An approach for a hierarchical system to classify and to describe soil associations

JAHN R. (1), SCHMIDT R. (2), WITTMANN O. (3) and SPONAGEL H. (4)

(1) Institute of Soil Science and Plant Nutrition, University Halle, Weidenplan 14, D-06108 Halle, Germany
(2) (2)University of Applied Sciences Eberswalde, Alfred-Möller-Str. 1, D-16225 Eberswalde
(3) Föhrenstr. 9, D-85640 Putzbrunn
(4) Lower Saxony Geological Survey (NLfB),Stilleweg 2, D-30655 Hannover

Abstract

The Working Group on Soil Classification of the German Soil Science Society is now working on grasping and systematically arranging of soil associations from Germany. The presented approach is based on former work and combine the hierarchical system of soil classification (pedon, subvariety, variety, subtype, type, order, division) with the choric idea of soil geography (pedotop, nanochore, microchore, mesochore, macrochore, region) and is the base to map well defined classes of soil associations at different categories of complexity from parts of a soil association up to soil zones. According to this approach soil associations are derived inductive-synthetically from available soil maps.

Especially for practical use it is necessary to add relevant soil information to the system. In development is a broad set of modules giving the possibility to describe soil associations very detailed as a whole as well as with regard to their members. It is also possible to use some of the modules as reference modules to agglomerate or differentiate associations. Modules which characterise ecological functions or properties of association members (or the association as a whole) are more for practical use in landscape planning and soil protection. This opens also the way to transfer the data of soils to soil association maps and characterise (based on proportion by area) classification details and properties of each unit. The modules can be used theoretically in any hierarchical class of the system.

Examples from Germany, one in terms according to the FAO legend, are used to present the recent position of discussion. Attributes of SOTER or related data files can be used to organize the data of the terrain, climate and land use.

Keywords: soil classification, soil associations, classification system, landscape planning, soil protection

Introduction

For purposes of soil evaluation focused on sustainable land use and soil protection, up to date soil information is needed which includes quantitative data about the composition of soils in a heterogeneous landscape. Therefore, a system is necessary for aggregation of soil information and to classify soilscapes, or parts of it, based on rational and accepted rules. This should allow: (i) to compare objectively soilscapes of different regions, (ii) to differentiate soilscapes with different dynamics and combinations of soil-forming processes, (iii) to link the soilscapes with specific ecological properties and (iv) to evaluate soilscapes, e.g., for land-use suitability, sensitivity and carrying capacity with respect to natural and man-made influences. Soil associations are choric units of the soil cover and so far, their classification should summarise the soil assemblage as well as characteristics of their distribution in space. Soil associations are choric units of the soil cover and so far, their classification should summarise the content as well as characteristics of the distribution in space.

In comparison to systems of soil classification, the classification of soil associations is in a very early stage. After finishing the work on the "Systematik der Böden und der bodenbildenden Substrate Deutschlands" (DBG, 1998), the Working Group on Soil Classification of the German Soil Science Society is now working on grasping and systematically arranging of soil associations from Germany. The presented approach (based on the work of Haase and Schmidt, 1970; Schmidt, 1982; Blume, 1984; Wittmann, 1984, 1999; Schmidt, 1999; and others) combine the hierarchical soil classification (pedon, variety, subtype, type, order [Klasse], division [Abteilung]) with the choric idea of soil geography (pedotop, nanochore, microchore, mesochore, macrochore, region; Haase, 1968; AG Boden, 1994) and is the base to map well defined classes of soil associations at different categories of complexity from parts of a soil association up to soil zones.

The system

The system structures within defined land form classes soil associations in a natural way according to their relationship and therefore according to soil and landscape forming processes. Following the German system of soil classification, the association classification has also seven hierarchical categories (Table 1). At the uppermost category of soil association (divisions [Abteilung]), landscapes are differentiated according to their direction of matter-movement and related soil forming processes (Schmidt, 1999). In the slope division (inclinal-morphology) soil associations are summarised which are commonly matter-connected (catenas) by surface and subsurface transport processes (Figure 1). Boundaries are uphill boundaries of watersheds or the shoulder of a plateau. Downwards the boundary is found either at the low line or with the beginning of fluvial sediments. It seems to be necessary to have subdivisions for stair-slopes and slopes with large differences in elevation (large climatic gradients). The slope is dissected into crest, upper slope, middle slope, lower slope, footslope and cuesta-shaped planes. The depression division (infusion-morphology) combines soil associations with groundwater determined soil forming processes. The position within a depression is described with rim, centre, deep, deep and near a river and transition. In the case of very deep groundwater levels the plate division is recommended. This division combines soil associations in which vertical processes are dominant and lateral processes of secondary importance. It seems to be necessary to have subdivisons for combinations of lateral and vertical processes, e.g., a slope-plate, undulated-plate and a weak inclined plate subdivision. Positions within a plate are differentiated with rim, centre and transition. For soil associations which are influenced by tidal water the tidal littoral division is used.

Table 1 Hierarchical structure and short definitions of the classification system (soil family ≅ soil type or subtype or variety + substrate, substrate means the altered parent material).

Having the same						(Soil) Association Division [Abteilung]
landform (water and transportation regimes) - slope - depression - plate - tidal-littoral	Having the same					Order [Klasse]
	geomorphic unit	Having the same				Community [Verband]
		assemblage of soil types and the same substrate main class	Having two or more			Type
			diagnostic (1. dominant 2. continuity ≥60 %) soil families (subtype + substrate class)	Having a		Subtype
				differentiating soil family (subtype) with a continuity ≥60%	Having a	Variety
					differentiating texture (subtexture class)	**Subvariety** Having differences through land use (e.g. by erosion)

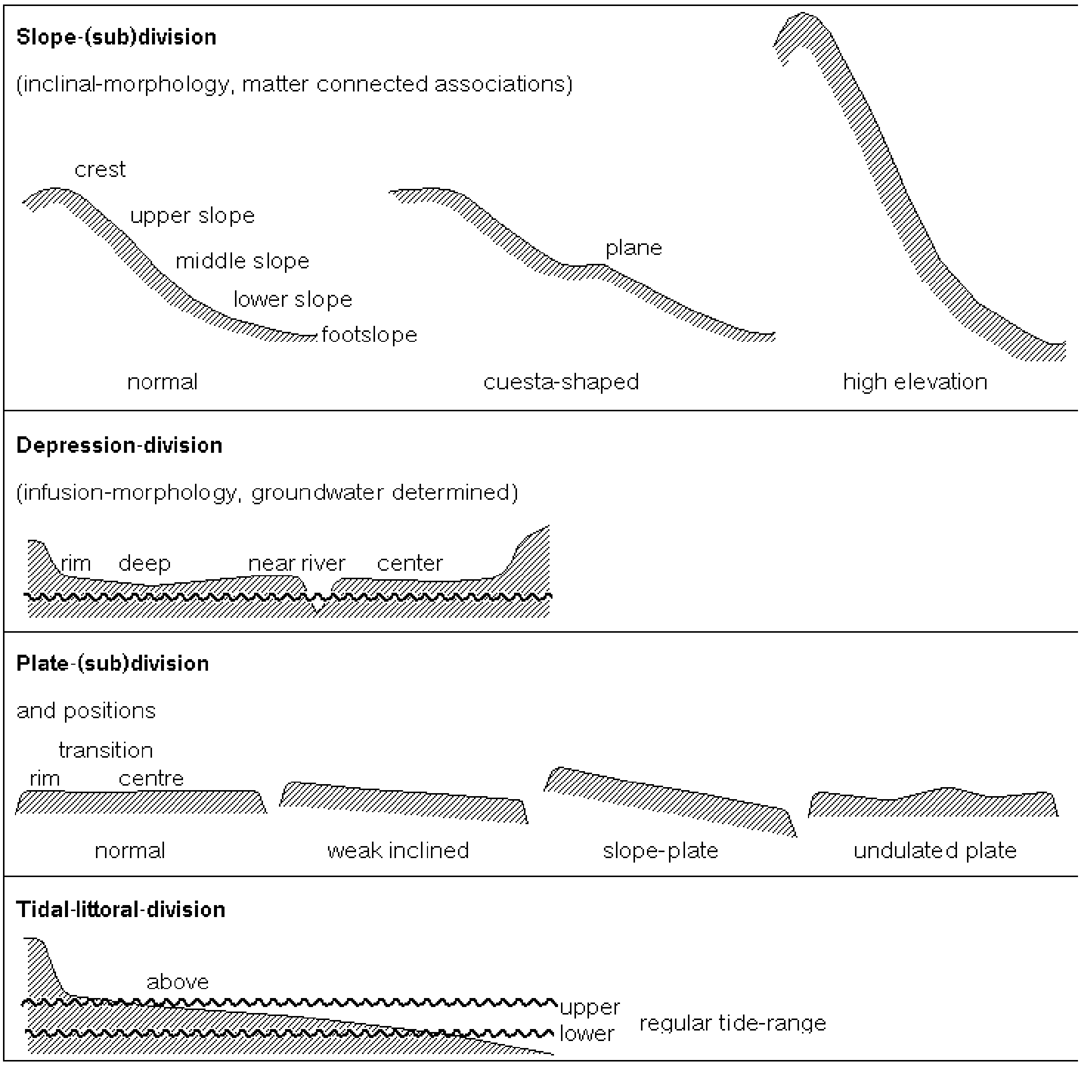

Figure 1 Divisions and subdivisions of the system.

In the category of orders differentiating is made by 20 to 30 geomorphic units. The assemblage of soils (in soil type category) and main texture classes (skeleton, sand, silt, clay, peat) are used to differentiate between association communities. In the category of types of the system, associations can be distinguished by the occurrence of soils (at subtype category) and texture classes within the boundaries of a community by continuity of occurrence at certain landscape positions and the proportion of area. Smaller differences of texture (subtexture classes) distinguish between varieties of associations. Diagnostic soils which are used for naming the associations (max. of three soils) have a continuity ≥60 %. A high proportion of area (dominant) of one member of the soil association may be related with high continuity but is not a prior condition for diagnostic soils.

A fairly quick method to derive soil associations from paper maps is to use cross-sections of soil maps 1: ≤25,000 and to estimate continuity of occurrence and the proportion in classes (Table 2).

Table 2 Used classes for continuity of occurrence and proportion of area (AG Boden, 1994).

Class	continuity of occurrence	class	proportion of area
+	<10%		
I	10-20%	1	<10%
II	20-40%	2	10-30%
III	40-60%	3	30-70%
IV	60-80%	4	70-90%
V	>80%	5	>90%

The principle of identification and naming soil associations down to the category of varieties is shown in Table 3 with to examples from a humid area of the low- mountain region (Bavarian Forest, southeastern Germany) with a soil cover which is developed on gneiss and have only little differences in the texture of the substrates. In the category of the association community and higher, these both examples are not to distinguish. By using the subtype category in soil classification the both associations can be distinguished at the category of association type and lower.

Working with digital soil maps will allow to evaluate the soil cover more precise and to receive additional information, e.g., about the length of soil boundaries, and to use methods of landscape analysis to describe diversity, heterogeneity and complexity of the structure by statistical parameters (Sponagel *et al*., 1999).

According to this approach soil associations are inductive-synthetically derived. Each in the classification listed association type (including subtypes, varieties and subvarieties) should be documented for different areas with uniform rules and data files.

The more abstract (and in principle independent from scales) classification system (Figure 2) is the base to represent the actual existent soil-space-organisation systematically in maps at different categories of complexity with defined rules. The basic unit (mapping unit) of large and medium scaled maps is identical with a member of a soil association of any hierarchical class.

Table 3 Examples of soil associations in southeastern Germany derived by continuity of occurrence of soil subtypes (BK 25, 6945, Zwiesel).

Soil Subtype	Substrate	Upper slope	middle slope	Lower slope	Foot hill	Upper slope	middle slope	lower slope	foot hill
(Norm) Syrosem + (Norm) Braunerde Et2)	gneiss	III				III	II		
(Norm) Braunerde Et4	xSl2, gneiss	[V]	[V]	IV	II		IV	V	II
(Norm) Braunerde Et4	xSl3, gneiss			IV	III		II	IV	I
(Norm) Braunerde Et3	xSl2, gneiss	IV	II	I					V
podsolige Lockerbraunerde Et3	xSl2, gneiss					[V]	[V]		
Gley-Braunerde	xSl3, periglacial layers				I				
Hanggley-Braunerde	xSl3, periglacial layers			I	I		II	II	
(Norm) Podsol	x4Sl2, gneiss					II			II
(Norm) Pseudogley	Ls3, solifluction layers					+			
(Norm) Gley	Sl2-3, valley sediment				[V]			II	
(Norm) Naßgley	Sl3, valley sediment				II		+		V
Anmoorgley	Sl3, valley sediment				II				
Hanggley	xSl3-Ls3, periglacial layers		I	III	IV		III	IV	
(Norm) Niedermoor	peat				III				[V] II I

variety	(Norm) Braunerde/(Norm) Gley, gravely, loamy sand, silt poor, of the slopes of ...
subtype	(Norm) Braunerde/(Norm) Gley, gravely loamy sand, of the slopes of ...
type	(Norm) Braunerde/(Norm) Gley, sandy, of the slopes of ... gneiss ...
community	of Braunerde/Gley, sandy, of the slopes of ...
order	slopes of low-mountains with magmatic and metamorphic rocks
division	of slopes

variety	Podsolige Lockerbraunerde/Hanggley, gravely, loamy sand, silt poor, of the slopes of ...
subtype	Podsoliger Lockerbraunerde/Hanggley, gravely loamy sand, of the slopes of ...
type	Podsoliger Lockerbraunerde/Hanggley, sandy, of the slopes of ... gneiss ...
community	of Braunerde/Gley, sandy, of the slopes of ...
order	slopes of low-mountains with magmatic and meta-morphic rocks
division	of slopes

Characteristics which are defining within the classification categories are underlined.

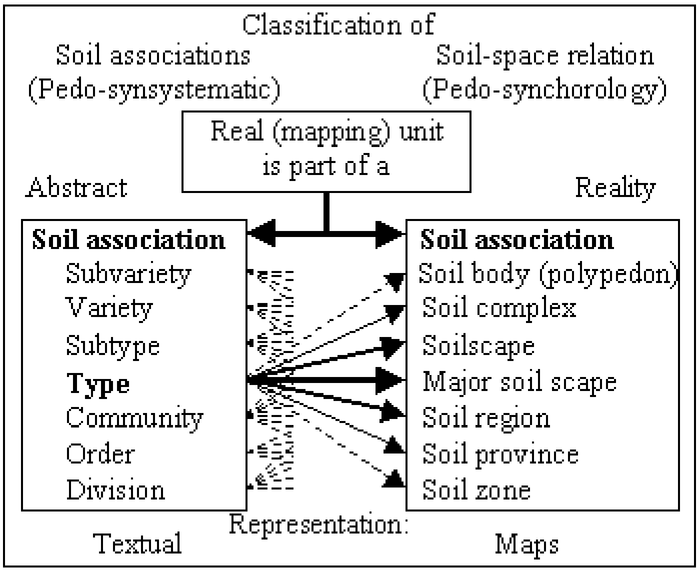

Figure 2 Relationship between the abstract soil association classification system and the real soil-space relation which are used at different mapping scales.

Two or more associations form an association complex. The same or different complexes which are found in repetitions within a certain landscape form a soilscape. Major soilscapes are areas in which specific soilscapes, geology, landscape history and relief form a unit which is distinctly different from neighbouring units. Soil region, provinces and zones are units of usually country and continental wide small scaled maps in which climatically differentiation is getting more and more important.

Extensions of the System

Especially for practical use it is necessary to add relevant information to the system. In discussion is a broad set of modules giving the possibility to describe soil associations very detailed as a whole as well as with regard to their members (Schmidt, 1999; Sponagel *et al*., 1999). It is also possible to use some of the modules as reference modules (Schmidt, 1999) to agglomerate associations to higher categories or differentiate associations from each other or for lower categories. Modules which characterise ecological functions or properties of association members (or the association as a whole) are more for practical use in landscape planning and soil protection. This opens also the way to transfer the data to soil association maps and characterise (based on cover area of the members of an association) classification details and properties of each unit. The modules can be used theoretically in any hierarchical class of the system.

Examples of the extended description of soil associations in discussion are:

- Modules to define soil associations

-continuity of occurrence	number or classes (see above)
-proportion of area	number or classes (see above)
-sociological function of members	diagnostic, associated, differentiating
-genetic function of members	source of matter fluxes, transformation type, enrichment type, climax type

- Modules to describe matter fluxes between association members
  -e.g., Fe from member A to B, erosion from member C to D
- Modules to describe the morphology of a soil association ([1)] King *et al.*, 1994)

-distribution/localisation of the members [1)]	random, regular, localised
-shape of the association [1)]	disk/including, blade, compact, concentric, feathered
-pattern of the members [1)]	simple, complex, very complex, boundary length/km^2
-neighbouring of the members [1)]	simple, manifold
-boundary contrast between members [1)]	very sharp, sharp progressive
-diversity/heterogeneity of the association	e.g., diversity index, evenness index patchy richness (examples see Sponagel *et al.*, 1999)

- Modules to describe ecological functions of members and associations
  -e.g., dryness, wetness, nutrient rich/poor, water storage
- Modules to describe properties of members and associations
  -e.g., available water capacity, pH, CEC level and ranges

The system of modules is until now very weak because of only little experiences and only rough ideas about possible and necessary definitions of classes. It is however an open system which can grow with the work on soil associations.

Example in terms according to the FAO-Legend

To demonstrate how the system works with international accepted rules of soil classification (FAO-Unesco, 1994), we use an example of a well described soilscape in the Black Forest, Germany (Schweikle, 1973; Schlichting and Schweikle, 1980) under forest (see Figure 3 and Tables below). The soils have been developed at the rim of plateau on material from a clayey intercalated hematitic sandstone that was cryoturbated. Soil development generally tends to the formation of Dystric Cambisols. Due to the impermeable rock, in flat and open depression under a humid climate Planosols and Stagnic Cambisols are developed. In smaller depressions Histic horicons occur which are not deep enough to qualify for Histosols. Nevertheless, it is more likely to speak from soil complexes than from soil bodies (polypedons) for the different mapping units (Blume, 1998). A distinct translocation of Fe (and other elements) occur from the Planosols along the slope. In positions where the slope angle is increasing and oxygen availability is high, the Fe is precipitated resulting in Fe-rich , reddish brown subsoils of low bulk density which is definitely not a spodic horizon. Due to the fact that stagnant water can be observed only during very short periods these soils key out as Chromi-Dystric Cambisols.

Soil association

Division:	Slope of an undulated plate
Order:	Low mountains of Central Europe with nonemetamorphic sandstones
Community:	Cambisol/Planosol
Type:	Dystric Cambisol/Umbric Planosol, sand
Subtype:	Dystric Cambisol/Umbric Planosol/Chromi-Dystric Cambisol, sandy loam

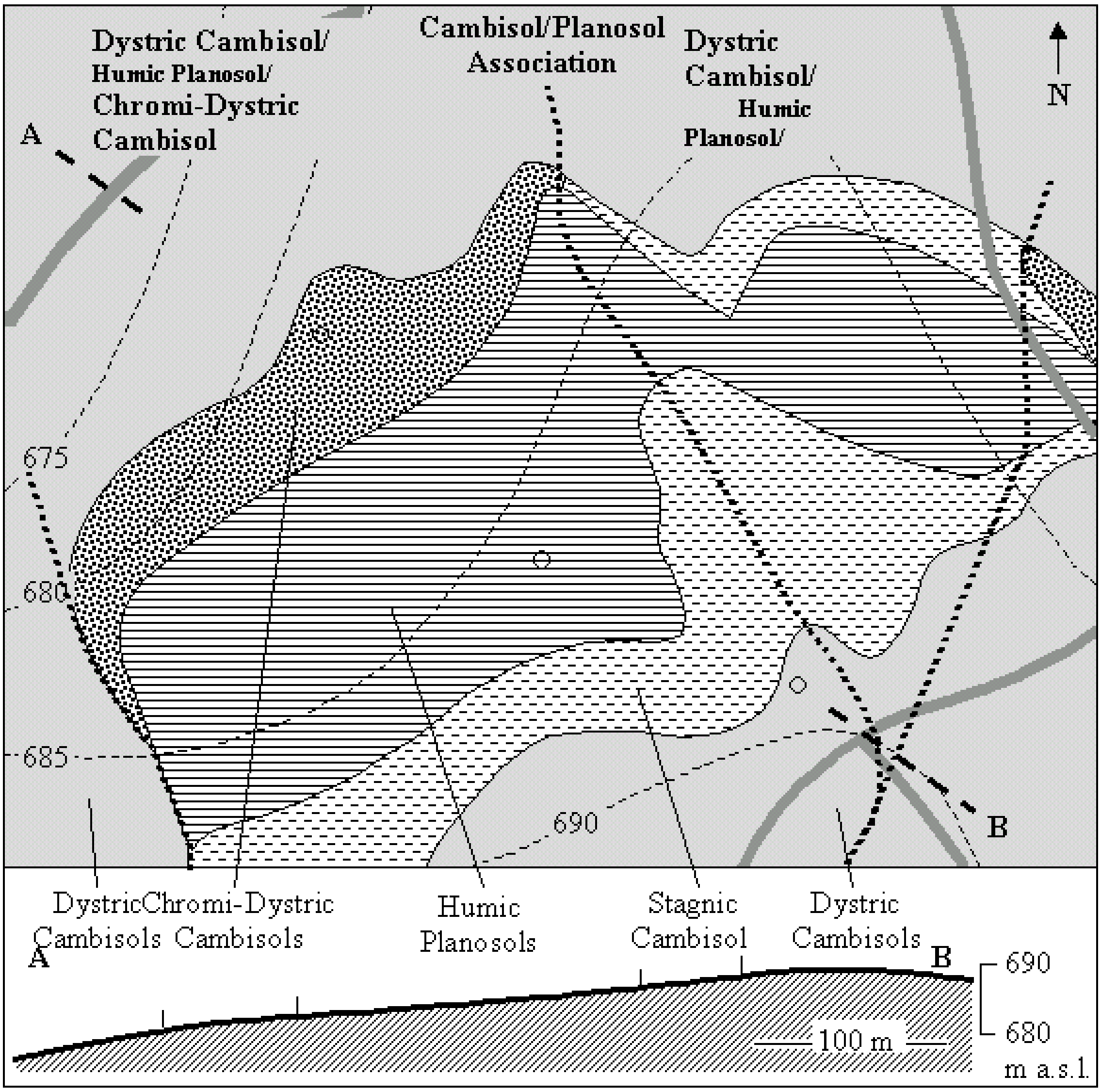

Figure 3 Examples of soil associations of a soilscape at a sandstone-plateau in the Black Forest, SW-Germany (Schweikle, 1973; Schlichting and Schweikle, 1980) consisting of six soil complexes arranged in 2 soil associations at the association-type categoryTerrain data, climate and land cover (reduced to the most important data)(here the terms and classes of SOTER; FAO, 1995 are used).

Terrain data, climate and land cover
(Reduced to the most importanat data)
(here the terms and classes of soil association of SOTER; FAO, 1995 are use)

description in the category of soil association		type/soilscape
minimum elevation	675	[m a. s. l.]
maximum elevation	695	[m a. s. l.]
slope gradient	3	[%]
relief intensity	32	[m/km]
major landform	SP	[plateau of dissected plain], rim, sloping land
regional slope	G	[gently undulating]
hypsometrie	3	[medium level]
dissection	- -	none
general lithology	SC2	[sandstone] with clay intercalated hematitic sandstone, upper Buntsandstein, Scythian
permanent water surface	- -	none
rain	1200	[mm]
temperature	6.5	[ºC]
land use	FP	[plantation forestry]
vegetation	IIB3	[cold-deciduous woodland with evergreen trees] spruce forest with some fires and pines and a ground cover of Vaccinium and Spagnum

The data should be available for each member of the soil association

Module to define soil associations

member	continuity of occurrence	proportion of area	sociological function	genetic function of members
CMd Dystric Cambisols (crest)	class V	23 %	diagnostic	transformation
CMj Stagnic Cambisols	class V	10 %	associated	transformation
PLu Umbric Planosols	class V	33 %	diagnostic	source of matter fluxes
CMdx Chromi-Dystric Cambis.	class V	12 %	differentiating	enrichment and transformation
CMd Dystric Cambisol	class V	22 %	associated	transformation

Module to describe matter fluxes between association members

member	matter flux	
CMd (1)	↓	
CMj	↓ water	
PLu	↓	↓ Fe, Mn, DOC, Al (?)
CMdx	↓	
CMd (2)	↓	

Module to describe the morphology of a soil association (King *et al*., 1994)

member	localisation	shape	neighbourhood	boundary contrast	pattern
CMd (1)	localised, crest	blade	simple, CMj	progressive	simple
CMj	localised, crest-depr.	blade	manyfold, CMd (1), PLu	progressive	complex
PLu	localised, open depression	blade	manyfold, CMj, CMdx	sharp	complex
CMdx	localised, below PLu	blade	manyfold Plu, CMd (2)	sharp	simple
CMd (2)	regular	blade	simple, CMdx		simple

Module to describe ecological functions of members and associations

member	ecological functions
CMd (1)	nutrient poor
CMj	weak wetness, nutrient poor
PLu	strong wetness, nutrient poor, water storage
CMdx	nutrient poor
CMd (2)	nutrient poor

Module to describe properties of members and associations

member	Clay kg/m^2 *)	OM storage kg/m^2 **)	Fe_d kg/m^2 *)	pH H_2O *)	CEC eff mol(+) *)
CMd (1)	226	n.d.	13.4	n.d.	n.d.
CMj	144	12 + 9	7.3	4.1	38
PLu	183	14 + 15	5.6	4.0	68
CMdx	237	20 + 6	12.6	4.4	24
CMd (2)	n.d.	n.d.	n.d.	n.d.	n.d.

*) mineral soil 1 m deep, **) mineral soil 1 m deep + surface layer

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