon → organic material.
- ✓ Organic material saturated with water for ≥ 30 consecutive days in most years (unless drained) → histic horizon.
- ✓ Organic material saturated with water for < 30 consecutive days in most years → folic horizon.
- ✓ Weighted average of ≥ 6 percent organic carbon, and ≥ 4 percent organic carbon in all parts → fulvic and melanic horizon.
- ✓ Organic carbon content of ≥ 0.6 percent → mollic and umbric horizon.
- ✓ Organic carbon content of ≥ 1.5 percent → voronic horizon.

(Note: the ratio of organic carbon to organic matter is about 1:1.7–2.)
Write the range or average value in the description sheet.

ORGANIZATION OF SOIL CONSTITUENTS

This section describes the primary physical organization of arrangement of the soil constituents, together with the consistence of the constituents. Primary organization is considered as being the overall arrangement of the soil mass without concentrations, reorientations and biological additions. It will not always be possible to make clear distinctions between primary and secondary elements of the organization. Voids (pores), which relate to the structural organization of soil, are described in a later section.

Soil structure

Soil structure refers to the natural organization of soil particles into discrete soil units (aggregates or peds) that result from pedogenic processes. The aggregates are separated from each other by pores or voids. It is preferred to describe the structure when the soil is dry or slightly moist. In moist or wet conditions, it is advisable to leave the description of structure to a later time when the soil has dried out. For the description of soil structure, a large lump of the soil should be taken from the profile, from various parts of the horizon if necessary, rather than observing the soil structure *in situ*.

Soil structure is described in terms of grade, size and type of aggregates. Where a soil horizon contains aggregates of more than one grade, size or type, the different kinds of aggregates should be described separately and their relationship indicated.

Grade

In describing the grade or development of the structure, the first division is into apedal soils (lacking soil structure) and pedal soils (showing soil structure).

In apedal or structureless soil, no aggregates are observable in place and there is no definite arrangement of natural surfaces of weakness. Structureless soils are subdivided into single grain and massive (see below). Single-grain soil material has a loose, soft or very friable consistence and consists on rupture of more than 50 percent discrete mineral particles. Massive soil material normally has a stronger consistence and is more coherent on rupture. Massive soil material may be further defined by consistence (below) and porosity (below).

Grades of structure of pedal soil materials are defined as per Table 47.

TABLE 47
Classification of structure of pedal soil materials

WE	Weak	Aggregates are barely observable in place and there is only a weak arrangement of natural surfaces of weakness. When gently disturbed, the soil material breaks into a mixture of few entire aggregates, many broken aggregates, and much material without aggregate faces. Aggregate surfaces differ in some way from the aggregate interior.
MO	Moderate	Aggregates are observable in place and there is a distinct arrangement of natural surfaces of weakness. When disturbed, the soil material breaks into a mixture of many entire aggregates, some broken aggregates, and little material without aggregates faces. Aggregates surfaces generally show distinct differences with the aggregates interiors.
ST	Strong	Aggregates are clearly observable in place and there is a prominent arrangement of natural surfaces of weakness. When disturbed, the soil material separates mainly into entire aggregates. Aggregates surfaces generally differ markedly from aggregate interiors.
Combined classes may be constructed as follows:		
WM	Weak to moderate	
MS	Moderate to strong	

FIGURE 6
Soil structure types and their formation

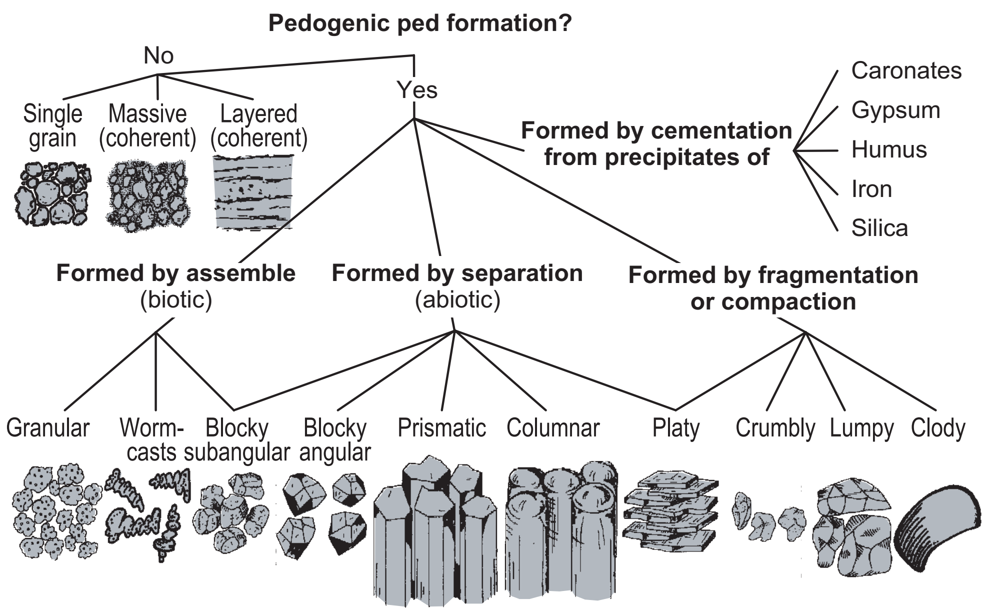


TABLE 48
Classification of types of soil structure

Blocky	Blocks or polyhedrons, nearly equidimensional, having flat or slightly rounded surfaces that are casts of the faces of the surrounding aggregates. Subdivision is recommended into angular, with faces intersecting at relatively sharp angles, and subangular blocky faces intersecting at rounded angles.
Granular	Spheroids or polyhedrons, having curved or irregular surfaces that are not casts of the faces of surrounding aggregates.
Platy	Flat with vertical dimensions limited; generally oriented on a horizontal plane and usually overlapping.
Prismatic	the dimensions are limited in the horizontal and extended along the vertical plane; vertical faces well defined; having flat or slightly rounded surfaces that are casts of the faces of the surrounding aggregates. Faces normally intersect at relatively sharp angles. Prismatic structures with rounded caps are distinguished as Columnar.
Rock structure	Rock structure includes fine stratification in unconsolidated sediment, and pseudomorphs of weathered minerals retaining their positions relative to each other and to unweathered minerals in saprolite from consolidated rocks.
Wedge-shaped	Elliptical, interlocking lenses that terminate in sharp angles, bounded by slickensides; not limited to vertic materials.
Crumbs, lumps and clods	Mainly created by artificial disturbance, e.g. tillage.

TABLE 49
Codes for types of soil structure

RS	Rock structure	
	SS	Stratified structure
SG	Single grain	
MA	Massive	
PM	Porous massive	
BL	Blocky	
	AB	Angular blocky
	AP	Angular blocky (parallelepiped)
	AS	Angular and subangular blocky
	AW	Angular blocky (wedge-shaped)
	SA	Subangular and angular blocky
	SB	Subangular blocky
	SN	Nutty subangular blocky
PR	Prismatic	
	PS	Subangular prismatic
WE	Wedge-shaped	
CO	Columnar	
GR	Granular	
WC	Worm casts	
PL	Platy	
CL	Cloddy	
CR	Crumbly	
LU	Lumpy	

Type

The basic natural types of structure (Figure 6) are defined as per Table 48.

Where required, special cases or combinations of structures may be distinguished, which are subdivisions of the basic structures. The recommended codes are given in Table 49.

Size

Size classes vary with the structure type. For prismatic, columnar and platy structures, the size classes refer to the measurements of the smallest dimension of the aggregate (Table 50).

Combined classes may be constructed as per Table 51.

Where a second structure is present, its relation to the first structure is described. The first and second structures may both be present (e.g. columnar and prismatic structures). The primary structure may break down into a secondary structure (e.g. prismatic breaking into angular blocky). The first structure may merge into the second structure (e.g. platy merging into prismatic). These can be indicated as per Table 52.

TABLE 50
Size classes for soil structure types

		Granular/platy (mm)	Prismatic/columnar/wedge-shaped (mm)	Blocky/crumbly/lumpy/cloddy (mm)
VF	Very fine/thin	< 1	< 10	< 5
FI	Fine/thin	1–2	10–20	5–10
ME	Medium	2–5	20–50	10–20
CO	Coarse/thick	5–10	50–100	20–50
VC	Very coarse/thick	> 10	100–500	> 50
EC	Extremely coarse	–	> 500	–

TABLE 51
Combined size classes for soil structure types

FF	Very fine and fine
VM	Very fine to medium
FM	Fine and medium
FC	Fine to coarse
MC	Medium and coarse
MV	Medium to very coarse
CV	Coarse and very coarse

TABLE 52
Combinations of soil structures

CO + PR	Both structures present
PR → AB	Primary breaking to secondary structure
PL / PR	One structure merging into the other

Note for classification purposes

- ✓ Soil structure, or absence of rock structure (the term "rock structure" also applies to unconsolidated sediments in which stratification is still visible) in half of the volume or more of the fine earth → cambic horizon.
- ✓ Soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry (prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms) → mollic, umbric and anthric horizons.
- ✓ Granular or fine subangular blocky soil structure (and worm casts) → voronic horizon.
- ✓ Columnar or prismatic structure in some part of the horizon or a blocky structure with tongues of an eluvial horizon → natric horizon.
- ✓ Moderate to strong, angular blocky structure breaking to flat-edged or nut-shaped elements with shiny ped faces → nitic horizon.
- ✓ Wedge-shaped structural aggregates with a longitudinal axis tilted 10–60 ° from the horizontal → vertic horizon.
- ✓ Wedge-shaped aggregates → vertic properties.
- ✓ Platy structure → puddled layer (anthraquic horizon).
- ✓ Uniformly structured → irragric horizon.
- ✓ Separations between structural soil units that allow roots to enter have an average horizontal spacing of ≥ 10 cm → fragic horizon.
- ✓ Platy or massive structure → takyric horizon.
- ✓ Platy layer → yermic horizon.

- ✓ Strong structure finer than very coarse granular → Grumic qualifier.
- ✓ Massive and hard to very hard in the upper 20 cm of the soil → Mazic qualifier.
- ✓ A platy structure and a surface crust → Hyperochric qualifier.
- ✓ Stratification in ≥ 25 percent of the soil volume → fluvic material.

Consistence

Consistence refers to the degree of cohesion or adhesion of the soil mass. It includes soil properties such as friability, plasticity, stickiness and resistance to compression. It depends greatly on the amount and type of clay, organic matter and moisture content of the soil.

For reference descriptions (Status 1, Chapter 2), a recording of consistence is required for the dry, moist and wet (stickiness and plasticity) states. Where applicable, the smeariness (thixotropy) and fluidity may also be recorded. For routine descriptions, the soil consistence in the natural moisture condition of the profile may be described. Wet consistence can always be described, and moist conditions where the soil is dry, by adding water to the soil sample.

Consistence when dry

The consistence when dry (Table 53) is determined by breaking an air-dried mass of soil between thumb and forefinger or in the hand.

Consistence when moist

Consistence when moist (Table 54) is determined by attempting to crush a mass of moist or slightly moist soil material.

Consistence when wet: maximum stickiness and maximum plasticity

Soil stickiness depends on the extent to which soil structure is destroyed and on the amount of water present. The determination of stickiness should be performed under standard conditions on a soil sample in which structure is completely destroyed and which contains enough water to express its maximum stickiness. In this way, the maximum stickiness will be determined and comparison between degrees of stickiness of various soils will be feasible. The same principle applies to soil plasticity.

TABLE 53
Consistence of soil mass when dry

LO	Loose	Non-coherent.
SO	Soft	Soil mass is very weakly coherent and fragile; breaks to powder or individual grains under very slight pressure.
SHA	Slightly hard	Weakly resistant to pressure; easily broken between thumb and forefinger.
HA	Hard	Moderately resistant to pressure; can be broken in the hands; not breakable between thumb and forefinger.
VHA	Very hard	Very resistant to pressure; can be broken in the hands only with difficulty.
EHA	Extremely hard	Extremely resistant to pressure; cannot be broken in the hands.

Note: Additional codes, needed occasionally to distinguish between two horizons or layers, are: SSH, soft to slightly hard; SHH, slightly hard to hard; and HVH, hard to very hard.

TABLE 54
Consistence of soil mass when moist

LO	Loose	Non-coherent.
VFR	Very friable	Soil material crushes under very gentle pressure, but coheres when pressed together.
FR	Friable	Soil material crushes easily under gentle to moderate pressure between thumb and forefinger, and coheres when pressed together.
FI	Firm	Soil material crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.
VFI	Very firm	Soil material crushes under strong pressures; barely crushable between thumb and forefinger.
EFI	Extremely firm	Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger.

Note: Additional codes are: VFF, very friable to friable; FRF, friable to firm; and FVF, firm to very firm.

Stickiness is the quality of adhesion of the soil material to other objects determined by noting the adherence of soil material when it is pressed between thumb and finger (Table 55).

Plasticity is the ability of soil material to change shape continuously under the influence of an applied stress and to retain the compressed shape on removal of stress. Determined by rolling the soil in the hands until a wire about 3 mm in diameter has been formed (Table 56).

TABLE 55
Classification of soil stickiness

NST	Non-sticky	After release of pressure, practically no soil material adheres to thumb and finger.
SST	Slightly sticky	After pressure, soil material adheres to both thumb and finger but comes off one or the other rather cleanly. It is not appreciably stretched when the digits are separated.
ST	Sticky	After pressure, soil material adheres to both thumb and finger and tends to stretch somewhat and pull apart rather than pulling free from either digit.
VST	Very sticky	After pressure, soil material adheres strongly to both thumb and finger and is decidedly stretched when they are separated.

Note: Additional codes are: SSS, slightly sticky to sticky; and SVS, sticky to very sticky.

TABLE 56
Classification of soil plasticity

NPL	Non-plastic	No wire is formable.
SPL	Slightly plastic	Wire formable but breaks immediately if bent into a ring; soil mass deformed by very slight force.
PL	Plastic	Wire formable but breaks if bent into a ring; slight to moderate force required for deformation of the soil mass.
VPL	Very plastic	Wire formable and can be bent into a ring; moderately strong to very strong force required for deformation of the soil mass.

Note: Additional codes are: SPP, slightly plastic to plastic; and PVP, plastic to very plastic.

Note for classification purposes

- ✓ Extremely hard consistence when dry → petrocalcic horizon.
- ✓ Surface crust with very hard consistence when dry, and very plastic and sticky consistence when wet → takyric horizon.
- ✓ Air-dry clods, 5–10 cm in diameter, slake or fracture in water within 10 minutes → fragic horizon.
- ✓ Penetration resistance at field capacity of ≥ 50 kN m^{-1} → fragic horizon.
- ✓ Penetration resistance of ≥ 450 N cm^{-2} → petroplinthic horizon.

TABLE 57
Classification of moisture status of soil

Crushing	Forming (to a ball)	Moistening	Rubbing (in the hand)	Moisture	pF*
dusty or hard	not possible, seems to be warm	going very dark	not lighter	very dry	5
makes no dust	not possible, seems to be warm	going dark	hardly lighter	dry	4
makes no dust	possible (not sand)	going slightly dark	obviously lighter	slightly moist	3
is sticky	finger moist and cool, weakly shiny	no change of colour	obviously lighter	moist	2
free water	drops of water	no change of colour		wet	1
free water	drops of water without crushing	no change of colour		very wet	0

* pF (p = potential, F = free energy of water) is log hPa.

Soil-water status

Soil-water status is the term used for the moisture condition of a horizon at the time the profile is described. The moisture status can be estimated in the field as per Table 57.

Note for classification purposes

- ✓ The definitions of mineral and organic materials and of the histic, folic and cryic horizons depend on the soil-water status.
- ✓ Temporarily water-saturated → Gelistagnic, Oxyaquic and Reductaquic qualifiers.
- ✓ Organic material floating on water → Floatic qualifier.
- ✓ Permanently submerged under water < 2 m → Subaquatic qualifier.
- ✓ Flooded by tidewater, but not covered at mean low tide → Tidalic qualifier.
- ✓ Artificially drained histic horizon → Drainic qualifier.

BULK DENSITY

Bulk density is defined as the mass of a unit volume of dry soil (105 °C). This volume includes both solids and pores and, thus, bulk density reflects the total soil porosity. Low bulk density values (generally below 1.3 kg dm^{-3}) generally indicate a porous soil condition. Bulk density is an important parameter for the description of soil quality and ecosystem function. High bulk density values indicate a poorer environment for root growth, reduced aeration, and undesirable changes in hydrologic function, such as reduced water infiltration.

There are several methods of determining soil bulk density. One method is to obtain a known volume of soil, dry it to remove the water, and weigh the dry mass. Another uses a special coring instrument (cylindrical metal device) to obtain a sample of known volume without disturbing the natural soil structure, and then to determine the dry mass. For surface horizons, a simple method is to dig a small hole and fill it completely with a measured volume of sand.

Field determinations of bulk density may be obtained by estimating the force required to push a knife into a soil horizon exposed at a field moist pit wall (Table 58).

TABLE 58
Field estimation of bulk density for mineral soils

Observation	Frequent ped shape	Bulk density ($kg\ dm^{-3}$) Code
Sandy, silty and loamy soils with low clay content		
Many pores, moist materials drop easily out of the auger; materials with vesicular pores, mineral soils with andic properties.	granular	< 0.9 BD1
Sample disintegrates at the instant of sampling, many pores visible on the pit wall.	single grain, granular	0.9–1.2 BD1
Sample disintegrates into numerous fragments after application of weak pressure.	single grain, subangular, angular blocky	1.2–1.4 BD2
Knife can be pushed into the moist soil with weak pressure, sample disintegrates into few fragments, which may be further divided.	subangular and angular blocky, prismatic, platy	1.4–1.6 BD3
Knife penetrates only 1–2 cm into the moist soil, some effort required, sample disintegrates into few fragments, which cannot be subdivided further.	prismatic, platy, (angular blocky)	1.6–1.8 BD4
Very large pressure necessary to force knife into the soil, no further disintegration of sample.	prismatic	> 1.8 BD5
Loamy soils with high clay content, clayey soils		
When dropped, sample disintegrates into numerous fragments, further disintegration of subfragments after application of weak pressure.	angular blocky	1.0–1.2 BD1
When dropped, sample disintegrates into few fragments, further disintegration of subfragments after application of mild pressure.	angular blocky, prismatic, platy, columnar	1.2–1.4 BD2
Sample remains mostly intact when dropped, further disintegration possible after application of large pressure.	coherent, prismatic, platy, (columnar, angular blocky, platy, wedge–shaped)	1.4–1.6 BD3
Sample remains intact when dropped, no further disintegration after application of very large pressure.	coherent (prismatic, columnar, wedge–shaped)	>1.6 BD4, 5

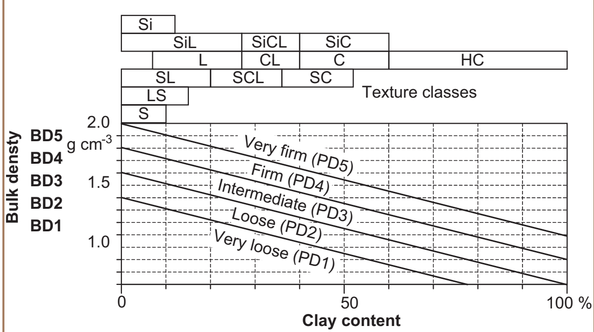
Note: If organic matter content is > 2%, bulk density has to be reduced by 0.03 $kg\ dm^{-3}$ for each 1% increment in organic matter content.

Note for classification purposes

- ✓ Bulk density of 0.90 $kg\ dm^{-3}$ or less → andic properties.
- ✓ In the plough pan, a bulk density ≥20 percent (relative) higher than that of the puddled layer → anthraquic horizon.

Root penetration is not only limited by bulk density, but also by texture. Fine-textured soils contain fewer pores in size and abundance than needed for unrestricted root growth. Therefore, the evaluation of bulk density has to take soil texture into account. For evaluation purposes the "packing density" (PD = BD + 0.009 ·% clay) can also be used (Figure 7).

FIGURE 7
Qualification of bulk density



Source: according to Ad-hoc-AG-Boden, 2005.

TABLE 59
Field estimation of volume of solids and bulk density of peat soils

Drainage conditions		Peat characteristics	Classes of decomposition		Solid volume	Bulk density
Bog	Fen				Vol. (%) Code	g cm^{-3}
Undrained	Undrained	Almost swimming	D1	Very low (fibric)	< 3 SV1	< 0.04
Weakly drained	Weakly drained	Loose	D2	Low (fibric)	3– < 5 SV2	0.04–0.07
Moderately drained	Weakly drained	Rather loose	D3	Moderate (fibric)	5– < 8 SV3	0.07–0.11
Well drained	Moderately drained	Rather dense	D4	Strong (hemic)	8– < 12 SV4	0.11–0.17
Well drained	Well drained	Dense	D5	Very strong (sapric)	≥ 12 SV5	> 0.17

Source: Adapted from Ad-hoc-AG-Boden, 2005.

Bulk density and volume of solids of organic soils may be estimated after the decomposition stage or the extent of peat drainage. Weakly drained and weakly decomposed peat materials are characterized by a lower bulk density and a lower solid volume than well-drained and strongly decomposed peat materials (Table 59).

Organic surface horizons of mineral soils may be treated like strongly decomposed peat layers.

VOIDS (POROSITY)

Voids include all empty spaces in the soil. They are related to the arrangement of the primary soil constituents, rooting patterns, burrowing of animals or any other soil-forming processes, such as cracking, translocation and leaching. The term void is almost equivalent to the term pore, but the latter is often used in a more restrictive way and does not, for example, include fissures or planes.

Voids are described in terms of type, size and abundance. In addition, continuity, orientation or any other feature may also be recorded.

Porosity

The porosity is an indication of the total volume of voids discernible with a ×10 hand-lens measured by area and recorded as the percentage of the surface occupied by pores (Table 60).

TABLE 60
Classification of porosity

		%
1	Very low	< 2
2	Low	2–5
3	Medium	5–15
4	High	15–40
5	Very high	> 40

Type

There is a large variety in the shape and origin of voids. It is impractical and usually not necessary to describe all different kinds of voids comprehensively. Emphasis should be given to estimating the continuous and elongated voids.

TABLE 61
Classification of voids

I	Interstitial	Controlled by the fabric, or arrangement, of the soil particles, also known as textural voids. Subdivision possible into simple packing voids, which relate to the packing of sand particles, and compound packing voids, which result from the packing of non-accommodating peds. Predominantly irregular in shape and interconnected, and hard to quantify in the field.
B	Vesicular	Discontinuous spherical or elliptical voids (chambers) of sedimentary origin or formed by compressed air, e.g. gas bubbles in slaking crusts after heavy rainfall. Relatively unimportant in connection with plant growth.
V	Vughs	Mostly irregular, equidimensional voids of faunal origin or resulting from tillage or disturbance of other voids. Discontinuous or interconnected. May be quantified in specific cases.
C	Channels	Elongated voids of faunal or floral origin, mostly tubular in shape and continuous, varying strongly in diameter. When wider than a few centimetres (burrow holes), they are more adequately described under biological activity.
P	Planes	Most planes are extra-pedal voids, related to accommodating ped surfaces or cracking patterns. They are often not persistent and vary in size, shape and quantity depending on the moisture condition of the soil. Planar voids may be recorded, describing width and frequency.

The major types of voids may be classified in a simplified way as per Table 61.

In most cases, it is recommended that only the size and abundance of the channels, which are mostly continuous tubular pores, be described (Figure 8). For the other types of voids, the following size and abundance classes should serve as a guide for the construction of suitable classes for each category.

Size

The diameter of the elongated or tubular voids is described as per Table 62.

Abundance

The abundance of very fine and fine elongated pores as one group, and of medium and coarse pores as another group is recorded as the number per unit area in a square decimetre (Table 63).

Note for classification purposes

✓ Vesicular layer below a platy layer or pavement with a vesicular layer → yermic horizon.

✓ Sorted soil aggregates and vesicular pores → anthraquic horizon.

CONCENTRATIONS

This section deals with the most common concentrations of soil materials, including secondary enrichments, cementations and reorientations.

TABLE 62
Classification of diameter of voids

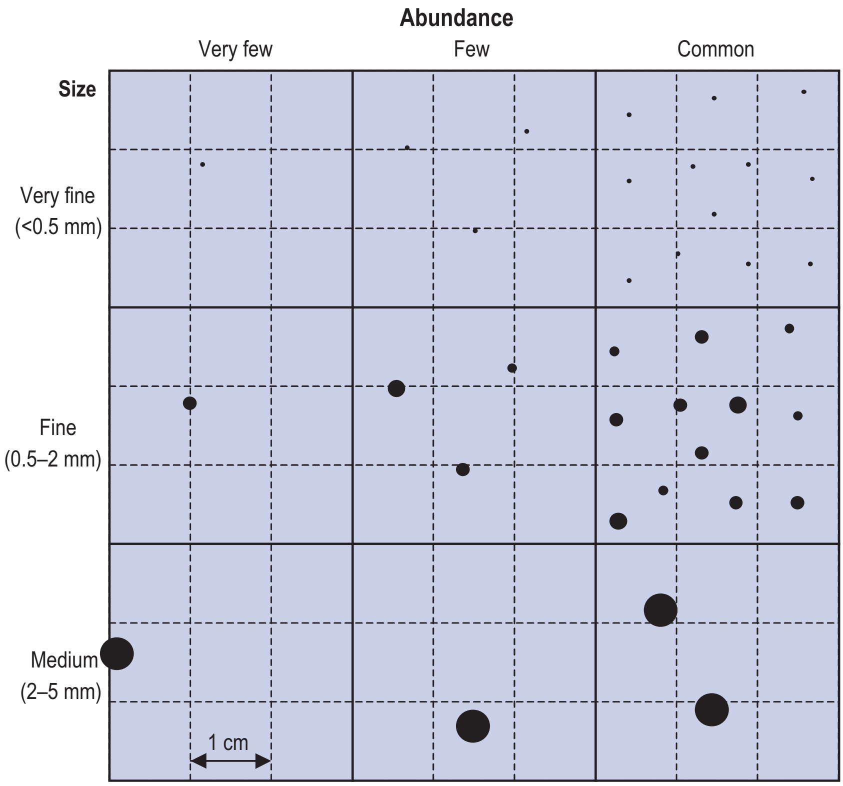
		mm
V	Very fine	< 0.5
F	Fine	0.5–2
M	Medium	2–5
C	Coarse	5–20
VC	Very coarse	20–50

Note: Additional codes are: FM, fine and medium; FF fine and very fine; and MC, medium and coarse.

TABLE 63
Classification of abundance of pores

		< 2 mm (number)	> 2 mm
N	None	0	0
V	Very few	1–20	1–2
F	Few	20–50	2–5
C	Common	50–200	5–20
M	Many	> 200	> 20

FIGURE 8
Charts for estimating size and abundance of pores



Coatings

This section describes clay or mixed-clay illuviation features, coatings of other composition (such as calcium carbonate, manganese, organic or silt), reorientations (such as slickensides and pressure faces), and concentrations associated with surfaces but occurring as stains in the matrix ("hypodermic coatings"). All these features are described according to their abundance, contrast, nature, form and location.

Abundance

For coatings, an estimate is made of how much of the ped or aggregate faces is covered (Table 64). Corresponding criteria should be applied when the cutanic feature is related to other surfaces (voids, and coarse fragments) or occurs as lamellae.

Contrast

Table 65 shows the classification of the contrast of coatings.

Nature

The nature of coatings may be described as per Table 66.

Form

For some coatings, the form may be informative for their genesis (Table 67). For example, manganese and iron–manganese coatings of dendroidal form indicate their formation owing to poor infiltration and periodically reductive conditions because of percolating water.

Location

The location of the coatings or clay accumulation is indicated (Table 68). For pressure faces and slickensides, no location is given because they are by definition located on pedfaces.

TABLE 64
Classification of abundance of coatings

		%
N	None	0
V	Very few	0–2
F	Few	2–5
C	Common	5–15
M	Many	15–40
A	Abundant	40–80
D	Dominant	> 80

TABLE 65
Classification of the contrast of coatings

F	Faint	Surface of coating shows only little contrast in colour, smoothness or any other property to the adjacent surface. Fine sand grains are readily apparent in the cutan. Lamellae are less than 2 mm thick.
D	Distinct	Surface of coating is distinctly smoother or different in colour from the adjacent surface. Fine sand grains are enveloped in the coating but their outlines are still visible. Lamellae are 2–5 mm thick.
P	Prominent	Surface of coatings contrasts strongly in smoothness or colour with the adjacent surfaces. Outlines of fine sand grains are not visible. Lamellae are more than 5 mm thick.

TABLE 66
Classification of the nature of coatings

C	Clay
S	Sesquioxides
H	Humus
CS	Clay and sesquioxides
CH	Clay and humus (organic matter)
CC	Calcium carbonate
GB	Gibbsite
HC	Hypodermic coatings (Hypodermic coatings, as used here, are field-scale features, commonly only expressed as hydromorphic features. Micromorphological hypodermic coatings include non-redox features [Bullock *et al.*, 1985].)
JA	Jarosite
MN	Manganese
SL	Silica (opal)
SA	Sand coatings
ST	Silt coatings
SF	Shiny faces (as in nitic horizon)
PF	Pressure faces
SI	Slickensides, predominantly intersecting (Slickensides are polished and grooved ped surfaces that are produced by aggregates sliding one past another.)
SP	Slickensides, partly intersecting
SN	Slickensides, non intersecting

Source: Adapted from Schoeneberger *et al*, 2002.

TABLE 67
Classification of the form of coatings

C	Continuous
CI	Continuous irregular (non-uniform, heterogeneous)
DI	Discontinuous irregular
DE	Dendroidal
DC	Discontinuous circular
O	Other

TABLE 68
Classification of the location of coatings and clay accumulation

P	Pedfaces
PV	Vertical pedfaces
PH	Horizontal pedfaces
CF	Coarse fragments
LA	Lamellae (clay bands)
VO	Voids
BR	Bridges between sand grains
NS	No specific location

TABLE 69
Classification of the continuity of cementation/compaction

B	Broken	The layer is less than 50 percent cemented or compacted, and shows a rather irregular appearance.
D	Discontinuous	The layer is 50–90 percent cemented or compacted, and in general shows a regular appearance.
C	Continuous	The layer is more than 90 percent cemented or compacted, and is only interrupted in places by cracks or fissures.

TABLE 70
Classification of the fabric of the cemented/compacted layer

P	Platy	The compacted or cemented parts are plate-like and have a horizontal or subhorizontal orientation.
V	Vesicular	The layer has large, equidimensional voids that may be filled with uncemented material.
P	Pisolithic	The layer is largely constructed from cemented spherical nodules.
D	Nodular	The layer is largely constructed from cemented nodules or concretions of irregular shape.

Note for classification purposes

- ✓ Evidence of silica accumulation, e.g. as coatings → petroduric horizon.
- ✓ Slickensides → vertic horizon and vertic properties.
- ✓ Evidence of clay illuviation → argic and natric horizons.
- ✓ Cracked coatings on sand grains → spodic horizon.
- ✓ Uncoated sand and silt grains → Greyic qualifier.
- ✓ Clay coatings in the argic horizon → Cutanic qualifier.
- ✓ Illuviation in the form of lamellae in the argic, natric and spodic horizon → Lamellic qualifier.
- ✓ Coatings that have a different colour from the matrix (section on mottling [above]).

Cementation and compaction

The occurrence of cementation or compaction in pans or otherwise is described according to its nature, continuity, structure, agent and degree.

Compacted material has a firm or stronger consistence when moist and a close packing of particles. Cemented material does not slake after 1 hour of immersion in water.

Continuity

Table 69 indicates the classification of the continuity of cementation/compaction.

Structure

The fabric or structure of the cemented or compacted layer may be described as per Table 70.

Nature

The nature of cementation or compaction is described according to the cementing agent or compacting activity, as indicated in Table 71.

TABLE 71
Classification of the nature of cementation/compaction

K	Carbonates
Q	Silica
KQ	Carbonates–silica
F	Iron
FM	Iron–manganese (sesquioxides)
FO	Iron–organic matter
I	Ice
GY	Gypsum
C	Clay
CS	Clay–sesquioxides
M	Mechanical
P	Ploughing
NK	Not known

Degree

Table 72 indicates the classification of the degree of cementation/compaction.

Note for classification purposes

- ✓ Ice overlain by organic material → Histosols.
- ✓ Cementation by ice or readily visible ice crystals → cryic horizon.
- ✓ ≥ 75 percent ice (by volume) → Glacic qualifier.
- ✓ Cementation by organic matter and aluminium → spodic horizon.
- ✓ Cemented spodic horizon → Ortsteinic qualifier.
- ✓ Iron pan that is 1–25 mm thick and is continuously cemented by a combination of organic matter, iron and/or aluminium → Placic qualifier.
- ✓ Strongly cemented or indurated → petrocalcic, duric, gypsic and plinthic horizons, Petric, Petrogleyic and Petrosalic qualifiers.
- ✓ Cementation on repeated wetting and drying → plinthic horizon.
- ✓ Roots cannot penetrate except along vertical fractures that have an average horizontal spacing of ≥ 10 cm and occupy < 20 percent (by volume) of the layer → petrocalcic, petroduric and petrogypsic horizons.
- ✓ Strongly cemented or indurated horizon consisting of clods with an average horizontal length of < 10 cm → Fractipetric and Fractiplinthic qualifiers.
- ✓ Natural or artificial compaction → Densic qualifier.

TABLE 72
Classification of the degree of cementation/compaction

N	Non-cemented and non-compacted	Neither cementation nor compaction observed (slakes in water).
Y	Compacted but non-cemented	Compacted mass is appreciably harder or more brittle than other comparable soil mass (slakes in water).
W	Weakly cemented	Cemented mass is brittle and hard, but can be broken in the hands.
M	Moderately cemented	Cemented mass cannot be broken in the hands but is discontinuous (less than 90 percent of soil mass).
C	Cemented	Cemented mass cannot be broken in the hands and is continuous (more than 90 percent of soil mass).
I	Indurated	Cemented mass cannot be broken by body weight (75-kg standard soil scientist) (more than 90 percent of soil mass).

Mineral concentrations

Mineral concentrations cover a large variety of secondary crystalline, microcrystalline and amorphous concentrations of non-organic substances as infillings, soft concretions, irregular concentrations (mottles), nodules of mainly pedogenetically formed materials. Gradual transitions exist with mottles (above), some of which may be considered as weak expressions of nodules. The mineral concentrations are described according to their abundance, kind, size, shape, hardness, nature and colour.

Abundance (by volume)

Table 73 describes the classification of the abundance of mineral concentrations.

TABLE 73
Classification of the abundance of mineral concentrations, by volume

		%
N	None	0
V	Very few	0–2
F	Few	2–5
C	Common	2–15
M	Many	15–40
A	Abundant	40–80
D	Dominant	> 80

Kind

Table 74 describes the classification of the kinds of mineral concentrations.

TABLE 74
Classification of the kinds of mineral concentrations

T	Crystal	
C	Concretion	A discrete body with a concentric internal structure, generally cemented.
SC	Soft concretion	
S	Soft segregation (or soft accumulation)	Differs from the surrounding soil mass in colour and composition but is not easily separated as a discrete body.
N	Nodule	Discrete body without an internal organization.
IP	Pore infillings	Including pseudomycelium of carbonates or opal.
IC	Crack infillings	
R	Residual rock fragment	Discrete impregnated body still showing rock structure.
O	Other	

Size and shape

Table 75 describes the classification of the size and shape of mineral concentrations.

TABLE 75
Classification of the size and shape of mineral concentrations

	Size	(mm)		Shape
V	Very fine	< 2	R	Rounded (spherical)
F	Fine	2–6	E	Elongated
M	Medium	6–20	F	Flat
C	Coarse	> 20	I	Irregular
			A	Angular

Hardness

Table 76 describes the classification of the hardness of mineral concentrations.

TABLE 76
Classification of the hardness of mineral concentrations

H	Hard	Cannot be broken in the fingers.
S	Soft	Can be broken between forefinger and thumb nail
B	Both hard and soft.	

Nature

Mineral concentrations are described according to the composition or impregnating substance. Table 77 provides some examples.

Colour

The general colour names given in Table 78 are usually sufficient to describe the colour of the nodules (similar to mottles) or of artefacts.

Note for classification purposes

- ✓ ≥ 10 percent (by volume) of weakly cemented to indurated, silica-enriched nodules (durinodes) → duric horizon.
- ✓ Reddish to blackish nodules of which at least the exteriors are at least weakly cemented or indurated → ferric horizon.
- ✓ Firm to weakly cemented nodules or mottles with a stronger chroma or redder hue than the surrounding material → plinthic horizon.
- ✓ Strongly cemented or indurated reddish to blackish nodules → pisoplinthic horizon.

TABLE 77
Examples of the nature of mineral concentrations

K	Carbonates (calcareous)
KQ	Carbonates–silica
C	Clay (argillaceous)
CS	Clay–sesquioxides
GY	Gypsum (gypsiferous)
SA	Salt (saline)
GB	Gibbsite
JA	Jarosite
S	Sulphur (sulphurous)
Q	Silica (siliceous)
F	Iron (ferruginous)
FM	Iron–manganese (sesquioxides)
M	Manganese (manganiferous)
NK	Not known

TABLE 78
Colour names of mineral concentrations

WH	White
RE	Red
RS	Reddish
YR	Yellowish red
BR	Brown
BS	Brownish
RB	Reddish brown
YB	Yellowish brown
YE	Yellow
RY	Reddish yellow
GE	Greenish
GR	Grey
GS	Greyish
BU	Blue
BB	Bluish-black
BL	Black
MC	Multicoloured

BIOLOGICAL ACTIVITY

In this section, evidence of past or present biological activity, including human activity, is recorded.

Roots

The recording of both the size and the abundance of the roots is in general sufficient to characterize the distribution of roots in the profile. In specific cases, additional information can be noted, such as a sudden change in root orientation.

The abundance of roots can only be compared within the same size class. The abundance of fine and very fine roots may be recorded similarly as for voids (Figure 8), expressed in the number of roots per decimetre square.

Size (diameter)

Table 79 indicates the classification of the size of roots.

Abundance

Table 80 indicates the classification of the abundance of roots.

TABLE 79
Classification of the diameter of roots

		mm
VF	Very fine	< 0.5
F	Fine	0.5–2
M	Medium	2–5
C	Coarse	> 5

Note: Additional codes are: FF, very fine and fine; FM, fine and medium; and MC, medium and coarse.

TABLE 80
Classification of the abundance of roots

		< 2 mm	> 2 mm
N	None	0	0
V	Very few	1–20	1–2
F	Few	20–50	2–5
C	Common	50–200	5–20
M	Many	> 200	> 20

TABLE 81
Classification of the abundance of biological activity

N	None
F	Few
C	Common
M	Many

TABLE 82
Examples of biological features

A	Artefacts
B	Burrows (unspecified)
BO	Open large burrows
BI	Infilled large burrows
C	Charcoal
E	Earthworm channels
P	Pedotubules
T	Termite or ant channels and nests
I	Other insect activity

Other biological features

Biological features, such as krotovinas, termite burrows, insect nests, worm casts and burrows of larger animals, are described in terms of abundance and kind. In addition, specific locations, patterns, size, composition or any other characteristic may be recorded.

Abundance

Abundance of biological activity is recorded in the general descriptive terms indicated in Table 81.

Kind

Examples of biological features are given in Table 82.

Note for classification purposes

- ✓ ≥ 50 percent (by volume) of wormholes, casts or filled animal burrows → voronic horizon and Vermic qualifier.
- ✓ ≥ 25 percent (by volume) of animal pores, coprolites or other traces of animal activity → hortic and irragric horizons.

HUMAN-MADE MATERIALS

With the growing human influence in the world, especially in urban and mining areas, it becomes increasingly important to document the type and degree of influence. Of particular importance are the human-made materials found in soils. Their age, amount, state and composition determine to a large extent the duration of human influence and the environmental impact.

Artefacts

Artefacts (IUSS Working Group WRB, 2006) are solid or liquid substances that are: (i) created or modified substantially by humans as part of an industrial or artisanal manufacturing process; or (ii) brought to the surface by human activity from a depth where they were not influenced by surface processes. They have properties substantially different from the environment where they are placed, and they have substantially the same properties as when first manufactured, modified or excavated.

This definition has several implications:

- "Liquid" includes chemicals of industrial origin.
- It does not include mining overburden that has been influenced by surface processes or transported soil.
- It includes excavated natural solids and liquids, such as coal, spilled crude oil and bitumen.
- The human origin must be evident in the material itself, not from written records or inference.
- If it has been transformed so that its origin is no longer identifiable, it is no longer an artefact.

Some examples of artefacts are:

- synthetic solids (compounds not found in nature): slag and plastic;
- synthetic liquids: creosote and refined hydrocarbons;
- waste liquids: sludges (e.g. brewery and municipal);
- natural materials recognizably reworked by humans: flint knives and arrowheads;
- natural materials processed by humans into a form or composition not found in nature: pottery, bricks, concrete, asphalt and lead shot;
- mixed materials: building rubble;
- industrial dusts (both natural and synthetic);
- pavements and paving stones;
- natural materials minimally processed but mixed in a way not found in nature: organic garbage.
- mine spoil or crude oil

Note for classification purposes

✓ ≥ 20 percent (by volume, by weighted average) artefacts → Technosols.

Human-transported material (HTM)

Human-transported material (HTM) is any material in the soil to be classified brought from "outside", often by machinery. This can be for agricultural purposes (e.g. large-scale terracing, mine spoil re-vegetation), for human settlement, or simply to dispose of material that is unwanted in its original location (e.g. dredgings). It is a parent material for pedogenesis, by analogy to fluvial sediments and colluvium.

It has been defined as: "Human-transported material (abbreviation 'HTM'): Any solid or liquid material moved into the soil from a source area outside of its immediate vicinity by intentional human activity, usually with the aid of machinery, without substantial reworking or displacement by natural forces" (Rossiter, 2004).

The definition has several implications:

- The restriction to "intentional" excludes dusts from wind erosion or mass movement (e.g. slumps) caused by human activity. The intention must be inferred from the type of material and manner of deposition, not from historical records.
- "Liquids" can be of any viscosity and include slurries, liquid manures, hydrocarbons and other industrial chemicals transported by humans.
- If material originally transported by humans has been further moved by natural forces, such as erosion (water or wind) or flooding, the human influence is reduced, and it is no longer HTM. It is a different substrate and could be referred to as e.g. "colluvium from HTM".
- Similarly, if the material is substantially reworked *in situ* (e.g. by frost), the human influence is reduced, and so it is no longer HTM. It could be referred to as "cyroturbated soil material originally human-transported".
- The requirement that materials be moved farther than from the "immediate vicinity" excludes materials from ditching, terracing, etc. where the transported material is placed as close as possible to the source; the "transportation" is too local.

HTM may be mixed with non-transported material, e.g. spoil that is partially ploughed into underlying natural soil. Thus, a soil layer may consist of part HTM and part non-transported (but reworked *in situ*) material. HTM may have substantial pedogenesis and still be identified as such.

HTMs may be identified in several ways:

- by evidence of deposition processes after transportation (e.g. voids, compaction, and disorganized fragments of diagnostic horizons);
- by artefacts (not always present), although isolated artefacts may be mixed into non-transported soil by ploughing or bioturbation;
- by absence of evidence of transportation by natural forces (e.g. layering from flooding) or reworking *in situ* (e.g. cryoturbation);
- by absence of pedogenesis that masks evidence of deposition.

In each case, the classifier must state the specific evidence for HTM. Historical evidence, e.g. site plans, may be used as an indication of where to find HTM but it is not diagnostic; this is the same as for fluvic sediments, which must be identified only from morphology, not from records of flooding.

Note for classification purposes

✓ HTM → Transportic qualifier.

Geomembranes and technic hard rock

A geomembrane (IUSS Working Group WRB, 2006) is a synthetic membrane laid on the surface or into the soil or any other substrate. Many geomembranes are made of polyvinyl chloride (PVC) or high-density polyethylene (HDPE). Technic hard rock (IUSS Working Group WRB, 2006) is consolidated material resulting from an industrial process, with properties substantially different from those of natural materials.

Note for classification purposes

✓ A continuous, very slowly permeable to impermeable, constructed geomembrane starting within 100 cm of the soil surface → Technosols with the Linic qualifier.

✓ Technic hard rock starting within 5 cm of the soil surface and covering ≥ 95 percent of the horizontal extent of the soil → Technosols with the Ekranic qualifier.

Description of artefacts

Artefacts are described according to their abundance, kind, size, hardness, weathering stage, and colour, if applicable.

Abundance

Abundance is described with the same rules as for rock fragments (above).

Kind

Table 83 lists the kinds of artefacts classified.

Size

Size is described with the same rules as for rock fragments (above) or mineral nodules (above).

Hardness

Hardness is described with the same rules as for mineral nodules (above).

Weathering

State of weathering of the material is described with the same rules as for rock fragments (above).

Colour

Colour is described with the same rules as for mineral nodules (above).

Note for classification purposes

✓ ≥ 35 percent of the artefacts consisting of organic waste materials → Garbic qualifier.

✓ ≥ 35 percent of the artefacts consisting of industrial waste materials (mine spoil, dredgings, rubble, etc.) → Spolic qualifier.

TABLE 83
Classification of kinds of artefacts

AN	Artesanal natural material
ID	Industrial dust
MM	Mixed material
OG	Organic garbage
PS	Pavements and paving stones
SL	Synthetic liquid
SS	Synthetic solid
WL	Waste liquid

TABLE 84
Determination table and codes for human-made deposits

1	Observation at the profile		
	a) stratified (spoiled materials)	go to step 2	s...
	b) not stratified but clods of different colour, texture and/or artefacts (dumped substrate)	go to step 3	d...
2	Test for colour and texture		
	a) light to dark grey, fine sand to silt, coarser grains have vesicular pores	fly and bottom ash	...UA2
	b) dark grey to black, visible particles of coal	coke mud	...UA2
	c) light to dark brown, fine sand to silt, small Fe/Mn concretions	dredge mud of rivers	...UA1
	d) dark grey to black, H_2S smell	dredge mud of lakes	...UA1
	e) dark grey to black, NH_3 smell, artefacts	sewage sludge	...UA2
	f) dark grey to black, faecal smell, artefacts	faecal sludge	...UA2
3	Test for texture, consistence and colour		
	a) earthy, humic (grey to blackish grey)	topsoil material	...UA1
	b) loamy, with carbonates	calcareous loam	...UU3
	c) mainly sandy	sand	...UU3
	d) clayey	clay	...UU1
	e) mixture of sand, silt and clay	loam	...UU2
	f) mainly gravel	gravel	...UU5
	g) mainly broken rock	broken rock	...UU5
	h) > 30 percent pieces of grey to reddish-brown slag	slag	...UA2
	i) > 30 percent pieces of bricks and mortar and concrete	construction rubble	...UA2
	j) grey to black, H_2S smell, > 30 percent artefacts (glass, ceramic, leather, wood, plastic, metals)	waste	...UA2

Source: According to Meuser (1996), shortened.

- ✓ ≥ 35 percent of the artefacts consisting of rubble and garbage of human settlements → Urbic qualifier.

Description and determination of human-transported material

Where HTM is dominant, i.e. it occupies more than 50 percent (by volume) of the soil, it is sufficient to identify the type of HTM. Use the determination table (Table 84) and record the code.

SAMPLING

The sample code and sampling depth are given.

It is recommended that the number given to the sample be the profile number followed by an additional capital letter (A, B, C, D, etc.) and depth range at which each sample has been collected from top to bottom, regardless of the horizon they are taken from (some may not be sampled while others may be sampled twice). Samples are never taken across horizon boundaries. The weight of material taken for each sample is usually 1 kg.

Horizon symbols should not be used as sample codes because the horizon classifications may be changed later.

There are basically two methods of collecting samples:

- To collect the sample in equal proportions over the whole horizon. This is the recommended method and should be used for reference (Status 1) descriptions where a dense sampling is required.
- To take the sample in equal proportions within a depth of 20 cm, either from the centre (area of maximum expression) of the horizon, or, if more than one sample is to be taken from the same horizon, at balanced intervals.

In both methods, the boundary area itself should not be sampled. In detailed descriptions of soils with horizons no more than 30–40 cm thick, there will be little difference between the two methods in practice.

It is recommended that the topsoil be sampled within the first 20 cm of the surface, or shallower where the horizon depth is less. This will facilitate comparison of topsoil characteristics in soil inventories and land evaluation. If the presence of a mollic horizon is assumed, the sampling depth for a soil with a solum more than 60 cm thick may be more than 20 cm but not exceeding 30 cm.

Depth criteria of diagnostic horizons and properties should be taken into account in determining the depth of sampling. To indicate the occurrence of an argic horizon that is defined as having a specified clay increase over a vertical distance of 15 or 30 cm, the samples are preferably taken at that depth interval (e.g. A 0–20 cm, B 20–30 cm or 30–50 cm). Another example is for the classification of Nitisols: a sample should be taken at a depth of 140–160 cm, in addition to the one taken from that part of the B horizon where the clay content is assumed to be highest.

Chapter 5

Genetic and systematic interpretation – soil classification

SOIL HORIZON DESIGNATION

The soil horizon designation summarizes many observations of the soil description and gives an impression about the genetic processes that have formed the soil under observation. In this chapter, the soil morphological and other characteristics are presented as they are described by horizon.

Horizon symbols consist of one or two capital letters for the master horizon and lower case letter suffixes for subordinate distinctions, with or without a figure suffix. For the presentation and understanding of the soil profile description, it is essential that correct horizon symbols be given.

Master horizons and layers

The capital letters H, O, A, E, B, C, R, I, L and W represent the master horizons or layers in soils or associated with soils. The capital letters are the base symbols to which other characters are added in order to complete the designation. Most horizons and layers are given a single capital letter symbol, but some require two.

Currently, ten master horizons and layers and seven transitional horizons are recognized.

The master horizons and their subdivisions represent layers that show evidence of change and some layers that have not been changed. Most are genetic soil horizons, reflecting a qualitative judgement about the kind of changes that have taken place. Genetic horizons are not equivalent to diagnostic horizons, although they may be identical in soil profiles. Diagnostic horizons are quantitatively defined features used in classification.

Three additional layers associated with some soils are identified, viz. I for ice, L for limnic materials, and W for water layers.

H horizons or layers

These are layers dominated by organic material formed from accumulations of undecomposed or partially decomposed organic material at the soil surface, which may be underwater. All H horizons are saturated with water for prolonged periods, or were once saturated but are now drained artificially. An H horizon may be on top of mineral soils or at any depth beneath the surface if it is buried.

O horizons or layers
These are layers dominated by organic material consisting of undecomposed or partially decomposed litter, such as leaves, needles, twigs, moss and lichens, that has accumulated on the surface; they may be on top of either mineral or organic soils. O horizons are not saturated with water for prolonged periods. The mineral fraction of such material is only a small percentage of the volume of the material and is generally much less than half of the weight.

An O layer may be at the surface of a mineral soil or at any depth beneath the surface where it is buried. A horizon formed by illuviation of organic material into mineral subsoil is not an O horizon, although some horizons formed in this manner contain much organic matter.

A horizons
These are mineral horizons that formed at the surface or below an O horizon, in which all or much of the original rock structure has been obliterated and which are characterized by one or more of the following:

- an accumulation of humified organic matter intimately mixed with the mineral fraction and not displaying properties characteristic of E or B horizons (see below);
- properties resulting from cultivation, pasturing, or similar kinds of disturbance;
- a morphology that is different from the underlying B or C horizon, resulting from processes related to the surface.

If a surface horizon (or epipedon) has properties of both A and E horizons but the dominant feature is an accumulation of humified organic matter, it is designated an A horizon. In some places, where warm and arid climates prevail, the undisturbed surface horizon is less dark than the underlying horizon and contains only small amounts of organic matter. It has a morphology distinct from the C layer, although the mineral fraction may be unaltered or only slightly altered by weathering. Such a horizon is designated A because it is at the surface. Examples of epipedons that may have a different structure or morphology owing to surface processes are Vertisols, soils in pans or playas with little vegetation, and soils in deserts.

However, recent alluvial or aeolian deposits that retain fine stratification are not considered to be an A horizon unless cultivated.

E horizons
These are mineral horizons in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles, and in which all or much of the original rock structure has been obliterated.

An E horizon is usually, but not necessarily, lighter in colour than an underlying B horizon. In some soils, the colour is that of the sand and silt particles, but in many soils coatings of iron oxides or other compounds mask the colour of the primary particles. An E horizon is most commonly differentiated from an underlying B horizon in the same soil profile: by colour of higher value or lower chroma, or both; by coarser texture; or by a combination of these properties. An E horizon is commonly near the surface, below an O or A horizon and above a B horizon. However, the symbol E may be used without regard to position in the profile for any horizon that meets the requirements and that has resulted from soil genesis.

B horizons

These are horizons that formed below an A, E, H or O horizon, and in which the dominant features are the obliteration of all or much of the original rock structure, together with one or a combination of the following:

- illuvial concentration, alone or in combination, of silicate clay, iron, aluminium, humus, carbonates, gypsum or silica;
- evidence of removal of carbonates;
- residual concentration of sesquioxides;
- coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;
- alteration that forms silicate clay or liberates oxides or both and that forms a granular, blocky or prismatic structure if volume changes accompany changes in moisture content;
- brittleness.

All kinds of B horizons are, or were originally, subsurface horizons. Included as B horizons are layers of illuvial concentration of carbonates, gypsum or silica that are the result of pedogenetic processes (these layers may or may not be cemented) and brittle layers that have other evidence of alteration, such as prismatic structure or illuvial accumulation of clay.

Examples of layers that are not B horizons are: layers in which clay films either coat rock fragments or are on finely stratified unconsolidated sediments, whether the films were formed in place or by illuviation; layers into which carbonates have been illuviated but that are not contiguous to an overlying genetic horizon; and layers with gleying but no other pedogenetic changes.

C horizons or layers

These are horizons or layers, excluding hard bedrock, that are little affected by pedogenetic processes and lack properties of H, O, A, E or B horizons. Most are mineral layers, but some siliceous and calcareous layers, such as shells, coral and diatomaceous earth, are included. The material of C layers may be either like or unlike that from which the solum presumably formed. A C horizon may have been modified even where there is no evidence of pedogenesis. Plant roots can penetrate C horizons, which provide an important growing medium.

Included as C layers are sediments, saprolite, and unconsolidated bedrock and other geological materials that commonly slake within 24 hours when air dry or drier chunks are placed in water and when moist can be dug with a spade. Some soils form in material that is already highly weathered, and such material that does not meet the requirements of A, E or B horizons is designated C. Changes not considered pedogenetic are those not related to overlying horizons. Layers having accumulations of silica, carbonates or gypsum, even if indurated, may be included in C horizons unless the layer is obviously affected by pedogenetic processes; then it is a B horizon.

R layers

These consist of hard bedrock underlying the soil. Granite, basalt, quartzite and indurated limestone or sandstone are examples of bedrock that are designated R. Air-dry or drier chunks of an R layer when placed in water will not slake within 24 hours. The R layer is sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scraped. Some R layers can be ripped with heavy power equipment. The bedrock may contain cracks, but these are so few and so small that few roots can penetrate. The cracks may be coated or filled with clay or other material.

I layers

These are ice lenses and wedges that contain at least 75 percent ice (by volume) and that distinctly separate organic or mineral layers in the soil.

Ice comes and goes in soils in areas affected by permafrost. Ice bodies in soils can grow to such an extent that they form lenses of wedges that separate entire soil layers. In case such, where ice concentrations occur within the depth of soil description, they can be designated as an I layer. The I symbol is not used in transitional horizon designations.

L layers

These are sediments deposited in a body of water (subaqueous) composed of both organic and inorganic materials, also known as limnic material.

Limnic material is either: (i) deposited by precipitation or through action of aquatic organisms, such as algae or diatoms; or (ii) derived from underwater and floating aquatic plants and subsequently modified by aquatic animals (USDA Soil Survey Staff, 2003). L layers include coprogenous earth or sedimentary peat (mostly organic), diatomaceous earth (mostly siliceous), and marl (mostly calcareous). The L symbol is not used in transitional horizon designations.

W layers

These are water layers in soils or water submerging soils, either permanently or cyclic within the time frame of 24 hours.

Some organic soils float on water. In such cases, the W symbol may be used at the end of the soil description to indicate the floating character. In other cases, shallow water (i.e. water not deeper than 1 m) may cover the soil permanently, as in the case of shallow lakes, or cyclic, as in tidal flats. The symbol W is then used to indicate the depth of submergence at the start of the horizon or layer sequence. The occurrence of tidal water can be indicated by (W).

Transitional horizons

There are two kinds of transitional horizons: those with properties of two horizons superimposed; and those with the two properties separate.

For horizons dominated by properties of one master horizon but having subordinate properties of another, two capital letter symbols are used, such as AB, EB, BE and BC. The master horizon symbol that is given first designates the kind of horizon whose properties dominate the transitional horizon. For example, an AB horizon has characteristics of both an overlying A horizon and an underlying B horizon, but it is more like the A than like the B.

In some cases, a horizon can be designated as transitional even if one of the master horizons to which it is apparently transitional is not present. A BE horizon may be recognized in a truncated soil if its properties are similar to those of a BE horizon in a soil in which the overlying E horizon has not been removed by erosion. An AB or a BA horizon may be recognized where bedrock underlies the transitional horizon. A BC horizon may be recognized even if no underlying C horizon is present; it is transitional to assumed parent material. A CR horizon can be used for weathered bedrock that can be dug with a spade although roots cannot penetrate except along fracture planes.

Horizons in which distinct parts have recognizable properties of two kinds of master horizons are indicated as above, but the two capital letters are separated by a virgule (/), such as E/B, B/E, B/C and C/R. Commonly, most of the individual parts of one of the components are surrounded by the other.

The I, L and W symbols are not used in transitional horizon designations.

Subordinate characteristics within master horizons and layers

Designations of subordinate distinctions and features within the master horizons and layers are based on profile characteristics observable in the field and are applied during the description of the soil at the site. Lower case letters are used as suffixes to designate specific kinds of master horizons and layers, and other features. The list of symbols and terms is shown in Table 85 and explanations of them are given below:

a. Highly decomposed organic material: Used with H and O horizons only, to indicate the state of decomposition of the organic material. Highly decomposed organic material has less than one-sixth (by volume) visible plant remains.

b. Buried genetic horizon: Used in mineral soils to indicate identifiable buried horizons with major genetic features that were formed before burial. Genetic horizons may or may not have formed in the overlying materials, which may be either like or unlike the assumed parent materials of the buried soil. The symbol is not used in organic soils or to separate an organic layer from a mineral layer, in cryoturbated soils, or with C horizons.

TABLE 85
Subordinate characteristics within master horizons

Suffix	Short description	Used for
a	Highly decomposed organic material	H and O horizons
b	Buried genetic horizon	mineral horizons, not cryoturbated
c	Concretions or nodules	mineral horizons
c	Coprogenous earth	L horizon
d	Dense layer (physically root restrictive)	mineral horizons, not with m
d	Diatomaceous earth	L horizon
e	Moderately decomposed organic material	H and O horizons
f	Frozen soil	not in I and R horizons
g	Stagnic conditions	no restriction
h	Accumulation of organic matter	mineral horizons
i	Slickensides	mineral horizons
i	Slightly decomposed organic material	H and O horizons
j	Jarosite accumulation	no restriction
k	Accumulation of pedogenetic carbonates	no restriction
l	Capillary fringe mottling (gleying)	no restriction
m	Strong cementation or induration (pedogenetic, massive)	mineral horizons
m	Marl	L horizon
n	Pedogenetic accumulation of exchangeable sodium	no restriction
o	Residual accumulation of sesquioxides (pedogenetic)	no restriction
p	Ploughing or other human disturbance	no restriction, E, B or C as Ap
q	Accumulation of pedogenetic silica	no restriction
r	Strong reduction	no restriction
s	Illuvial accumulation of sesquioxides	B horizons
t	Illuvial accumulation of silicate clay	B and C horizons
u	Urban and other human-made materials	H, O, A, E, B and C horizons
v	Occurrence of plinthite	no restriction
w	Development of colour or structure	B horizons
x	Fragipan characteristics	no restriction
y	Pedogenetic accumulation of gypsum	no restriction
z	Pedogenetic accumulation of salts more soluble than gypsum	no restriction
@	Evidence of cryoturbation	no restriction

c. Concretions or nodules: In mineral soil, it indicates a significant accumulation of concretions or nodules. The nature and consistence of the nodules is specified by other suffixes and in the horizon description.
   Coprogenous earth: With limnic material L it denotes coprogenous earth, i.e. organic materials deposited under water and dominated by faecal material from aquatic animals.

d. Dense layer: Used in mineral soils to indicate a layer of relatively unaltered, mostly earthy material that is non-cemented, but that has such bulk density or internal organization that roots cannot enter except in cracks; the symbol is not used in combination with the symbols m (cementation) and x (fragipan).
   Diatomaceous earth: In combination with limnic material L, it is used

to indicate diatomaceous earth, i.e. materials deposited under water and dominated by the siliceous remains of diatoms.

e. Moderately decomposed organic materials: Used with H and O horizons only, to indicate the state of decomposition of the organic material. Moderately decomposed organic material has between one-sixth and two-thirds (by volume) visible plant remains.

f. Frozen soil: Designates horizons or layers that contain permanent ice or are perennially colder than 0 °C. It is not used for seasonally frozen layers or for bedrock layers (R). If needed, "dry frozen soil" layers may be labelled (f).

g. Stagnic conditions: Designates horizons in which a distinct pattern of mottling occurs that reflects alternating conditions of oxidation and reduction of sesquioxides, caused by seasonal surface waterlogging. If aggregates are present, the interiors of the aggregates show oxidizing colours and the surface parts reducing colours.

h. Accumulation of organic matter: Designates the accumulation of organic matter in mineral horizons. The accumulation may occur in surface horizons, or in subsurface horizons through illuviation.

i. Slickensides: Denotes in mineral soils the occurrence of slickensides, i.e. oblique shear faces 20–60 ° of horizontal owing to the shrink–swell action of clay; wedge-shaped peds and seasonal surface cracks are commonly present. Slightly decomposed organic material: In organic soils and used in combination with H or O horizons, it indicates the state of decomposition of the organic material; slightly decomposed organic material has in more than two-thirds (by volume) visible plant remains.

j. Jarosite: Indicates the presence of jarosite mottles, coatings or hypodermic coatings.

k. Accumulation of pedogenetic carbonates: Indicates an accumulation of alkaline earth carbonates, commonly calcium carbonate.

l. Capillary fringe mottling: Indicates mottling caused by ascending groundwater. If aggregates are present, the interiors of the aggregates show reducing colours and the surface parts oxidizing colours.
Strong cementation or induration: Indicates in mineral soils continuous or nearly continuous cementation, and is used only for horizons that are more than 90 percent cemented, although they may be fractured. The layer is root restrictive and roots do not enter except along fracture planes. The single predominant or codominant cementing agent may be indicated using defined letter suffices single or in pairs. If the horizon is cemented by carbonates km is used; by silica, qm; by iron, sm; by gypsum, ym; by both lime and silica, kqm; and by salts more soluble than gypsum, zm.
Marl: In combination with limnic material it is used to indicate marl, i.e. materials deposited under water and dominated by a mixture of clay and calcium carbonate; typically grey in colour.

n. Pedogenetic accumulation of exchangeable sodium: Indicates an accumulation of exchangeable sodium.

o. Residual accumulation of sesquioxides: Indicates residual accumulation of sesquioxides. It differs from the use of symbol s, which indicates illuvial accumulation of organic matter and sesquioxide complexes.
p. Ploughing or other human disturbance: Indicates disturbance of the surface layer by ploughing or other tillage practices. A disturbed organic horizon is designated Op or Hp. A disturbed mineral horizon, even though clearly once an E, B or C, is designated Ap.
q. Accumulation of pedogenetic silica: Indicates an accumulation of secondary silica. If silica cements the layer and cementation is continuous or nearly continuous, qm is used.
r. Strong reduction: Indicates presence of iron in reduced state. If r is used with B, pedogenetic change in addition to reduction is implied; if no other change has taken place, the horizon is designated Cr.
s. Illuvial accumulation of sesquioxides: Used with B to indicate the accumulation of illuvial, amorphous, dispersible organic matter–sesquioxide complexes if the value and chroma of the horizon are more than 3. The symbol is also used in combination with h as Bhs if both the organic matter and sesquioxides components are significant and both value and chroma are about 3 or less.
t. Accumulation of silicate clay: Used with B or C to indicate an accumulation of silicate clay that either has formed in the horizon or has been moved into it by illuviation, or both. At least some part should show evidence of clay accumulation in the form of coatings on ped surfaces or in pores, as lamellae, or as bridges between mineral grains.
u. Urban and other human-made materials: Used to indicate the dominant presence of human-made materials, including technogenic ones. The symbol can be used in combination with H, O, A, E, B and C.
v. Occurrence of plinthite: Indicates the presence of iron-rich, humus-poor material that is firm or very firm when moist and that hardens irreversibly when exposed to the atmosphere. When hardened, it is no longer called plinthite but a hardpan, ironstone, a petroferric or a skeletic phase. In that case, v is used in combination with m.
w. Development of colour or structure in B: Used with B only to indicate development of colour or structure, or both. It is not used to indicate a transitional horizon.
x. Fragipan characteristics: Used to indicate genetically developed firmness, brittleness or high bulk density. These features are characteristic of fragipans, but some horizons designated x do not have all the properties of a fragipan.
y. Pedogenetic accumulation of gypsum: Indicates an accumulation of gypsum.
z. Pedogenetic accumulation of salts more soluble than gypsum: Indicates an accumulation of salts more soluble than gypsum.
@ Evidence of cryoturbation: irregular or broken boundaries, sorted rock fragments (patterned ground), or organic matter in the lower boundary

between the active layer and permafrost layer. The suffix is always used last, e.g. Hi@.

Conventions for using letter suffixes

Many master horizons and layers that are symbolized by a single capital letter will have one or more lowercase letter suffixes. More than three suffixes are rarely used. The following rules apply:

- Letter suffixes should follow the capital letter immediately.
- When more than one suffix is needed, the following letters, if used, are written first: r, s, t, u and w. The symbol t has precedence over all other symbols, e.g. Btr, Btu. In all other combinations, the symbols are listed alphabetically, e.g. Cru.
- If more than one suffix is needed and the horizon is not buried, these symbols, if used, are written last: c, f, g, m, v and x. Some examples: Btc, Bkm, and Bsv.
- If a horizon is buried, the suffix b is written last.
- A B horizon that has significant accumulation of clay and also shows evidence of development of colour or structure, or both, is designated Bt (t has precedence over w, s and h). A B horizon that is gleyed or that has accumulations of carbonates, sodium, silica, gypsum, salts more soluble than gypsum, or residual accumulation or sesquioxides carries the appropriate symbol g, k, n, q, y, z or o. If illuvial clay is also present, t precedes the other symbols, e.g. Bto.
- Suffixes h, s and w are normally not used with g, k, n, q, y, z or o unless needed for explanatory purposes.
- Suffixes a and e are used only in combination with H or O.
- Suffixes c, d, i and m have two different meanings, depending on the master horizon designation they are coupled to. The different combinations are mutually exclusive, e.g. Bi indicates presence of slickensides in the B horizon, whereas Hi indicates a slightly decomposed H horizon. Similarly, Bd indicates a dense B horizon, and Ld diatomaceous earth in a limnic layer.
- Suffix @ is always used last, and cannot be combined with b.
- Unless otherwise indicated, suffixes are listed alphabetically.

Vertical subdivisions

Horizons or layer designated by a single combination of letter symbols can be subdivided using Arabic numerals, which follow all the letters. For example, within a C, successive layers could be C1, C2, C3, etc.; or if the lower part is gleyed and the upper part is not, the designations could be C1-C2-Cg1-Cg2 or C-Cg1-Cg2-R.

These conventions apply whatever the purpose of subdivision. A horizon identified by a single set of letter symbol may be subdivided on the basis of evident morphological features, such as structure, colour or texture. These subdivisions are numbered consecutively. The numbering starts with 1 at whatever level in the profile. Thus, Bt1-Bt2-Btk1-Btk2 is used, not Bt1-Bt2-Btk3-Btk4. The numbering of vertical subdivisions within a horizon is not interrupted at a discontinuity (indicated by a numerical prefix) if the same letter combination is used in both materials: Bs1-Bs2-2Bs3-2Bs4 is used, not Bs1-Bs2-2Bs1-2Bs2. A and E horizons can be subdivided similarly, e.g. Ap, A1, A2; Ap1, Ap2; A1, A2, A3; and E1, E2, Eg1, Eg2.

Discontinuities

In mineral soils, Arabic numerals are used as prefixes to indicate discontinuities. Wherever needed, they are used preceding A, E, B, C and R. They are not used with I and W, although these symbols clearly indicate a discontinuity. These prefixes are distinct from Arabic numerals used as suffixes to denote vertical subdivisions.

A discontinuity is a significant change in particle-size distribution or mineralogy that indicates a difference in the material from which the horizons formed or a significant difference in age or both, unless that difference in age is indicated by the suffix b. Symbols to identify discontinuities are used only when they will contribute substantially to the reader's understanding of relationships among horizons. The stratification common in soils formed in alluvium is not designated as discontinuities unless particle-size distribution differs markedly from layer to layer even though genetic horizons have formed in the contrasting layers.

Where a soil has formed entirely in one kind of material, a prefix is omitted from the symbol; the whole profile is material 1. Similarly, the uppermost material in a profile having two or more contrasting materials is understood to be material 1, but the number is omitted. Numbering starts with the second layer of contrasting material, which is designated 2. Underlying contrasting layers are numbered consecutively. Even where a layer below material 2 is similar to material 1, it is designated 3 in the sequence. The numbers indicate a change in the material, not the type of material. Where two or more consecutive horizons formed in one kind of material, the same prefix number applies to all of the horizon designations in that material: Ap-E-Bt1-2Bt2-2Bt3-2BC. The number suffixes designating subdivisions of the Bt horizon continue in consecutive order across the discontinuity.

If an R layer is below a soil that formed in residuum and the material of the R layer is judged to be like that from which the material of the soil weathered, the Arabic number prefix is not used. If the R layer would not produce material like that in the solum, the number prefix is used, as in A-Bt-C-2R or A-Bt-2R. If part of the solum formed in residuum, R is given the appropriate prefix: Ap-Bt1-2Bt2-2Bt3-2C1-2C2-2R.

Buried horizons (designated b) are special problems. A buried horizon is not the same deposit as horizons in the overlying deposit. However, some buried horizons formed in material lithological like that of the overlying deposit. A prefix is not used to distinguish material of such buried horizons. If the material in which a horizon of a buried soil formed is lithological unlike that of the overlying material, the discontinuity is designated by number prefixes and the symbol for a buried horizon is used as well: Ap-Bt1-Bt2-BC-C-2ABb-2Btb1-2Btb2-2C.

In organic soils, discontinuities between different kinds of layers are not identified. In most cases, the differences are shown by the letter suffix designations, if the different layers are organic, or by the master symbol if the different layers are mineral.

Use of the prime

Identical designations may be appropriate for two or more horizons or layers separated by at least one horizon or layer of a more different kind in the same pedon. The sequence A-E-Bt-E-Btx-C is an example – the soil has two E horizons. To make communication easier, a prime is used with the master horizon symbol of the lower of two horizons having identical letter designations: A-E-Bt-E'-Btx-C. The prime is applied to the capital letter designation, and any lower case symbol follows it: B't. The prime is not used unless all letters of the designations of two different layers are identical. Rarely, three layers have identical letter symbols; a double prime can be used: E".

The same principle applies in designating layers of organic soils. The prime is used only to distinguish two or more horizons that have identical symbols: O-C-C'-C". The prime is added to the lower C layer to differentiate it from the upper.

PRINCIPLES OF CLASSIFICATION ACCORDING TO THE WRB

The surveyor should attempt to classify the soil in the field as precisely as possible on the basis of the soil morphological features that have been observed and described. The final classification is made after the analytical data have become available. It is recommended that the occurrence and depth of diagnostic horizons, properties and materials identified be listed (below).

The general principles on which the classification according to the WRB is based (IUSS Working Group WRB 2006)can be summarized as follows:

- The classification of soils is based on soil properties defined in terms of diagnostic horizons, properties and materials, which to the greatest extent possible should be measurable and observable in the field.
- The selection of diagnostic characteristics takes into account their relationship with soil forming processes. It is recognized that an understanding of soil-forming processes contributes to a better characterization of soils but that they should not, as such, be used as differentiating criteria.
- To the extent possible at a high level of generalization, diagnostic features are selected that are of significance for soil management.
- Climate parameters are not applied in the classification of soils. It is fully realized that they should be used for interpretation purposes, in dynamic combination with soil properties, but they should not form part of soil definitions.

- The WRB is a comprehensive classification system that enables people to accommodate their national classification system. It comprises two tiers of categorical detail:
  - the Reference Base, limited to the first level only and having 32 RSGs;
  - the WRB Classification System, consisting of combinations of a set of prefix and suffix qualifiers that are uniquely defined and added to the name of the RSG, allowing very precise characterization and classification of individual soil profiles.
- Many RSGs in the WRB are representative of major soil regions so as to provide a comprehensive overview of the world's soil cover.
- The Reference Base is not meant to substitute for national soil classification systems but rather to serve as a common denominator for communication at an international level. This implies that lower-level categories, possibly a third category of the WRB, could accommodate local diversity at country level. Concurrently, the lower levels emphasize soil features that are important for land use and management.
- The Revised Legend of the FAO/UNESCO Soil Map of the World (FAO, 1988) has been used as a basis for the development of the WRB in order to take advantage of international soil correlation that has already been conducted through this project and elsewhere.
- The first edition of the WRB, published in 1998, comprised 30 RSGs; the second edition, published in 2006, has 32 RSGs.
- Definitions and descriptions of soil units reflect variations in soil characteristics both vertically and laterally in order to account for spatial linkages within the landscape.
- The term Reference Base is connotative of the common denominator function that the WRB assumes. Its units have sufficient width to stimulate harmonization and correlation of existing national systems.
- In addition to serving as a link between existing classification systems, the WRB also serves as a consistent communication tool for compiling global soil databases and for the inventory and monitoring of the world's soil resources.
- The nomenclature used to distinguish soil groups retains terms that have been used traditionally or that can be introduced easily in current language. They are defined precisely in order to avoid the confusion that occurs where names are used with different connotations.

Although the basic framework of the FAO Legend (with its two categorical levels and guidelines for developing classes at a third level) was adopted, it has been decided to merge the lower levels. Each RSG of the WRB is provided with a listing of possible prefix and suffix qualifiers in a priority sequence, from which the user can construct the second-level units.

The broad principles that govern the WRB class differentiation are:

- At the higher categorical level, classes are differentiated mainly according to the primary pedogenetic process that has produced the characteristic soil features, except where special soil parent materials are of overriding importance.

- At the second level, soil units are differentiated according to any secondary soil-forming process that has affected the primary soil features significantly. In certain cases, soil characteristics that have a significant effect on use may be taken into account.

It is recognized that a number of RSGs may occur under different climate conditions. However, it was decided not to introduce separations on account of climate characteristics so that the classification of soils is not subordinated to the availability of climate data.

Including the soil description, classification is done in four steps.

Step 1

The profile description is checked to find references to soil-forming processes (qualitatively) and express them in the horizon designation. Examples may be:

- Darkening of topsoil in comparison to subsoil → enrichment with organic material → Ah-horizon.
- Browning and finer texture in the middle part of a soil profile in comparison to the parent material → enrichment of Fe-oxides and clay → weathering → Bw-horizon.

Step 2

The profile description and the horizon designation are to be checked whether the expression, thickness and depth of certain soil characteristics correspond with the requirements of WRB diagnostic horizons, properties and materials. These are defined in terms of morphological characteristics and/or analytical criteria (IUSS Working Group WRB, 2006). In line with the WRB objectives, attributes are described as much as possible to support field identification.

Step 3

The described combination of diagnostic horizons, properties and materials is compared with the WRB Key (IUSS Working Group WRB, 2006) in order to find the RSG, which is the first level of WRB classification. The user should go through the Key systematically, starting at the beginning and excluding one by one all RSGs for which the specified requirements are not met. The soil belongs to the first RSG for which it meets all specified requirements.

Step 4

For the second level of WRB classification, qualifiers are used. The qualifiers are listed in the Key with each RSG as prefix and suffix qualifiers. Prefix qualifiers comprise those that are typically associated to the RSG and the intergrades to other RSGs. All other qualifiers are listed as suffix qualifiers. For classification at the second level, all applying qualifiers have to be added to the name of the RSG. Redundant qualifiers (the characteristics of which are included in a previously set qualifier) are not added.

Specifiers can be used to indicate the degree of expression of qualifiers. Buried layers can be indicated by the Thapto- specifier, which can be used with any qualifier, listed in IUSS Working Group WRB (2006).

Where a soil is buried under new material, the following rules apply:

1. The overlying new material and the buried soil are classified as one soil if both together qualify as Histosol, Technosol, Cryosol, Leptosol, Vertisol, Fluvisol, Gleysol, Andosol, Planosol, Stagnosol or Arenosol.
2. Otherwise, the new material is classified at the first level if the new material is 50 cm or more thick or if the new material, if it stood alone, fits the requirements of a RSG other than a Regosol.
3. In all other cases, the buried soil is classified at the first level.
4. If the overlying soil is classified at the first level, the buried soil is recognized with the Thapto- specifier and -ic added to the RSG name of the buried soil. The whole is placed in brackets after the name of the overlying soil, e.g. Technic Umbrisol (Greyic) (Thapto-Podzolic). If the buried soil is classified at the first level, the overlying material is indicated with the Novic qualifier.

Principles and use of the qualifiers in the WRB

A two-tier system is used for the qualifier level, comprising:

- Prefix qualifiers: typically associated qualifiers and intergrade qualifiers; the sequence of the intergrade qualifiers follows that of the RSGs in the WRB Key, with the exception of Arenosols; this intergrade is ranked with the textural suffix qualifiers (see below). Haplic closes the prefix qualifier list indicating that neither typically associated nor intergrade qualifiers apply.
- Suffix qualifiers: other qualifiers, sequenced as follows: (1) qualifiers related to diagnostic horizons, properties or materials; (2) qualifiers related to chemical characteristics; (3) qualifiers related to physical characteristics; (4) qualifiers related to mineralogical characteristics; (5) qualifiers related to surface characteristics; (6) qualifiers related to textural characteristics, including coarse fragments; (7) qualifiers related to colour; and (8) remaining qualifiers.

Prefix qualifier names are always put before the RSG; suffix qualifier names are always placed between brackets following the RSG name. Combinations of qualifiers that indicate a similar status or duplicate each other are not permitted, such as combinations of Thionic and Dystric, Calcaric and Eutric, or Rhodic and Chromic.

Specifiers such as Epi-, Endo-, Hyper-, Hypo-, Thapto-, Bathy-, Para-, Proto-, Cumuli- and Ortho- are used to indicate a certain expression of the qualifier.

When classifying a soil profile, all applying qualifiers of the listing must be recorded. For mapping purposes, the scale will determine the number of qualifiers used. In that case, prefix qualifiers have priority over the suffix qualifiers.

The qualifier listing for each RSG accommodates most cases. Where not listed qualifiers are needed, the cases should be documented and reported to the WRB Working Group.

The field classification provides a preliminary assessment using all observable or easily measurable properties and features of the soil and associated terrain. The final classification is made when analytical data are available. It is recommended that *Procedures for Soil Analysis* (Van Reeuwijk, 2006) be followed in determining chemical and physical characteristics.

Example of WRB soil classification

A soil has a ferralic horizon; texture in the upper part of the ferralic horizon changes from sandy loam to sandy clay within 15 cm. The pH is between 5.5 and 6, indicating moderate to high base saturation. The B horizon is dark red; below 50 cm, mottling occurs. The field classification of this soil is: Lixic Ferralsol (Ferric, Rhodic). If subsequent laboratory analysis reveals that the cation exchange capacity of the ferralic horizon is less than 4 $cmol_c\ kg^{-1}$ clay, the soil finally classifies as: Lixic Vetic Ferralsol (Ferric, Rhodic).

CHECKLIST OF WRB DIAGNOSTIC HORIZONS, PROPERTIES AND MATERIALS

While still in the field, it is advisable to determine or estimate, for each horizon, the diagnostic characteristics that apply to the classification system used. Table 86 provides a checklist of diagnostic horizons, properties and materials in the order as they appear in the WRB (IUSS Working Group WRB, 2006).

TABLE 86
Checklist of WRB diagnostic horizons, properties and materials

Diagnostic horizons		Diagnostic properties	Diagnostic materials
Albic horizon	Natric horizon	Abrupt textural change	Artefacts
Anthraquic horizon	Nitic horizon	Albeluvic tonguing	Calcaric material
Anthric horizon	Petrocalcic horizon	Andic properties	Colluvic material
Argic horizon	Petroduric horizon	Aridic properties	Fluvic material
Calcic horizon	Petrogypsic horizon	Continuous rock	Gypsiric material
Cambic horizon	Petroplinthic horizon	Ferralic properties	Limnic material
Cryic horizon	Pisoplinthic horizon	Geric properties	Mineral material
Duric horizon	Plaggic horizon	Gleyic colour pattern	Organic material
Ferralic horizon	Plinthic horizon	Lithological discontinuity	Ornithogenic material
Ferric horizon	Salic horizon.	Reducing conditions	Sulphidic material
Folic horizon	Sombric horizon	Secondary carbonates	Technic hard rock
Fragic horizon	Spodic horizon	Stagnic colour pattern	Tephric material
Fulvic horizon	Takyric horizon	Vertic properties	
Gypsic horizon	Terric horizon	Vitric properties	
Histic horizon	Thionic horizon		
Hortic horizon	Umbric horizon		
Hydragric horizon	Vertic horizon		
Irragric horizon	Voronic horizon		
Melanic horizon	Yermic horizon		
Mollic horizon			

APPENDING TEXTURE AND PARENT MATERIAL INFORMATION TO THE REFERENCE SOIL GROUP

In its present state, the WRB (IUSS Working Group WRB, 2006) is, by history and practical purposes, mixing information about soil genesis (e.g. podzolization – Podzol, gleysation – Gleysol), texture (e.g. Arenosol, skeletic, arenic, siltic, and clayic subunits), parent materials (e.g. Anthrosols, Fluvisols, calcaric, and gypsiric subunits) and others. The system distinguishes second-level units only in a generalized manner by texture and only in the parent material of some RSGs. In order to overcome this problem and to provide users with more systematic and precise information about texture, parent material and layering, the following framework for a reference soil series is recommended (Jahn, 2004).

Example

A Cambisol to which only the Dystric qualifier applies and which has variations in texture and in which the upper part has developed from loess with some fluvial gravelly sand and the lower part has developed from glacio-fluvial gravelly sand.

The full description is:

Haplic Cambisol (Dystric); silt loam from loess with glacio-fluvial gravelly sand over sandy skeleton from glacio-fluvial gravel

It is coded: CMdy; SiL(UE2, UG2)/SSK(UG3)
1 2 3 4 5

1 = Coding of soil unit according to the WRB (IUSS Working Group WRB, 2006).

2 = Coding of texture class for the upper part of the soil body. The texture class for the fine earth is used according to Chapter 4 and combined with four classes of coarse fragments, e.g.:
SiL = silt loam with coarse fragments < 10 percent (by volume);
skSiL= skeletal silt loam with coarse fragments of from 10 to < 40 percent (by volume);
silSK = silt loamy skeleton with coarse fragments of from 40 to <80 percent (by volume);
SK = skeleton with coarse fragments of 80 percent or more (by volume).

3 = The parent material is given in descending order of importance from left to right within brackets. For coding, an extended hierarchical lithology list, based on updated SOTER (ISRIC, 2005) is used.

4 = A change of material with depth (either by texture or by parent material or by both is coded with:
...\... as "shallow … over …" where occurring at a depth of 0–3 dm;
.../... as "… over …" where occurring at a depth of 3–7 dm;
(the intermediate of 5 dm is corresponding with the WRB-epi and -endo);
...//... as "… over deep …" where occurring at a depth of 7–12 dm.

5 = The lower part of the soil body is described according to 2 and 3.

Further rules in describing texture and parent material are:

- e.g.: skSiL(UE2, UG2/UG3) where no change in texture but in parent material;
- e.g.: SiL/skSiL(UE2, UG3) where no change in parent material but in texture;
- e.g.: .../R(and lithology) means: over massive rock;
- Horizons are combined to one complex and described with the average where not more than one of the three parameters: (1) texture (fine earth); (2) coarse fragments; and (3) lithology differs for one class. Thin (extension < 2 cm) horizons are neglected.

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Annex 1
Explanation of soil temperature regimes[1]

The temperature of a soil is one of its important properties. Within limits, temperature controls the possibilities for plant growth and for soil formation. Below freezing point, there is no biotic activity, water no longer moves as a liquid, and, unless there is frost heaving, time stands still for the soil. Between 0 and 5 °C, root growth of most plant species and germination of most seeds are impossible. A horizon as cold as 5 °C is a thermal pan to the roots of most plants.

Each pedon has a characteristic temperature regime that can be measured and described. For most practical purposes, the temperature regime can be described by: the mean annual soil temperature; the average seasonal fluctuations from that mean; and the mean warm or cold seasonal temperature gradient within the main rootzone, which is the zone from a depth of 5 to 100 cm.

MEAN ANNUAL SOIL TEMPERATURE

Each pedon has a mean annual temperature that is essentially the same in all horizons at all depths in the soil and at depths considerably below the soil. The measured mean annual soil temperature is seldom the same in successive depths at a given location. However, the differences are so small that it seems valid and useful to take a single value as the mean annual temperature of a soil.

The mean annual soil temperature is related most closely to the mean annual air temperature, but this relationship is affected to some extent by: the amount and distribution of rain; the amount of snow; the protection provided by shade and by O horizons in forests; the slope aspect and gradient; and irrigation. Other factors, such as soil colour, texture, and content of organic matter, have negligible effects.

FLUCTUATIONS IN SOIL TEMPERATURE

The mean annual temperature of a soil is not a single reading but the average of a series of readings. Near the surface, the readings may fluctuate from the mean fully as much as those of the air temperature, especially where there is no insulating cover. The fluctuations occur as daily and annual cycles, which weather events make somewhat irregular in most places. The fluctuations decrease with increasing depth and are ultimately damped out in the substrata

[1] Adapted from USDA, 1999.

in a zone where the temperature is constant and is the same as the mean annual soil temperature.

ESTIMATION OF SOIL TEMPERATURE

Soil temperature can often be estimated from climatological data with a precision that is adequate for the present needs of soil surveys. Where it is not possible to make reasonably precise estimates, the measurement of soil temperature need not be a difficult or a time-consuming task.

Frequently, the mean annual soil temperature for much of the United States of America is estimated by adding 1 °C to the mean annual air temperature.

The mean summer soil temperature at a specific depth can also be estimated. To make this estimate, it is possible to take the average summer temperatures of the upper 100 cm and correct for the temperature-depth gradient by adding or subtracting 0.6 °C for each 10 cm above or below a depth of 50 cm. The mean winter temperature of many mid-latitude soils can be estimated from the difference between the mean annual temperatures and the mean summer temperatures because the differences are of the same magnitude but have opposite signs.

CLASSES OF SOIL TEMPERATURE REGIMES

The following is a description of the soil temperature regimes used in defining classes at various categoric levels in the soil taxonomy of the United States of America.

PG – Pergelic (Latin *per*, throughout in time and space, and *gelare*, to freeze; meaning permanent frost). Soils with a pergelic temperature regime have a mean annual temperature lower than 0 °C. These are soils that have permafrost if they are moist, or dry frost if there is no excess water.

CR – Cryic (Greek *kryos*, coldness; meaning very cold soils). Soils in this temperature regime have a mean annual temperature lower than 8 °C but do not have permafrost.

1. In mineral soils, the mean summer soil temperature (June, July and August in the Northern Hemisphere, and December, January, and February in the Southern Hemisphere) either at a depth of 50 cm from the soil surface or at a densic, lithic or paralithic contact, whichever is shallower, is as follows:
   a. if the soil is not saturated with water during some part of the summer and:
      (1) If there is no O horizon: lower than 15 °C; or
      (2) If there is an O horizon: lower than 8 °C; or
   b. if the soil is saturated with water during some part of the summer and:
      (1) If there is no O horizon: lower than 13 °C; or
      (2) If there is an O horizon or a histic epipedon: lower than 6 °C.
2. In organic soils, the mean annual soil temperature is lower than 6 °C.

Cryic soils that have an aquic moisture regime are commonly churned by frost.

Isofrigid soils could also have a cryic temperature regime. A few with organic materials in the upper part are exceptions. The concepts of the soil temperature regimes described below are used in defining classes of soils in the low categories.

FR – Frigid

A soil with a frigid temperature regime is warmer in summer than a soil with a cryic regime. However, its mean annual temperature is lower than 8 °C and the difference between mean summer (June, July and August) and mean winter (December, January and February) soil temperatures is more than 6 °C either at a depth of 50 cm from the soil surface or at a densic, lithic or paralithic contact, whichever is shallower.

IF – Isofrigid

The mean annual soil temperature is lower than 8 °C and the mean summer and mean winter soil temperatures differ by less than 6 °C at a depth of 50 cm or at a densic, lithic or paralithic contact, whichever is shallower.

ME – Mesic

The mean annual soil temperature is 8 °C or higher but lower than 15 °C, and the difference between mean summer and mean winter soil temperatures is more than 6 °C either at a depth of 50 cm from the soil surface or at a densic, lithic or paralithic contact, whichever is shallower.

IM – Isomesic

The mean annual soil temperature is 8 °C or higher but lower than 15 °C and the mean summer and mean winter soil temperatures differ by less than 6 °C at a depth of 50 cm or at a densic, lithic or paralithic contact, whichever is shallower.

TH – Thermic

The mean annual soil temperature is 15 °C or higher but lower than 22 °C, and the difference between mean summer and mean winter soil temperatures is more than 6 °C either at a depth of 50 cm from the soil surface or at a densic, lithic or paralithic contact, whichever is shallower.

IT – Isothermic

The mean annual soil temperature is 15 °C or higher but lower than 22 °C and the mean summer and mean winter soil temperatures differ by less than 6 °C at a depth of 50 cm or at a densic, lithic or paralithic contact, whichever is shallower.

HT – Hyperthermic

The mean annual soil temperature is 22 °C or higher, and the difference between mean summer and mean winter soil temperatures is more than 6 °C at a depth of

50 cm from the soil surface or at a densic, lithic or paralithic contact, whichever is shallower.

IH – Isohyperthermic

The mean annual soil temperature is 22 °C or higher and the mean summer and mean winter soil temperatures differ by less than 6 °C at a depth of 50 cm or at a densic, lithic or paralithic contact, whichever is shallower.

Annex 2
Explanation of soil moisture regimes[1]

The term "soil moisture regime" refers to the presence or absence either of groundwater or of water held at a tension of less than 1 500 kPa (pF 4.2) in the soil or in specific horizons during periods of the year. Water held at a tension of 1 500 kPa or more is not available to keep most mesophytic plants alive. The availability of water is also affected by dissolved salts. Where a soil is saturated with water that is too salty to be available to most plants, it is considered salty rather than dry. Consequently, a horizon is considered dry when the moisture tension is 1 500 kPa or more, and it is considered moist when water is held at a tension of less than 1 500 kPa but more than zero. A soil may be continuously moist in some or all horizons either throughout the year or for some part of the year. It may be either moist in winter and dry in summer or the reverse. In the Northern Hemisphere, summer refers to June, July and August, and winter refers to December, January and February.

SIGNIFICANCE TO SOIL CLASSIFICATION

The moisture regime of a soil is an important property of the soil as well as a determinant of processes that can occur in the soil. During geological time, there have been significant changes in climate. Soils that could have formed only in a humid climate are now preserved in an arid climate in some areas. Such soils have relict features that reflect the former moisture regime and other features that reflect the present moisture regime.

Each of the moisture regimes in the history of a soil is a factor in the genesis of that soil and is the cause of many accessory characteristics. However, most of the accessory characteristics and those most important for interpretations are associated with the present moisture regime, even if the present regime differs widely from some of the earlier.

More importantly, the present climate determines use and management of the soil. It is a property of the soil. Furthermore, the moisture regimes of most soils are inferred from the present climate, and small-scale maps can be interpreted in terms of the many accessory characteristics that are common to most of the soils that have a common climate. These characteristics include: the amount, nature and distribution of organic matter; the base status of the soil; and the presence or absence of salts.

[1] Adapted from USDA, 1999.

NORMAL YEARS

In the discussions that follow and throughout the keys, the term “normal years” is used. A normal year is defined as a year that has plus or minus one standard deviation of the long-term mean annual precipitation (long term refers to 30 years or more). In addition, the mean monthly precipitation in a normal year must be plus or minus one standard deviation of the long-term monthly precipitation for 8 of the 12 months. Normal years can usually be calculated from the mean annual precipitation. However, when catastrophic events occur during a year, the standard deviations of the monthly means should also be calculated.

ESTIMATION

The landscape position of every soil is subject to extremes in climate. While no two years have exactly the same weather conditions, the moisture status of the soil must be characterized by probability. Weather probabilities can be determined from long-term weather records and observations of how each soil responds to weather conditions as modified by its landscape position.

A number of methods have been devised to relate soil moisture to meteorological records. To date, all these methods have some shortcomings, even for gently sloping soils that depend primarily on precipitation for their moisture. Dew and fog can add appreciable amounts of moisture to some soils, but quantitative data are rare.

SOIL MOISTURE CONTROL SECTION

The intention in defining the soil moisture control section is to facilitate estimation of soil moisture regimes from climate data. The upper boundary of this control section is the depth to which a dry (tension of more than 1 500 kPa, but not air-dry) soil will be moistened by 2.5 cm of water within 24 hours. The lower boundary is the depth to which a dry soil will be moistened by 7.5 cm of water within 48 hours. These depths do not include the depth of moistening along any cracks or animal burrows that are open to the surface.

The boundaries for the soil moisture control section correspond to the rooting depths for many crops. However, there are natural plant communities that have their roots either above or below the control section. Attempts are currently being made to improve the parameters of the soil moisture control section.

If 7.5 cm of water moistens the soil to a densic, lithic, paralithic or petroferric contact or to a petrocalcic or petrogypsic horizon or a duripan, the contact or the upper boundary of the cemented horizon constitutes the lower boundary of the soil moisture control section.

The concept of the soil moisture control section does not apply well to the cracking clays, because these clays remoisten from both the surface and the bases of the cracks. The soil moisture patterns of these soils are defined in terms of the pattern of cracking over time.

If moistening occurs unevenly, the weighted average depth of moistening in a pedon is used for the limits of the moisture control section.

The moisture control section of a soil extends approximately:

- from 10 to 30 cm below the soil surface if the particle-size class of the soil is fine-loamy (> 15 percent particles 0.1–75 mm and 18–35 percent clay), coarse-silty (< 15 percent particles 0.1–75 mm and < 18 percent clay in fine earth), fine-silty (< 15 percent particles 0.1–75 mm and 18–35 percent clay in fine earth), or clayey (> 35 percent clay);
- from 20 to 60 cm if the particle-size class is coarse-loamy silty (>15 percent particles 0.1–75 mm and < 18 percent clay in fine earth);
- from 30 to 90 cm if the particle-size class is sandy (texture of sand or loamy sand).

If the soil contains rock and pararock fragments that do not absorb and release water, the limits of the moisture control section are deeper. The limits of the soil moisture control section are affected not only by the particle-size class but also by differences in soil structure or pore-size distribution or by other factors that influence the movement and retention of water in the soil.

CLASSES OF SOIL MOISTURE REGIMES

The soil moisture regimes are defined in terms of the level of groundwater and in terms of the seasonal presence or absence of water held at a tension of less than 1 500 kPa in the moisture control section. It is assumed in the definitions that the soil supports whatever vegetation it is capable of supporting, i.e., crops, grass or native vegetation, and that the amount of stored moisture is not being increased by irrigation or fallowing. These cultural practices affect the soil moisture conditions as long as they continued.

AQ – Aquic moisture regime

The aquic (Latin *aqua*, water) moisture regime is a reducing regime in a soil that is virtually free of dissolved oxygen because it is saturated by water. Some soils are saturated with water at times while dissolved oxygen is present, either because the water is moving or because the environment is unfavourable for micro-organisms (e.g. where the temperature is less than 1 °C); such a regime is not considered aquic.

It is not known how long a soil must be saturated before it is said to have an aquic moisture regime. However, the duration must be at least a few days, because it is implicit in the concept that dissolved oxygen is virtually absent.

PQ – Peraquic moisture regime

Very commonly, the level of groundwater fluctuates with the seasons. However, there are soils in which the groundwater is always at or very close to the surface. Examples are soils in tidal marshes or in closed, landlocked depressions fed by perennial streams. Such soils are considered to have a peraquic moisture regime.

AR – Aridic and TO – torric (Latin *aridus*, dry, and *torridus,* hot and dry) moisture regimes

These terms are used for the same moisture regime but in different categories of the taxonomy.

In the aridic (torric) moisture regime, the moisture control section in normal years is both:

- dry in all parts for more than half on the cumulative days per year when the soil temperature at a depth of 50 cm from the soil surface is above 5 °C;
- moist in some or all parts for less than 90 consecutive days when the soil temperature at a depth of 50 cm is above 8 °C.

Soils that have an aridic (torric) moisture regime normally occur in areas of arid climates. A few are in areas of semi-arid climates and either have physical properties that keep them dry, such as a crusty surface that virtually precludes the infiltration of water, or are on steep slopes where runoff is high. There is little or no leaching in this moisture regime, and soluble salts accumulate in the soils if there is a source.

UD – Udic moisture regime

The udic (Latin *udus*, humid) moisture regime is one in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years. Where the mean annual soil temperature is lower than 22 °C and where the mean winter and mean summer soil temperatures at depth of 50 cm from the soil surface differ by 6 °C or more, the soil moisture control section in normal years is dry in all parts for less than 45 consecutive in the 4 months following the summer solstice. In addition, the udic moisture regime requires, except for short periods, a three-phase system, solid–liquid–gas, in part or all of the soil moisture control section when the soil temperature is above 5 °C.

The udic moisture regime is common to the soils of humid climates that: have well-distributed rainfall; have enough rain in summer so that the amount of stored moisture plus rainfall is approximately equal to, or exceeds, the amount of evapotranspiration; or have adequate winter rains to recharge the soils and cool, foggy summers, as in coastal areas. Water moves downwards though the soils at some time in normal years.

PU – Perudic moisture regime (Latin *per*, throughout in time, and *udus*, humid)

In climates where precipitation exceeds evapotranspiration in all months of normal years, the moisture tension rarely reaches 100 kPa (pF 3) in the soil moisture control section, although there are occasional brief periods when some stored moisture is used. The water moves through the soil in all months when it is not frozen. Such an extremely wet moisture regime is called perudic.

US – Ustic moisture regime

The ustic (Latin *ustus*, burnt; implying dryness) moisture regime is intermediate between the aridic regime and the udic regime. Its concept is one of moisture that is limited but is present at a time when conditions are suitable for plant growth. The concept of the ustic moisture regime is not applied to soils that have permafrost or a cryic soil temperature regime (defined above).

If the mean annual soil temperature is 22 °C or higher or if the mean summer and winter soil temperatures differ by less than 6 °C at a depth of 50 cm below the soil surface, the soil moisture control section in areas of the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal years. However, it is moist in some part either for more than 180 cumulative days per year or for 90 or more consecutive days.

If the mean annual soil temperature is lower than 22 °C and if the mean summer and winter soil temperatures differ by 6 °C or more at a depth of 50 cm from the soil surface, the soil moisture control section in areas of the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal years, but it is not dry in all parts for more than half of the cumulative days when the soil temperature at a depth of 50 cm is higher than 5 °C. If in normal years the moisture control section is moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice, the moisture control section is dry in all parts for less than 45 consecutive days in the 4 months following the summer solstice.

In tropical and subtropical regions that have a monsoon climate with either one or two dry seasons, summer and winter seasons have little meaning. In such regions, the moisture regime is ustic if there is at least one rainy season of three months or more. In temperate regions of subhumid or semi-arid climates, the rainy seasons are usually spring and summer or spring and autumn, but never winter. Native plants are mainly annuals or plants that have a dormant period while the soil is dry.

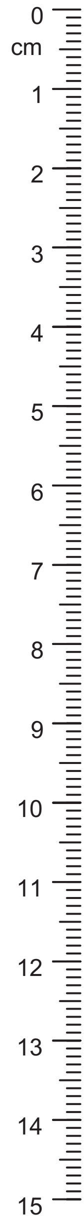
XE – Xeric moisture regime

The xeric (Greek *xeros*, dry) moisture regime is the typical moisture regime in areas of Mediterranean climates, where winters are moist and cool and summers are warm and dry. The moisture, which falls during the winter, when potential evapotranspiration is at a minimum, is particularly effective for leaching.

In areas of a xeric moisture regime, the soil moisture control section, in normal years, is dry in all parts for 45 or more consecutive days in the 4 months following the summer solstice and moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice. Moreover, in normal years, the moisture control section is moist in some part for more than half of the cumulative days per year when the soil temperature at a depth of 50 cm from the soil surface is higher than 6 °C or for 90 or more consecutive days when the soil temperature at a depth of 50 cm is higher than 8 °C. The mean annual soil temperature is lower than 22 °C, and the mean summer and mean winter soil temperatures differ by 6 °C or more either at a depth of 50 cm from the soil surface or at a densic, lithic or paralithic contact if shallower.

Annex 3

Equipment necessary for field work



Map of topography (at least 1:25 000), geology (geomorphology, land use, vegetation where available)
Global positioning system unit, compass

Guideline for soil description
Guideline for soil classification

Field book, reading form
Munsell soil color charts

Shovel, spade, pick-axe, auger and hammer
Field pH-/conductometer, standard solutions
Box with:

- pocket rule
- knife, palette-knife
- hand lens (×10)
- platinum electrodes (redox measurement)
- bottle with tap water
- bottle with aqua dest
- bottle with 1 *M* KCl or 0.01 *M* $CaCl_2$ solution (25 ml per pH measurement)
- five transparent plastic cups with marks for 8 cm^3 soil (~ 10 g) and 25 ml water, per pH or EC measurement
- drop flask with 10 percent HCl (~ 50 ml)
- drop flask with phenolphthalein pH indicator (8.2...9.8) solution (~ 30 ml)
- drop flask with 1 *M* NaF adjusted to pH 7.5 (~ 30 ml)
- drop flask with 0.2 percent (M/V) α,α-dipyridyl solution in 10 percent (V/V) acetic acid solution (~ 50 ml).

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