United Nations Economic Commission for Europe (UNECE)
Convention on Long-range Transboundary Air Pollution (CLRTAP)

International Co-operative Programme on Assessment and
Monitoring of Air Pollution Effects on Forests (ICP Forests)

ANNEX II–VII TO MANUAL

on

methods and criteria for harmonized sampling, assessment,
monitoring and analysis of the effects of air pollution on forests

Part X

Sampling and Analysis of Soil

Version 05/2016

CONTENTS

Annex II – Guidelines for Forest Soil Description

0 Introduction

These guidelines are intended to help you to make the necessary field recordings and to collect other additional information enabling proper description of a forest soil profile and subsequent classification according to the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015) as asked by the Manual Part X on Sampling and Analysis of Soil. These guidelines elaborate on variables which are not described elsewhere in this ICP Forests Manual. On the other hand, information collected in the other surveys can be very relevant to understand and interpret the soil profile correctly. In that case, reference is made to the concerning Parts of this Manual.

These guidelines are largely based on the FAO (2006) Guidelines for soil description (4^{th} edition) but do deviate for a number of parameters:

Concerning the horizon designation of the organic layer (master symbol 'O'), the ICP Forests Manual continues to use the symbols OL, OF and OH, which is a tradition in the description of European forest soils whereas the FAO (2006) adopted recently the subordinate symbols i, e and a from the American soil classification system.

By consequence, there is not need to change the subordinate symbol 'a' standing for 'evidence of cryoturbation' as in FAO (1989) into the @ symbol as in FAO (2006).

1 General site information

1.1 Observation plot number

(to be reported in *.PLS, *.PRF, *.PFH, *.SOM and *.LQA file)

The observation plot number is the unique number given to each plot. It is reported with 4 digits.

Example: Observation plot number [1012]

1.2 Profile ID

(to be reported in *.PRF and *.PFH file)

The soil profile identification number/code. It is reported with 4 characters.

Example: Profile number [0149]

1.3 Date of profile description

(to be reported in *.PRF file)

The date of description in forms how old the data are and in what season they are recorded. The date of description is given as DDMMYY (6 digits).

Example: 160504 (16 May 2004)

1.4 Profile latitude-/ longitude coordinates

(to be reported in *.PRF file)

The coordinates of the centre of the observation plot is mandatory information. In addition it is also recommended to record the latitude and longitude coordinates of the soil profile pit as accurately as possible (in degrees and sexagesimal minutes and seconds). The point observation of the soil profile is the central point of the described soil profile wall.

If possible, by preference a Global Positioning System (GPS) is used. If recording of the soil profile coordinates is impossible, then the distance (in metres and centimetres) and direction (in degrees) from the experimental plot centre should be measured and recalculated in coordinates.

The location of the profile pit is reported as:

Latitude geographic coordinates (+/- degrees, minutes, seconds) [WGS84]

Longitude geographic coordinates (+/- degrees, minutes, seconds) [WGS84]

Example:	Latitude:	51° 23´ 31´´ N; is reported as +512331
	Longitude:	11° 52´ 40´´ E; is reported as +115240

1.5 Elevation

(to be reported in *.PRF file)

The elevation or altitude (m above sea level) of the site should be obtained as accurately as possible.

2 Soil forming factors

Although the description of the soil forming factors are important for the correct interpretation of the soil profile, the soil module of the database does not ask to report most of these parameters, except for land use, parent material, water availability, mean highest and mean lowest groundwater level, profile depth (root, rock, obstacle depths). On the other hand, FSCC strongly recommends to record and store all soil forming variables at national level. The information may be derived from a combination of field measurements/observations, climatic records, topographical, geological and geomorphological maps and documents, and partly from the other surveys already conducted on the observation plots.

2.1 Climate and weather conditions

For the collection of meteorological data, see Manual IX on Meteorological Measurements.

2.1.1 Present weather conditions

The weather condition at the time of the profile description is recorded, using following classes (after BBC weather)

Code	Description
1	sunny
2	partly cloudy
3	overcast
4	light rain
5	heavy rain
6	thunder storm
7	sleet [1)]
8	hail [2)]
9	snow

[1)] Sleet refers to snow that has partially melted when it touches the ground, due to surrounding air that is sufficiently warm to partially melt it while falling, but not warm enough to fully melt droplets into rain. Thus it refers to partially melted droplets, a mixture of snow and rain. It does not tend to form a layer on the ground, unless the ground has a temperature that is below freezing, when it can form a dangerous layer of invisible ice on surfaces known as 'black ice'. This similarly occurs when rain freezes upon contact with the ground (freezing rain) [http://en.wikipedia.org/].

[2)] Hail is a type of graupel, a form of precipitation, composed of spears or irregular lumps of ice. It occurs when supercooled water droplets (remaining in a liquid state despite being below the freezing point, 0 °C) in a storm cloud aggregates around some solid object, such as a dust particle or an already-forming hailstone. The water then freezes around the object. Depending on the wind patterns within the cloud, the hailstone may continue to circulate for some time, increasing in size. Eventually, the hailstone falls to the ground, when the updraft is no longer strong enough to support its weight (http://en.wikipedia.org/).

2.1.2 Former weather conditions (AG-Boden, 2004)

This refers to the weather conditions prior to the time of the profile description.

Code	Description
1	no rain during the last month
2	no rain during the last week
3	no rain during the last 24 hours
4	light rain during the last 24 hours
5	heavy rain or thunder during the last 24 hours
6	extremely rainy or snow melting

2.2 Soil climate

2.2.1 Cryic horizon

Providing information on the soil climate is optional, except for those soils that may have a cryic horizon[1] . A cryic horizon has following definition with respect to soil temperature:

A cryic horizon must have a soil temperature at or below 0°C for two or more years in succession.

2.2.2 Soil climate classification (FAO, 2006)

The soil climate classification can be indicated, if applicable. The soil moisture and temperature regimes according to the USDA Keys to Soil Taxonomy (Soil Survey Staff, 2003) may be used. Where such information is not available or cannot be derived from representative climatic data with

[1] Note that the temperature requirement for a cryic diagnostic horizon is different than for a cryic soil temperature regime. Whereas the temperature for the cryic soil temperature regime is measured at 50 cm depth, the cryic horizon may be present in all depths within the upper 100 cm to qualify for Cryosols, or within the upper 200 cm for other reference soil groups.

confidence, it is better to leave the space blank. Other agro-climatic variables worth mentioning would be a local climate class, the agro-climatic zone and length of growing period.

Soil Temperature Regime			
Code	Description	Code	Description
PG	Pergelic		
CR	Cryic		
FR	Frigid	IF	Isofrigid
ME	Mesic	IM	Isomesic
TH	Thermic	IT	Isothermic
HT	Hyperthermic	IH	Isohyperthermic

Soil Moisture Regime			
Code	Description	Code	Description
AQ	Aquic	PQ	Peraquic
AR	Aridic		
TO	Torric		
UD	Udic	PU	Perudic
US	Ustic		
XE	Xeric		

2.3 Topography

2.3.1 Slope position

(after FAO, 2006)

The position of the soil profile with respect to the slope is very important. Not only will the slope position have an influence on the external and internal drainage, but also the runoff and the subsurface flow are affected. A separate terminology is used for flat or almost flat (slopes of <10%) and undulating to mountainous terrains (slopes >10%) (Figure 1):

Position in flat or almost flat terrain

Code	Description
1	Higher part (rise)
2	Intermediate part
3	Lower part (and dip)
4	Bottom (drainage line)

Position in undulating to mountainous terrain

Code	Description
5	Crest (summit)
6	Upper slope (shoulder)
7	Middle slope
8	Lower slope (foot slope)
9	Toe slope
10	Bottom (flat)

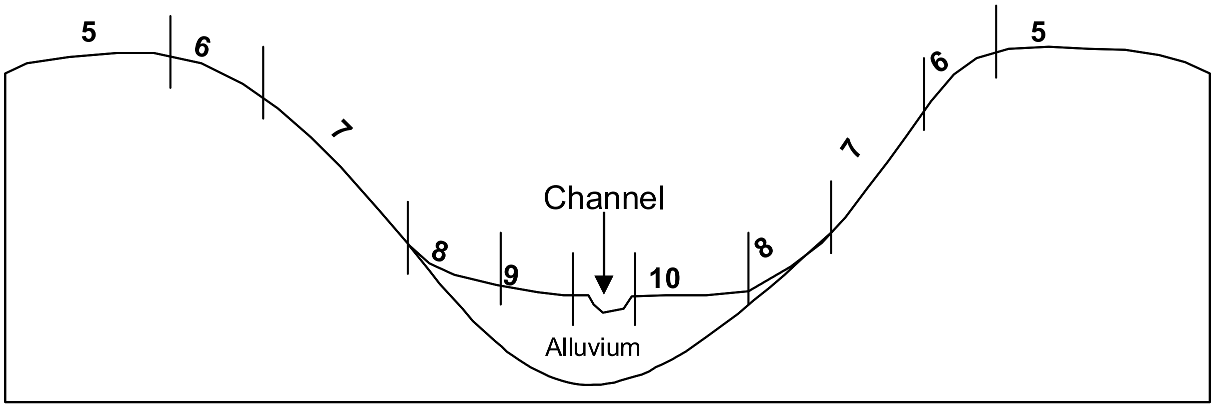

Figure 1: Slope positions in undulating and mountainous terrain (after Ruhe, 1975; Schoeneberger et al., 2002; FAO, 2006)

2.3.2 Slope form

(after Schoeneberger et al., 2002; FAO, 2006)

The slope form is described in two directions: up and down slope, which is perpendicular to the contour, and across slope, which is along the horizontal contour. The slope form classes defined are provided in Figure 2:

Code		Description
1	SS	Straight, straight
2	SV	Straight, convex
3	SC	Straight, concave
4	VS	Convex, straight
5	VV	Convex, convex
6	VC	Convex, concave
7	CS	Concave, straight
8	CV	Concave, convex
9	CC	Concave, concave
10		Terraced
11		Complex (irregular)

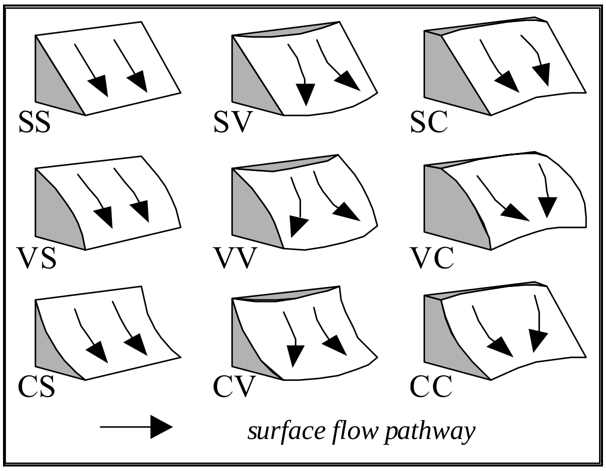

Figure 2: Slope forms and surface drainage pathways (after Schoeneberger et al., 2002)

2.3.3 Slope gradient

(Modified from FAO, 2006)

The slope gradient in the immediate surrounding of the soil profile should be measured using a clinometer, an abney level or a similar instrument. If measurements in the field are not possible, then the gradient can be calculated from the contour lines on detailed topographical maps.

In practice, measuring slopes in forest can be problematic especially when the slope gradient is very gentle because then a longer distance is necessary to make an accurate measurement. If so, it is advised to base very gentle gradients (<2%) on topographical map readings.

If the slope gradient is measured in degrees, then the gradient is calculated into percent, knowing that 45° equals 100%. Values above 100% are possible (often such steeps slopes are indeed left for forests).

Code	Description	Class limits
1	Flat	0 – 0.2 %
2	Level	0.2 – 0.5 %
3	Nearly level	0.5 – 1.0 %
4	Very gently sloping	1 – 2 %
5	Gently sloping	2 – 5 %
6	Sloping	5 – 10 %
7	Strongly sloping	10 – 15 %
8	Moderately steep	15 – 30 %
9	Steep	30 – 60 %
10	Very steep	60 – 100 %
11	Extremely steep	>100 %

2.3.4 Slope length (FAO, 2006)

In addition to the above attributes of slope, the slope length along the slope (particularly above the site) is recorded in meters.

2.3.5 Slope orientation

The slope orientation (azimuth) of the plot is mandatory to report in the general plot file at the time of the installation of the monitoring plot (XXGENER.PLT file) according to classes. See Part II of this Manual.

2.4 Land use

(to be reported in *.PRF file)

Land use applies to the current use of the land. Land use greatly influences the direction and rate of soil formation; its recording greatly enhances the interpretative value of the soil data. The land-use should be described according to following list:

Code		Description
50		Natural forest and woodland (mostly natural regeneration)
	51	Natural forest and woodland without felling
	52	Natural forest and woodland with selective felling
	53	Natural forest and woodland with clear felling
60		Plantation forestry (mostly planted)
	61	Plantation forestry without felling
	62	Plantation forestry with selective felling
	63	Plantation forestry with clear felling
70		Agro-forestry
80		Nature protection
90		Other (explain)

Further information:

- Is hunting allowed? (**Y/N/X;** where X stands for no information)
- Is the wild life protected including density control? (**Y/N/X;** where X stands for no information)
- Is grazing by domesticated animals (e.g. cattle, pigs…) practised, or not? (**Y/N/X**; where X stands for no information)

2.5 Human influence

(modified from FAO, 2006)

Any evidence of human activity, which is likely to have affected the landscape or the physical and chemical properties of the soil should be recorded (erosion is dealt with separately, see paragraph 2.16). Below are the most common examples of human influence listed. Observations of human impact on the soil profile is reported in chapter 3.20 (Man Made Materials) and 3.21 (Human Transported materials). Here only observations observed in the landscape on meso and micro scale are recorded.

Code	Description	Code	Description
1	No influence	15	Raised beds
2	Vegetation disturbed (not specified)	16	Terracing
3	Vegetation slightly disturbed	17	Land fill
4	Vegetation moderately disturbed	18	Levelling
5	Vegetation strongly disturbed	19	Artificial drainage
6	Mineral additions (not specified)	20	Irrigation (not specified)
7	Sand additions	21	Clearing
8	Organic additions (not specified)	22	Burning
9	Ploughing (not specified)	23	Surface compaction
10	Shallow ploughing (<20 cm)	24	Traffic traces
11	Ploughing (20-40 cm)	25	Application of fertilizers
12	Deep ploughing (>40 cm)	26	Pollution
13	Spitting (traces of spade marks)	30	Others (explain)
14	Plaggen		

2.6 Vegetation

2.6.1 Forest type classification

The forest type is described, according the European forest type classification, which was validated in the BioSoil biodiversity project of the majority o the Level I plots (EEA, 2007). On Level I, Level II and the Level II core plots, the forest type should be described in the general plot file (see Manual Part II).

2.6.2 Tree species composition

The main tree species together with the type of tree species mixture (single tree wise mixture, group wise mixture, mixture by layers, etc.) is to be reported in the general plot file at the installation of the monitoring plot. See Manual Part II. The social class is mandatory to report on Level II for crown condition assessment.

2.7 Parent material

(originating from Finke et al. 2001; **to be reported in *.PRF file)**

The parent material is the material from which the soil has been derived and in which the soil profile has been developed. There are two groups of parent material: either unlithified materials (mostly sediments), or weathering materials overlying the hard rock from which they originate. There are also restored natural soil materials or sediments as well as man-made (technogenic) materials.

The detailed table on parent material applied by the Soil Geographical Data Base (-Finke et al. 2001) is presented in the explanatory items. The parent material should be described at least on the major class level. The 9 major classes summarised below are <u>not listed hierarchically</u>:

Code	Description of Major Class level
0000	No information
1000	Consolidated-clastic-sedimentary rocks
2000	Other sedimentary rocks (chemically precipitated, evaporated, or organogenic or biogenic in origin)
3000	Igneous rocks
4000	Metamorphic rocks
5000	Unconsolidated deposits (alluvium, weathering residuum and slope deposits)
6000	Unconsolidated glacial deposits / glacial drift
7000	Aeolian deposits
8000	Organic materials
9000	Anthropogenic deposits

2.8 Natural Drainage Classes

(Soil Survey Staff, 1993)

Soil drainage is usually reflected by soil colour, but relict features may persist after natural or artificial changes in drainage. The depth of occurrence and intensity of gley features usually indicate the drainage status of the soil but not always: some soil materials will not develop strong features of gleying because of their specific chemical composition, texture, structure or porosity, other mottles may be the results of weathering minerals, rather than an impact of drainage conditions.

Code	Class name	Description
1	Excessively drained	Water is removed from the soil very rapidly. Internal free (“gravitational”) water commonly is very rare or very deep. The soils are commonly coarse-textured, and have very high saturated hydraulic conductivity, or are very shallow.
2	Somewhat excessively drained	Water is removed from soil rapidly. Internal free water occurrence commonly is very rare or very deep. The soils are commonly coarse-textured, and have high saturated hydraulic conductivity or are very shallow.
3	Well drained	Water is removed from the soil readily, but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of the deep to redoximorphic features that are related to wetness.
4	Moderately well drained	Water is removed from the soil somewhat slowly during some periods of the year. Internal free water commonly is moderately deep and may be transitory or permanent. The soil is wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. The soil commonly has a moderately low or lower saturated hydraulic conductivity within 1 m of the surface, or periodically receives high rainfall, or both.
5	Somewhat poorly drained	Water is removed slowly so that the soil is wet at a shallow depth for significant periods during the growing season. Internal free water is commonly shallow to moderately deep and transitory to permanent. Unless the soil is artificially drained, the growth of most mesophytic plants is markedly restricted. The soil commonly has a low or very low saturated hydraulic conductivity or a high water table, or receives water from lateral flow, or persistent rainfall, or some combination of these factors.
6	Poorly drained	Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods. Internal free water is shallow to very shallow and common or persistent. Unless the soil is artificially drained, most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below ploughing depth (±25 cm). Free water at shallow depth is usually present. The water table is commonly the result of low or very low saturated hydraulic conductivity or persistent rainfall, or a combination of both factors.
7	Very poorly drained	Water is removed from the soil so slowly that free water remains at or near the soil surface during much of the growing season. Internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is persistent or high, the soil can be very poorly drained even on gentle slopes.
X	Not known	

2.9 Water availability

(to be reported in *.PLS file)

An estimate of the water availability to principal tree species during the growing season is made:

Code	Description
1	Insufficient
2	Sufficient
3	Excessive

2.10 Period of water saturation

(FAO, 1990)

In the description of drainage classes, the period when the soil is saturated or very wet is not satisfactory, especially where the rainfall is strongly seasonal or irregular. Very permeable sands may be permanently or seasonally waterlogged and impermeable clays may never be saturated or only for a few days a year.

The period during which the soil near the surface is saturated should be indicated, based on local information or judgment supplemented by gleying features in the profile:

Code	Description
1	Never saturated
2	Rarely saturated (a few days in some years)
3	Saturated for short periods in most years (up to 30 days)
4	Saturated for long periods every year
5	Always saturated

2.11 External drainage

(FAO, 1990)

The external drainage of a site refers to its relative position in the landscape. Is the site in a landscape position where it will overall receive water from upslope or rather shed water downslope? And if shedding, by which speed is the water lost? The following classes are defined:

Code	Description
1	Ponded (run-on site)
2	Neither receiving nor shedding water
3	Slow run-off
4	Moderately rapid run-off
5	Rapid run-off

2.12 Flooding

(FAO, 1990)

Flooding is described according to its frequency, duration and depth. At most sites it is difficult to assess flooding accurately. Information may be obtained from records of past flooding or from local enquiry. The frequency and duration classes give an indication of the average occurrence of flooding. It is very important to evaluate if the flooding is a relict or if it is still active at present.

2.12.1 Frequency

Code	Description
1	Daily
2	Weekly
3	Monthly
4	Annually
5	Biennially
6	Once every 2-4 years
7	Once every 5-10 years
8	Rare (less than once in 10 years)
9	Inactive today, but has been active in historical time
10	Inactive today, but has once been active (ancient time)
11	None

2.12.2 Duration (days/year)

Code	Description
1	Less than 1 day
2	1- 15 days
3	15- 30 days
4	30- 90 days
5	90 -180 days
6	180- 360 days

2.12.3 Depth (of standing water)

Code	Description	Class limits
1	Very shallow	0 - 25 cm
2	Shallow	25 - 50 cm
3	Moderately deep	50 - 100 cm
4	Deep	100 - 150 cm
5	Very deep	> 150 cm

2.13 Groundwater table

(Modified from SG-DBEM, 2003)

The groundwater table level within or below a soil profile often varies in time. Therefore, the mean highest and mean lowest permanent or perched groundwater table level should be the average for at least the past 10 years. This information can in some cases be derived from maps. Seasonal variations are not recorded. The different groundwater table classes to be used are as follows:

2.13.1 Mean highest and mean lowest groundwater table

(to be reported in *.PRF file)

The mean highest and mean lowest permanent or perched groundwater table level is the average level for at least the past 10 years. Generally this information is lacking and so these values need generally to be estimated by an expert.

The depth classes for groundwater for mean lowest and mean highest depth levels are:

Code	Description	Class limits
9	No water table observed or unknown	
1	Very shallow to shallow	0 - 50 cm
2	Moderately deep	50 - 100 cm
3	Deep	100 - 150 cm
4	Very deep	150 - 200 cm
5	Extremely deep	>200 cm

2.13.2 Type of water table

(to be reported in *.PRF file)

Code	Description
9	No water table
1	Perched water table (= stagnating water table)
2	Permanent water table (= groundwater table)

2.14 Rock outcrops

(after FAO, 2006)

Rock outcrops should be described in terms of percentage surface cover, size and spacing of the individual outcrops. It is necessary to walk around in increasing larger circles around the profile plot in order to make a correct estimate. The classes of percentage of surface cover and of average distance between rock outcrops (single or clusters) are as follows:

2.14.1 Surface cover

Code	Description	Class limits
1	None	0 %
2	Very few	0 - 2 %
3	Few	2 - 5 %
4	Common	5 - 15 %
5	Many	15 - 40 %
6	Abundant	40 - 80 %
7	Dominant	>80 %
8	Rock outcrops are present but mostly hidden below forest litter	

2.14.2 Distance between rock outcrops

Code	Description
1	>50 m
2	20 - 50 m
3	5 - 20 m
4	2 - 5 m
5	<2 m

2.15 Coarse surface fragments

(FAO, 2006)

Coarse surface fragments, boulders and stones, including those that are partly buried, should be described in terms of percentage of surface cover and size of the fragments. It is often not easy to observe boulders and stones under forest due to the litter layer, so a careful survey may be necessary. Remember, a stone or boulder partly buried is only included in the coverage and class estimate based on the visible part, it is not the purpose to uncover partly or completely buried coarse fragments. The classes of coverage and size handled are:

2.15.1 Surface cover

Code	Description	Class limits
9	None	0 %
1	Very few	0 - 2 %
2	Few	2 - 5 %
3	Common	5 - 15 %
4	Many	15 - 40 %
5	Abundant	40 - 80 %
6	Dominant	>80 %

2.15.2 Size classes

Size classes according to the greatest dimension of the individual gravels/stones:

Code	Description	Class limits
1	Fine gravel	0.2 - 0.6 cm
2	Medium gravel	0.6 - 2.0 cm
3	Coarse gravel	2 - 6 cm
4	Stones	6 - 20 cm
5	Boulders	20 - 60 cm
6	Large boulders	- 200 cm

2.16 Erosion and sedimentation

(modified from FAO, 2006)

Although under most forest covers erosion and sedimentation will be of minor importance, these variables have been included in these guidelines. Since, when it is present, it is of great importance for the soil formation and dynamics.

2.16.1 Type of erosion/sedimentation

Erosion and sedimentation can be described according to the agency - water, wind, mass movements (landslides and related phenomena). In forested sites the major or only erosion may occur along patches, roads, timber tracks etc. Description should also include deposition of transported material:

Code	Description
9	No evidence of erosion
1	Water erosion and sedimentation
2	Sheet erosion by water
3	Rill erosion by water
4	Gully erosion by water
5	Tunnel erosion by water
6	Mass movement (landslides and similar phenomena)
7	Sedimentation by water
8	Wind erosion and sedimentation
9	Sedimentation by wind
10	Shifting sands
11	Salt deposition
12	Other erosion/sedimentation, related to human

2.16.2 Area affected

The proportion of total area affected by erosion/sedimentation is estimated:

Code	Description
9	0 %
1	0 - 5 %
2	5 - 10 %
3	10 - 25 %
4	25 - 50 %
5	> 50 %

2.16.3 Degree

It is difficult to define classes of the degree of erosion which are equally appropriate for all soils, environments, and the various types of erosion. Classes may have to be defined further for each type or combination of erosion and sedimentation and each specific environment. For example, in the case of gully and rill erosion, the depth and spacing may be recorded; for sheet erosion the loss of topsoil; for dunes the height; for sedimentation the thickness of the layer. The following classes are recommended to describe the degree of erosion:

Code	Class name	Description
9	None	No erosion nor sedimentation
1	Heavy sedimentation	Soils buried below >50 cm of accumulated sediment
2	Considerable sedimentation	Soils buried below 5 - 50 cm of accumulated sediment
3	Noticeable sedimentation	Soils buried below <5 cm of accumulated sediment, continuously distributed
4	Traces sedimentation	Soils buried below <5 cm of accumulated sediment, discontinuously distributed
5	Slight erosion	Some evidence of damage to the topsoil; original biotic functions largely intact
6	Moderate erosion	Removal of topsoil; original biotic functions partly destroyed
7	Severe erosion	Surface layers completely removed and subsurface layers exposed
8	Extreme erosion	Substantial removal of deeper subsurface horizons (badlands)

2.16.4 Activity

The period of activity of accelerated erosion, or sedimentation, may be described as follows:

Code	Description
9	Accelerated and natural erosion not observed
1	Period of activity not known
2	Active in historical times
3	Active in recent past (up till past 50 - 100 years)
4	Active at present

2.17 Surface sealing

(FAO, 2006)

Where the mineral soil is exposed, a surface crust may develop. Only in extreme cases a surface sealing will develop on forest soils, as the soil should be exposed to wetting and drying and not be protected by a litter layer. If surface crusts develop it will have a negative effect on seed germination, reduce water infiltration and increase run-off. The thickness and the consistence of the crust is described (for consistence definitions see paragraph 3.11):

2.17.1 Thickness

Code	Description	Class limits
9	None	
1	Thin	<2 mm
2	Medium	2 - 5 mm
3	Thick	5 - 20 mm
4	Very thick	>20 mm

2.17.2 Consistence when dry

Code	Description
1	Slightly hard
2	Hard
3	Very hard
4	Extremely hard

2.18 Surface cracks

(FAO, 2006)

Mineral surface cracks develop in many clay-rich soils during drying. The width (average, or average width and maximum width) of the cracks, and the average spacing between cracks are measured.

2.18.1 Size (Width)

Code	Description	Class limits
1	Fine	<1 cm
2	Medium	1 - 2 cm
3	Wide	2 - 5 cm
4	Very wide	5 - 10 cm
5	Extremely wide	>10 cm

2.18.2 Distance between cracks

Code	Description	Class limits
1	Very closely spaced	<0.2 m
2	Closely spaced	0.2 - 0.5 m
3	Moderately widely spaced	0.5 - 2 m
4	Widely spaced	2 - 5 m
5	Very widely spaced	>5 m

2.19 Salt

(FAO, 2006)

The occurrence of surface salt may be described in terms of cover and appearance. Classes for the percentage of surface cover and thickness are:

2.19.1 Cover

Code	Description	Class limits
9	None	0 - 2 %
1	Low	2 - 15 %
2	Moderate	15 – 40 %
3	High	40 – 80 %
4	Dominant	>80 %

2.19.2 Thickness

Code	Description	Class limits
1	Thin	<2 mm
2	Medium	2 - 5 mm
3	Thick	5 - 20 mm
4	Very thick	>20 mm

2.20 Profile depth

(to be reported in *.PRF file)

The depth of the soil is defined with 3 attributes: effective rooting depth, rock depth and obstacle depth. The depth must be given in cm from the top of the mineral soil surface.

The 'Effective rooting depth' is defined as the depth of the soil at which root growth is strongly inhibited. As rooting depth is plant specific, it is recommended that representative species are used to indicate the effective rooting depth of the soil. The effective rooting depth is governed by such factors as the presence of cemented, toxic or compacted layers, hard rock, or indurated gravel layers. A high permanent water table may also control the rooting depth, but may change after drainage. The effective hydrological depth may be much greater. Apart from obvious situations such as the presence of hard rock, it is realized that the estimation of effective soil depth is subject to individual interpretation.

The depth to the underlying bedrock should be recorded under 'Rock depth of the soil profile'.

The field 'Obstacle depth of the soil profile' can be used to record the depth to any other limiting horizon, such as a petrocalcic horizon, fragipan, duripan, waterlogging, accumulation of toxic elements.

3 Soil horizon description

In the following chapter, the horizon variables are presented. The sequence is different from those presented in the FAO guidelines (FAO 1990; FAO 2006).

Usually a forest soil is composed of mineral and organic horizons, stones, bedrock etc., which together constitute the soil profile. In the following chapter a series of variables are listed, but not all of them are equal relevant to particular organic horizons. For the definitions of organic material and organic horizons, see Annex 7.

In principle knowledge of the content of organic matter is required to differentiate between organic and mineral materials. In the field, organic horizons are usually easy to recognise, only border cases will need analytical data to check for the content of organic carbon. In the table below the subchapters relevant for organic and mineral horizons are summarised:

Relevant for:	**organic horizons**	**mineral horizons**
3.1 Horizon boundary	Yes	Yes
3.2 Photographic recordings	Yes	Yes
3.3 Soil Colour	Yes	Yes
3.4 Mottling	**No**	Yes
3.5 Redoximorphic properties	Yes	Yes
3.6 Texture	**No**	Yes
3.7 Rock fragments	Yes	Yes
3.8 Andic material	**No**	Yes
3.9 Soil structure	**No**	Yes
3.10 Consistence	**No**	Yes
3.11 Cutanic features	**No**	Yes
3.12 Porosity	Yes	Yes
3.13 Cementation and compaction	**No**	Yes
3.14 Nodules	**No**	Yes
3.15 Roots	Yes	Yes
3.16 Other biological features	Yes	Yes
3.17 Carbonates	Yes	Yes
3.18 Gypsum	**No**	Yes
3.19 Readily soluble salts	Yes	Yes
3.20 Man-made materials	Yes	Yes
3.21 Human transported material	**No**	Yes
3.22 Soil horizon designation	Yes	Yes

After having selected the most representative location for the soil profile (see also Annex 3), the profile is opened and cleaned. A list of suggested field equipment is presented in Annex 4. The recommended sequence of description is as follows:

- delineation and description of the horizon boundaries,
- photographic recordings of the soil in general and of special features in detail,
- colour measurements (see also Annex 5),
- from this stage on, the profile wall is gently broken apart to record texture, rock fragments, structure, consistence, porosity, cutans, cementations and nodules, this is followed by
- the description of roots and other biological activity, and by
- the description of carbonates, gypsum and salts,
- each horizon is designated one or more horizon master and subordinate symbols, and
- the necessary samples are collected.

3.1 Horizon boundary (modified from FAO, 2006)

The nature of the boundaries between soil layers, or horizons, may indicate the processes that have formed the soil. In some cases, they reflect anthropogenic impacts. Horizon boundaries are described in terms of depth, distinctness and topography.

3.1.1 Horizon number

(to be reported in *.PFH file)

After delineation of the horizon boundaries, each horizon is numbered: 1, 2, 3 etc. While the horizon symbols may change according to new information, the horizon number is not to be changed at any point of the further profile description and sampling. The numbering starts from the interface between air and soil no matter whether the surface horizon is an organic or a mineral horizon (see Figure 3). If at a later stage, a new horizon is discovered or an existing horizon is subdivided, a new number should be created. Avoid renumbering of the existing horizons to keep the link with the initial description in the field.

3.1.2 Depth of horizon limits

(to be reported in *.PFH file)

The depth of the upper and lower boundary of each horizon is measured in centimetres <u>from the surface of the mineral soil</u>.

If the soil is covered by (an) organic layer(s), either:

(a) 10 cm or more thick from the soil surface to a lithic or paralithic contact, or
(b) 40 cm or more thick,

then the depth is measured from the surface of the organic cover. The depth requirements correspond to the limit for Histosols (organic soils).

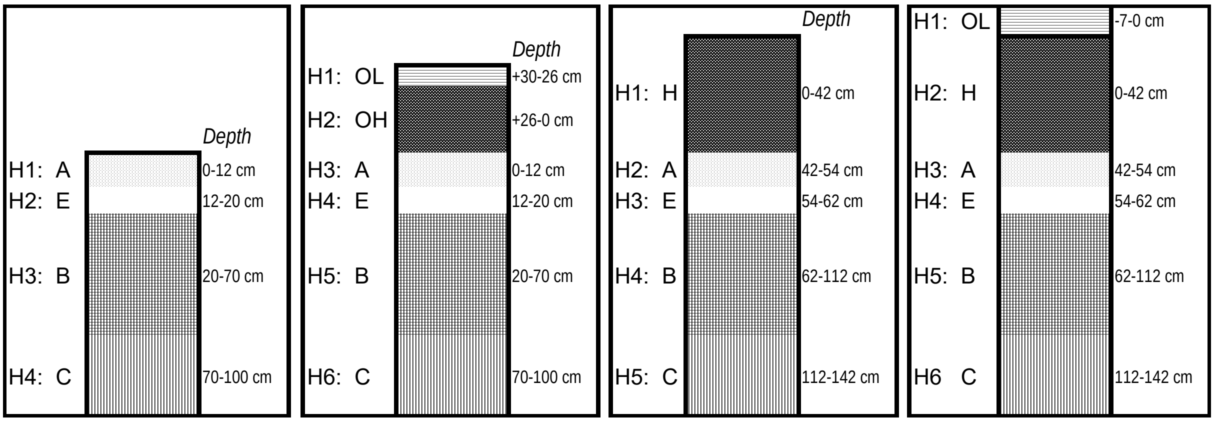

Figure 3: Examples on how the horizon depth should be recorded in the field. These depths are important for the profile description and for the sampling.

- If the organic layer(s) is (are) too shallow to fulfil the above depth requirement(s), then its depth is recorded from the zero-point and upwards (see Figure 3), using negative depths.
- The depth is measured perpendicular to the slope.
- Most soil boundaries are zones of transition rather than sharp breaks. The distinctness together with the topography describe the transition between the different horizons and substitute for the need to describe the depth ranges as for instance from 28 (25-31) cm to 45 (39-51) cm.

3.1.3 Distinctness

(to be reported in *.PFH file)

The distinctness of the lower horizon boundary refers to the thickness of the boundary zone in between adjacent horizons.

Code	Description	Class limits
3	Abrupt	0 - 2 cm
4	Clear	2 - 5 cm
5	Gradual	5 - 15 cm
6	Diffuse	>15 cm

Concerning the boundary between the organic (as in forest floors) and the organo-mineral horizons, following classes of distinctness shall be used:

Code	Distinctness	Class limits
7	Very sharp	< 0.3 cm
8	Sharp	≥ 0.3 and < 0.5 cm
9	Not sharp	≥ 0.5 cm

3.1.4 Topography

(to be reported in *.PFH file)

The topography of the boundary indicates its shape (see Figure 4).

Code	Class name	Description
1	Smooth	Nearly plane surface
2	Wavy	Pockets shallower than they are wide
3	Irregular	Pockets deeper than they are wide
4	Broken	Discontinuous
5	Complex	

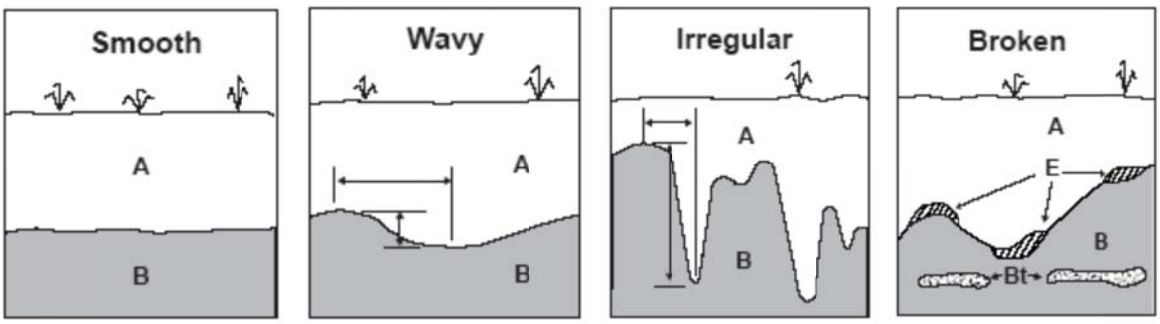

Figure 4: Illustration of the most common horizon topographies, which is the lateral undulation and continuity of the boundary between horizons (after Schoeneberger et al., 2002)

3.2 Photographic recordings

Quality photographs are essential for the soil database. A scale is needed on all photos, preferentially a bicoloured centimetre-scale. The use of tools for scaling should be avoided. If a tool e.g. a spade is used anyway the length of the spade should be clearly stated in the photo legend.

Partly shade partly sunshine on the profile wall should be avoided. You may use a dark and uniform coloured umbrella to shade the profile. If possible avoid the use of a camera flash by using a tripod or a monopod. If an analogue camera is used, try always to use the same brand of film rolls. If using a digital camera, use a high resolution (5 Mega Pixels or more) and a camera with a good quality lens. The photographic database can/should include following images:

- General photo illustrating the geomorphology and vegetation of the area surrounding the profile
- Photo of the immediate vicinity of the profile
- The profile after cleaning and before indication of the soil horizons on the profile wall.
- The profile after the soil horizons are outlined gently on the profile wall with e.g. a knife
- The profile with partly visible structure and partly with a cleaned surface
- The profile with indications where to sample
- Close-up of the organic topsoil horizon(s)
- Horizontal sections, e.g. in de depths where the bulk density (BD) is sampled
- Special features

3.3 Soil colour

(to be reported in *.PFH file)

The colour of the soil matrix in each horizon should be recorded in moist and dry condition using the Munsell notation (e.g. Munsell, 2000). The colour notation is composed of hue, value and chroma. Hue is the dominant spectral colour (red, yellow, green, blue, 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). If there is no dominant colour, the horizon is described as mottled and two or more colours are given, making use of the observation field. In addition to the colour notations, the standard Munsell colour names should be recorded as well.

Example: Greyish brown 10YR 5/2 (moist) and light brownish grey 10YR 6/2 (dry);
where 10YR (yellowish red) is the hue, 5 (or 6) is the value and 2 the chroma.

Example: Dark greyish brown to greyish brown 2.5Y 4.5/2 (moist) and light brownish grey 2.5Y 6/2 (dry);
Notice that interpolation between colours is possible for hue, value and/or chroma

Example: Dark greenish grey 5GY 4/1 (moist) and greenish grey 10GY 5/1 (dry);
where 5GY or 10GY (greenish yellow) is the hue, 4 (or 5) is the value and 1 is the chroma.

More detailed information about optimal colour measurements and special colours required for soil classification is to be found in Annex 5.

3.4 Mottling

(FAO, 2006)

Mottles are spots of different colours interspersed with the dominant colour of the soil. They commonly indicate that the soil has been subject to alternate wet (reducing) and dry (oxidizing) conditions. Other mottles can be the result of rock weathering, clay (+iron) migration and accumulation, selective decay by fungi of organic matter etc.

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

3.4.1 Colour

Measure the colours using the Munsell Soil Colour Charts.

If the colour changes after exposure to the air, measure both the colours before and after oxidation.

3.4.2 Abundance

Abundance is described as an exact figure or in classes indicating the percentage of the exposed surface occupied by the mottles. When mottles are so abundant that distinction of matrix and mottle colour is not possible, the predominant colours should be described as soil matrix colours.

Code	Description	Class limits
1	None	0 %
2	Very few	0 - 2 %
3	Few	2 - 5 %
4	Common	5 - 15 %
5	Many	15 - 40 %
6	Abundant	>40 %

3.4.3 Size

The following classes are used to indicate the approximate diameters of individual mottles.

Code	Description	Class limits
1	Very fine	< 2 mm
2	Fine	2 - 6 mm
3	Medium	6 - 20 mm
4	Coarse	20 - 40 mm
5	Very coarse	40 - 80 mm
6	Extremely coarse	> 80 mm

3.4.4 Contrast

The colour contrast between mottles and soil matrix can be described as:

Code	Description
1	**Faint**: mottles are evident only on close examination. Soil colours in both the matrix and mottles are similar.
2	**Distinct**: although not striking, the mottles are readily seen. The hue, chroma or value of the matrix is easily distinguished from the mottles. They may vary by as much as 2.5 units of hue or several units in chroma or value.
3	**Prominent**: the mottles are conspicuous. Hue, chroma and value, alone or in combination, are several units apart.

3.4.5 Boundary

The boundary between mottle and matrix is described according to the width of the transition zone.

Code	Description	Class limits
1	Sharp	<0.5 mm
2	Clear	0.5 - 2 mm
3	Diffuse	2 - 5 mm
4	Very diffuse	>5 mm

3.5 Redoximorphic properties (IUSS Working Group WRB, 2015)

Redoximorphic features concerns a colour pattern observed in the soil, which is the result of depletion or concentration compared to the matrix colour, formed by oxidation/reduction of iron and/or manganese.

3.5.1 Reducing conditions

If reducing conditions prevail in a soil horizon, it can be tested in following ways:

- Is the negative logarithm of the hydrogen partial pressure (rH, calculated as Eh 29^{-1} + 2pH) less than 20?
- Are Fe^{2+} ions present, as tested by spraying the freshly exposed soil surface with a 0.2% (m/v) α,α dipyridyl solution in 10% (v/v) acetic acid solution? The test yields a striking reddish colour in the presence of Fe^{2+} ions (be careful, the chemical is slightly toxic). Did a reddish colour (almost like red wine) appear on the tested soil surface after a few minutes?
- Is iron sulphide present?
- Is methane present?

If the answer to any of above 4 questions is yes, report: **Y**

If none of the test above are positive, report: **N**

If data for some reason are missing or impossible to collect, indicate: **X**

3.5.2 Reductimorphic and oximorphic colours

If oximorphic and/or reductomorphic mottles as present they are first of all described according to the chapter on mottles (see chapter 3.4). Note that gleyic mottles should be recorded as fast as possible after the profile has been prepared, sometimes even while digging the profile, due to the fast oxidation of certain minerals.

- Are <u>redu</u>ctimorphic colours, reflecting permanently wet conditions, present on more than 90% of the soil surface? Reductimorphic colours are neutral white to black (Munsell N1/ to N8/) or bluish to greenish (Munsell 2.5Y, 5Y, 5G, 5B).

Y/N/X (Yes/No/Not known)

- <u>Oxim</u>orphic colours reflect alternating reducing and oxidizing conditions, as is the case in the capillary fringe and in the surface horizons with fluctuating groundwater levels. They comprise any colour, excluding reductimorphic colours (see above). Are 5% or more of the soil surface cover by oximorphic coloured mottles?

Y/N/X (Yes/No/Not known)

The above described field tests may to some degree illustrate the actual redoximorphic conditions at the moment of fieldwork, rather than the general condition of the soil. For the same reason it is strongly recommended in case of gley soils to give special attention to:

- roots (presence/absence), and
- the soil water (indications of a fluctuating or permanent water tables etc.)

3.5.3 Stagnic and gleyic colour pattern

Depending on the origin of the water, which is either the groundwater table, either surface water that is (at least temporarily) saturating the soil layer, two different colour patterns will develop. It is important to distinguish between both type of colour patterns during the profile description.

Note: When a stagnic colour pattern is identified in a genetic horizon, it is designated by the horizon subordinate symbol 'g'. When a gleyic colour pattern is seen, the horizon received the subordinate symbol 'l'. See Annex 7. The latter symbol did not yet exist during the BioSoil demonstration project (Mikkelsen et al., 2006) and so is only applied in the ICP Forests programme from 2010 onwards.

Stagnic properties

General description

Soil materials develop stagnic properties (from Latin stagnare, to stagnate) if they are, at least temporarily, saturated with surface water (or were saturated in the past, if now drained) for a period long enough that allows reducing conditions to occur (this may range from a few days in the tropics to a few weeks in other areas).

Diagnostic criteria

Stagnic properties comprise one of the following:

(1) a mottled layer with two or more colours and one or both of the following:

- (a) mottles and/or concretions and/or nodules, the colour of which is considered to be oximorphic, that:
  - (i) are, if soil aggregates are present, predominantly inside the aggregates; and
  - (ii) are black, surrounded by lighter-coloured material, or have, moist, a Munsell colour hue ≥ 2.5 units redder than the surrounding material and a Munsell colour chroma ≥ 1 unit higher than the surrounding material; or
- (b) parts, the colour of which is considered to be reductimorphic, that:
  - (i) are predominantly around root channels, and if soil aggregates are present, predominantly at or near the surfaces of the aggregates; and
  - (ii) have, moist, a Munsell colour value ≥ 1 unit higher than the surrounding material and a Munsell colour chroma ≥ 1 unit lower than the surrounding material; or

(2) a layer with albic material, the colour of which is considered as being reductimorphic, above an abrupt textural difference; or

(3) a combination of two layers: a layer with albic material, the colour of which is considered as being reductimorphic, and a directly underlying mottled layer with the colour properties as specified in diagnostic criterion 1.

Additional characteristics

Stagnic properties result from a reduction of iron and/or manganese (hydr-)oxides around the larger pores. Mobilized Mn and Fe may be washed out laterally resulting in albic material (especially in the upper part of the profile that is in many soils coarser textured) or may migrate into the interiors of the soil aggregates where they are reoxidized (especially in the lower part of the profile).

If the stagnic properties are weakly expressed, the reductimorphic and oximorphic colours cover only some parts of the soil volume, and the other parts show the original colour that prevailed in the soil before the redox processes started. If the stagnic properties are strongly expressed, the whole volume of the fine earth shows either reductimorphic or oximorphic colours. In the latter case, the chroma requirements of criteria 1a and 1b sum up to a difference of two units.

Gleyic properties

General description

Soil materials develop gleyic properties (from Russian gley, mucky soil mass) if they are saturated with groundwater (or were saturated in the past, if now drained) for a period that allows reducing conditions to occur (this may range from a few days in the tropics to a few weeks in other areas).

Diagnostic criteria

A gleyic colour pattern shows one of the following:

(1) a layer with ≥ 95% (exposed area) having colours considered to be reductimorphic, that have:

(a) a Munsell colour hue of N, 10Y, GY, G, BG, B, PB, moist; or

(b) a Munsell colour hue of 2.5Y or 5Y with a chroma of . 2, moist; or

(2) a layer with > 5% (exposed area) mottles, the colour of which is considered to be oximorphic, that:

(a) are predominantly around root channels, and if soil aggregates are present, predominantly at or near the surfaces of the aggregates; and

(b) have, moist, a Munsell colour hue . 2.5 units redder than the surrounding material and a Munsell colour chroma . 1 unit higher than the surrounding material; or

(3) a combination of two layers: a layer fulfilling diagnostic criterion 2 and a directly underlying layer fulfilling diagnostic criterion 1.

Field identification

Gleyic properties results from a redox gradient between groundwater and capillary fringe causing an uneven distribution of iron and manganese (hydr)oxides. In the lower part of the soil and/or inside the peds, the oxides are either transformed into insoluble Fe/Mn compounds or they are translocated; both processes lead to the absence of colours with a hue redder than 2.5 Y. Translocated Fe and Mn compounds can be concentrated in the oxidized form (Fe[III], Mn[IV]) on ped surfaces or in biopores (rusty root channels), and towards the surface even in the matrix. Manganese concentrations can be recognized by strong effervescence using a 10-percent H_2O_2 solution.

3.6 Texture of the fine-earth fraction

(FAO, 1990) (to be reported in *.PFH file)

Soil texture refers to the proportion of the various particle-size classes in a given soil volume and is described as soil textural classes (see Figure 5). The 2000 – 63 – 2 µm system for particle-size fractions is used.

The names of the textural classes, which describe combined particle-size classes, are coded as in Figure 5. With a lot of training field estimates of the texture can be made, a method for finger testing of the textural classes is presented in Annex 6. Otherwise calculating the texture class based on the analytical data from pipette texture is recommended.

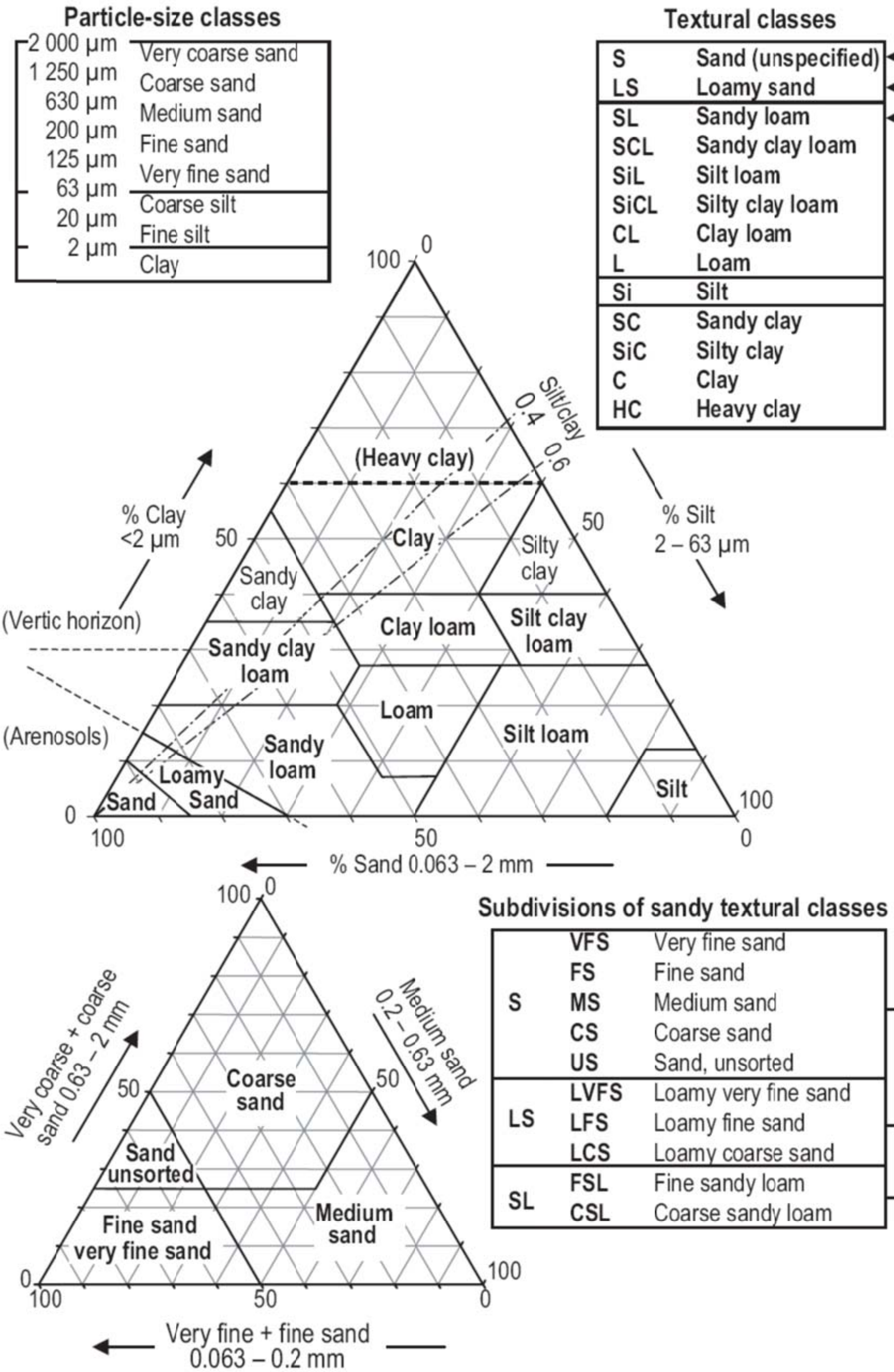

Figure 5: The fine earth by size and defined in textural classes. Textural classes based on USDA (1951), adopted by FAO (1990) and refined by FAO (FAO, 2006)

3.7 Rock fragments

(modified from FAO, 2006)

Large fragments (>2 mm) are described according to abundance, size, shape, state of weathering and nature of the fragments. The abundance classes correspond with those for surface coarse fragments and mineral nodules.

3.7.1 Abundance

(to be reported in *.PFH file)

The abundance of rock fragments is estimated (Figure 6) and expressed as a percent (by volume) of the total soil. By preference, the exact figure is provided rather than abundance classes.

Code	Description (FAO, 2006)	Class limits (volume%)	Description SGDBE (Lambert et al. 2003)
9	None	0 %	No stones or gravel
1	Very few to few	0 - 5 %	Very few
2	Common	5 - 15 %	Few
3	Many	15 - 40 %	Frequent or many
4	Abundant	40 - 80 %	Very frequent, very many
5	Dominant	>80 %	Dominant or skeletal

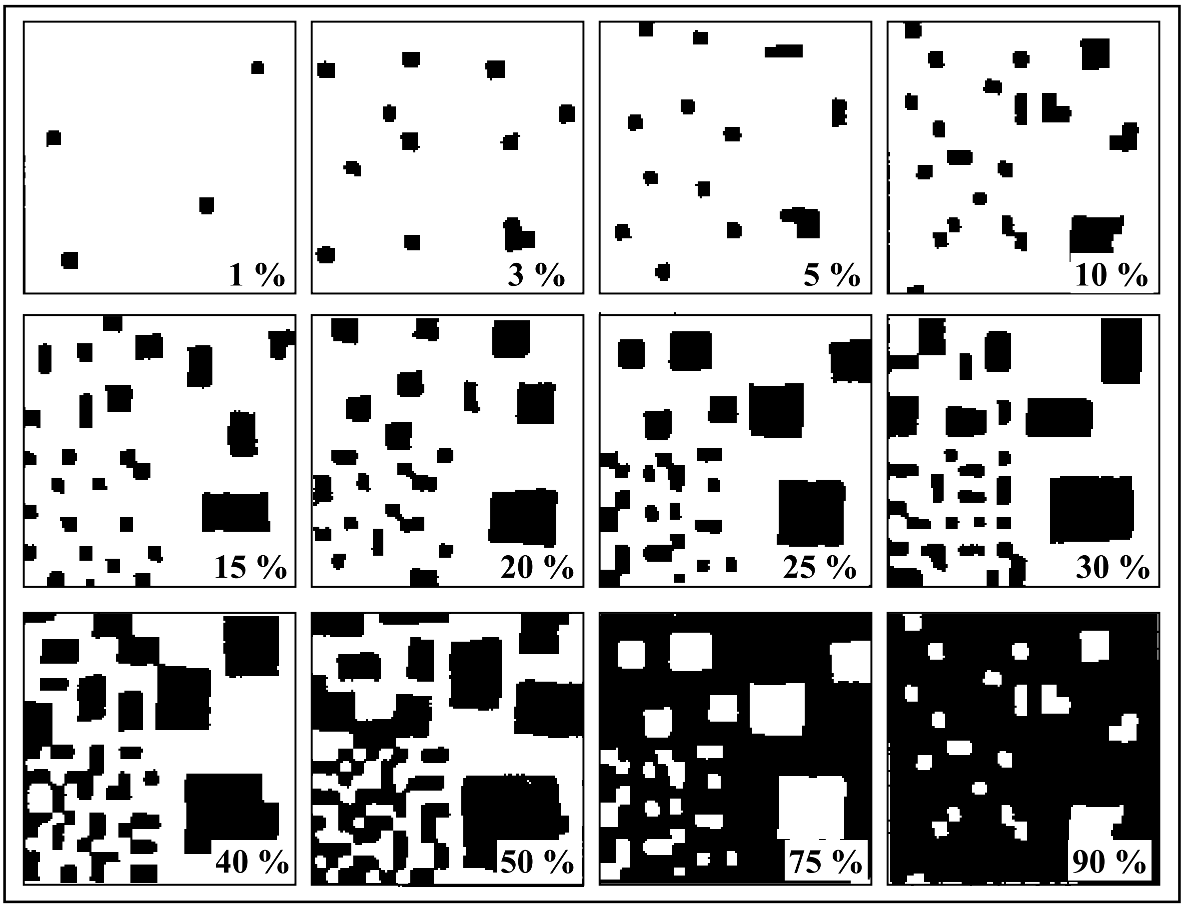

Figure 6: Charts for estimating proportions of coarse fragments, mottles or other elements

3.7.2 Size of rock fragments and artefacts

Code	Description	Class limits
1	Fine gravel	0.2 - 0.6 cm
2	Medium gravel	0.6 - 2 cm
3	Coarse gravel	2 - 6 cm
4	Stones	6 - 20 cm
5	Boulders	20 - 60 cm
6	Large boulders	60 - 200 cm

3.7.3 Dominant shape of rock fragments

The shape may be described as:

Code	Description
1	Flat
2	Angular
3	Sub-rounded
4	Rounded

3.7.4 State of weathering of rock fragments

The state of weathering is described as:

Code	Description
9	Fresh or slightly weathered: fragments show little or no signs of weathering
1	Weathered: partial weathering is indicated by discolouration and loss of crystal form in the outer parts of the fragments while the centres remain relatively fresh; fragments have lost little of their original strength.
2	Strongly weathered: all but the most resistant minerals are strongly discoloured and altered throughout; the fragments tend to disintegrate under hand pressure.

3.7.5 Nature (type) of rock fragments

The nature of rock fragments is described by the same terminology as for the parent material.

3.8 Andic material

(modified from FAO, 2006)

Soils formed from young volcanic materials often have andic properties: a bulk density of 900 kg/m^3 or less, and <10 % clay with a smeary consistence (caused by allophane and/or ferrihydrite). Surface horizons with andic material are normally black because of the combination of allophane with humic material, or humic material immobilized by aluminium. Andic material may exhibit thixotropy, changing under pressure, or by rubbing, from a plastic solid into a liquefied stage and back into the solid condition.

Is andic material present? Yes/No/Not known (reported as: **Y/N/X**)

3.9 Soil structure (modified from FAO, 2006)

Soil structure relates to the grouping or arrangement of soil particles into discrete soil units (peds). The aggregates are separated from each other by pores or voids and are characterised primarily on basis of their dominant shape: spheroidal (granular, crumb), platy, prism (columnar- top of the prisms are rounded and prismatic- top of the prisms are level) and blocky (angular blocky and subangular blocky).

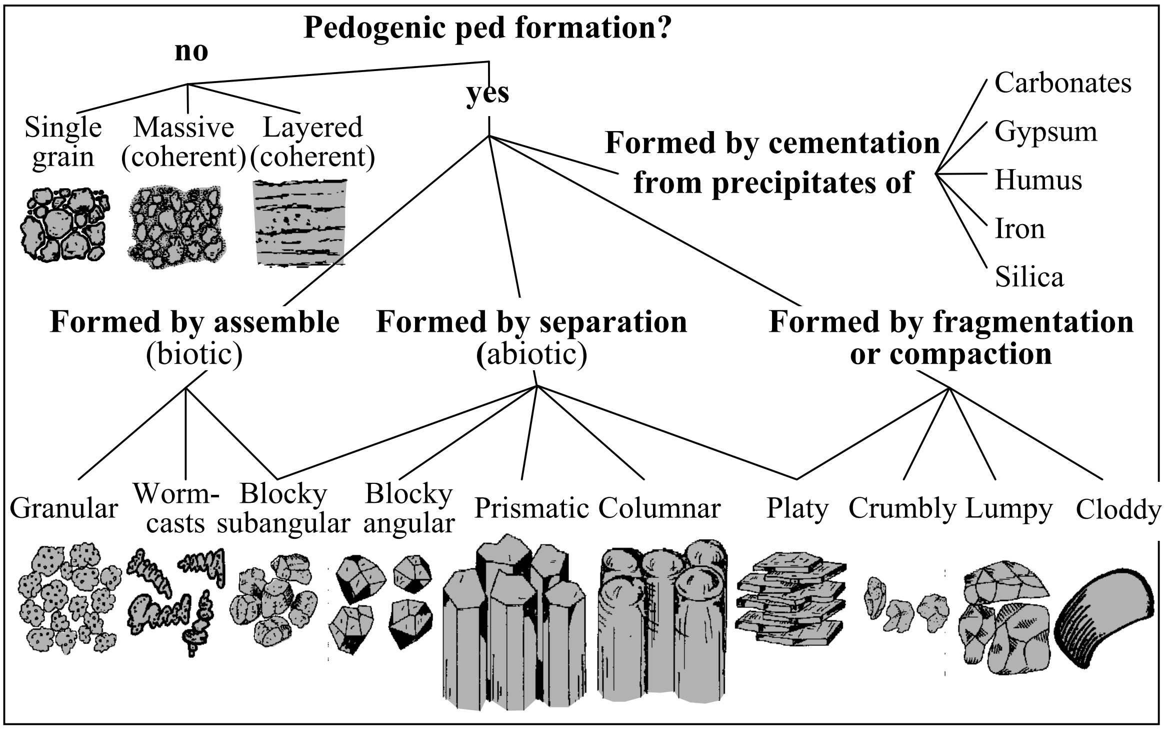

Figure 7: Soil structure types and their formation (FAO, 2006)

With decreasing soil humidity, the soil structure becomes increasingly pronounced. In moist or wet conditions, if no clear structure is visible, a large lump of undisturbed soil material can be dried, which will possible reveal a specific structure. Another method is to take a large lump of soil on the spade and let it fall from about a meter height, and then to observe how the block of soil breaks into pieces. A third possibility is to use a knife to gentle loosen the soil material on the profile wall. Try to loosen the soil in such a way that it breaks along the natural ped faces rather than breaking through the peds (it demands a bit of practice).

Besides the structure type, also grade and size of aggregates are recorded. When 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.

3.9.1 Type

(to be reported in *.PFH file)

The soil can be structureless or shows some kind of structure. If a structure is present the degree of development and the size characteristics to record.

In 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 Figure 7).

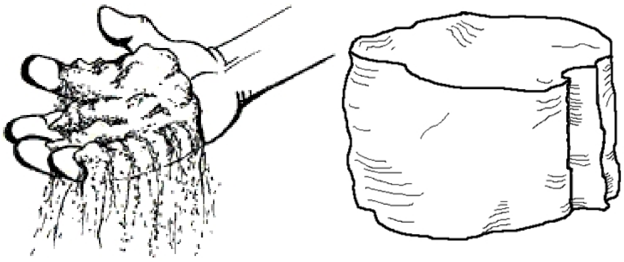

Figure 7: Absence of structure, either as single grain (left) or as massive (right) soil material (http://soil.gsfc.nasa.gov)

Structured soils:

Code	Structure name	Description
1	Platy	Flat with vertical dimensions limited; generally oriented parallel to soil surface horizontally and, usually, overlapping with other structure types.
2	Prismatic	The dimensions are greater in the vertical than horizontal direction; vertical faces well defined, having flat or slightly rounded surfaces which are casts of the faces of the surrounding aggregates. Faces normally intersect at relatively sharp angles
3	Columnar	Structures are prisms with rounded caps instead of flat surfaces.
4	Angular Blocky	Blocks or polyhedrons, nearly equidimensional, having flat surfaces which are casts of the faces of the surrounding aggregates. In an angular blocky structure, the faces intersect at relatively sharp angles.
5	Subangular blocky	Same as 4 but with rounded faces.
6	Granular	Spheroids or polyhedrons, having curved or irregular surfaces which are not casts of the faces of surrounding aggregates. Units do not fit into each other
7	Crumbs, lumps and clods	Granular like pedality but with a very high inped porosity. Mainly created by artificial disturbance (e.g. tillage) (FAO, 2006).
8	Massive (coherent)	Soil material (PT2) has normally a stronger consistence and is more coherent on rupture. Massive soil material may be further defined by consistence (see section 3.13).
9	Single grain	Soil material (PT1) has a loose, soft or very friable consistence and consists on rupture of more than 50 % discrete mineral particles.
10	Wedge-shaped	Elliptical, interlocking lenses that terminate in sharp angles, bounded by slickensides; not limited to vertic materials.
11	Nutty	Polyhedric blocky structure with many shiny ped faces which cannot or can only partially be attributed to clay illuviation
12	Rock structure	Rock structure includes fine stratification in unlithified sediment, and pseudomorphs of weathered minerals retaining their positions relative to each other and to unweathered minerals in saprolite.
13	Worm casts	A worm cast or vermicast is a structure created by worms, typically on soils such as those on beaches,, that gives the appearance of multiple worms.
14	Layered (coherent)	

The natural types of structure are defined as follows (Figure 8). More than one type in one horizon is possible.

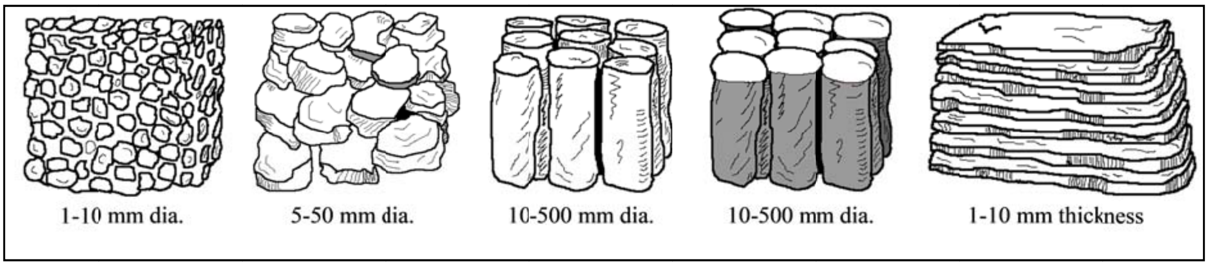

Figure 8: Illustrations of some of the most common types of soil structures. From left to right, these are granular, blocky, prismatic, columnar and platy [http://soil.gsfc.nasa.gov]. The sizes indicated are the normal range, smaller or larger sizes are possible.

3.9.2 Size

If a structure is present, the size should be determined. The size classes vary with structure type. For granular, crumble and blocky structures the general size is measured (they are more or less equidimensional), for prismatic, columnar and wedged structures the size classes refer to the measurements of the smallest dimension of the aggregate. For platy structures the thickness of the plates are important, but it is recommended to notice the orientation as well.

		Structure		
Code	**Size class**	**Crumbly / Blocky (mm)**	**Granular / Prismatic / Columnar / Wedge-shaped (mm)**	**Platy (mm)**
1	Very fine or thin	< 5	< 10	< 1
2	Fine or thin	5 - 10	10 - 20	1 - 2
3	Medium	10 - 20	20 - 50	2 - 5
4	Coarse or thick	20 - 50	50 - 100	5 - 10
5	Very coarse or thick	> 50	100 - 500	> 10
6	Extremely coarse	-	> 500	-

3.9.3 Grade

If the structure is not well developed it can be difficult to estimate the degree of development of the structure, especially if the moisture content is high. Observe if the structural units are well defined on all sides, or only on a few and how easy the units are separated from each other. Grades of structured soil materials are defined as follows:

Code	Class	Description
0	None	Structureless, such as for single grain and massive.
1	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.
2	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 their interiors.
3	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 their interiors.

3.10 Consistence

(FAO, 2006)

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

For reference descriptions, consistence is required for the soil in dry, moist and wet (both stickiness and plasticity) state. If applicable, thixotropy may be recorded. For routine descriptions, the soil consistence is described in the natural moisture condition of the profile. Wet consistence can always be described, and moist conditions if the soil is dry, by adding water to the soil sample.

3.10.1 Consistence when dry

This is determined by breaking the air-dried soil in the hand:

Code	Class	Description
9	Loose	Non-coherent.
1	Soft	Very weakly coherent and fragile; breaks to powder or individual grains under very slight pressure.
2	Slightly hard	Weakly resistant to pressure; easily broken between thumb and forefinger.
3	Hard	Moderately resistant to pressure; can be broken in the hands but not between thumb and forefinger.
4	Very hard	Very resistant to pressure; can be broken in the hands only with difficulty.
5	Extremely hard	Extremely resistant to pressure; cannot be broken in the hands.

3.10.2 Consistence when moist

This is determined by squeezing a mass of moist soil material:

Code	Class	Description
9	Loose	Non-coherent.
1	Very friable	Soil material crushes under very gentle pressure, but coheres when pressed together.
2	Friable	Soil material crushes easily under gentle pressure between thumb and forefinger, and coheres when pressed together.
3	Firm	Soil material crushes under moderate pressure between thumb and forefinger, but distinct resistance is felt.
4	Very firm	Soil material crushes under strong pressure; barely crushable between thumb and forefinger.
5	Extremely firm	Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger.

3.10.3 Consistence when wet

Stickiness depends on water content and the extent to which soil structure is broken down. Wet consistence is described in terms of stickiness and plasticity. It should be assessed under standard conditions on a soil sample in which structure is completely destroyed and which contains just enough water to create maximum stickiness.

Stickiness is the quality of adhesion of the soil to other objects, assessed by observing its adherence when pressed between thumb and finger.

Code	Class	Description
9	Non sticky	After release of pressure, practically no soil material adheres to thumb and finger.
1	Slightly sticky	After pressure, soil 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.
2	Sticky	Soil adheres to both thumb and finger and tends to stretch and pull apart rather than pulling free.
3	Very sticky	Soil adheres strongly to both thumb and finger and is decidedly stretched when they are separated.

Plasticity is the ability of soil material to change shape continuously under stress and to retain the given shape on removal of stress. It is determined by rolling the soil into a wire about 3 mm in diameter, then bending the wire.

Code	Class	Description
9	Non plastic	Will not form a wire.
1	Slightly plastic	Wire can be formed but immediately breaks if bent; soil deformed by very slight force.
2	Plastic	Wire can be formed but breaks if bent into a ring; slight to moderate force required for deformation of the soil mass.
3	Very plastic	Wire formed and can be bent into a ring; strong force required for deformation of the soil.

3.11 Cutanic features

(FAO, 2006)

This section describes clay or mixed-clay illuviation features, coatings of other composition such as calcium carbonate, manganese, organics 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 type, abundance, contrast, and location.

3.11.1 Type

The type of coatings may be described, following Schoeneberger et al. (2002), as:

Code	Description
1	Clay
2	Iron oxides (sesquioxides)
3	Clay and iron oxides (sesquioxides)
4	Clay and humus
5	Humus
6	Silt coatings
7	Sand coatings
8	Calcium carbonate [$CaCO_3$]
9	Silica (opal) [$SiO_2 \cdot nH_2O$]
10	Gibbsite [$Al(OH)_3$]
	Jarosite [$KFe^{3+}{}_3(OH)_6(SO_4)_2$]
11	Manganese oxide [Mn_2O_3]
12	Pressure faces
13	Shiny faces
14	Slickensides[2], predominantly intersecting
15	Slickensides, partly intersecting
16	Slickensides, non-intersecting

3.11.2 Abundance

For coatings (cutans), an estimate is made how much of the faces of soil aggregates, stones, or pores is covered. Similarly, the proportion of the soil layer occupied by lamellae is estimated.

Code	Description	Class
9	None	0 %
1	Very few	0 - 2 %
2	Few	2 - 5 %
3	Common	5 - 15 %
4	Many	15 - 40 %
5	Abundant	40 - 80 %
6	Dominant	>80 %

3.11.3 Contrast

Code	Class	Description
1	Faint	Surface of coating shows little contrast with the adjacent surface. Fine sand grains are readily apparent in the coating. Lamellae are less than 2 mm thick.
2	Distinct	Surface of coating is smoother than, or different in colour from the adjacent surface. Fine sand grains are enveloped but their outlines are visible. Lamellae are between 2 and 5 mm thick.
3	Prominent	Surface of coating contrasts strongly in smoothness or colour with the adjacent surface. Outlines of fine sand grains are not visible. Lamellae are more than 5 mm thick.

[2] A slickenside, is a term describing the surfaces of the cracks produced in soils containing a high proportion of swelling clays. Slickensides are a type of cutan (http://en.wikipedia.org/wiki/Slickenside)

3.11.4 Location

The location of the coatings is indicated. For pressure faces and slickensides no location is given since they are, by definition, located on the faces of structural aggregates (ped faces).

Code	Description
9	No specific location
1	Ped faces
2	Horizontal ped faces
3	Vertical ped faces
4	Bridges between sand grains
5	Lamellae (clay bands)
5	Voids
6	Coarse fragments

If the coatings are associated with coarse fragments, following subdivision can be made:

Code	Description
7	Above stones
8	Below stones
9	All around stones

3.12 Porosity

(simplified from FAO, 2006) (to be reported in *.PFH file)

Voids are related to the arrangement of the primary soil constituents and aggregates. They are the results of rooting, burrowing of animals and other soil forming processes such as cracking, translocation, leaching. The term void includes all air and water-filled spaces in the soil; the term pore is often used in a more restrictive way and does not include fissures or planes.

For many purposes, a qualitative description of porosity will suffice. For reference descriptions, voids are described in terms of type, size and abundance; continuity and orientation may also be recorded.

The porosity is an indication of the total volume of voids discernible with a x10 hand lens assessed by area and recorded as the percentage of the surface occupied by pores.

Code	Description	Class limits
1	Very low	<2 %
2	Low	2 - 5 %
3	Medium	5 - 15 %
4	High	15 - 40 %
5	Very high	> 40 %

3.13 Cementation and compaction

(modified from FAO, 2006)

The occurrence of cementation or compaction, as pans or otherwise, is described according to their nature, continuity, structure, agent and degree. Cemented material does not slake after one hour of immersion in water.

3.13.1 Nature (type)

The cementing agent or compaction activity composes of:

Code	Description
1	Gypsum
2	Silica
3	Carbonates
4	Iron oxides
5	Iron-manganese oxides
6	Iron-organic matter
7	Organic matter
8	Others
9	Not known

3.13.2 Continuity

Code	Class	Description
1	Broken	The layer is less than 50 % cemented/compacted and appears irregular
2	Discontinuous	The layer is 50 - 90 % cemented/compacted and appears regular
3	Continuous	The layer is more than 90 % cemented/compacted, and has few cracks only

3.13.3 Structure

The structure (or fabric) of the cemented/compacted layer may be described as:

Code	Class	Description
9	None	Massive without recognizable orientation
1	Platy	The cemented/compacted parts are plate-like with more or less horizontal orientation
2	Vesicular	The layer has large, equidimensional voids which may be filled with uncemented material
3	Pisolithic	The layer is composed of cemented, spherical nodules
4	Nodular	The layer is composed of cemented nodules or concretions of irregular shape

3.13.4 Degree

Code	Class	Description
9	Non-cemented and non-compacted	No compaction/compaction is observed (slakes in water)
1	Compacted	Compacted soil material is harder or more brittle than non-compacted soil material. Non-cemented.
2	Weakly cemented	Cemented mass is brittle and hard, but can be broken in the hands
3	Moderately cemented	Cemented mass cannot be broken in the hands but is discontinuous (less than 90 % of soil mass)
4	Cemented	Cemented mass cannot be broken in the hands and is continuous (more than 90 % of soil mass)
5	Indurated	Cemented mass cannot be broken by body weight (75 kg standard soil scientist) (more than 90% of soil mass)

3.14 Nodules and other mineral concentrations

(FAO, 2006)

Mineral nodules cover a large variety of secondary concentrations. There are gradual transitions with mottles. Nodules are described according to their kind, type, abundance, size, shape, hardness and colour, as well as their presence within the horizon:

3.14.1 Kind

Code	Class	Description
1	Crystal	
2	Concretion	A discrete body with a concentric internal structure, generally cemented
3	Soft segregation	Differs from the surrounding soil mass in colour and composition but is not easily separated as a discrete body
4	Nodule	Discrete body without an internal organization
5	Pore infillings	Including pseudomycelium of carbonates and opal
6	Crack infillings	
7	Residual rock fragment	Discrete body still showing rock structure

3.14.2 Type

Nodules are described according to their composition or impregnating substance. Examples:

Code	Description
1	Gypsum
2	Silica
3	Carbonates
4	Carbonates-silica
5	Salt
6	Clay
7	Clay-oxides
8	Manganese oxides
9	Iron-manganese oxides
10	Iron oxides
11	Sulphur
12	Not known

3.14.3 Abundance (by volume)

Code	Description	Class limits
9	None	0 %
1	Very few	0 - 2 %
2	Few	2 - 5 %
3	Common	5 - 15 %
4	Many	15 - 40 %
5	Abundant	40 - 80 %
6	Dominant	> 80 %

3.14.4 Size

Code	Description	Class limits
1	Very fine	< 2 mm
2	Fine	2 - 6 mm
3	Medium	6 - 20 mm
4	Coarse	> 20 mm

3.14.5 Shape

Code	Description
1	Rounded (spherical)
2	Elongated
3	Flat
4	Irregular
5	Angular

3.14.6 Hardness

Code	Class	Description
1	Hard	Cannot be broken between the fingers
2	Soft	Can be broken between forefinger and thumb nail
3		Both hard and soft

3.14.7 Colour

General colour names are usually sufficient to describe nodules, in the same way as mottles:

Code	Description
1	White
2	Yellow
3	Yellowish red
4	Reddish yellow
5	Red
6	Yellowish brown
7	Reddish brown
8	Brown
9	Green
10	Blue
11	Bluish-black
12	Grey
13	Black
14	Multicoloured

3.15 Roots

3.15.1 Abundance

(FAO, 2006) (to be reported in *.PFH file)

Presence/absence of roots is the most essential information to take notice of. A qualitative description of the size and the abundance of roots is important. Remember the abundance of roots should only be compared within the same size class.

Abundance (number of roots/dm²) per size class:

Code	Size class	Very fine <0.5 mm	Fine 0.5-2 mm	Medium 2-5 mm	Coarse >5 mm
	Abundance				
9	None	0	0	0	0
1	Very few	1 - 20	1 - 20	1 - 2	1 - 2
2	Few	20 - 50	20 - 50	2 - 5	2 - 5
3	Common	50 - 200	50 - 200	5 - 20	5 - 20
4	Many	>200	>200	>20	>20

3.15.2 Distribution

If there is a sudden change in the quantity and/or size of the roots it is very important to explain why. Possible root limiting factors are: compaction (check the bulk density), cementations, discontinuous pore system, etc. Sometimes it may be useful to record additional information, such as an abrupt change in root orientation.

Code	Description
1	Continuous
2	in the space of cracks
3	in the space of vughs and channels
4	concentrated in nests

3.16 Other biological features

(FAO, 2006)

Krotovinas (an animal burrow which has been filled with material from another horizon), termite burrows, insect nests, worm casts, burrows or other disturbances 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.

3.16.1 Kind

Examples of biological features are the following:

Code	Description
1	Burrows (unspecified)
2	Open large burrows
3	Infilled large burrows
4	Earthworm channels
5	Termite or ant channels and nests
6	Other insect activity
7	Pedotubules[3] (voids filled with soil material by faunal and floral activity, for further info read the footnote)
8	Charcoal

3.16.2 Abundance

Abundance of biological activity is recorded as a percentage of the exposed surface:

Code	Description	Class limits
1	Few	<5%
2	Common	5 - 15%
3	Many	15 - 40%
4	Abundant	> 40%

[3] The term pedotubules is proposed for a group of pedological features which have a tubular external form and which are distinguished from cutans by their complex internal composition and fabric. Pedotubules are classified according to their internal fabric and composition, details of external form, distinctness, and by a comparison of their fabric and composition with that of the horizons of the soil profile. Their general morphology suggests their origin as voids caused by faunal and floral (root) activity which have been filled, or partially filled, with soil material. Since little is known of the details of the effects of faunal activity on soil materials, such interpretations are tentative (Brewer and Sleeman, 1963)

3.16.3 Continuity

Abundance of biological activity is recorded as a percentage of the exposed surface:

Code	Description
1	Continuous
2	Discontinuous
3	Patchy
4	Locally
5	Other (explain)

3.17 Carbonates

(modified from FAO, 2006)

The presence of calcium carbonate ($CaCO_3$) is indicated by adding some drops of 10% HCl to the soil. Following information should be collected per horizon:

- Is the matrix calcareous or non-calcareous (the exact quantity of carbonates will be tested in the laboratory). If traces are found in at least one horizon of the profile, the presence/absence should be recorded for all horizons.
- Is the carbonate at least partly secondary (pedogenic).

3.17.1 Presence of carbonates

Following categories apply:

Code	Description
9	No presence of carbonates
1	Matrix is non-calcareous, presence of secondary carbonate
2	Matrix is calcareous, no evidences of secondary carbonate
3	Matrix is calcareous, presence of secondary carbonates

3.17.2 Type of secondary carbonates

The type of secondary carbonates should be described. Following categories has been defined, more can be defined where applicable:

Code	Description
1	Capping
2	Coatings
3	Nodules
4	Pendants
5	Pseudomycelia
6	Others (define)

3.18 Gypsum

(modified from FAO, 2006)

Gypsum ($CaSO_4 \cdot 2H_2O$) may occur as residual, gypsous parent material or as newly formed features such as pseudomycelia, coarse crystals (commonly as nests, beards or coatings, or as elongated groups of fibrous crystals), or loose to compact powdery accumulations.

Is gypsum present in the horizon? If so, where is it present (in the matrix, as nodules… …) and in which form is it present (crystals, powder,…; primary or secondary etc.). If gypsum is present in the soil, recommendations should be made for the laboratory on which samples the content of gypsum should be measured. The presence/absence of gypsum is explained applying following categories:

3.18.1 Abundance of gypsum

Code	Abundance (by volume)
9	0%
1	0 - 5%
2	5 - 15%
3	15 - 25%
4	25 - 60%
5	> 60%

3.18.2 Abundance of secondary gypsum

Code	Abundance (by volume)
0	0%
1	0 - 5%
2	> 5%

3.19 Readily soluble salts (modified from FAO, 2006)

Readily soluble salts are more soluble than gypsum; the most common salts are chlorides. The salt content of the soil can be estimated from the electrical conductivity (EC in dS/m = mS/cm) measured in a saturated soil paste or a more diluted suspension of soil/water.

If salts are observed during fieldwork, the electric conductivity of a saturated paste should be analysed for all horizons in the soil.

Is salt present?

Y Evidences of soluble salts
N No evidences of soluble salts
X Not known

3.20 Man-made materials

(simplified from FAO, 2006)

The areas dominated or significantly changed by human activity are rapidly extending, especially in urban and mining areas. Of particular importance are the man-made materials found in soils; their age, amount, state and composition determine their durability and environmental impact. Any human impact on the soil should be recorded. Examples are:

- Evidences of past agriculture
- Presence of artefacts (e.g. ceramics)
- Remains of past structures (e.g. postholes)
- Other features of possible human origin (e.g. charcoal, brick fragments)

3.21 Human-transported material (simplified from FAO, 2006)

This is any material brought onto the site. This may be for agricultural purposes (e.g. large-scale terracing, mine spoil…), for human settlement, or simply to dispose of material (e.g. dredged sediment). It is a soil parent material in the same way as alluvium.

3.22 Soil horizon designation

The term horizon indicates a soil layer presumed to bear the imprint of soil forming processes, as opposed to layers that are laid down by sedimentation, volcanic activity or other geological events.

Horizons are identified by symbols that 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. The detailed definitions of the different horizon symbols and rules that apply are found in Annex 7. This annex also explains the use of symbols to express lithologic discontinuities and the vertical subdivision when two horizons have the same set of master and subordinate symbols.

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Annex III – Recommendations for locating and describing a soil profile

Location of the soil profile

The location of the soil profile should be as representative for the level plot as possible. Obviously only surface characteristics can help us in this search. Factors of importance can be:

- Composition of ground vegetation, e.g. if most of the experimental plot hosts no ground vegetation do not locate the profile where vegetation is present
- Composition of tree stand; dig the profile under the canopy of dominant tree species.
- Avoid areas of strong human influence, such as ditches, earth banks, forest roads, tracks from tree harvesting machines…
- Avoid micro-lows and micro-highs, as they will allow more or less litter to accumulate, which will have an influence on the biological activity and hydrology.
- On experimental plots with steeper slopes, it is important to locate the profile as representative as possible with respect to the general slope inclination. If the general slope is concave or convex, then try to locate the profile at the level of the plot centre with respect to the slope (meaning in the zone immediate outside the experimental plot to the left or the right of this plot centre: not down- or upslope).
- Other factors such as surface stoniness, rock outcrop, different land-use practice etc. should also be taken into consideration so that the profile location is as representative as possible.

Orientation of the soil profile

Factors to take into consideration are:

- If the slope inclination is such that it will have an important impact on the hydrology, then the profile should be oriented with its long axe in the slope direction.
- If the slope inclination is not important, the profile is oriented in such a way that by the time the profile is to be studied the light should be equally distributed over the complete profile wall (e.g. if you start to dig at 10 AM and you estimate that it takes 2h to dig the profile, and 30min to clean it for taking photos, then orient the profile towards SSW (180-200°). By the time you can take photos the profile will have a perfect angle towards the sun. A wall that is partly shaded partly with sunshine is impossible to describe optimally, and no quality photos can be produced.
- If the slope and light is not a problem, then other factors can help with the orientation of the profile, such as microtopography, vegetation, etc. For example, if the experimental plot is characterised by drainage ditches, orienting the profile with its long axis perpendicular to the ditch will result in a profile where on the side walls it will be possible to observe the changes from a wetter soil closest to the ditch towards a drier soil between the ditches.

Observations to be made while digging the profile

If the field work is organised in such a way that the person that will do the profile description will be present when the profile is dug, it is advisable to make some first observations during this process. Following aspects of a standard profile description can by substantially improved if already considered during the profile digging, simply because the observations are made not only based on a two dimensional profile wall, but based on about one cubic metre of soil that is removed:

- The rock fragments: description of the abundance, size, shape, and type is considerable improved, and special features such as presence/absence of pendants/cappings on the stones are better observed.
- Soil structure, especially type and degree of development
- Cutanic features, especially if the quantity is low working in a three dimension will improve the chance to observe such features
- Presence of cementations and compactions will undoubtedly be discovered when the profile is worked with the spade, shovel and pickaxe.
- If carbonate is present, observing if at least part of the carbonate is secondary will be easier.
- Quantification and size estimates of roots, as well as the total root depth is more accurately observed

Observations in three dimensions

A standard profile is typically 80-100 cm wide, 180-200 cm long and should have a depth of 200 cm. The wideness and length can be reduced if e.g. the soil is very stony, but be careful not to diminish the profile beyond the size where proper use of spade, showel, pickaxe is restricted. The profile depth can be limited by a series of factors, such as:

- The groundwater table. If the permeability of the soil is low, digging below the groundwater table is possible and even soil sampling and/or making a few observations such as colour, reductomorphic properties, … is possible. Remember to measure the actual groundwater depth
- Bedrock, either continuous or discontinuous rock that prevents further digging
- Cementations of any kind, For example a Petrocalcic, Petroduric, Petrogypsic, Petroplinthic or Pisoplinthic cemented horizon which makes any further digging impossible.
- Parent material. If the C horizon material is reached at a shallower depth than 200 cm, further digging can be stopped. It is though recommended to continue 20-50 cm to control that it indeed is the C-horizon that has been reached.

When the profile in its full length has reach a depth of about 100-120 cm, further digging is restricted to the 80-100 cm of the profile closest to the front wall. This creates a soil pit with 2 or more steps.

After digging the profile, it is essential to clean the profile walls.

- This is done by e.g. a knife, trowel, or another scraping tool with an metal blade, make sure that the metal blade has rounded edges to avoid sharp scraping lines on the profile wall.
- While the profile is cleaned, the soil is carefully observed, with respect to colours, presence absence of roots, biogalleries, stones and other characteristics that might be important to outline the horizons.
- Take the first round of photos (see paragraph 3.2 of Annex 2): Of the profile, details of the profile, and the surrounding landscape
- Draw on the profile wall with the knife the horizon boundaries. The most important feature to delineate horizons from each other is change of colour. Other feature that can be used to differentiate genetic horizons from each other are a relatively sharp change over (vertical)

distance of mottles, texture, coarse fragments, structure, porosity, cementation, compaction, nodules, roots or carbonates.

- A second round of photos ((see paragraph 3.2 of Annex 2) is taken of the profile with and without the horizon boundaries indicated, and of particular details such as mottles, involutions, biogalleries, disturbances etc.

If a soil is composed of well-developed relatively uniform horizons, focussing on the front wall for the profile description is usually sufficient. If on the other hand the profile is more irregular and/or the horizons are less developed, it might be necessary to study also the side walls. This should appear from the profile description. For example the horizon depths in soil profiles located on a strong slope should be measured perpendicular to the surface, which is easiest on the side wall.

For certain pedological features, it might be useful to study them on a horizontal surface. This is for example possible while digging the profile, or when the first or second stair has been made at the correct depth. If necessary, a new sub-profile is dug on the sidewall to the depth(s) where a horizontal section is needed.

Annex IV – Field equipment

Equipment for profile description:	Number	Further information
Spade, pickaxe	1	
Shovel	2	
Bucket	1	
Scraper	1	Make the corners rounded to avoid sharp lines on the cleaned profile wall
Trowel	1	Sharpen the edges to allow a better cutting in the soil
Knife	1	The blade should be straight (e.g. to cut bulk density samples straight) and as long as possible (recommended is 15-20 cm)
Field umbrella	1	To shade for sun and rain
Pruner or horticulture sheer	1	To cut roots
Small painting brush	optional	To highlight certain special features e.g. slickensides, stones, etc.
Munsell Colour Chart	1	Try to avoid dirt on the colour chips
Folding ruler or measuring tape	2	Two coloured ones are preferred
Note book	1	Large enough e.g. A5 format, with squared lines on the paper to facility profile drawings
Writing pen/pencil	2	
Marker pen	2	For sample labelling, black colours are more resistant to sun light
Sample labels	sufficient	
Hand lens	1	Magnifications x10 (4 +6 or 2 + 8)
Soil thermometer	optional	Especially if the soil at or below 0°C
Penetration rod	1	Required if the soil is compacted, cemented or is stony
Clinometer or Abney-level	1	To measure slope inclinations
GPS system	1	Measuring coordinates of key points on the plot
Compass	1	For orientation of e.g. slope direction
Auger handle	1	
Auger heads	selection	Selection in accordance to soil type, see table below
Extension rods	1	With one extension a depth of 225 cm can be reach
Photo camera and tripod	1	
Water bottle	1	
Water sprayer	1	
For sampling	**Number**	**Further information**
Sampling tray	optional	
Sample recipients	sufficient	Quality bags (plastic, cloth..) or boxes
Sample labels	sufficient	
Sample frame	1 - 3	To sample the organic layer
For pF and BD	**Number**	**Further information**
Bulk density cylinders (volume between 100 cm^3 and 250 cm^3) and lids	sufficient	Take care not to destroy the cutting edge of the ring while inserting it into the soil
Ring holder	optional	Needed if the soil is hard (e.g. due to dryness and/or a high clay content)
Impact free hammer	1	Eventually a geological hammer if fieldwork is done in mountainous regions
Wood piece	1	To distribute the hammer impact equally
Hammering head	optional	For very hard soils, to be used with the guide cylinder
Cylinder guide	optional	
Small iron saw	1	To cut the edges of the sampling rings

Liquids:	Number	Further information
Distilled water*	±100 cl	To test moist colours; testing for water repellence
Concentrated H_2O_2*	±100 cl	Reacts to manganese (charcoal and organic matter not)
10% HCl*	±100 cl	Reacts to carbonates
α, α dipyridyl*	±100 cl	Reddish colour reaction if Fe^{2+} is present Read also: http://soils.usda.gov/use/hydric/ntchs/tech_notes/note8.html

* The liquids are by preference stored in bottles, which allow drop wise application (like eye drops). If this is not possible, bring along plastic pipettes for careful application.

Soil augers:

Soil texture	Moisture condition	Type of Edelman augers	Riverside auger	Gouge auger
	wet	Sand	-	-
Sandy	moist	Combi, sand	(+)	+
	dry	Sand	-	(+)
	wet	Combi	-	+
Loamy/silty	moist	Combi	-	+
	dry	-	+	-
	wet	Clay	-	+
Clayey	moist	Clay	-	+
	dry	-	+	-
	wet	Gravel	-	-
Stony	moist	Gravel	-	-
	dry	-	+	-
Frozen soil		(Gravel)	(+)	-

"-" : not suitable
"(+)" : possibly suitable
"+" : suitable (recommended)

Clay-auger: thin blades, good for clayey and/ sticky soils when moist and wet

Combi-auger: all round auger best for medium textured soils when moist and wet

Sand-auger: has wide blades, so the sand stays in the auger even if the soil is relatively dry

Gravel-auger: with two cutting blades at the end that can drill and remove small stones

Riverside-auger: closed with drilling blades, the only auger that can be used in dry loamy or dry clayey soils. It should be avoided when these soils are moist or wet! Sometimes also useful in frozen soils

Gouge-auger: for non-stony soils preferentially moist or wet. It can take undisturbed samples. Mode length variable, mostly 50 to 100 cm long.

For the sampling of the organic layer a frame of 25 by 25 cm is recommended, but alternatives with a minimum total surface of 500 cm^2 are acceptable. For mor humus, an auger with a diameter of 8 cm can be used.

Annex V – Additional information on colour measurements

This annex provide additional information on the colours, particular for optimal measurements for classification purposes (IUSS WG on WRB, 2015)

Colour should be determined, if possible, under uniform conditions out of direct sunlight. Early morning and late evening readings are not accurate. Determination of colour has proven to be often inconsistent between individuals or, even for the same person. Since colour is significant with respect to many soil properties and for soil classification, routine cross-checks are recommended. To save time in the field and to improve the colour measurements, it is recommended to measure the colours in the laboratory. Let fragments of the soil air-dry before the dry colours are measured, then gently add vaporised water to moisten the sample to field capacity. The wet colour can be measured after saturation of the sample with water. Colours for waterlogged soils should be measured immediately before the soil gets oxidised.

For all horizons, at least the moist colours should be recorded (if the soil is arid or wet, respectively dry and wet colours may replace the moist ones). In those soils where one or more diagnostic horizons or properties might be present, additional colours are mandatory as summarised in the table. For example, for a soil with a spodic horizon (diagnostic for Podzols), information on the moist crushed colour is required according to the WRB.

Table 4: Required colour measurements

Soil moisture condition	Measured colour	Horizons for which colours are required				
		O, H	A	E	B	C
Dry	Matrix (broken)		2a, 2b	4	5	3
	Crushed		2a, 2b			
Moist	Matrix (broken)	1	1, 2a, 2b	1	1	1
	Crushed		2a, 2b		6	
Wet	Matrix	1b	1b	1b	1b	1b

1 Moist colours should always be recorded for all horizons in the profile, except for those soils that 1b) naturally are wet (e.g. Gleysols, Histosols). For those soils, the wet colours are measured instead of moist colours. The matrix colour can be considered the same as the broken colour.

2a Broken colours are mandatory to record if the soil has a dark topsoil with colours of 3.5/3.5 (value/chroma) or less when moist, and a value of 5.5 or darker when dry.

2b If the soil may have aridic properties (relative low organic carbon content, evidences of aeolian activity, high base saturation…) these colour measurements are required too.

3 Should be measured if the topsoil has colours of 3.5/3.5 (value/chroma) or less when moist, and a value of 5.5 or darker when dry (see 2a). If no C-horizon is present, the colour should be measured for the horizon immediately underlying the surface horizon(s).

4 If the eluvial horizon has a colour value of 4 or more and a chroma of 4 or less, then measure also the dry colour.

5 If the moist colour is redder than 5YR (3.5YR or redder) then also the dry colour should be measured (required for the rhodic qualifier).

6 If the soil may have a spodic horizon (required for Podzols), then the crushed colour is mandatory to record. The colour required for a spodic horizon (moist) is 10YR or redder with value of 3 or less and chroma of 2 or less. If the colour is 7.5YR or redder the value required is 5 or less and the chroma 4 or less.

Annex VI – Guidelines for field estimates of textural classes

The textural class can be estimated in the field by feel. For this, the soil sample must be moist (as close as possible but not exceeding the field capacity). Fragments >2 mm must be removed.

Clay	Soil can be rubbed, is sticky, can be moulded but is stiff (high plasticity), smeared surface is shiny
Silt	Soil can be rubbed, is non-sticky, and feels floury (like talc)
Sand	Cannot be moulded, does not soil fingers and feels gritty

Key to the soil texture classes (adapted from Schlichting et al., 1995)

y	**Cannot be rolled into a ball**		**% clay**
	• Not dirty, not floury, no fine material adhering to fingers: ***sand***	**S**	<5
	• If grain sizes are mixed: ***Unsorted sand***	**US**	<5
	• If most grains are very coarse (>0.5 mm): ***very coarse and coarse sand***	**CS**	<5
	• If most grains are of medium size (0.25-0.5 mm): ***medium sand***	**MS**	<5
	• If most grains are of fine size (<0.25 mm) but still grainy: ***fine sand***	**FS**	<5
	• If most grains are of very fine size (<0.1 mm), almost floury: ***very fine sand***	**VFS**	<5
2	**Can be rolled into a ball but not into a wire**		
	• Not floury, grainy, scarcely any fine material sticking to fingers, forms a ball weakly, adheres slightly to the fingers: ***loamy sand***	**LS**	<12
	• As 2.1 but floury: ***sandy loam***	**SL**	<10
3	**Can be rolled into a wire of about 3 to 7 mm in diameter (about half the diameter of a pencil) but breaks when trying to bend into a ring, sticks to the fingers**		
	Floury and not cohesive		
	• Some grains to feel: ***silt loam***	**SiL**	<10
	• Floury and not cohesive, no grains to feel: ***silt***	**Si**	<12
	Cohesive, sticks to the fingers, has a rough and smeared surface after squeezing between fingers		
	• Is very grainy and not sticky: ***sandy loam***	**SL**	10-25
	• Neutral feel, neither sticky, nor gritty, nor floury: ***loam***	**L**	8-27
	• Is not grainy but distinctly floury and somewhat sticky: ***silt loam***	**SiL**	10-27
	• Is very grainy and not sticky: ***sandy loam***	**SL**	10-25
	• Sticky and grainy to very grainy: ***sandy clay loam***	**SCL**	20-35
4	**Can be rolled into a wire smaller than 3 mm in diameter (less than half of that of a pencil) and bent to form a ring of about 2-3 cm in diameter, cohesive, sticky, shiny smeared surface**		
	• Very grainy: ***sandy clay***	**SC**	35-55
	• Grains can be seen and felt: ***clay loam***	**CL**	25-40
	• No grains to see and to feel, low plasticity: ***silty clay loam***	**SiCL**	25-40
	• No grains to see and to feel, high plasticity: ***silty clay***	**SiC**	40-60
5	**Shiny smeared surface and high plasticity**		
	• Some grains to see or to feel, grates between teeth: ***clay***	**C**	40-60
	• No grains to see or to feel, does not grate between teeth: ***heavy clay***	**HC**	>60

Annex VII – Detailed definitions, rules and conventions on master and subordinate horizon symbols

1 Vocabulary

Organic material (OM) (IUSS Working Group WRB, 2007) (from Greek *organon*, tool) consists of a large amount of organic debris that accumulates at the surface under either wet or dry conditions and in which the mineral component does not significantly influence the soil properties.

Diagnostic criteria. Organic soil material must have one of the two following:

(1) 20 percent or more organic carbon (by mass) in the fine earth; ***or***

(2) if saturated with water for 30 consecutive days or more in most years (unless drained), one or both of the following:

> (a) (12 + [clay percentage of the mineral fraction * 0.1] percent or more organic carbon in the fine earth (by mass), ***or***
>
> (b) 18 percent or more organic carbon (by mass) in the fine earth.

Organic horizons

The organic horizons (codes: OL, OF, OH) are formed by dead organic matter (OM), mainly leaves, needles, twigs, roots and, under certain circumstances, materials such as mosses and lichens. This OM can mainly be transformed in animal faeces. An organic horizon contains 20 % or more organic carbon (by mass) in dry samples, without living roots.

Hemorganic horizons

The hemorganic horizons (code: A) are formed near the soil surface, generally beneath the organic horizons. Coloured by organic matter, these horizons are generally darker than the underlying mineral part of the soil profile. It is generally accepted that in the soil fraction < 2mm of the A horizon, the organic carbon has to be less than 20% by mass (following WRB, FAO 2006, Broll et al. 2006).

Recognisable remains

Recognisable remains within an organic or hemorganic horizon are organic materials like leaves, needles, roots, bark, twigs and wood, fragmented or not, whose original organs are recognizable by the naked eye or with a 5-10 X magnifying hand lens. Fresh litter generally consists for 100% of recognizable remains (Zanella et al. 2010)

Humic components

Humic components of an organic or hemorganic horizon are small particles of organic remains and/or grains of organic or organo-mineral matter mostly comprised of animal droppings of different sizes. The original organs which compose the litter and generate the small particles (free or incorporated in animal faeces) are not recognizable by the naked eye or with a 5-10 X magnifying hand lens. Bound mineral particles can be visible within the mass.

Well decomposed organic substrate generally consists for 100% out of humic components. However, the generated humic component can also be in the hemorganic (A) and organic (OL, OF, OH) horizons. Thus, an A horizon made of anecic and endogeic earthworm hemorganic faeces as well as a totally, finely decomposed and mostly organic OH horizon resulting from enchytreid and microarthropod activities, can both be composed for 100% of humic components, despite differences in the animals responsible for the structure of the horizons (Zanella et al. 2010).

Fibric component

Non-decomposed or very weakly decomposed hygrophilous plant remains like sphagnum species, sedges, rushes, reeds... Whole plants, parts of them and/or free plant organs (leaves, needles, twigs, wood, roots...) sometimes lying in more or less dark coloured layers.

Sapric component

Homogeneous dark organic and organo-mineral matter comprised of well decomposed plant remains partly mixed with mineral particles. Plant structures are not visible to the naked eye or with a 5-10 X magnifying hand lens. Animal droppings are possible in periodically drained horizons and can be abundant in drained peats.

Mineral components

Mineral components of an organic or hemorganic horizon are mineral particles of different sizes, free or very weakly bound to humic components and visible by the naked eye or with a 5-10 X magnifying hand lens.

Zoogenic transformed material

Zoogenic transformed materials are recognizable remains and humic components processed by animals (i.e. leaves, needles and other plant residues more or less degraded by soil animals, mixed with animal droppings. A fine, powdered and/or grained structure (less than 1 mm) is typical in a terminal stage of faunal attack in an organic horizon. At this last level of biotransformation, the substrate (OH horizon) is essentially comprised of organic animal droppings of varying size (droppings of epigeic earthworms, macro-arthropods such as millipedes, woodlice and insect larvae, micro-arthropods such as mites and springtails and enchytraeids dominate). Within hemorganic horizons, animal activity leads to different types of A horizons, depending on the animals' ability to dig into the mineral soil and thoroughly mix organic and mineral matter.

Non zoogenic transformed material

Non zoogenic transformed materials are recognizable remains and humic component processed by fungi or other non-faunal processes (i.e. leaves, needles and other plant residues more or less fragmented and transformed into fibrous matter by fungi. Recognizable and recent animal droppings are absent or not detectable by the naked eye in the organic horizons; fungal hyphae can be recognized as white, brown or yellow strands permeating the organic or hemorganic substrates; traces of animal activity (old bite marks, mucus) may sometimes be detectable but are always marginal. In the last stage of biodegradation of an organic horizon, non zoogenic substance may essentially be composed of brown, dry plant residues more or less in powder form or tiny fragments (OF and OH horizons), or be massive like a dark wet plastic clay (OH or very organic A horizons).

By the naked eye or with a 5-10 X magnifying hand lens, each topsoil horizon appears to be composed of recognizable remains, humic and mineral components (fig. 1). At the soil surface, the animals or plant cover shed litter (remains) on and within the soil. Animal remains exist too, but they are quite negligible compared to plant remains and often overlooked by the neophyte. Litter is made up of recognizable residues and humic components (because of soil biological activity). In the other direction, the geological substrate "leaks" fragments of rock, which in the topsoil become mineral (free grains) and humic (grains incorporated in faeces) components. The mineral component can also be increased by surface erosion. The process perceived by the naked eye hides a more complex world of chemical-physical–biological processes. In unfavourable conditions for soil fauna the process is mainly dominated by fungi. Therefore, the new definitions of zoogenic and non zoogenic transformed material have been coined to distinguish zoogenic biological transformation from mycogenic transformation. The aim of a naked eye examination is to collect initial data and information for the purposes of a more detailed research on the same system. The vocabulary terms have been selected with regards to a dynamic interpretation of current knowledge on the topsoil.

2 Soil horizon designation

2.1 Master horizons and layers

2.1.1 The Organic horizons

2.1.1.1 O horizon or layer

The O horizon or layer is dominated by organic material, consisting of fresh, partially or completely decomposed litter (such as leaves, needles, twigs, mosses, and lichens) that has accumulated on the surface; it may be on top of either mineral or organic soil. It is not saturated with water for prolonged periods. The mineral fraction of such material is only a small part of the volume of the material and generally is much less than half of the mass.

An O layer may be at the surface of a mineral soil or at any depth beneath the surface if it is buried. However, a horizon formed by illuviation of organic material into mineral subsoil is not an O horizon (FAO, 2006).

A subdivision of the organic O-layers is made according to the following definitions (Zanella et al. 2010):

OL-horizon (Litter, Förna): this organic horizon is characterised by an accumulation of mainly leaves/needles, twigs and woody materials (including bark), fruits etc.

This sublayer is generally indicated as litter (Klinka et al., 1981, Green et al., 1993, Jabiol et al., 1995, Delecour, 1980). It must be recognized that, while the litter is essentially unaltered, it is in some stage of decomposition from the moment it hits the floor and therefore it should be considered as part of the humus layer.

There may be some fragmentation, but the plant species can still be identified. So most of the original biomass structures are easily discernible. Leaves and/or needles may be discoloured and slightly fragmented. The humic components amounts to less than 10 % by volume; recognisable remains 10% and more, up to 100% in non-decomposed litter.

OL types (suffixes: n, v, t)

- OLn: new litter (age < 1 year), neither fragmented nor transformed/discoloured leaves and/or needles;
- OLv: old litter (aged more than 1 year, vetust, verändert, verbleicht), slightly altered, discoloured, bleached, softened up, glued, matted, skeletonized, sometimes only slightly fragmented leaves and/or needles.

- OLt: transitional (t) litter made of leaf petioles, twigs, bark and surface cast accumulation in very active mull forms (eumull generally in mixed hardwood forest – described in ash/beech stands).

Note: The passage from OLn to OLv can be very rapid (1 to 3 months) or very slow (more than a year) according to types of litter (plant species composition), climate, season and level of soil biological activity

OF-horizon (fragmented and/or altered) is a zone immediately below the litter layer. This organic horizon is characterised by an accumulation of partly decomposed (i.e. fragmented, bleached, spotted) organic matter derived mainly from leaves/needles, twigs and woody materials. The material is sufficiently well preserved to permit identification as being of plant origin (no identification of plant species).The proportion of humic components is between 10 % and 70 % by volume. Depending on humus form, decomposition is mainly accomplished by soil fauna (OFzo) or cellulose-lignin decomposing fungi (OFnoz). Slow decomposition is characterised by a partly decomposed matted layer, permeated by hyphae.

Note: this is the **fragmented layer** in non-saturated soils (Klinka et al., 1981, Green et al., 1993, Jabiol et al., 1995, Delecour, 1980)

OF types (suffixes: zo, noz)

OFzo = content in zoogenic transformed material > 10% of the volume of the horizon;

OFnoz = content in non-zoogenic transformed material 90% or more of the volume of the horizon;

OH-horizon (humus, humification): characterised by an accumulation of dark, well-decomposed, amorphous organic matter. It is partially coprogenic, whereas the F horizon has not yet passed through the bodies of soil fauna. The humified H horizon is often not recognized as such because it can have friable crumb structure and may contain considerable amounts of mineral materials. It is therefore often misinterpreted and designated as the Ah horizon of the mineral soil and not as part of the forest floor as such. To qualify as organic horizon, it should fulfil the FAO requirement, as described above. The original structures and materials are not discernible. Humic components amounts to more than 70 % by volume. The OH is either sharply delineated from the mineral soil where humification is dependent on fungal activity (mor) or partly incorporated into the mineral soil (moder).

Note: This horizon coincides with what is called the **humus layer** (Klinka et al., 1981, Green et al., 1993, Jabiol et al., 1995, Delecour, 1980)

OH types (suffixes: zo, noz, r, f)

- OHzo = content in zoogenic transformed material > 30% of the volume of the horizon;
- OHnoz = content in non-zoogenic transformed material 70% or more of the volume of the horizon;

Concerning the organic layers, a distinction is made between the water saturated organic layers, designated as 'H', and the aerated organic materials indicated as 'O'.

2.1.1.2 H horizon or layer

The H horizon or layer is dominated by organic material, formed from accumulations of fresh or partially decomposed organic material at the soil surface (which may be under water). All H horizons are saturated with water for prolonged periods or were once saturated but are now drained. A H horizon may be on top of mineral soils or at any depth beneath the surface if it is buried (FAO, 2006).

Distinction of subhorizons in the organic H-layers (Zanella et al., 2010):

Hf (from Histic and fibric) horizon

Histic organic horizon consisting almost entirely of almost unchanged plant remains. Fibric component ≥ 90%, sapric component < 10% of horizon volume. Content of rubbed fibres ≥ 40% of soil by dry weight (105 °C)[4]. Von Post scale of decomposition: 1 to 3 (4, 5 possible)[5].

Remarks: Plant remains from mosses like Sphagnum species, sedges, rushes and reeds are recognizable. Fibric horizons are quite common in bogs and oligotrophic parts of isolated fens. These horizons are mainly composed of remains of Sphagnum and Eriophorum species. In mesotrophic fens, the Hf-horizon is mainly composed of remains of sedges and rushes. Fibric horizons in eutrophic fens are less common because of the fast decomposition in those environments. A further differentiation could be made on the base of the origin of the plant material (oligotrophic mosses, mesotrophic sedges, mesotrophic sedges and reeds).This could be adapted to national, regional and local circumstances.

Note: this horizon coincides with what is classified as **fibric** (Klinka et al., 1981, Green et al., 1993) or **fibrist** (Delecour, 1980).

Hfs (from Histic, between fibric and sapric)

Histic organic horizon consisting of half decomposed organic material not fitting the definition of fibric (Hf) or sapric (Hs). Fibric component 10% to 70%, sapric component 90% to 30% by volume (Figure 9). Content of rubbed fibres 10 to 40% of soil by dry weight (soil dried at 105 °C), Von Post scale of decomposition: 4 to 7 (8 possible)[6].

Note: This horizon coincides with what is classified as **mesic** (Klinka et al., 1981, Green et al., 1993) or **hemist** layer in saturated soils;

Hs (from Histic and sapric)

Histic organic horizon in advanced stage of decomposition. Sapric content ≥ 70% of the horizon volume; fibric component less than 30% (Figure 9). Content of rubbed fibres < 10% of soil by dry weight (soil dried at 105 °C). Von Post scale of decomposition: 8 to 10[7].

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[4] The content (by mass) of the total organic fraction is generally more than 80%. When saturated, this fibric horizon can have a water content of far more than 850% of the oven-dry weight (Soil Taxonomy 1975).

[5] von Post scale: (1) Undecomposed; plant structure unaltered; yields only clear water coloured light yellow brown; (2) almost undecomposed; plant structure distinct; yields only clear water coloured light yellow brown; (3) very weakly decomposed; plant structure distinct; yields distinctly turbid brown water, no peat substance passes between the fingers, residue not mushy.

[6] von Post scale: (4) weakly decomposed; plant structure distinct; yields strongly turbid water, no peat substance escapes between the fingers, residue rather mushy; (5) Moderately decomposed; plant structure evident, but becoming indistinct; yields much turbid brown water, some peat escapes between the fingers, residue very mushy; (6) strongly decomposed; plant structure somewhat indistinct, but more evident in the squeezed residue than in the undisturbed peat; about one-third of the peat escapes between the fingers, residue strongly mushy; (7) Strongly decomposed; plant structure indistinct, but recognizable; about one-half of the peat escapes between the fingers.

[7] von Post scale: (8) very strongly decomposed; plant structure very indistinct; about two-thirds of the peat escapes between the fingers, residue almost entirely resistant remnants such as root fibres and wood; (9) Almost completely decomposed; plant structure almost unrecognizable; nearly all the peat escapes between the fingers; (10) Completely decomposed; plant structure unrecognizable; all the peat escapes between the fingers.

Remarks: Sapric horizons of brook valley systems and around wells have mostly a higher mineral fraction than those in fens or bogs. Although at first sight quite similar, the horizons can differ in structure, pH, nutrient content and base saturation due to differences in water quality, vegetation and soil organisms.

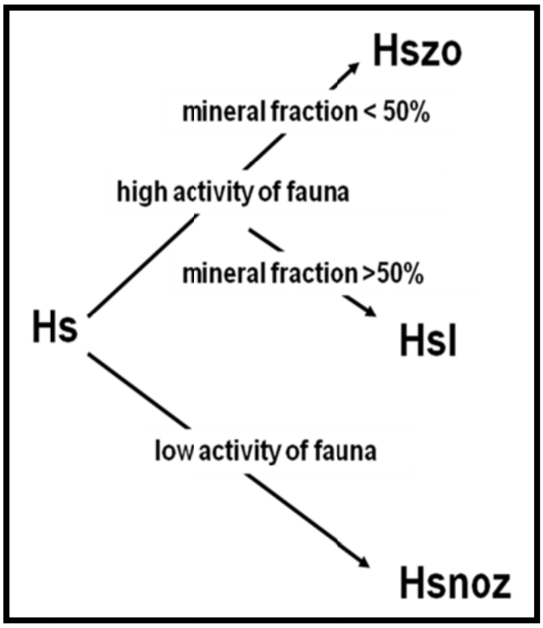
Note: This horizon coincides with what is classified as **humic** (Klinka et al., 1981, Green et al., 1993) or **saprist** (Delecour, 1980).

The following three horizons can be seen as special cases of the Hs horizon:

Hszo = Meso or macrostructured Hs horizon with a high activity of soil animals, especially earthworms. The mineral fraction is less than 50% (Figure 10). Typically present in drained semiterrestrial humus forms (both naturally and artificially drained). Activity of earthworms is high. The mineral fraction (clay, loam and/or sand) is commonly high compared to that of fibric horizons;

Hsnoz = Massive Hs horizon with low activity of soil animals. Common around bogs and rain fed ponds. Humification mainly results from the activity of microorganisms, which is typical of oligotrophic environments. Complexes of humic substances are acid and relatively poor in nutrients and bases and subject to eluviation when drained. The mineral fraction is variable;

Hsl = Hs horizon with a high percentage of mineral particles (clay, silt and sand). The mineral fraction is more than 50%. The mineral component may occur in the form of thin layers. The bioactivity is comparable to Hszo.



2.1.2 The mineral soil layer and its master horizons and layers

2.1.2.1 The A horizon

A mineral horizon formed at the surface or below an O horizon, in which all or much of the original structure of the parent material has been obliterated and 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 its surface position.

If a surface horizon 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.

Where the climate is warm and arid, the undisturbed surface horizon may be less dark than the underlying horizon and contains only small amounts of organic matter. It has a morphology distinct from the C layer, though 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 surface horizons which may have a different structure or morphology due to surface processes are Vertisols, soils in pans or playas with little vegetation, and soils in deserts.

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

The different diagnostic A horizons are identified in the field observing the soil mass by the naked eye or with 5-10X magnifying hand lens, assessing the structure (Soil Survey Manual (1993) and FAO Guidelines 2006) and consistence, and measuring the acidity (pHwater).

Zanella et al. (2010) distinguishes the following five diagnostic A horizons:

maA: biomacrostructured A horizon = A aneci-endovermic

General characteristic: mixed biogenic organo-mineral peds dominate

Diagnostic criteria:

To be identified as a biomacrostructured A horizon, a layer must have <u>at least four of the following</u>:

- structure grade, observable in place in undisturbed soil: never weak, never lack of structure;
- presence of peds, observable in place in undisturbed soil as well as in the palm of the hand after applying a weak-moderate pressure on a sample of soil: all sizes of peds are present, but the volume of peds larger than 4 mm is greater than the volume of all other peds or units of soil;
- structure (FAO and USDA) - grade: moderate or strong; size if granular shape: medium (2-5 mm) and/or coarser; size if subangular blocky shape: fine (5-10 mm) or fine (5-10 mm) and very fine (< 5 mm);
- living earthworms, or earthworm galleries and/or casts;
- earthworm galleries within underlying horizon;
- pH in water >5.

Origin:

<u>Biological</u>: the whole horizon is made of anecic and endogeic earthworm faeces (the limit of 4 mm is rarely reached by droppings of arthropods and epigeic earthworms); roots and fungal hyphae (visible or not) also play an important role in the formation and stability of aggregates. Living earthworms or their galleries and casts are always present within the horizon.

meA: biomesotructured A horizon = A endo-epivermic

General characteristic: composed of coloured organic (dark) or/and organo-mineral biogenic peds

Diagnostic criteria:

The biomesotructured A horizon has <u>all the following properties</u>:

- structure grade, observable in place in undisturbed soil: never weak, never lack of structure;
- presence of peds, observable in place in undisturbed soil as well as in the palm of the hand after applying weak pressure on a sample of soil: all sizes of peds are present, but the volume of the peds larger than 1 mm and smaller than 4 mm is greater than the volume of all the other peds or parts of soil;
- structure (FAO and USDA) - grade: moderate or strong (rarely weak); size if granular shape: fine (1-2 mm) and/or medium (2-5 mm); size if subangular blocky shape: very fine (<5 mm).
- living earthworms, arthropods or enchytraeids or their droppings.

Origin:

<u>Biological</u>: earthworms (mostly epigeic and small endogeic), enchytraeids and arthropods are responsible for the structure; roots and fungal hyphae are also involved. Anecic and large endogeic earthworm droppings, classified typically as biomacro peds, are generally larger than 4 mm.

NB.: Green et al. (1993) described a rhizomull characterized by an A horizon which could be a biomesostructured A horizon. In this case, the thick mat of fine roots of grasses plays a major role in determining the type of structure of the topsoil.

miA: biomicrostructured A horizon = A enchy-arthropodic

General characteristic: composed of fine mineral grains mixed with fine organic particles and dark-coloured biogenic peds (holorganic or hemiorganic)

Diagnostic criteria:

The biomicrostructured A horizon has at least five of the following properties:

- absence of peds > 4 mm; observable both in situ, in undisturbed soil, and in the palm of the hand after applying a slight pressure on a sample of soil: peds of varying size can be present, but the volume of peds smaller than 1 mm is greater than the volume of all other peds or parts of the soil; gently squeezing the soil, almost all large peds easily reduce into smaller units;
- structure (FAO and USDA) - grade: moderate, strong; shape: granular; size: very fine (< 1 mm);
- presence of (generally uncoated) mineral grains (mineral component > 10%);
- > 10% organic particles and dark-coloured biogenic peds (holorganic or hemiorganic = humic component)
- living arthropods, enchytraeids or their droppings;
- pH in water <5.

Origin:

<u>Biological</u>: the horizon has an important amount of faecal pellets, droppings of enchytraeids (potworms) (larval stages, insects, spiders, mites, springtails…), micro-arthropods and particles of organic matter (remains of decomposed litter). Hyphae and roots are also very common.

Field identification:

- Take a sample of A horizon rich organic soil material. If squeezed gently in the palm of the hand, the sample breaks up into units composed of organic and organo-mineral peds (single or bound droppings, droppings bound to mineral grains), organic particles and mineral grains. Observing the soil with a magnifying hand lens (5-10X) reveals a lot of complex holorganic and hemorganic peds. Their mean size is less than 1 mm but the structure of the soil is clearly expressed and never weak or absent. The appearance can be very similar to that of the OH horizon.
- Observed on sandy or loamy substrate (acid or non-calcareous). The large amount of quartz grains (> 50%) seems to prevent the formation of a larger size structure or a massive one.

sgA: single grain A horizon

General characteristic: single grained structure, biological aggregation absent or involving less than 5% of the soil volume

Diagnostic criteria:

To be identified as a single grain A horizon, a layer must have at least four of the following:

- an unbound loose consistence (undisturbed soil mass);
- structure (FAO and USDA): single grain;
- presence of clean (= uncoated) mineral grains;
- <10% of fine organic particles and/or dark-coloured biogenic (holorganic or hemorganic) peds;
- pH in water < 5.

Origin: Mineral grains coated with organic matter indicate a process of podzolisation in places. Faecal pellets of micro-arthropods or enchytraeids are sometimes present but irrelevant (< 10%).

Field identification for structure and consistency:

In undisturbed soil - Structure: single grain. Sub-units of soil do not appear bound together or are weakly bound in a casual manner. Sometimes, in a relatively organic sample, very small peds (< 1 mm) are detectable in the mass (animal pellets), because of their dark colour and organic composition in a light mineral mass. At other times the horizon looks like a brownish-red coloured nearly uniform fluffy mass. In this case, it is very difficult to separate mineral from scarcely present organic components.

In a sample of soil in the palm of the hand - When squeezing gently with the fingers, the sample breaks up progressively into large then fine, artificial units. The fine units are mostly mineral, more or less coloured by organic matter in coatings. Animal pellets are absent or in traces (less than 10%). The sample could be wrongly classified as weak medium granular structured but grains, never zoogenic, break easily into micro units because they are very weakly attached together in variable manner and size (no apparent soil structure).

Horizon designation: Because of observable processes of eluviation or podzolisation, the horizon could be classified as EA (or E) or AB following its similarity to mineral horizons.

msA: massive A horizon

General characteristic: massive structure, biological aggregation absent or involving less than 5% of the soil volume

Diagnostic criteria:

To be identified as a massive A horizon, a layer must have at least three of the following:

- heterogeneous but one-piece matrix;
- structure (FAO and USDA): massive;
- presence of clean (= uncoated) mineral grains;
- pH in water < 5.

Origin: Presence of mineral grains coloured by organic matter in coatings. Cohesion forces among parts of soil seem equally distributed in the soil, as they depend mostly on physical or chemical conditions rather than biological aggregation (peds originated by animals < 5%). Past biological activity (incorporation of organic matter) could also be involved in the process of formation of the horizon, but traces of current biological activity are never visible. Organic or hemorganic pellets of microarthropods or enchytraeids are present (< 5% of the soil volume). A 5-10 X magnifying hand lens is necessary to detect the composition of the pellets or grains, the size of the most common biostructured units being less than 1 mm.

Field identification for structure and consistency:

In undisturbed soil - Structure: massive. The units of soil are bound together in a relatively compact manner. No planes or zones of weakness are detectable in the mass, which appears as a heterogeneous coloured layer of organo-mineral soil.

If the soil is dry, when applying a moderate to strong pressure with the fingers, the soil sample progressively breaks up into finer artificial units. These fine units have a varying composition: mineral, organo-mineral and organic. If the soil is moist, the shape of the sample can be modified as in a tender, plastic, non-elastic matter.

Horizon designation: Because of observable processes of eluviation or initial podzolisation, the horizon could be classified as AE (or EA), following its resemblance to a mineral E horizon.

Zoogenic and non-zoogenic A horizon

Azo = zoogenic A horizon.

Azo = maA (implied maAzo) or meA (meAzo) or miA (miAzo).

Anoz = A horizon considered as non-zoogenic. To the naked eye, or with the help of a hand lens, this horizon does not show relevant (mass) signs of animal activity (absence of galleries; droppings, mucus, animal remains etc., < 5% of the soil volume). Zoological agents are not involved in the soil aggregation. Fungal structures can be visible.

Anoz = sgA (implied sgAnoz) or msA (msAnoz).

2.1.2.2 E horizon

A mineral horizon 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 structure of the parent material 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, but 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 processes.

2.1.2.3 B horizon:
A horizon 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 structure of the parent material, together with one or a combination of the following:

- Illuvial concentration of clay, iron, aluminium, humus, carbonates, gypsum, silica or some combination of these;
- Evidence of removal of carbonates;
- Residual concentration of iron and aluminium oxides;
- Coatings of humus and/or oxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons;
- 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;
- Brittle consistence.

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 (these horizons may or may not be cemented) and brittle horizons 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 with an overlying pedogenetic horizon; and layers with gley colours but no other pedogenetic changes.

2.1.2.4 C horizon
A horizon, excluding hard bedrock, that is little affected by pedogenetic processes (lacks properties of H, O, A, E, or B horizon). The material of C layers may be either like or unlike that from which the soil is presumed to have formed. A C layer may have been modified even if there is no evidence of pedogenesis. Plant roots can penetrate C layers, which provide an important growing medium.

Included as C layers are sediments, saprolite, and unlithified geological materials that, commonly, slake within 24 hours when air-dry chunks are placed in water and, when moist, can be dug with a spade. Some soils form in material that is already highly weathered; 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 layers, unless the layer is obviously affected by pedogenetic processes; then it is a B horizon.

2.1.2.5 R layer
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 bits of an R layer, when placed in water, will not slake within 24 hours and are resistant to pressure with the fingers. The R layer is sufficiently coherent when moist to make 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 be fissured, but few roots can penetrate. The cracks may be coated or filled with clay or other material.

2.1.2.6 I layer:

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

In areas affected by permafrost, ice bodies may form lenses of wedges that separate entire soil layers. Where such ice concentrations occur within the depth of soil description, they can be designated as I layer.

2.2 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 dominant properties: an AB horizon, for example, has characteristics of both an overlying A horizon and an underlying B horizon, but 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. 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 which can be dug with a spade though roots cannot penetrate except along fracture planes.

Horizons or layers 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 stroke (/), as E/B, B/E, B/C or C/R. Commonly, most of the individual parts of one component are surrounded by the other material.

2.3 Subordinate characteristics within master horizons and layers

Designations of subordinate distinctions and features within the master horizons and layers are based on characteristics observable in the field. 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 explained more in detail below:

Suffix	Description	Use for
a	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.	No restriction
b	Buried horizon: Used in mineral soils to indicate identifiable buried horizons with characteristics that were formed before burial. Horizons may or may not have developed in the overlying materials which may be either like, or unlike, the assumed parent material 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 layers.	Mineral horizon, not cryoturbated
c	Concretions or nodules: In mineral soil it indicates a significant accumulation of concretions or of nodules. The nature and consistence of the nodules is specified by other suffixes and in the horizon description.	Mineral horizon
d	Dense layer: Used in mineral soils to indicate a layer of relatively unaltered, mostly earthy material that is not cemented but that has such bulk density	Mineral horizon

Suffix	Description	Use for
	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).	
f	Frozen soil: Designates a horizon or layer that contains permanent ice or is perennially colder than 0°C. It is not used for seasonally frozen layers or for bedrock (R). Dry frozen soil layers may be labelled (f).	Not in I and R horizons
g	Stagnic conditions: Designates a horizon with a distinct pattern of mottling 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 oxidising colours and the surface parts reducing colours.	No restriction
h	Accumulation of organic matter: Designates the accumulation of organic matter in a mineral horizon. The accumulation may occur in a surface horizon or in subsurface horizons (through illuviation).	Mineral horizon
i	Slickensides: In mineral soils, denotes the occurrence of slickensides, i.e. oblique shear faces caused by the shrink-swell action of clay; wedge-shaped polished peds and seasonal surface cracks are commonly present.	No restriction
j	Jarosite: Indicates the presence of jarosite (straw-yellow) mottles, coatings or hypodermic coatings.	No restriction
k	Accumulation of pedogenetic carbonates: Indicates an accumulation of alkaline earth carbonates, commonly calcium carbonate.	No restriction
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 oxidising colours.	No restriction
m	Strong cementation or induration: In mineral soils, indicates continuous or nearly continuous cementation - used only for horizons that are more than 90 % cemented, though they may be fractured. The layer restricts rooting to fracture planes. The single predominant or co-dominant cementing agent may be indicated using defined letter suffixes 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; by salts more soluble than gypsum, zm.	Mineral horizons
n	Pedogenetic accumulation of exchangeable sodium.	No restriction
o	Residual accumulation of iron/aluminium oxides: Indicates residual accumulation of sesquioxides, as opposed to the symbol s, which indicates illuvial accumulation of oxides or organic and oxide mixture.	No restriction
p	Ploughing or other artificial disturbance: Indicates mixing 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 originally an E, B or C, is designated Ap.	No restriction; E, B or C as Ap
q	Accumulation of pedogenetic silica: If silica cements the layer and cementation is continuous or nearly continuous, qm is used.	No restriction
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.	No restriction
s	Illuvial accumulation of iron/aluminium oxides: Used with B to indicate the accumulation of illuvial, amorphous, dispersible organic matter-oxide 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 oxide components are significant and both value and chroma are approximately 3 or less.	B horizon
t	Accumulation of clay: Used with B or C to indicate an accumulation of 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.	B and C horizon
u	Urban and other man-made materials: Used to indicate the dominant	H, O, A, E, B and C

Suffix	Description	Use for
	presence of man-made materials.	horizons
v	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 which case v is used in combination with m.	No restriction
w	Development of colour or structure in B: Indicates development of colour or structure, or both, in B horizons lacking other diagnostic characteristics. It is not used to indicate a transitional horizon.	B horizons
x	Fragipan: Brittle consistency or high bulk density attributed to pedogenetic processes.	No restriction
y	Pedogenetic accumulation of gypsum.	No restriction
z	Pedogenetic accumulation of salts more soluble than gypsum.	No restriction

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 is cumbersome. The following rules apply:

- Letter suffixes should immediately follow the capital letter;
- 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);
- Suffixes are listed alphabetically.

2.4 Vertical subdivisions

A horizon or layer designated by a single combination of letter symbols can be subdivided using arabic numerals following the letters. Within a C, for example, 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 symbols may be subdivided on the basis of morphology, such as structure, colour, or texture. These subdivisions are numbered consecutively. The numbering restarts 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, for example Ap1, A1, A2, Ap2, A3; and E1, E2, Eg1, Eg2.

2.5 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, although this symbol 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, no prefix is used (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 though 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, e.g. 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.

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.