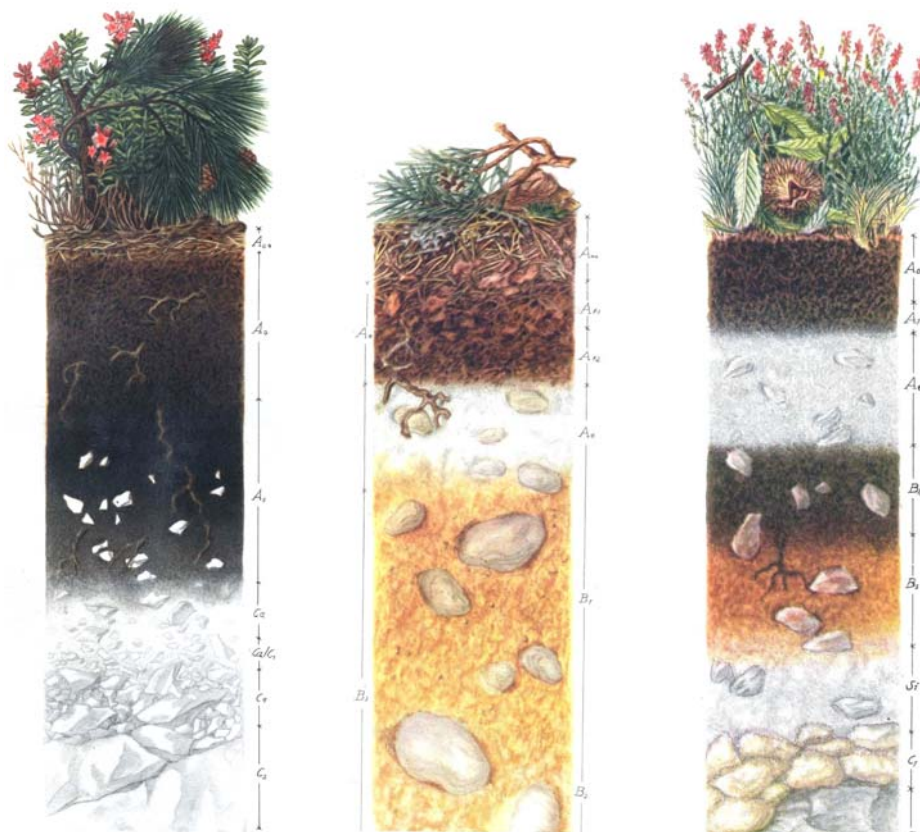


Soils of the European Union

Gergely Tóth, Luca Montanarella, Vladimir Stolbovoy, Ferenc Máté,
Katalin Bódis, Arwyn Jones, Panos Panagos
and Marc Van Liedekerke



Soils of the European Union

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European Commission
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Contact information

Address: Joint Research Centre, TP 280, 21027 Ispra (VA) Italy
E-mail: gergely.toth@jrc.it
Tel.: +39 0332 786483
Fax: +39 0332 786394

<http://ies.jrc.ec.europa.eu/>
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Cover pictures, from left to right:

Tangelrendsina below Pinus Montana and Rhododendron hirsutum on dolomite
(Dachsteingebiet, Styria, 1700 m)

Iron-podzol under pine forest (Pinus silveris) on moraine
(Heinavesi, Finland)

Humus-podsol on dune sands under Calluna heather with two ortstein layers (Bh1-Bh2)
followed by series of ortsteinbands
(Dorum, Bremen, North Sea Coast).

The originals of the pictures of the cover page can be found in: W. Kubiëna (1952) "The Soils of Europe". The book of Kubiëna was published by the CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (C.S.I.C.) in Madrid in 1952. The C.S.I.C. kindly provided the permission to use these pictures for the cover page of this publication.

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Gergely Tóth, Luca Montanarella, Vladimir Stolbovoy, Ferenc Máté¹
Katalin Bódis, Arwyn Jones, Panos Panagos
and Marc Van Liedekerke

Institute for Environment and Sustainability
Land Management and Natural Hazards Unit
Action SOIL



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¹ Georgikon Faculty of Agricultural Sciences, University of Pannonia, Keszthely, Hungary

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We offer our apologies and thanks if we have inadvertently and unintentionally omitted anybody.

1. Introduction

Soil is a nonrenewable natural resource which is one of the key life support systems on the planet, responsible for basic ecological and social functions such as the:

- Biomass production
- Storing, filtering and transforming nutrients, substances and water
- Biodiversity pool such as for habitats, species and genes
- Physical and cultural environment for humans and human activities
- Source of raw materials
- Acting as carbon pool
- Archive of geological and archaeological heritage

The EU's Thematic Strategy for Soil Protection (EC 2006) has stated that these soil functions are under serious pressure in many parts of Europe. The understanding of soil as an important contributor to water systems, the global carbon cycle and to other systems is still evolving and needs to be developed further; so far soil has predominantly been perceived in the context of arable land and the fertility for crop production. The perception of soil as an environmental medium providing substantial goods and services for all land and aquatic ecosystems has developed over the last decades.

Soil forms a continuum that comprises many biological, chemical and physical characteristics. A marked spatial and temporal variability of soil characteristics makes building soil classification difficult. In addition, there is a common opinion that different soil classifications result in different pattern of soil representation: different soil maps.

The current report overviews soils of the European Union classified in a new standard which is the World Reference Base for Soil Resources (WRB; FAO 1998). This system originates from the approach of the FAO to correlate soil resources globally. The advantage of using the system of the FAO is that the soil resources of the European Union are integrated into the world-wide context.

This volume provides an in depth summary of the current position regarding the detail and availability of soil information, particularly spatial data at the EU level. This edition of the Soils of the European Union incorporates chapters on all major soil types of the Member States of the EU, including those countries that joined the Union in 2007. In order to provide full global reference the authors introduced a grouping of soils of the EU related to basic soil-forming factors that are known as "Sets" of soils (FAO 2001). This soil classification is useful for ecological interpretation of soil resources.

Our current efforts are closely linked to previous publications on the soils of Europe, notably, on the 1:4.5 M wall chart that gave the first view of European soils based on the WRB (EC 2001), on the report of the soil resources in Europe (Jones et al. 2005) and the Soil Atlas of Europe (ESBN-EC 2005). These publications are results of the recent cooperative activities of the European Soil Bureau Network and the Joint Research Centre of the European Commission.

The intention of the JRC is that within the newly establishes European Soil Data Center, an enhanced soil information on the soils of the European Union will become accessible to the public both on-line and in printed format. The publication of this report is part of this process, which is hoped to contribute to the protection of soil resources in Europe in accordance with the Thematic Strategy of Soil Protection.

2. Materials and methods

2.1 Soil Geographical Database of Eurasia at scale 1:1,000,000 (SGDBE)

The Soil Geographical Database of Eurasia (SGDBE) has been used as the original source of information for our current soil mapping efforts.

The Soil Geographical Database of Eurasia at scale 1:1,000,000 is part of the European Soil Information System (van Liedekerke *et al.* 2004, Panagos 2006) and is the resulting product of a collaborative project involving soil survey institutions and soil specialists in Europe and neighboring countries.

The SGDBE consists of both a geometrical dataset and a semantic dataset (set of attribute files) which links attribute values to the polygons of the geometrical dataset. How map polygons, SMU's and STU's are linked together is illustrated in the Figure 1.

The database contains a list of Soil Typological Units (STU). Besides the higher level soil taxonomic classification units represented by a soil name, these units are described by variables (attributes) specifying the nature and properties of the soils: for example the texture, the water regime, the stoniness, etc. In our current soil mapping exercise we process the soil taxonomic component (first level taxonomic classes: Reference Soil Groups; second level taxonomic classes: soil units, composed by RSGs and qualifiers) included in the STU.

The geographical representation was chosen at a scale corresponding to the 1:1,000,000. At this scale, it is not feasible to delineate the STUs. Therefore they are grouped into Soil Mapping Units (SMU) to form soil associations and to illustrate the functioning of pedological systems within the landscapes. Each SMU corresponds to a part of the mapped territory and as such is represented by one or more polygons in a geometrical dataset. (Figure 2.1)

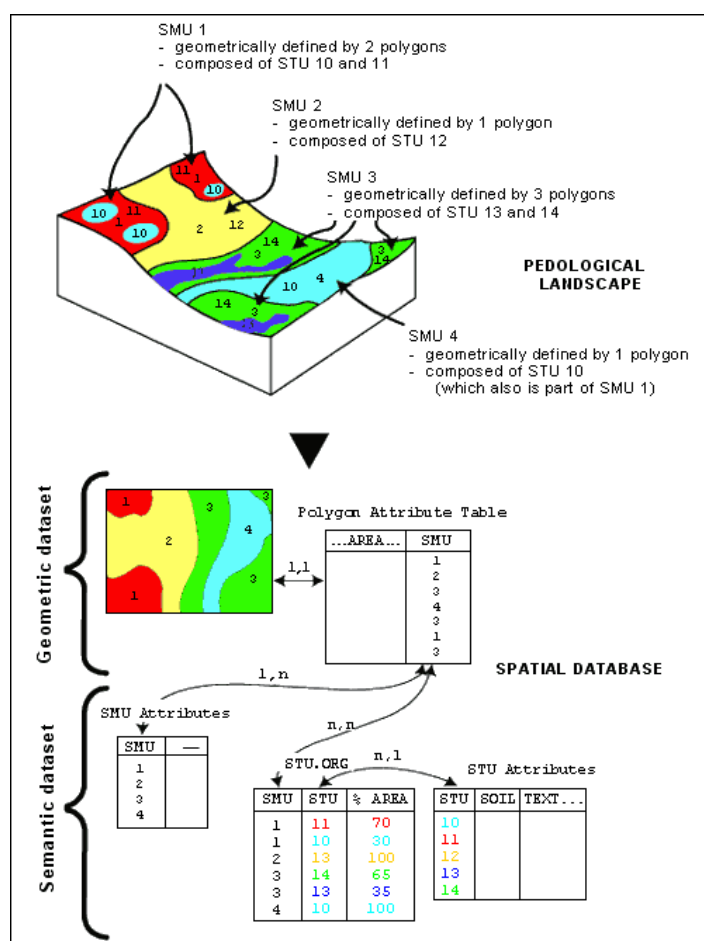


Figure 2.1 Information organization in the Soil Geographical Database of Europe (EC 2003)

Harmonization of the soil data from the member countries is based on a dictionary giving the definition for each occurrence of the variables. Considering the scale, the precision of the variables is weak. Furthermore these variables were estimated over large areas by expert judgment rather than measured on local soil samples. This expertise results from synthesis and generalization tasks of national or regional maps published at more detailed scales, for example 1:50,000 or 1:25,000 scales. Delineation of the Soil Mapping Units is also the result of expertise and experience. Heterogeneity can be considerable in European regions.

The spatial variability of soils is very important and is difficult to express at global levels of precision. Quality indices of the information (purity and confidence level) are included with the data in order to guide usage.

The Joint Research Centre (JRC) of the European Commission has developed a CDROM with full documentation of the SGDBE. The detailed documentation contains:

- Brief introduction
- Metadata (general description of the database (purpose, history, etc.).)
- Database dictionary (implementation details of the database structure in the ArcInfo GIS software environment)
- Attribute coding (detailed description of the database attribute values)

The documentation is provided in two levels of details:

- Easy Access to the Soil DB (for all the users)
- Advanced Access to the Soil DB (for experts users)

This detailed documentation can be found on-line in (JRC2008): http://eusoils.jrc.it/ESDB_Archive/ESDBv2/index.htm

Additionally, raster maps have been created with a cell size 10 km x 10 km and 1 km x 1 km. The Raster Library of the European Soil Data Center provides public access and data descriptions to these maps on the EUsoils website: <http://eusoils.jrc.it> (Panagos *et al.* 2006)

2.2 The working dataset

For an easy application of the database a dataset conversion has been performed.

Based on the non-spatial components of the Soil Geographical Database of Europe (SGDBE) a new GIS dataset was created for the analysis. The polygon attribute table of SGDBE (the attribute table of the spatial component) was extended by the stored information of all the occurring Soil Typological Units (STUs) within the given Soil Mapping Unit (SMU). In the case of the soils of the European Union only one SMU is linked to 10 STUs; marking the highest number of possible diversity.

The polygon attribute table resulted by sequential table-operations (SQL) contains the same number of records (and of course soil polygons) as the original spatial component of the SGDBE but the new polygon attribute table also contains the 32 descriptive attributes of the linked, maximum 10 Soil Typological Units.

In general, from conceptual point of view of databases and regarding the stored redundant information it is not "economical" to have such a complex table in the database, not to mention that because of the majority of the soil polygons and Soil Mapping Units can be characterized by less than 10 STUs many fields in the complex table are empty. On the other hand the elaborated GIS dataset is suitable for detached spatial queries making the analytical process faster and in this way probably more efficient.

Polygons of the elaborated GIS dataset bijectively related to the attribute table with the semantic information provided the basic spatial elements for the further analyses.

Polygons in the area of the European Union and related semantic information were selected for the working dataset.

The attributes of the polygon attribute table we applied for the mapping is explained in the Appendix 4.

2.3 Nomenclature of soil types

The Soil Geographical Database of Eurasia (SGDBE) contains information on soil name and soil characteristics. The methodology originally used to differentiate and name the main soil types is based on the terminology of the FAO legend for the Soil Map of the World at scale 1:5,000,000 (FAO et al. 1974, 1990). This terminology has been refined and adapted to take account of the specificities of the landscapes in Europe. The FAO legend is itself founded on the distinction of the main pedogenetic processes leading to soil differentiation: brunification, lessivage, podzolisation, hydromorphy, etc.

The Scientific Committee of the European Soil Bureau decided to use both the World Reference Base for Soil Resources (WRB; FAO 1998), as recommended by the International Union of Soil Sciences, and the FAO 1990 Soil Legend (FAO 1990) for defining soil names of the Soil Typological Units of the database.

Since the last update of the SGDBE, a new edition of the WRB has been published (FAO 2006) with structural changes in the designation of Reference Soil Groups and introducing two new Reference Soil Groups (Technosols and Stagnosols), new qualifiers, and changes in the application of qualifiers. The SGDBE holds data based on the correlation of soil types of the national soil inventories according to the 1998 edition of the WRB. Therefore, we present the areal specification of soil units with their name according to the scheme of the 1998 edition of the WRB.

Nevertheless, the WRB is the most important reference for harmonization. Therefore, in our current work we provide an approximate correlation between the WRB 1998 and 2006 soil nomenclatures for soils of the European Union derived from the SGDBE (Appendix 1.).

Significant feature of the WRB is that it uses two main levels of soil identification. The 'Reference base' is limited to the first level only, having 30 Reference Soil Groups (RSGs). Twenty-three of the thirty Reference Soil Groups of the WRB can be found in the SGDBE with relevance to the European Union (see Table 3.1 in Chapter 3). Based on their dominant soil forming factor or condition RSGs are clustered to ten sets (Appendix 2).

Soil units are presented on the second level of the hierarchy. Soil units are composed by the combination of Reference Soil Groups with qualifiers. Qualifiers correspond to special characteristics affecting the primary soil features. Qualifiers are included in the soil name (as prefix or suffix of the RSG) and allow a more accurate description of soil. The WRB is a non-hierarchical system (Krasilnikov 2002), hence, it sets priorities for sequencing qualifiers thus recognizing the different importance of certain soil characteristics within the RSGs. Description of the qualifiers with relevance to the soils of the European Union is presented in Appendix 3.

2.4 Map legend and representation

This report presents an overview map and 23 detailed map sheets. The overview map provides a synopsis of the main Reference Soil Groups of the EU in their spatial pedological context. The supplementing 23 maps sheets show detailed information on the extent of each RSG and their soil units in the EU. Maps of soil units are prepared on the 1:1 million scale and presented in this volume on the A4 size sheets (approximately 1:22.500.000 scale). Based on the electronic edition of this volume map sheets can be reproduced with a maximum precision of scale on 1:1 million. (for downloads see: <http://eussoils.jrc.ec.europa.eu/>)

The SGDBE segment for the European Union contains over 24000 individual polygons as basic spatial units of soil mapping in our analysis. A polygon can be composed of one dominant soil type or one or more component soil unit(s).

The legend of the Soil Map of the European Union comprises 93 soil units grouped into 23 Reference Soil Groups (of 10 sets). Map sheets present classified areal proportion of each soil units within the polygons.

Two methods have been applied for representation of soil patterns on maps:

- 1) for the general overview map
- 2) for detailed map sheets

1) In the case of the overview map, only a single RSG is shown for each polygon. Generally this is defined as the one with the largest area cover within the polygon (either dominating the entire area or having the largest extent among a number of component soils). This approach is based on the methodology used for the original Soil Map of the European Communities (CEC 1985) and the original Soil Map of the World (FAO 1985). The colors corresponding to each Reference Soil Group are those used by the JRC for past projects (1:4.5M, Soil Atlas of Europe) and are based on the color chart of the Food and Agricultural Organization (FAO) with slight modification. An alphabetical list of Reference Soil Groups together with their areal extends and proportional share within the European Union is given in Table 3.1.

In the case of several soils have equally high share (e.g. 50-50 % or 40-40 %) in the areal coverage within a polygon, the first Reference Soil Group in the alphabetical order will be selected as dominant.

2) In the cases of the detailed map sheets, 10 classes of dominant, associated and inclusion soils are distinguished. The classes represent the share of the RSG within the polygon with 10 % increases between them with an accuracy of 1%, based on the precision of the SGDBE. (Table 2.1)

Based on the data available in the SGDBE, the maximum number of component soil units within a polygon is ten. The colours are selected for the easy visualization and comparison of the extent of different soil units within the mapped polygons.

Table 2.1 Composition of Reference Soil Groups on the map sheets of the Soil Map of the European Union

Soil component according to FAO (1985)	% of area Map sheets <i>Soils of the European Union</i>	Color of representation Map sheets <i>Soils of the European Union</i>
Dominant Soil	91-100	dark
	81-90	
	71-80	
	61-70	
	51-60	
Associated Soil	41-50	↓
	31-40	↓
	21-30	↓
Soil Inclusion(s)	11-20	light
	1-10	

Further to the representation of Reference Soil Groups on map sheets, information is provided for each second level unit of the RSGs, including name and its symbol, together with the areal extend of the soil unit in the European Union (Tables 4.1 – 4.23.) and proportional share within the RSG (Figures 4.1 – 4.23).

The projection of the maps is the “GISCO Lambert System” (GISCO, 2001) which is a metrical Lambert Azimuthal Equal Area system given by the following parameters:

- Projection: LAMBERT_AZIMUTHAL
- Units: METRES
- Spheroid: SPHERE
- Parameters:
 - radius of the sphere of reference (metres): 6378388.0
 - longitude of centre of projection: 9° 0' 0.0''
 - latitude of centre of projection: 48° 0' 0.0''
 - false easting (metres): 0.0
 - false northing (metres): 0.0

Characterization of soils

The authors of this report followed a uniform presentation format for the characterization of the soils of the EU, including

1, Description of the geographic distribution of soils (“Geographical distribution”)

- supported by map sheets showing spatial extension of the Reference Soil Groups
- supported by written explanation of spatial location of second level units

2, Descriptions of the main pedological features, global extend and related international names of European soils (“Global reference”). This section is largely based on:

- Soil Map of the European Communities 1:1 000 000 (CEC 1985)
- Lecture Notes on the Major Soils of the World (FAO 2001)
- World reference base for soil resources (FAO 1998)

3. Soils of the European Union: an overview

A great variety of climatic, topographical and geological conditions, together with the diverse anthropogenic influences has resulted in a diverse soil cover in Europe (Map 3.1). The fact that twenty-three out of the total of thirty Reference Soil Groups (WRB 1998) of the world have representative in the EU shows the magnitude of this diversity. However, not all soil types have the same share in the soil coverage of the EU. While the most widespread Reference Soil Group – Cambisols – has a proportion of nearly 27 % of the total area, Umbrisols can be found on very limited areas (329 km²). Table 3.1 shows the summarized extent of Reference Soil Groups in the EU.

Table 3.1 Spatial extent of Reference Soil Groups (WRB 1998) in the European Union

Reference Soil Group	km ²	% of the total
Acrisols	10626	0.26
Albeluvisols	76865	1.85
Andosols	8705	0.21
Anthrosols	3428	0.08
Arenosols	149776	3.61
Calcisols	9288	0.22
Cambisols	1107598	26.71
Chernozems	78492	1.89
Fluvisols	221669	5.35
Gleysols	219781	5.30
Gypsisols	4110	0.10
Histosols	268741	6.48
Kastanozems	3532	0.09
Leptosols	435713	10.51
Luvissols	610941	14.74
Phaeozems	70439	1.70
Planosols	18981	0.46
Podzols	566874	13.67
Regosols	222322	5.36
Solonchaks	11728	0.28
Solonetz	9857	0.24
Umbrisols	329	0.01
Vertisols	36447	0.88
Total soil cover:	4146242	100

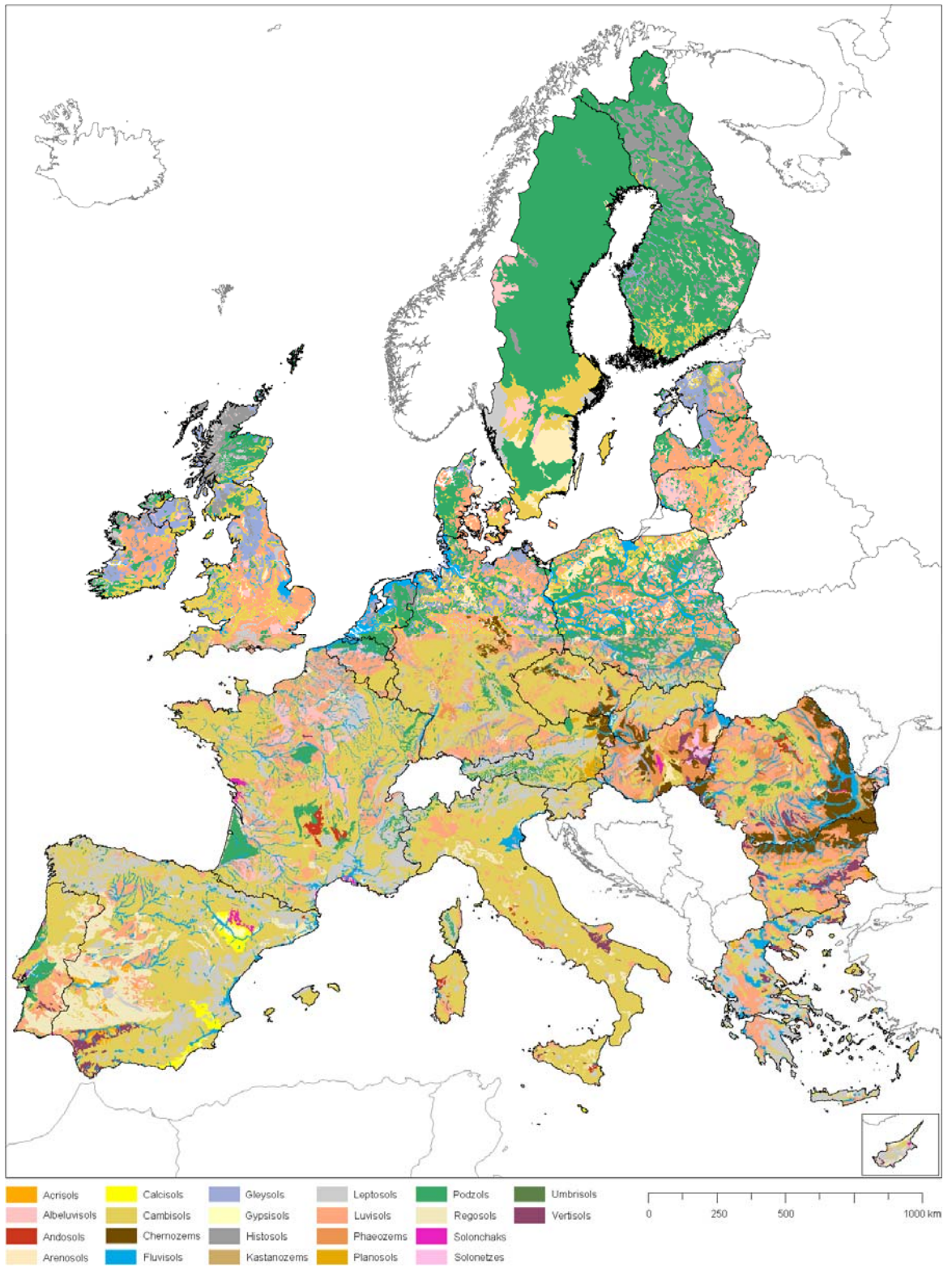
As can be seen from the table, the soils sum up to 4,146,242 km², thus to more than 95 % of the total surface area (4,324,782 km²) of the EU. The remaining 5% is occupied by the non-soil land cover types such as large continuous built up areas, water bodies and glaciers.

Twenty-two Reference Soil Groups are dominant (≥ 50 %) in some or in several mapping units. Anthrosols are exceptions; as this Reference Soil Group never dominates mapping units at the 1:1 million scale in Europe.

Following the Cambisols Reference Soil Group the second most widespread is that of Luvisols. Luvisols, like Cambisols, can be found in all parts of the continent in associations with other Reference Soil Groups. Podzols have similar area to Luvisols. However, this Reference Soil Group is mainly concentrated in northern Europe. Leptosols, the fourth largest Reference Soil Group, on the contrary, have smaller shares in the northern regions. Spatial extent of Histosols, Regosols, Fluvisols, Gleysols and Arenosols ranges around 5 % within the EU. However, while Histosols, Gleysols and Arenosols are predominantly soils of the Northern regions, most of Regosols can be found in the southern parts of Europe. Fluvisols are predominant in the river basins in all parts of the continent. Albeluvisols have similar areal coverage (~ 2%) with Chernozems and Phaeozems, however fundamentally different pedological features. Reference Soil Groups with smaller areal extent (< 1%) include soils with special abilities for performing important soil functions.

Map 3.1

DOMINANT REFERENCE SOIL GROUPS (WRB 1998)
IN THE EUROPEAN UNION



Following the approach of the FAO (2001) Reference Soil Groups can be arranged to sets, based on their dominant identifiers i.e. major soil forming factors (Table 1., Appendix 2.). When looking on soils from the viewpoint of the most important soil forming factors, we can observe the main patterns of soil formation in Europe (Figure 3.1)

In this view three main drivers dominate soil forming processes in the EU. More than four fifths (~ 84%) of the area of the EU is mainly influenced by the (sub-)humid temperate climate, the topography/phisiography of the terrain or by the limited time of soil formation.

The largest spatial extents (with over 30% of the land areas of the EU) have those mineral soils, of which the development is mainly conditioned by the climatic effects of the sub-humid temperate regions.

The second most widespread set is that with less developed mineral soils (Cambisols), with 26.71% share from the total area. Topography dominating soil formation of mineral soils on 26.52% of the land surface of the EU. However, most of organic soils (set 1, Histosols, 6.48%) are developed on flat lands as well, thus under the strong influence of (leveled) topography. However, main feature of Histosols is the high organic matter content, and therefore are considered as a separate set.

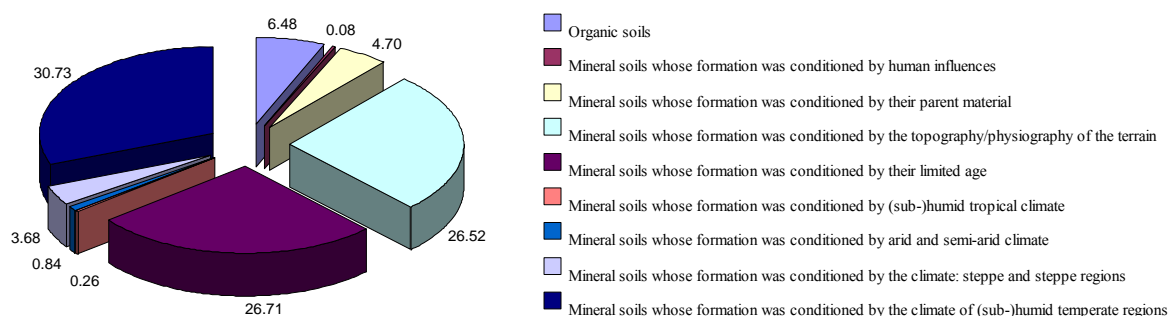


Figure 3.1 Share of soil sets by dominant identifiers in the European Union (%)

The dominating influence of parent material is evident on less than 5% of the areas having similar extent to those zonal soils which receive strong influence of continental (steppe region) climate. The importance of all soil forming factors in the genesis of soils has to be emphasized; for example, topography and parent material play a key role in the formations of steppe soils as well (e.g. Chernozems develop on level land). However soils in these set can only be found under specific climatic zone. Aridity (and the particular chemical composition of the soil solum) is a prerequisite for the genesis of soils in the 7th set which occupies approximately 0,80% in the EU. Another soil formation process is driven by the warm and (sub)humid climates. Acrisols found in these regions – having a small share of 0.26% in the EU’s total soil resources – contribute greatly to the pedological and ecological diversity of Europe.

There is hardly any part of the EU which is free from human impact, including soil management since ancient times. However, Anthrosols, where man has taken the role of dominating soil forming factor can be delineated only in limited areas in the continental scale soil survey (0.08%).

4. Spatial distribution of the major soils in the European Union

4.1 Acrisols

Geographical distribution

Acrisols cover about 10,000 km², 0.26% of the surface area of the EU. Most of the European Acrisols are located as associated soils on the Iberian Peninsula and in Greece, but also can be found in Southern England, Denmark and in limited areas in Romania and Bulgaria. They form the dominant soil in six associations and occur as associated soils in 70 associations and as inclusions in 372 cases.

Five soil units of the Acrisols Reference Soil Group can be found in the EU with Gleyic Acrisols and Haplic Acrisols occupying more than 90% of their area (Table 4.1, Figure 4.1).

Table 4.1 Area of the second level units of Acrisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Ferric Acrisol	ACfr	178
Gleyic Acrisol	ACgl	3359
Haplic Acrisol	ACha	6277
Humic Acrisol	AChu	803
Plinthic Acrisol	ACpl	10

Ferric Acrisols with their rather small area coverage can be found in Southern Portugal. Gleyic Acrisols occupy considerably larger areas and situated mainly on the south-western plains of Spain. **Haplic Acrisols** can be found in nearly all Acrisol areas of the EU, mostly as inclusions among other soils. **Humic Acrisols** are widespread in Denmark as associated soils. **Plinthic Acrisols** have very small spatial extend which is limited to some inclusions in soil associations in Portugal.

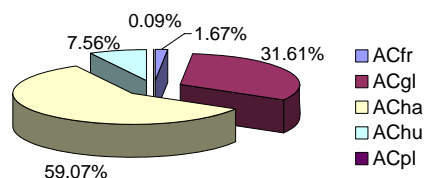


Figure 4.1 Share of the second level soil units in the area of Acrisols

Global reference

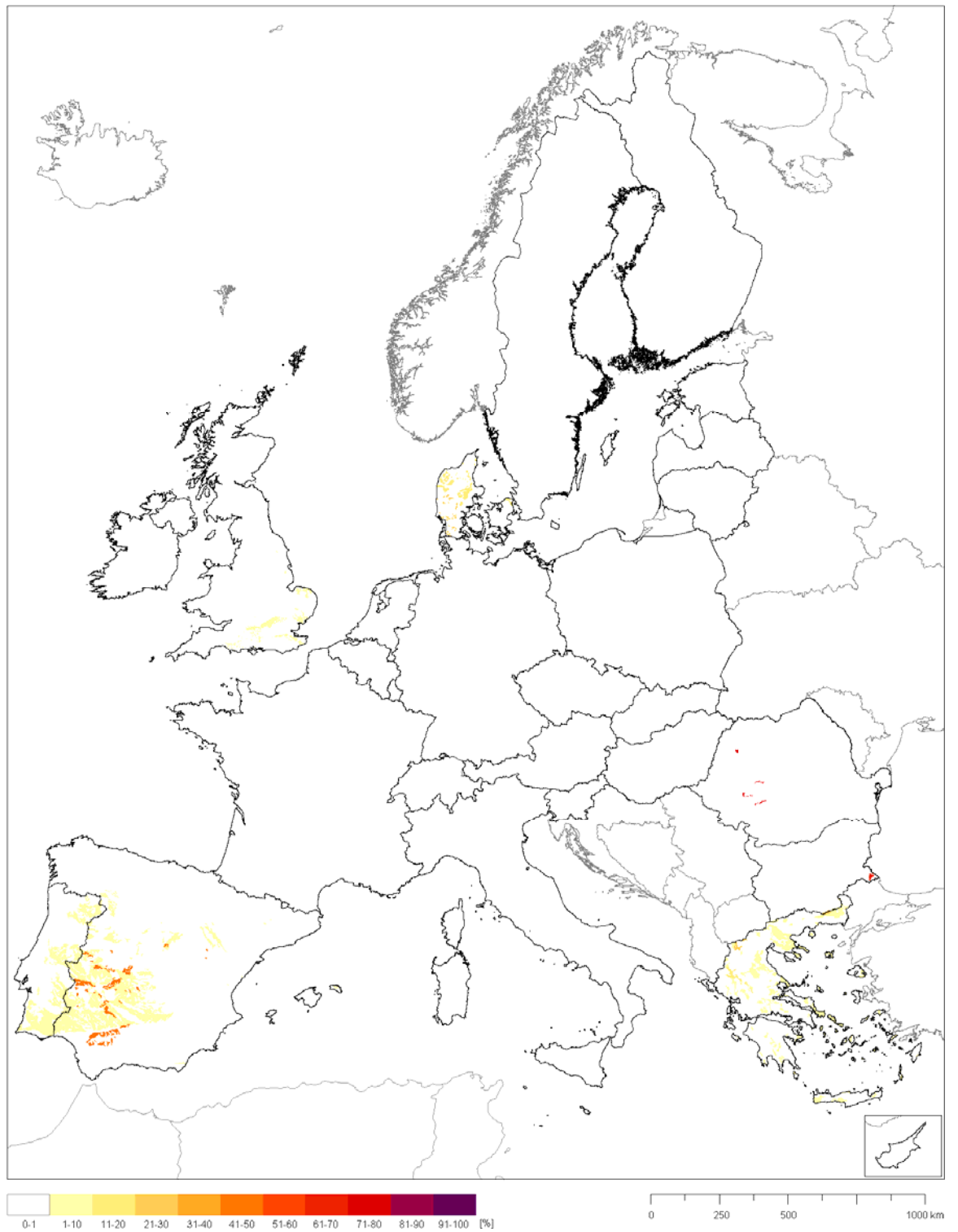
Acrisols are highly weathered soils occurring in warm temperate regions and the wetter parts of the tropics and subtropics. Acrisols develop mostly on old land surfaces with hilly or undulating topography with a natural vegetation type of a light forest. Being quite sensitive to erosion, Acrisols are often the dominant soil group on old erosional or depositional surfaces. There are approximately 10 million km² of Acrisols world-wide.

Acrisols can be characterized by accumulation of low activity clays in an argic subsurface horizon and by a low base saturation level. The chemical properties of Acrisols are quite poor, containing low level of nutrients and high levels of aluminum. These conditions mean rather limited soil use options.

Acrisols correlate to several subgroups of Alfisols and Ultisols of the Soil Taxonomy of the USDA, Desaturated Ferralitic Soils of France and are similar to Red-Yellow Podzolic soil in Indonesia.

Map 4.1

ACRISOLS IN THE EUROPEAN UNION



4.2 Albeluvisols

Geographical distribution

Albeluvisols cover more than 75,000 km² in the EU, spanning from the Atlantic coast of France to the Baltic States. Distribution of Albeluvisols follows a climatic pattern with cold winters and precipitation evenly spread during the year. Albeluvisols form soil associations in 1,755 polygons; in 537 cases as dominant, in 593 cases as associated and in 625 cases as inclusion soils. While being associated mainly with Luvisols and Podzols in most parts of Western and Northern Europe, Albeluvisols dominate in some regions in south-western France, Belgium and in Lithuania.

The Reference Soil Group of Albeluvisols in the EU is composed by units of Endoeutric-, Gleyic- and Haplic soil types (Table 4.2, Figure 4.2)

Table 4.2 Area of the second level units of Albeluvisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Endoeutric Albeluvisol	ABeun	30769
Gleyic Albeluvisol	ABgl	21176
Haplic Albeluvisol	ABha	24921

Endoeutric Albeluvisols are dominant at their occurrence in South-Western France and in the Baltics. **Gleyic Albeluvisols** dominate the coastal areas of Lithuania, have considerably high share in Central-France and are present in Romania, Slovakia and Poland, Germany and Belgium. **Haplic Albeluvisols** are found in the UK, Germany, Denmark, Poland, Lithuania, France and Belgium but have dominant proportion only in limited parts of the later three countries.

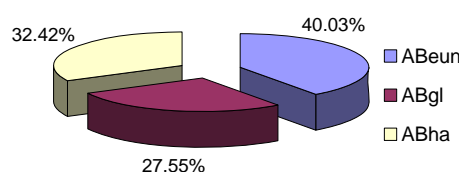


Figure 4.2 Share of the second level soil units in the area of Albeluvisols

Global reference

Albeluvisols generally develop on flat or undulating plains of unconsolidated glacial till, materials of lacustrine or fluvial origin and of aeolian deposits (loess) under harsh climate with precipitation of 500-1000 mm/year evenly distributed over the year or with a peak in the beginning of the summer. Most Albeluvisols occur under forest.

Albeluvisols cover an estimated 3.2 million km² in Europe, North Asia and Central Asia, with minor occurrences in North America.

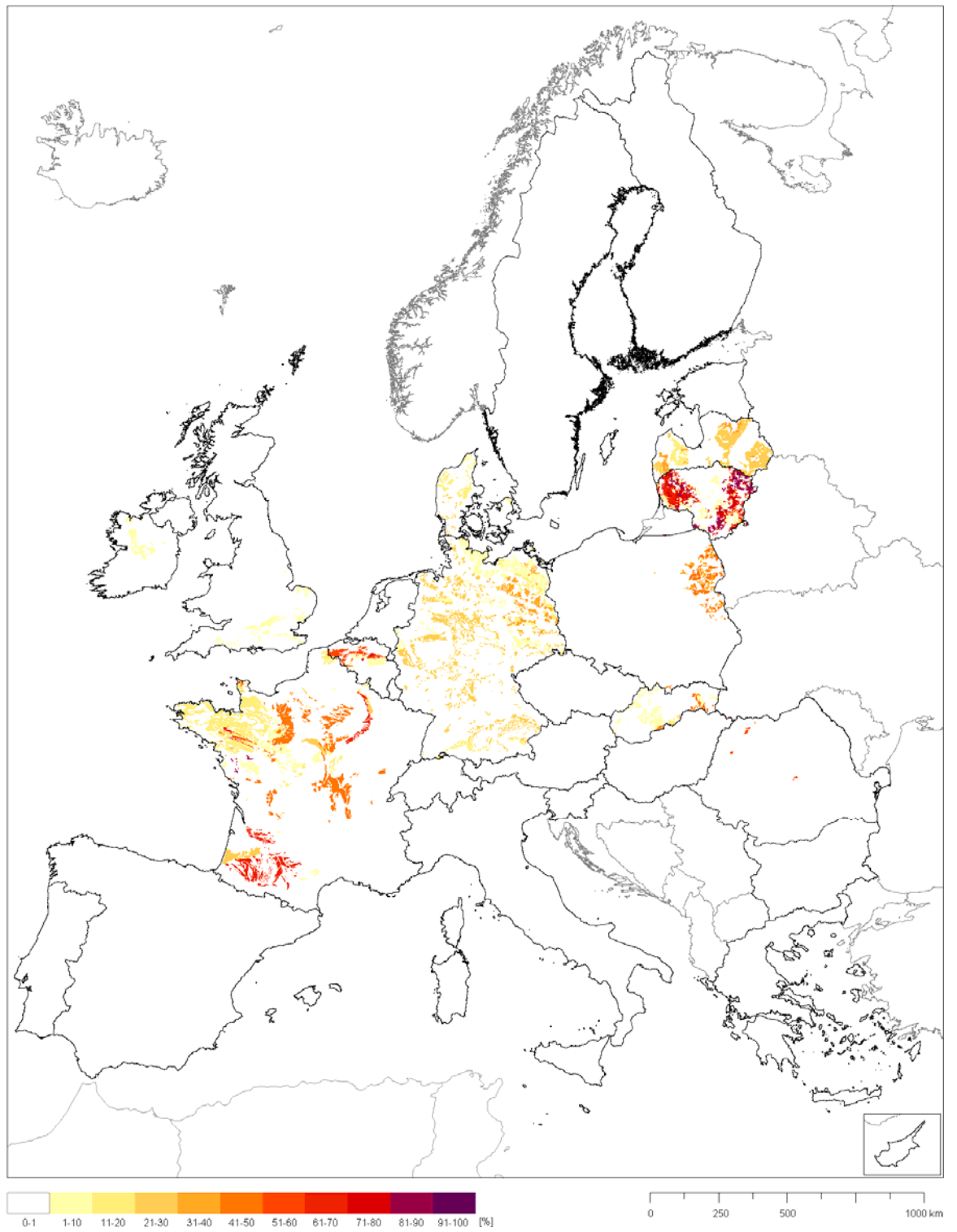
Profiles of Albeluvisols have a dark, thin ochric surface horizon over an albic subsurface horizon that tongues into an underlying brown clay illuviation horizon. Stagnic soil properties are common in boreal Albeluvisols.

Low nutrient status, acidity, tillage and drainage problems are serious limitations for the use of Albeluvisols, which are extended by the short growing season.

Common international names are Podzoluvisols (FAO), Derno-podzolic or Ortho-podzolic soils (Russia) and several suborders of the Alfisols (Soil Taxonomy).

Map 4.2

ALBELUVISOLS IN THE EUROPEAN UNION



4.3 Andosols

Geographical distribution

Andosols cover some 0.21% of the surface of the EU (8,705 km²). Large continuous areas with Andosols are found in the Massif Central of France, in the North-Eastern Carpathians in Romania and in the coastal volcanic areas of Sardinia and continental Italy. They form the dominant soil in 37 associations and occur as associated or inclusion soils in 22 associations.

Four soil units of the Andosol Reference Soil Group are present in the EU with Dystric Andosol occupying nearly half of the total area of Andosols (Table 4.3, Figure 4.3)

Table 4.3 Area of the second level units of Andosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Dystric Andosol	ANdy	3924
Umbric Andisol	ANum	2625
Mollic Andosol	ANmo	1224
Vitric Andosol	ANvi	932

Dystric Andosols are dominant among the Andosols in France. They form inclusions in the Andosol-covered areas of the Carpathians and are also present in the Western Pyrenees. In regions of the EU where Andosols are present **Umbric** units can always be found in associations with other soils (with other units of Andosols as well!). On a continental scale **Mollic Andosols** never dominate soil associations, however, they are present with considerably high share in Italy and as inclusion soils in France. The overall situation of **Vitric Andosols** are similar to that of Mollic Andosols. However, besides being inclusion soil in large regions of Italy, they are in association only in a very limited area in the Massif Central of France.

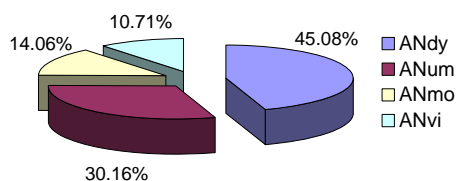


Figure 4.3 Share of the second level soil units in the area of Andosols

Global reference

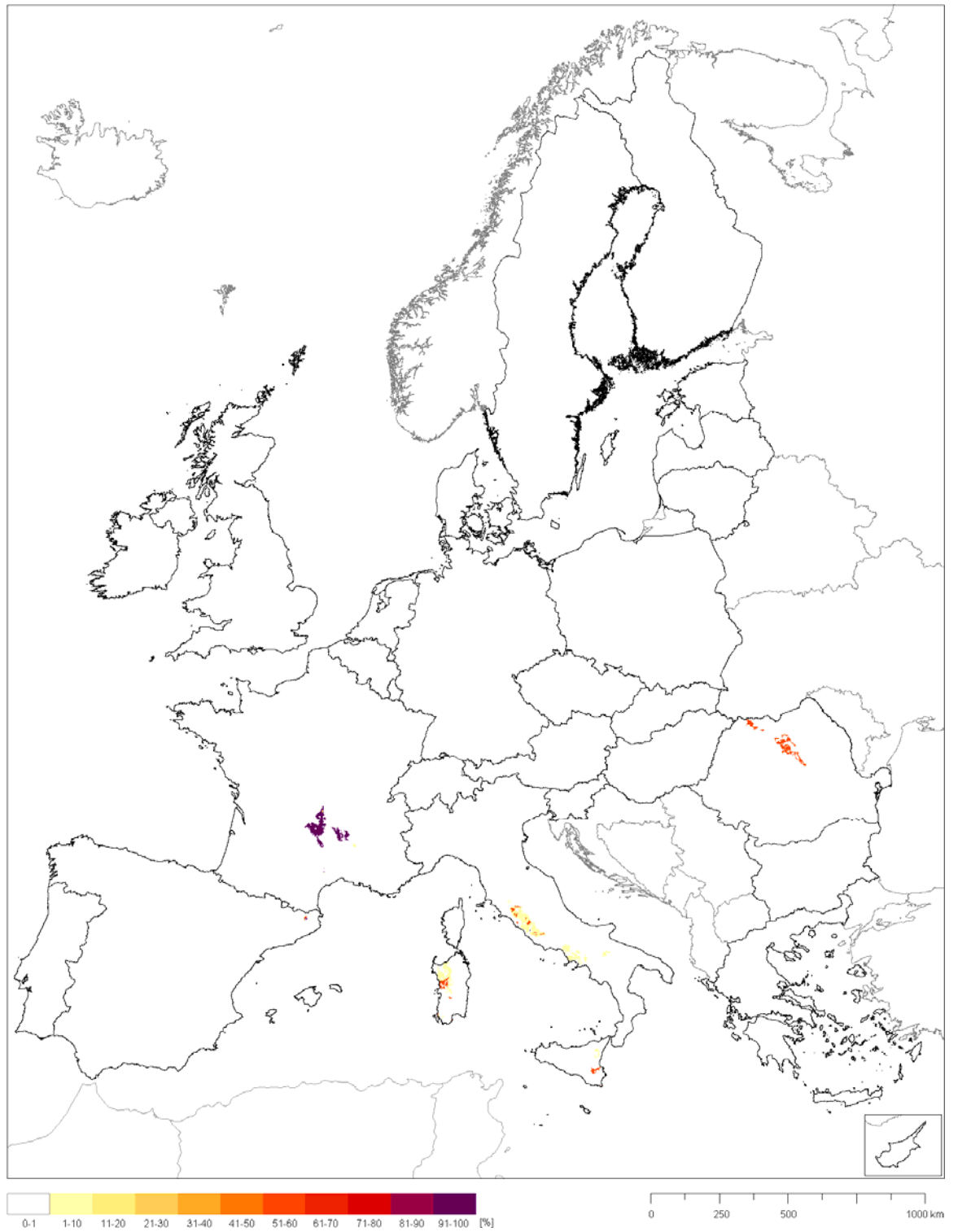
Andosols are azonal soils developed on volcanic deposits and are found in all climates and at all altitudes in volcanic regions all over the world. The total Andosol area is estimated at some 1.1 million km² or less than 1% of the global land surface. Andosols are characterised by the presence of either an andic horizon or a vitric horizon. An andic horizon is rich in allophanes (and similar minerals) or aluminium-humus complexes whereas a vitric horizon contains an abundance of volcanic glass.

Andosols typically have a dark humic A horizon on top of a brown B- or C-horizon. Topsoil and subsoil colours are distinctly different. The average organic matter content of the surface horizon is about 8% but some varieties may contain as much as 30% organic matter. The surface horizon is very porous and the good aggregate stability of Andosols and their high permeability to water make these soils both fertile and relatively resistant to water erosion.

Other international names are Andisols (Soil Taxonomy), Vitrisols (France) and volcanic ash soil.

Map 4.3

ANDOSOLS IN THE EUROPEAN UNION



4.4 Anthrosols

Geographical distribution

Based on the SGDBE Anthrosols cover some 3,500 km² in the EU, predominantly around Belgium, the Netherlands and, to a smaller extent, in north-west Germany. Anthrosols form associations mostly with Podzols, Gleysols and Arenosols (29 times as associated and 15 times as inclusion soils).

Based on the 1:1 M scale database all Anthrosols in the EU fall into the Plaggic Anthrosol unit. (Table 4.4, Figure 4.4)

Table 4.4 Area of the second level units of Anthrosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Plaggic Anthrosol	ATpa	3427

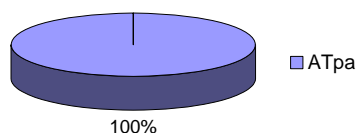


Figure 4.4 Share of the second level soil units in the area of Anthrosols

Global reference

The Reference Soil Group of the Anthrosols holds soils that were formed or profoundly modified through human activities such as addition of organic materials or household wastes, irrigation or cultivation.

Plaggic Anthrosols have the characteristic horizon plaggic produced by long-continued addition of 'pot stable' bedding material, a mixture of organic manure and earth. The man-made character of the plaggic horizon is evident from fragments of brick and pottery and/or from high levels of extractable phosphorus (more than 250 mg P₂O₅ per kg by 1% citric acid).

The formation of most plaggic horizons started in the medieval times when farmers applied a system of 'mixed farming' combining arable cropping with grazing of sheep and cattle on communal pasture land. In places, the system was in use for more than a thousand years evidenced by a plaggic horizon of more than 1 meter in thickness

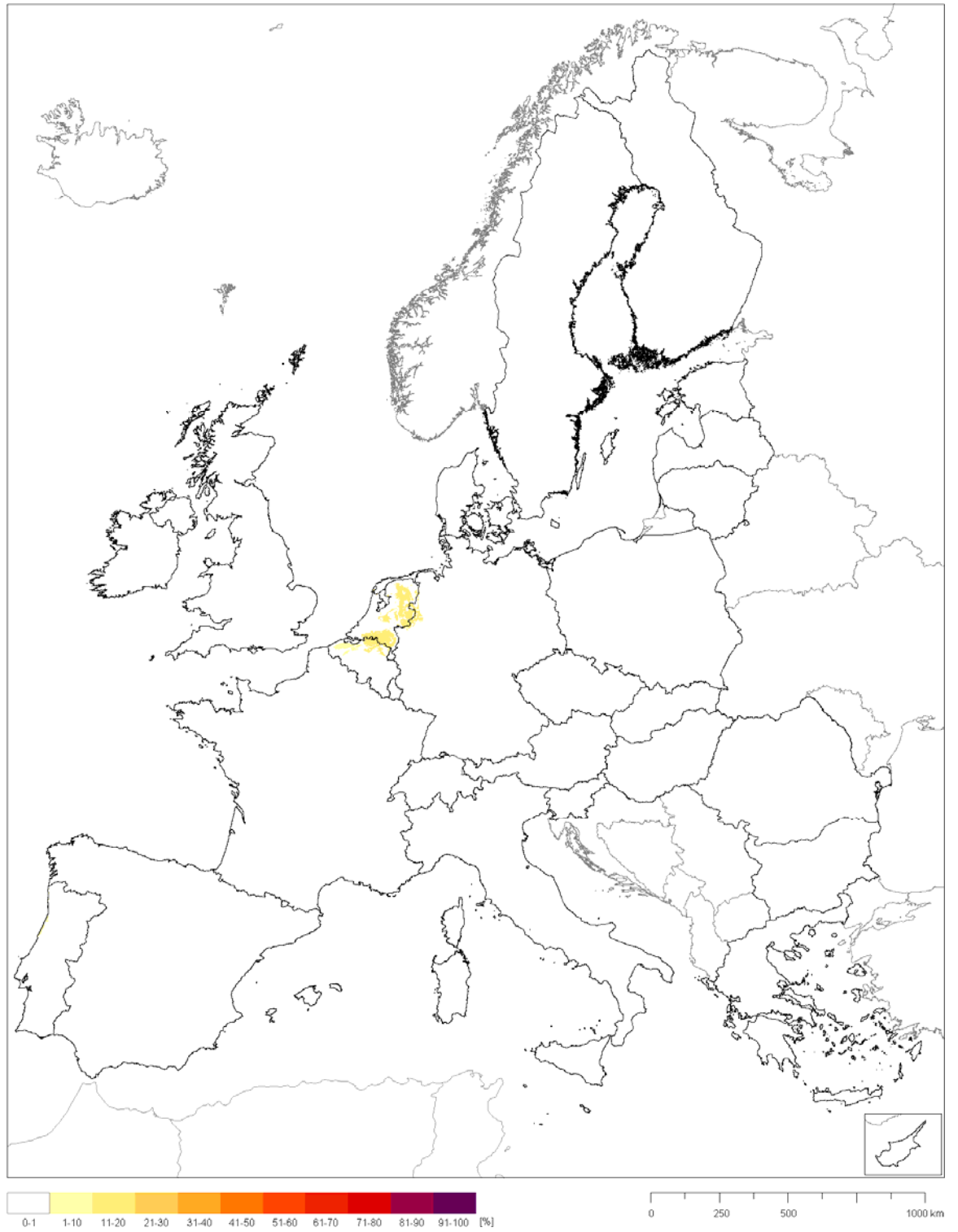
Plaggic and Terric Anthrosols are well-drained because of their thickened A-horizon

The physical characteristics of plaggic and terric horizons are excellent: penetration resistance is low and permits unhindered rooting, the pores are of various sizes and interconnected and the storage capacity of available soil moisture is high if compared to that of the underlying soil material. Mild organic matter in the surface soil stabilizes the structure of the soil and lowers its susceptibility to slaking. The upper part of a plaggic or terric horizon may become somewhat dense if tillage is done with heavy (vibrating) machinery.

Different varieties of Anthrosols are also known as Plaggen soils, Paddy soils, Oasis soils and Terra Preta do Indio.

Map 4.4

ANTHROSOLS IN THE EUROPEAN UNION



4.5 Arenosols

Geographical distribution

Arenosols cover approximately 145,000 km² corresponding to 3.61% of the land surface of the European Union. Major areas of Arenosols are located on the north-eastern regions of the EU. However, certain regions in Central Europe, the UK, France, Portugal and Spain are also covered by Arenosols. In 340 cases Arenosols form the dominant soil reference group, in 1061 cases as associated soil and in 1,229 times as inclusions in the soil associations (of the continental scale assessment).

Three soil units of the Arenosol Reference Soil Group, dominated by Haplic Arenosol, are present in the EU (Table 4.5, Figure 4.5)

Table 4.5 Area of the second level units of Arenosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Albic Arenosol	ARab	4317
Haplic Arenosol	ARha	145354
Protic Arenosol	ARpr	106

Albic Arenosols occur in two regions: in north-west Germany (Lower Saxony and Schleswig-Holstein) and in the western part of Latvia. As associated soils in the former and as dominant soils and inclusions in the latter. The overall pattern of Arenosols (Map 4.5.) is very similar to its **Haplic** soil unit. **Protic Arenosols** are characteristic in a small area in the Danube Delta (Romania).

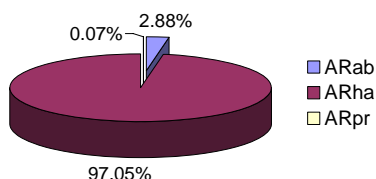


Figure 4.5 Share of the second level soil units in the area of Arenosols

Global reference

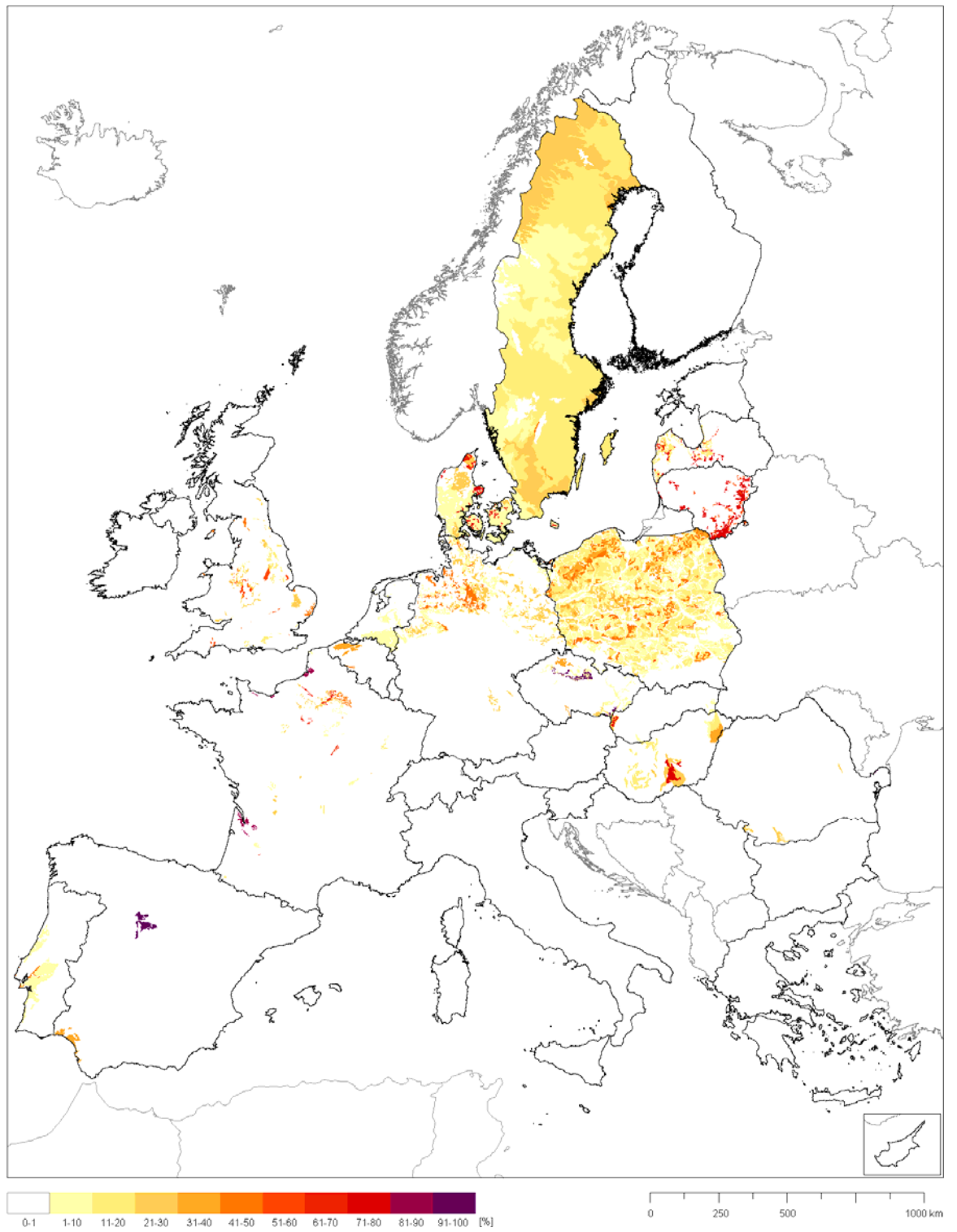
Arenosols are azonal soils with coarse texture to a depth of one meter or to a hard layer. They are developed both in residual sands, in situ after weathering of old, usually quartz-rich soil material or rock, and in recently deposited sands as occur in deserts and beach lands. Arenosols are present in all continents and cover around 7% of the earth surface (approximately 9 million km²) thus being one of the most common soil group in the world.

Arenosols in the Temperate Zone show signs of more advanced soil formation than Arenosols in arid regions. They occur predominantly in fluvio-glacial, alluvial, lacustrine, marine or aeolian quartzitic sands of very young to Tertiary age. Soil formation is limited by low weathering rate and frequent erosion of the surface. If vegetation has not developed, shifting sands dominate. Accumulation of organic matter in the top horizon and/or lamellae of clay, and/or humus and iron complexes, mark periods of stability. Arenosols are easily erodible with slow weathering rate, low water and nutrient holding capacity and low base saturation. However, the high permeability and easy workability qualifies these soils for high agricultural potential depending on the availability of water and fertilization.

Many Arenosols correlate with Psammments and Psammaquents of the Soil Taxonomy. In the French classification system, Arenosols correlate with taxa within the *Classe des sols minéraux bruts* and the *Classe des sols peu évolués*. Other international soil names to indicate Arenosols are siliceous, earthy and calcareous sands and various podsollic soils (Australia), red and yellow sands (Brazil) and the Arenosols of the FAO Soil Map of the World.

Map 4.5

ARENOSOLS IN THE EUROPEAN UNION



4.6 Calcisols

Geographical distribution

Calcisols cover less than 10,000 km², only 0.22% of the land surface of the European Union. Calcisols occur in two countries, being dominant on the islands of Malta and covering about 1.7% of total land area of Spain. The Reference Soil Group of Calcisol appears 34 times as dominant and 38 cases as associated (with rather high share of 30-50%) within their polygons.

Two soil units are represented in the European Union from the Calcisol Reference Soil Group, dominated (>95%) by Aridic Calcisol. (Table 4.6, Figure 4.6)

Table 4.6 Area of the second level units of Calcisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Aridic Calcisol	CLad	8972
Haplic Calcisol	CLha	317

Among the two soil units of the Calcisol Reference Soil Group *Aridic Calcisols* can be found in Spain, while the Maltese soils are fall into the *Haplic* category.

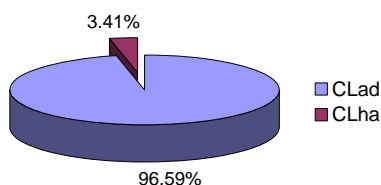


Figure 4.6 Share of the second level soil units in the area of Calcisols

Global reference

Calcisols are soil with significant accumulation of secondary calcium carbonates, generally developed in dry areas. Soils belonging to this Reference Soil Group are common on calcareous parent material in regions with distinct dry seasons, as well as in dry areas where carbonate-rich groundwater comes near the surface. The total Calcisol area amounts to some 10 million km², nearly all of it in the arid and semi-arid (sub)tropics of both hemispheres.

Many Calcisols are old soils if counted in years but their development was slowed down by recurrent periods of drought in which such important soil forming processes as chemical weathering, accumulation of organic matter and translocation of clay came to a virtual standstill. However, most Calcisols have substantial movement and accumulation of calcium-carbonate within the soil profile. The precipitation may occur as pseudomycelium (root channels filled with fine calcite), nodules or even in continuous layers of soft or hard lime (calcrete).

Most Calcisols have a thin (≤ 10 cm) brown or pale brown surface horizon over a slightly darker subsurface horizon and/or a yellowish brown subsoil that is speckled with white calcite mottles. The organic matter content of the surface soil is low, in line with the sparse vegetation and rapid decomposition of vegetal debris.

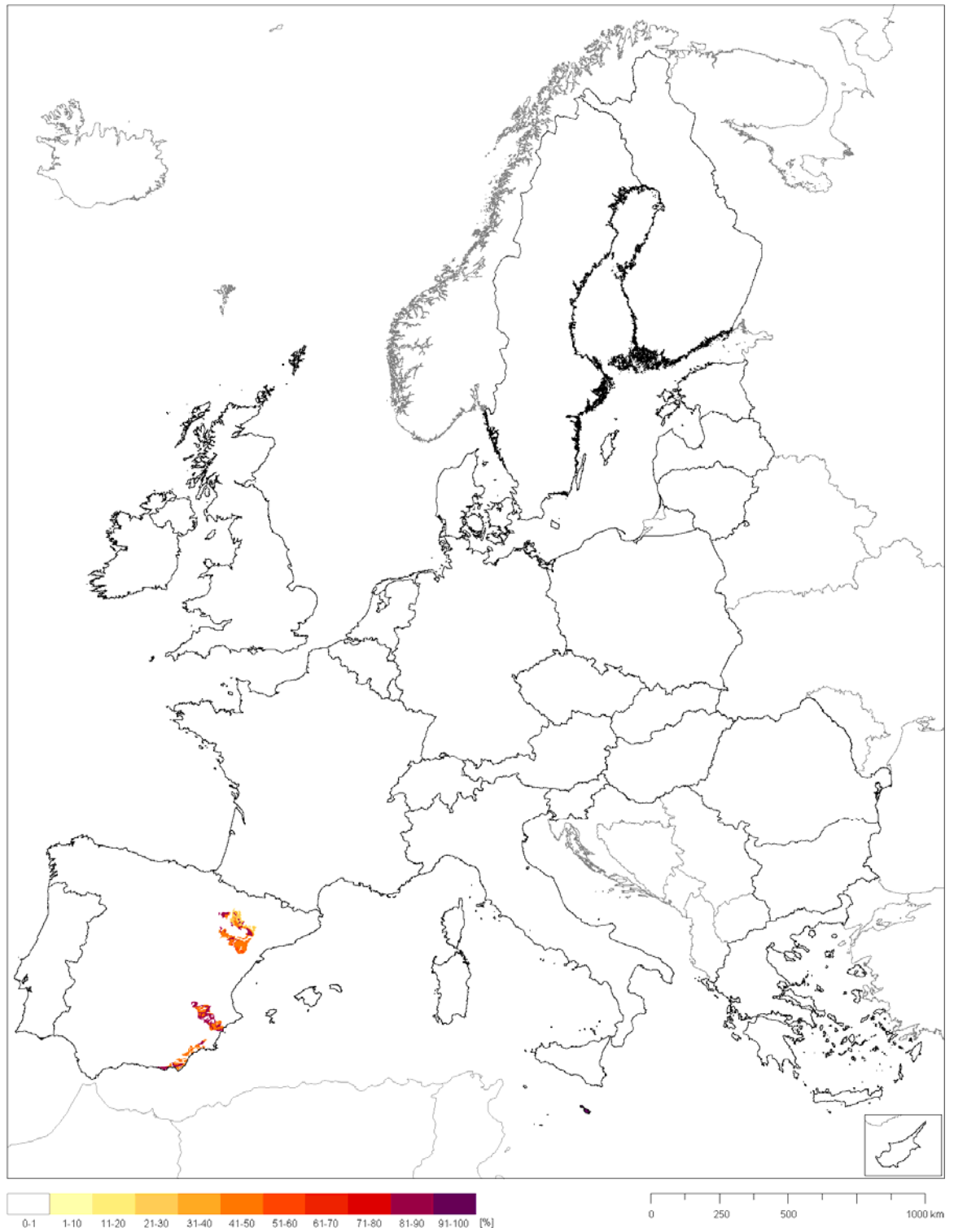
Most Calcisols have a medium or fine texture and good water holding properties. Slaking and crust formation may hinder the infiltration of rain and irrigation water, particularly where surface soils are silty. Surface run-off over the bare soil causes sheet wash and gully erosion and, in places, exposure of a petrocalcic horizon.

Vast areas of 'natural' Calcisols occur under shrubs, grasses and herbs and are used for extensive grazing. Drought-tolerant crops such as sunflower might be grown rain-fed, preferably after one or a few fallow years, but Calcisols reach their full productive capacity only when carefully irrigated.

Formerly Calcisols were internationally known as Desert Soil and Takys.

Map 4.6

CALCISOLS IN THE EUROPEAN UNION



4.7 Cambisols

Geographical distribution

Soil types in the Calcisol Reference Soil Group with over 1.1 million km² areal coverage account for the most widespread soils in the European Union, covering more than a quarter of its territory. Cambisols can be found nearly all regions of the EU; as dominant soil in 5,236, as associated soil in 4,098 and as inclusions in 3,231 polygons.

Eight different subgroups contribute to the Cambisol coverage of the European Union, with Dystric Cambisols having the largest and Haplic Cambisol the lowest share (Table 4.7., Figure 4.7).

Table 4.7 Area of the second level units of Cambisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcaric Cambisol	CMca	201257
Chromic Cambisol	CMcr	47566
Dystric Cambisol	CMdy	386271
Eutric Cambisol	CMeu	339972
Gleyic Cambisol	CMgl	45198
Haplic Cambisol	CMha	476
Mollic Cambisol	CMmo	53832
Vertic Cambisol	CMvr	33025

Calcaric Cambisols are most common in Spain. In most regions of France, Calcaric Cambisols are quite common too. Other countries with considerable Calcaric Cambisol areas include Italy, Germany, Greece, Poland, Estonia, Portugal and the Netherlands. **Cromic Cambisols** have the highest relative share in Hungary, but Italy, France and Portugal have also regions with dominantly Cromic Cambisol and this soil unit is present in the UK, Greece and Portugal as well. In the Czech Republic **Dystric Cambisols** are the most common soils and they also have a considerable share in the soil cover of almost all EU Member States (exceptions are the Baltic States, Poland, Hungary, Malta and the Netherlands). **Eutric Cambisols** can be found as associated soils all over the EU (Except Finland, Latvia, Estonia, Cyprus and Malta) and are also dominant in the Po plain, the Alsace-Loire region, Bretagne, Bavaria, the High Tatras, in the western Pyrenees and the Scottish Central Lowlands. **Gleyic Cambisols** are dominant in parts of central Lithuania, south-eastern England and are also abundant in the French Massif Central, in Central Europe, and as inclusion in the Po plain. Areas of Haplic Cambisols are limited to Cyprus and the Netherlands. **Mollic Cambisols** are widespread in north-western Iberia, in the Massif Central of France, the Pyrenees, throughout Hungary, and in some parts of Romania, Bulgaria and Greece. **Vertic Cambisols** are abundant in Germany, Finland, Italy and Greece and has inclusions in Austria, Cyprus and Czech Republic.

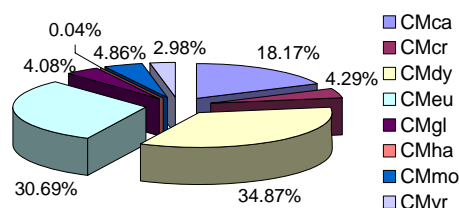


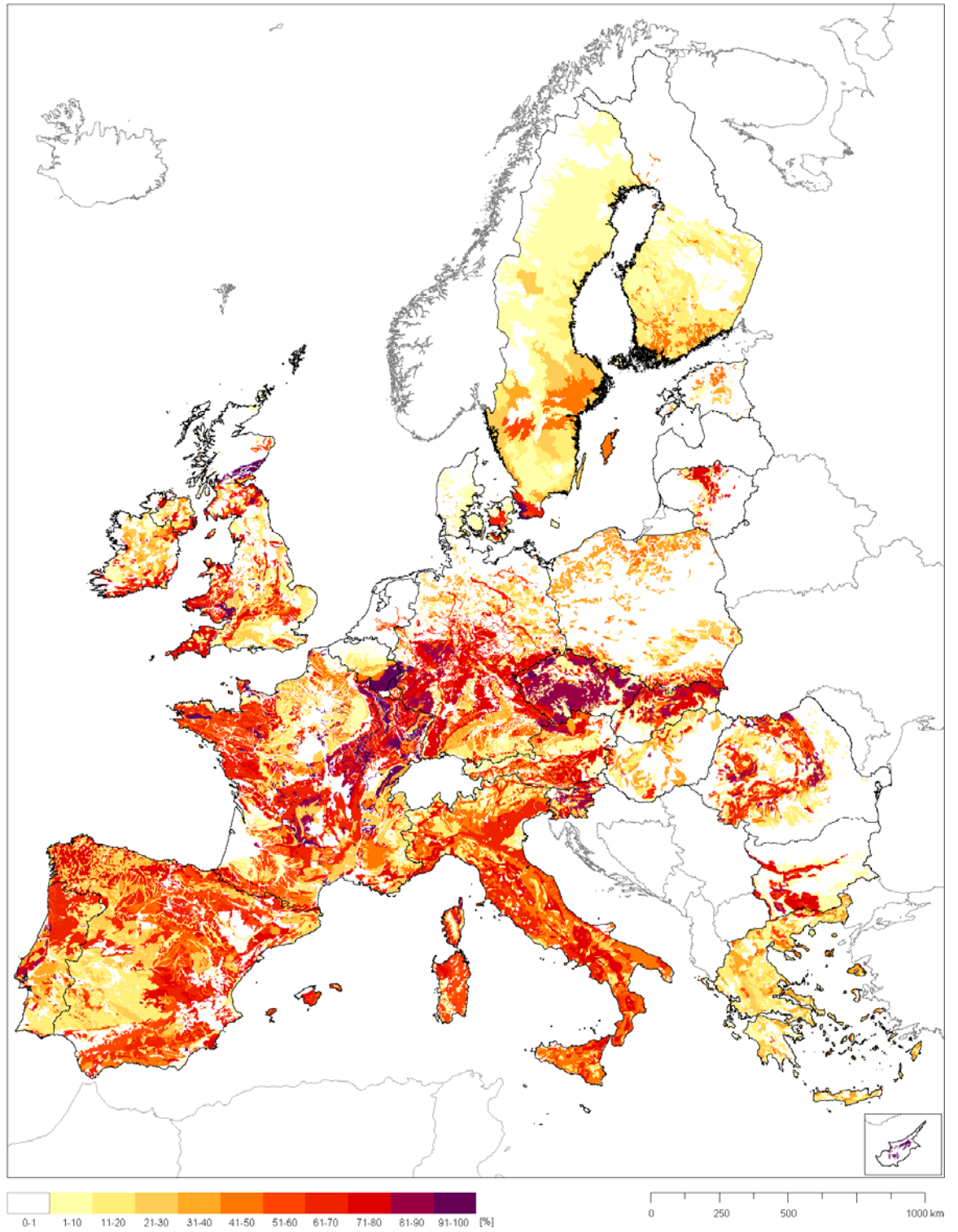
Figure 4.7 Share of the second level soil units in the area of Cambisols

Global reference

A Cambisol is a young soil. Pedogenic processes are evident from color development and/or structure formation below the surface horizon. Cambisols occur in a wide variety of environments around the world (15M km² global coverage) and under all kinds of vegetation. Cambisols in the international classifications are referred to as brown soil, Braunerde (Germany), Sols bruns (France) or Brunizems (Russia). The USDA Soil Taxonomy classifies Cambisols as Inceptisols.

Map 4.7

CAMBISOLS IN THE EUROPEAN UNION



4.8 Chernozems

Geographical distribution

Chernozems cover around 80,000 km², nearly 2% of the soil resources of the European Union. This Reference Soil Group spans around the Berlin-Budapest axis, on the western end of the Eurasian Chernozem zone. Chernozems can be found in Bulgaria, Romania, in four Central-European countries and in Germany. They form soil associations in 514 polygons; in 288 cases as dominant, in 83 cases as associated and in 143 cases as inclusion soils.

Four types of Chernozems are present in the European Union, Calcic Chernozems occupying two thirds and Haplic Chernozems an additional quarter of its total Chernozem lands. (Table 4.8, Figure 4.8)

Table 4.8 Area of the second level units of Chernozems

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcic Chernozem	CHcc	54179
Gleyic Chernozem	CHgl	947
Haplic Chernozem	CHha	20143
Luvic Chernozem	CHlv	3223

Calcic Chernozems are the dominant Chernozem soil units in Hungary and Romania and this soil type has quite a high share among Chernozems in Bulgaria and the Czech Republic while being also present in Austria and Slovakia. **Gleyic Chernozems** occur in Saxony-Anhalt (Germany). **Haplic Chernozems** are dominant on the Bulgarian, Slovakian, Austrian chernozem zones and also in Saxony-Anhalt. Hungary and the Czech Republic also have relatively large Haplic Chernozem areas, and this soil type is also present in Romania. **Luvic** types are the westernmost Chernozems, found in Slovakia, Czech Republic and in Germany.

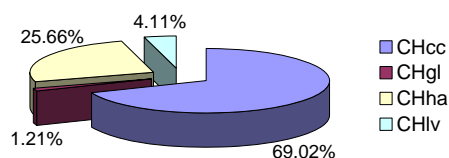


Figure 4.8 Share of the second level soil units in the area of Chernozems

Global reference

Chernozems are typically found in the long-grass steppe regions of the world, especially in Eastern Europe, Ukraine, Russia, Canada and the USA. Chernozem soils cover approximately 2.3 million km² worldwide.

Chernozem soil has a very dark brown or blackish surface horizon with a significant accumulation of organic matter and a high pH. Calcium carbonate accumulation in the lower part of the surface soil is common (within 50 cm of the lower limit of the humus rich horizon), secondary carbonates occur as pseudo-mycelium and/or nodules in a brownish grey to cinnamon subsoil. The subsurface horizon has blocky or weakly prismatic structure.

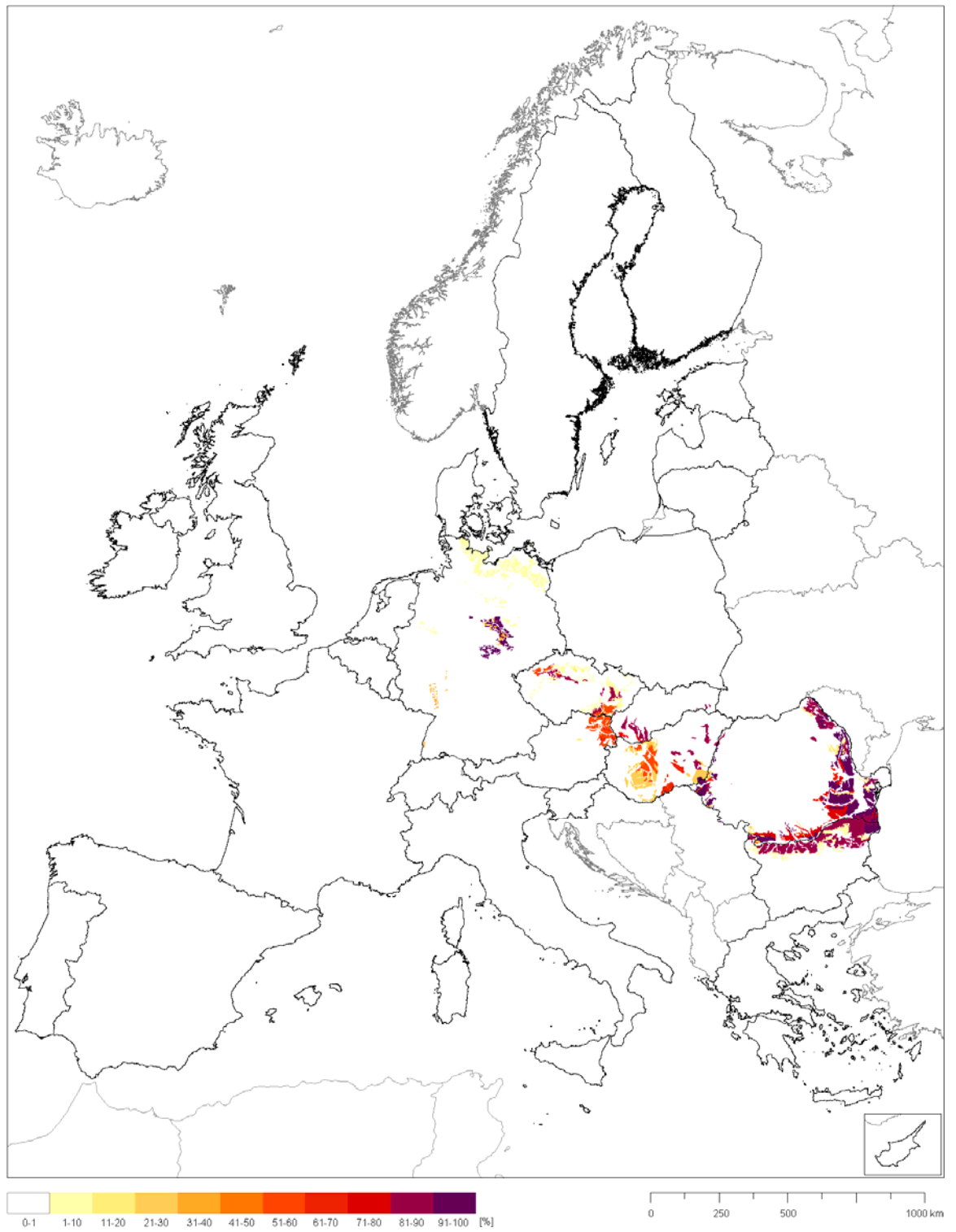
The ‘typical’ Chernozem has formed in uniformly textured, silty parent material (loess), under tall-grass vegetation with vigorous growth. Chernozems show high biological activity. Their soil fauna is very active in wet periods predominantly in the upper 50 cm layer but the animals move to deeper strata at the onset of the dry period.

Chernozems are amongst the most productive soil types in the world and are rather resistant to soil degradation threats.

International names of Chernozems include: Heigai tu (China), Calcareous Black Soils, Eluviated Black Soils (Canada), and (several suborders of) Mollisols (Soil Taxonomy).

Map 4.8

CHERNOZEMS IN THE EUROPEAN UNION



4.9 Fluvisols

Geographical distribution

Fluvisols cover areas over 220,000 km², thus more than 5% of the total land area of the European Union. Fluvisols are present in nearly all regions, forming dominant soil reference group in 1,532 cases, being associated soil in 704 and as inclusions in 997 soil associations (of the continental scale assessment).

Seven different subgroups contribute to the Fluvisol coverage of the European Union, with Eutric Fluvisols and Calcaric Fluvisols having the largest shares, together covering more than 90% of the Fluvisol lands. (Table 4.9, Figure 4.9)

Table 4.9 Area of the second level units of Fluvisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcaric Fluvisol	FLca	97224
Dystric Fluvisol	FLdy	6600
Eutric Fluvisol	FLeu	108733
Gleyic Fluvisol	FLgl	7854
Haplic Fluvisol	FLha	65
Mollic Fluvisol	FLmo	936
Thionic Fluvisol	FLti	257

Apart from Italy and the Central-North and North Easter quarter of the EU, *Calcaric Fluviols* occur in all of its regions. *Dystric Fluvisols* are less frequent; however they are present throughout the continent. *Eutric Fluviols*, the most widespread soil unit has its largest continuous coverage in the Po plain in Italy. *Gleyic Fluvisols* are characteristic for river basins in Poland. *Haplic* and *Thionic Fluvisols* are associated to other Fluvisols in southern England while the Mollic types can be found in Slovakia.

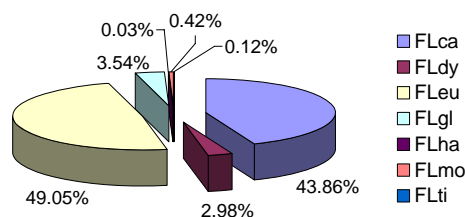


Figure 4.9 Share of the second level soil units in the area of Fluvisols

Global reference

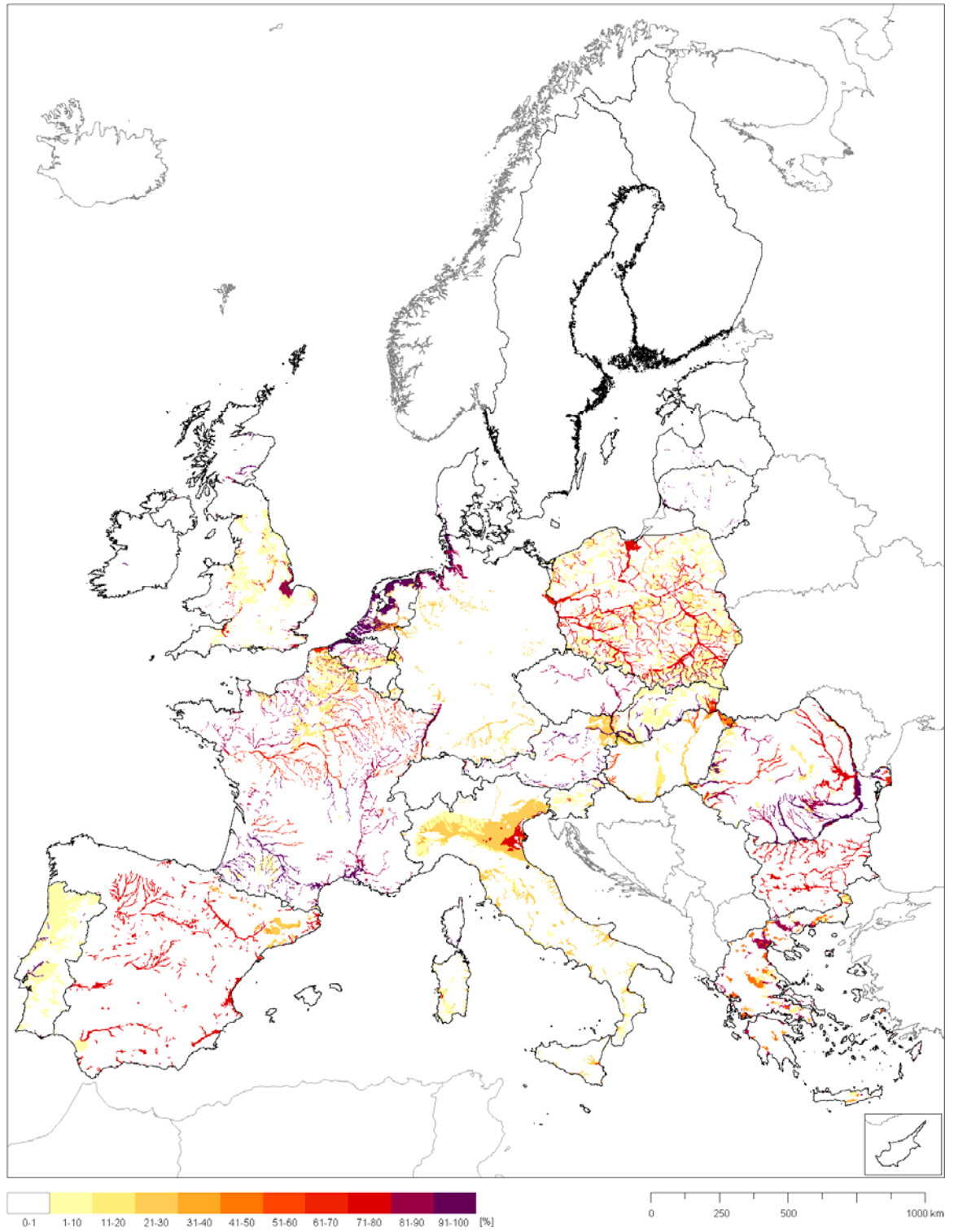
Fluvisols are common in periodically flooded areas such as alluvial plains, river fans, valleys and tidal marshes, on all continents and in all climate zones. They occupy some 3.5 million km² worldwide, of which more than half are in the tropics.

Fluvisols are young soils that have fluvic soil properties. For all practical purposes this means that they receive fresh sediment during regular floods (unless the land was empoldered) and (still) show stratification and/or an irregular organic matter profile. Fluvisols in upstream parts of river systems are normally confined to narrow strips of land adjacent to the actual riverbed. In the middle and lower stretches, the flood plain is wider and has the classical arrangement of levees and basins, with coarsely textured Fluvisols on the levees and more finely textured soils in basin areas further away from the river. Fluvisols show layering of the sediments rather than pedogenic horizons. Their characteristics and fertility depend on the nature and sequence of the sediments and length of periods of soil formation after or between flood events.

Common international names of Luvisols include Alluvial soil, Fluvents (Soil Taxonomy) and Auenböden (Germany).

Map 4.9

FLUVISOLS IN THE EUROPEAN UNION



4.10 Gleysols

Geographical distribution

Gleysols with their nearly 220,000 km² coverage accounts to 5.3% of the soil resources of the European Union. Gleysols are abundant north of the Paris-Bucharest line, but can be found in smaller inclusions in the southern countries as well.

Eight soil units of the Reference Soil Group is present in the EU (Table 4.10., Figure 4.10)

Table 4.10 Area of the second level units of Gleysols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcaric Gleysol	GLca	9690
Dystric Gleysol	GLdy	55085
Eutric Gleysol	GLeu	75653
Haplic Gleysol	GLha	14306
Histic Gleysol	GLhi	3315
Humic Gleysol	GLhu	44035
Mollic Gleysol	GLmo	14959
Thionic Gleysol	GLti	2738

Although *Calcaric Gleysols* are only dominant in five mapping units in Ireland, most of Calcaric Gleysols are found in France and England. The majority of *Dystric Gleysols* are in Ireland and in the western regions of the UK. However, apart from the Mediterranean and Balkan countries, this soil type can be found in most other countries of the EU also. *Eutric* types have the largest area coverage among Gleysols, concentrated mainly between the Paris-Bucharest and Glasgow-Helsinki lines. While Germany and France have all the *Haplic Gleysols* of the EU, *Histic Gleysols* are exclusive for Poland. *Humic Gleysols* follow the general pattern of distribution of Gleysols of the EU, but are absent in the Baltic States and Finland. *Mollic Gleysols* are dominant soils in mapping units in England, The Netherlands, Poland, Lithuania, and Romania and form associations with other soils in Bulgaria, Hungary, Slovakia France and Denmark. *Thionic Gleysols* can be found as dominant soils on the North-See coastline of Germany.

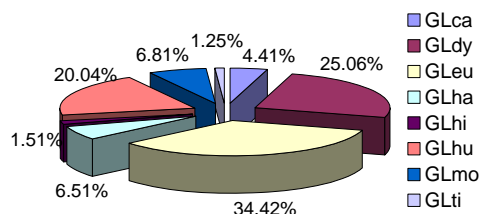


Figure 4.10 Share of the second level soil units in the area of Gleysols

Global reference

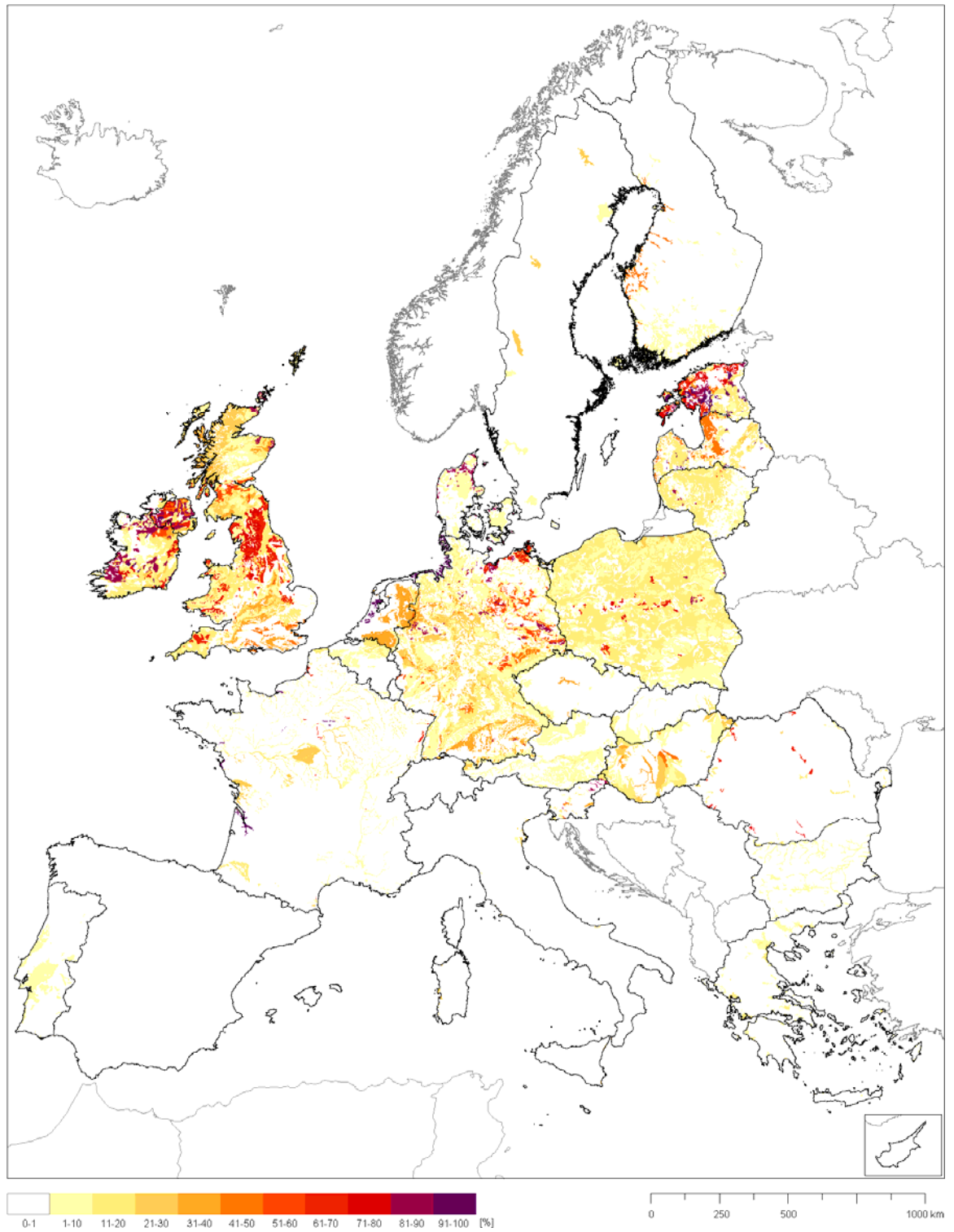
Gleysols are azonal soils and occur in nearly all climates, from perhumid to arid, mainly in lowland areas where the groundwater comes close to the surface and the soil is saturated with groundwater for long periods of time. Gleysols occupy an estimated 7.2 million km² world-wide.

Conditioned by excessive wetness at shallow depth, this type of soil develops gleyic colour patterns made up of reddish, brownish or yellowish colours on ped surfaces or in the upper soil layers, in combination with greyish/bluish colours inside the peds or deeper in the soil profile. The main obstacle to utilisation of Gleysols is the necessity to install a drainage system, designed to either lower the groundwater table, or intercept seepage or surface runoff water. Adequately drained Gleysols can be used for arable cropping, dairy farming or horticulture.

Common international names of Gleysols are Gleyzems (Russia), Gley (Germany), meadow soil, groundwater soil and hydromorphic soil.

Map 4.10

GLEYSOLS IN THE EUROPEAN UNION



4.11 Gypsisols

Geographical distribution

Gypsisols cover just over 4,000 km² in the European Union which makes up only a one per thousand of its total soil resources. Gypsisols are present only in Spain forming dominant soil reference group in 33 cases, being associated soil in 25 and as inclusions in one time in soil associations (Table 4.11, Figure 4.11).

Table 4.11 Area of the second level units of Gypsisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Aridic Gypsisol	GYad	4110

Based on the 1:1 M scale database all Gypsisols fall into the *Aridic Gypsisol* unit.

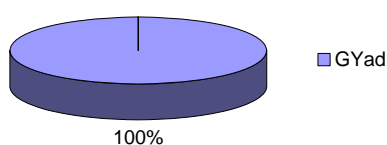


Figure 4.11 Share of the second level soil units in the area of Gypsisols

Global reference

Gypsisols can only be found in arid regions, in level or hilly land and depression areas (e.g. former inland lakes). World-wide extent of Gypsisols is approximately 1 million km².

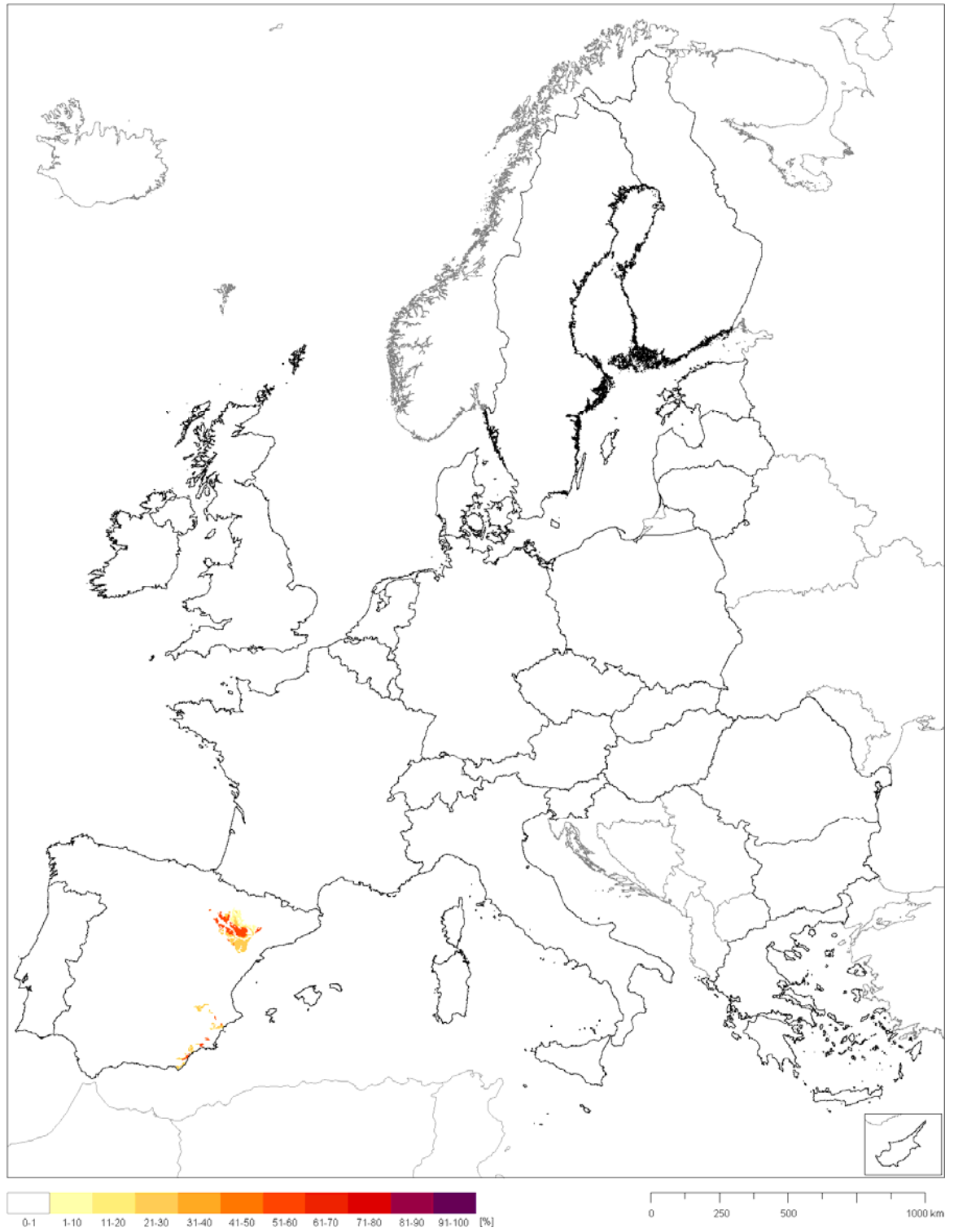
Gypsisols have substantial secondary accumulation of gypsum in the subsurface. Most Gypsisols formed when gypsum, dissolved from gypsiferous parent materials, moved through the soil with the soil moisture and precipitated in an accumulation layer. Where soil moisture moves predominantly upward (i.e. where a net evaporation surplus exists for an extended period each year), a gypsic or petrogypsic horizon occurs at shallower depth than a layer with lime accumulation (if present). Gypsum is leached from the surface soil in wet winter seasons. In arid regions with hot, dry summers, gypsum (CaSO₄·2H₂O) dehydrates to loose, powdery hemihydrate (CaSO₄·0.5H₂O), which reverts to gypsum during the moist winter. Gypsum precipitates in the soil body as fine, white, powdery crystals in former root channels (gypsum pseudomycelium) or in pockets, or as coarse crystalline gypsum sand, or in strongly cemented petrogypsic horizons. In places it forms pendants below pebbles and stones or rosettes (desert roses).

The natural vegetation is sparse and dominated by xerophytic shrubs and trees and/or ephemeral grasses. However, deep Gypsisols located close to water resources can be planted to a wide range of crops. Yields are severely depressed where a petrogypsic horizon occurs at shallow depth. Nutrient imbalance, stoniness, and uneven subsidence of the land surface upon dissolution of gypsum in percolating (irrigation) water are further limitations. Irrigation canals must be lined to prevent the canal walls from caving in. Most areas of Gypsisols are in use for low volume grazing.

As Gypsisols occur in the driest parts of the arid climate zone, therefore leading soil classification systems label them Desert soil (USSR), Aridisols (Soil Taxonomy) and Yermosols or Xerosols (FAO).

Map 4.11

GYPSISOLS IN THE EUROPEAN UNION



4.12 Histosols

Geographical distribution

Histosols cover nearly 270,000 km², or approximately 6.5% of the land surface of the European Union. Histosols have the largest extent in Northern Europe but with the exceptions of Cyprus and Malta all EU Member States have Histosols. Soils of this Reference Soil Group dominate in 1,497 polygons, are associated to other soils in 504 and are present as inclusion soils in 2,490 polygons.

Two soil units of the reference group are present in the EU (Table 4.12., Figure 4.12).

Table 4.12 Area of the second level units of Histosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Histosol (no subgrouping)	HS	163
Dystric Histosol	HSdy	194965
Eutric Histosol	HSeu	73614

The distribution pattern of *Dystric Histosols* are very similar to the whole of the Reference Soil Group, however they are missing from Portugal, Greece Poland and Slovakia. *Eutric Histosols* are the dominant soils in many areas (with small individual extents) of Finland, Estonia, Latvia, Lithuania, Germany, France, The Netherlands, the UK, Slovenia and Hungary. Other Histosols without further taxonomical distinction in the database are located in France, Belgium, Germany and Luxembourg.

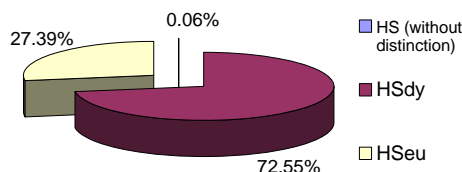


Figure 4.12 Share of the second level soil units in the area of Histosols

Global reference

The majority of Histosols are located in the boreal, subarctic and low arctic regions of the Northern Hemisphere. Most of the remaining Histosols occur in temperate lowlands and cool mountain areas; only one-tenth of all Histosols are found in the tropics. Histosols are found at all latitudes, but the vast majority of them occur at low altitudes.

The total extent of Histosols in the world is approximately 3.5 million km².

Histosols are composed mainly of organic soil material. During development, the organic matter production exceeds the rate of decomposition. The decomposition is retarded mainly by low temperatures or anaerobic (low oxygen) conditions which result in high accumulations of partially decomposed organic matter.

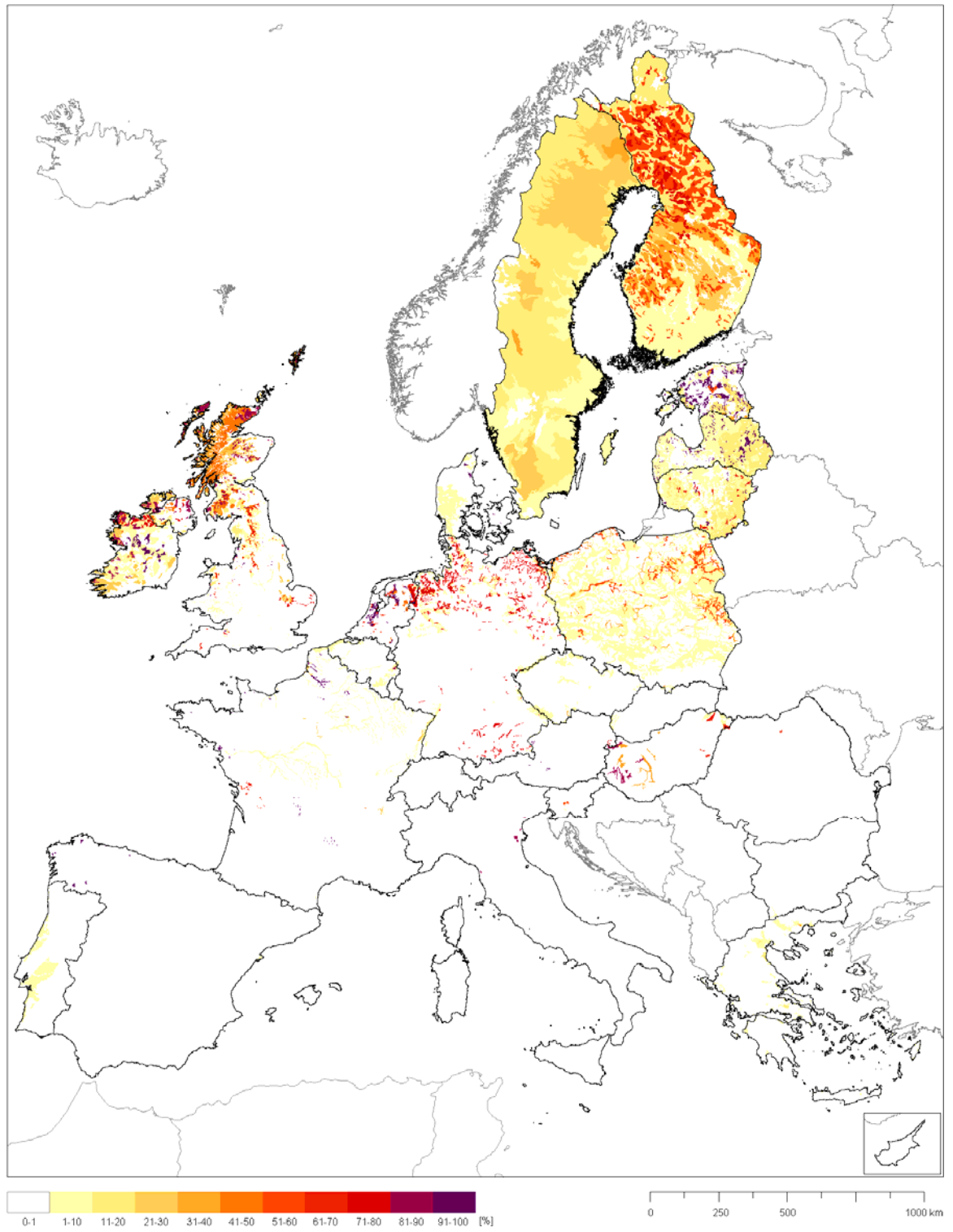
A Histosol has a surface or shallow subsurface histic or folic horizon, which consists of partially decomposed plant remains with or without admixed sand, silt and/or clay.

The properties of the organic soil material (botanical composition, stratification, degree of decomposition, packing density, wood content, mineral admixtures, etc.) and the type of peat bog (basin peat, raised bog, etc.) determine the management requirements and use possibilities of Histosols. Northern Histosols are of little use for agriculture but they are part of a unique ecosystem and a habitat for many plant and animal species. Elsewhere more and more bogs are reclaimed for agriculture, horticulture and forestry.

Histosols are also known as peat, muck, bog and organic soil.

Map 4.12

HISTOSOLS IN THE EUROPEAN UNION



4.13 Kastanozems

Geographical distribution

Kastanozems cover just over 3,500 km² in the European Union which is less than one per thousand of its total soil resources. Kastanozems are present as dominant soils only in 11 polygons, each in eastern Romania. They are associated soils in 3 polygons in Germany and form inclusions to 88 associations in Portugal and Greece.

Kastanozems of the European Union can be characterized by qualifiers *Calcic*, *Haplic* and *Luvic* (Table 4.13., Figure 4.13.). *Calcic* Kastanozems are the most important among them, covering nearly 95% of the total Kastanozem area.

Table 4.13 Area of the second level units of Kastanozems

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcic Kastanozem	KScC	3343
Haplic Kastanozem	KShA	46
Luvic Kastanozem	KSlv	143

Among the three soil units in the Kastanozem Reference Soil Group of Europe, those with *Calcic* properties can be found in Romania and Greece. The German Kastanozems fall into the *Haplic* soil unit, while the *Luvic Kastanozems* of the EU are located in Portugal.

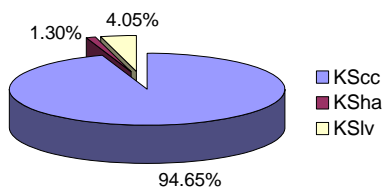


Figure 4.13 Share of the second level soil units in the area of Kastanozems

Global reference

Kastanozems occur mainly in the dry parts of the permanent grassland (steppe) regions of the world (the Great Plains of the USA, Mexico, the pampas of Latin America and the Eurasian short-grass-steppe-belt). The estimated total extent of Kastanozems is at about 4.65 million km².

Kastanozems have a deep, dark coloured surface horizon with a significant accumulation of organic matter, high pH and an accumulation of calcium carbonate within 100 cm of the soil surface. The morphology of dark Kastanozems is not very different from that of the southern, drier Chernozems whereas the light Kastanozems of the south grade into Calcisols.

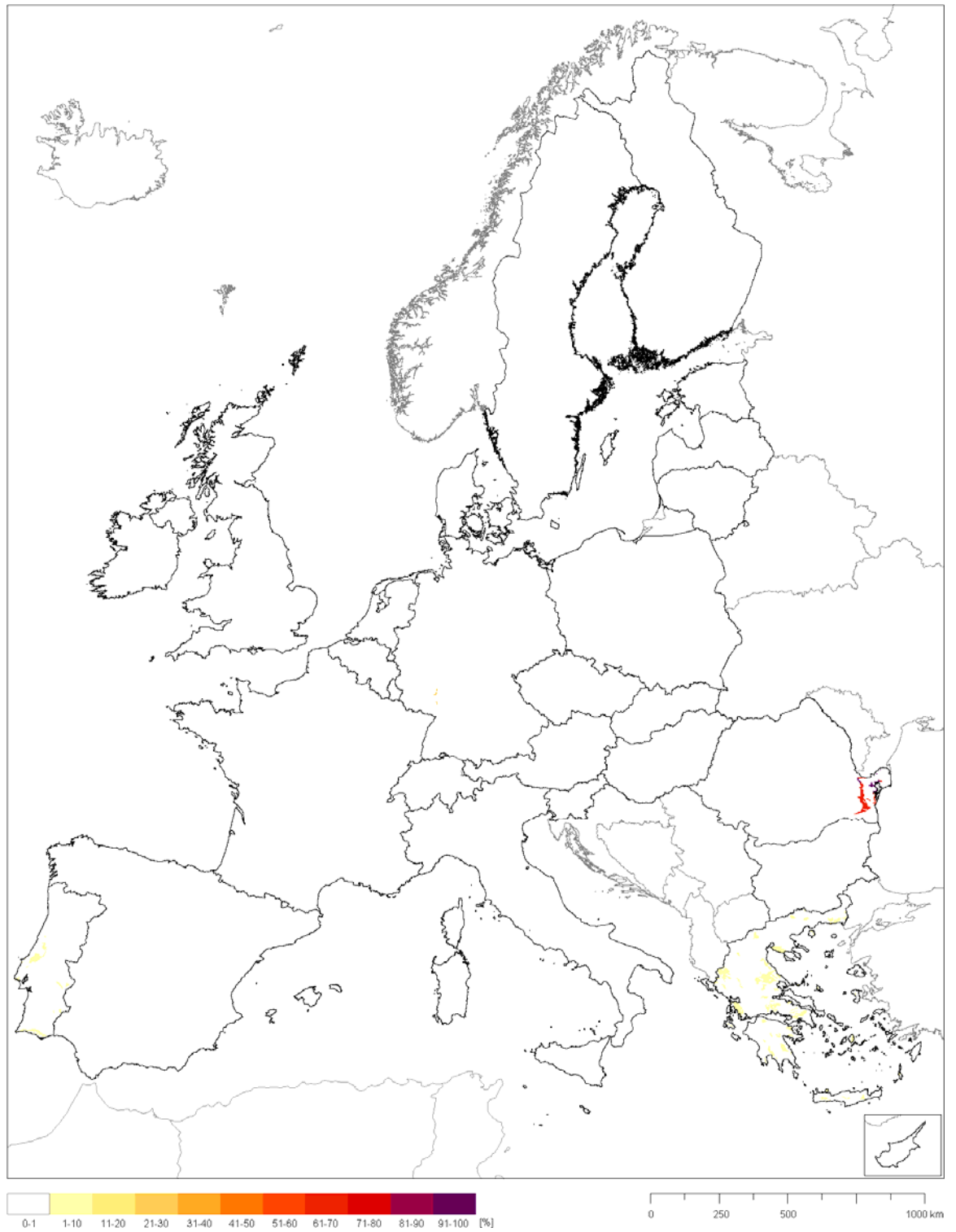
Climatic gradients in the Kastanozem belt are visible from pedogenic features. In Russia, the darkest surface horizons occur in the north of the Kastanozem belt (bordering on the Chernozems) whereas soils with shallower and lighter coloured horizons are more abundant in the south. The differentiation between horizons is clearer in the north than in the south in line with decreasing length and intensity of soil formation as conditions become more arid.

The typical arable land use is the production of small grains and irrigated cashcrops and vegetables. Kastanozem are also used for extensive grazing. Kastanozems are threatened by different forms of erosion and are often subjects of desertification processes.

The name of Kastanozem originates from the Latin, *castanea* (chestnut) and Russian *zemlja* (earth, land). International synonyms are (Dark) Chestnut Soils (Russia), (Dark) Brown Soils (Canada), and Ustolls and Borolls in the Order of the Mollisols (Soil Taxonomy).

Map 4.13

KASTANOZEMS IN THE EUROPEAN UNION



4.14 Leptosols

Geographical distribution

Leptosol is one of the four Reference Soil Groups that occupy more than 10% of the area of the European Union (435,713 km²). Leptosols are present throughout Europe. However, they are most typical in the Mediterranean. The majority of the soil types of Cyprus is Leptosols and they cover vast areas in Greece, Spain and France as well.

Six soil units make up the total Leptosol cover of the EU. (Table 4.14, Figure 4.14)

Table 4.14 Area of the second level units of Leptosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcaric Leptosol	LPca	65577
Dystric Leptosol	LPdy	102114
Eutric Leptosol	LPeu	34662
Haplic Leptosol	LPha	78221
Rendzic Leptosol	LPPrz	150347
Lithic Leptosol	LPli	4792

Calcaric Leptosols are typical to Greece and are quite frequent in Bulgaria, Italy, France and Spain. Highest concentration of *Dystric Leptosols* is in Corsica. However, these soils are common in many other regions of Europe. *Eutric Leptosols* are exclusive to the Mediterranean and Balkan countries. *Haplic* units of the Reference Soil Group are major soils of Galicia, the Pyrenees, the Northern Carpathians, the French Alps and Bretagne and Northern Scotland. *Rendzic Leptosol* has the largest areas within the Reference Soil Group covering much of the Alps, Northern France and Provence, Castalia and Andalusia, and the Apennines. *Lithic Leptosols* are the soils of Cyprus.

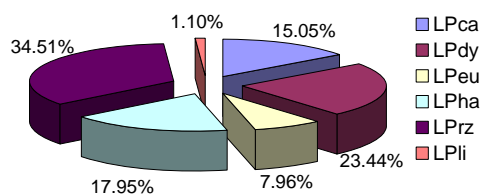


Figure 4.14 Share of the second level soil units in the area of Leptosols

Global reference

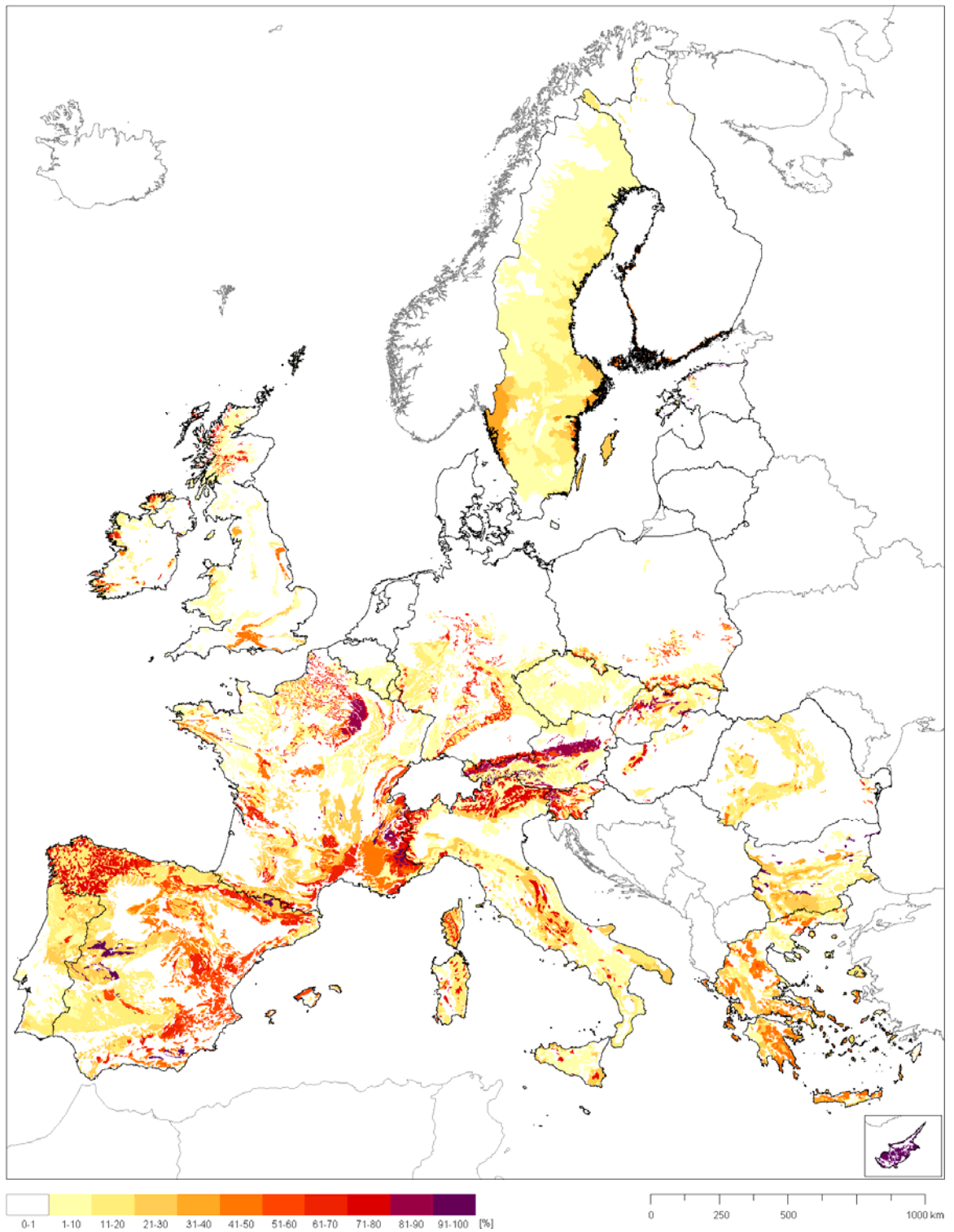
Leptosol is the Reference Soil Group with the most extensive coverage on the global scale, extending over approximately 16.55 million km². Leptosols are found in all climatic regions and all altitudes and are particularly frequent in mountain areas.

Leptosols are shallow over hard rock and comprise of very gravelly or highly calcareous material. Because of limited pedogenic development, Leptosols do not have much structure and have only weakly expressed horizons. Rendzic and Mollic Leptosols have more pronounced morphological features. The Reference Soil Group of the Leptosols includes a wide variety of soils with greatly differing chemical and physical properties. Leptosols are generally well-drained soils; however they have very few other favorable characteristics for agricultural utilization. The suitability of Leptosols in most areas is limited to forestry.

Lithosols of many international classification systems correlate with the Leptosol Reference Soil Group. Leptosols on limestone are called Rendzinas while those on acid rocks, such as granite, are called Rankers.

Map 4.14

LEPTOSOLS IN THE EUROPEAN UNION



4.15 Luvisols

Geographical distribution

Luvisols, with nearly 15% share (over 610,000 km²) in the area coverage constitute the second largest Reference Soil Group of the European Union. Apart from the northernmost regions of Europe, Luvisols can be found in all parts of the continent, either as dominant, associated or inclusion soils.

The nine different units of the Reference Soil Group indicate the diversity of the European Luvisols (Table 4.15., Figure 4.15)

Table 4.15 Area of the second level units of Luvisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Albic Luvisol	LVab	5431
Arenic Luvisol	LVar	16370
Calcic Luvisol	LVcc	12165
Chromic Luvisol	LVcr	110259
Dystric Luvisol	LVdy	1669
Ferric Luvisol	LVfr	1897
Gleyic Luvisol	LVgl	187539
Haplic Luvisol	LVha	266017
Vertic Luvisol	LVvr	9593

Most *Albic Luvisols* are located in Central-Europe, but they can be found in a few regions of France too. *Arenic Luvisols* are present in nine countries of the EU while Hungary and the eastern part of Germany have the largest proportions of them. Most *Calcic Luvisols* are shared between the three Baltic States and the two Iberians, but to limited extent they are present in Cyprus, Romania, Sardinia and in the French Alps too. Bulgaria has the highest share of *Chromic Luvisols* within its area. However, these soils are present from Greece to England. *Dystric Luvisols* are dominant in some mapping units in Slovakia and associated to a few in eastern-central France. While all *Ferric Luvisols* of the EU are in Portugal, *Gleyic Luvisols* can be found all around the continent (and is the most important soil in Latvia). *Haplic Luvisols* are distributed around the continent and are the major soils of Ireland and Belgium. *Vertic Luvisols* are located only in Portugal, Spain, Greece and France.

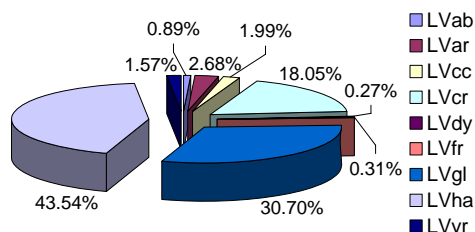


Figure 4.15 Share of the second level soil units in the area of Luvisols

Global reference

Luvisols extend to approximately 6 million km² world-wide, for the greater part in temperate regions.

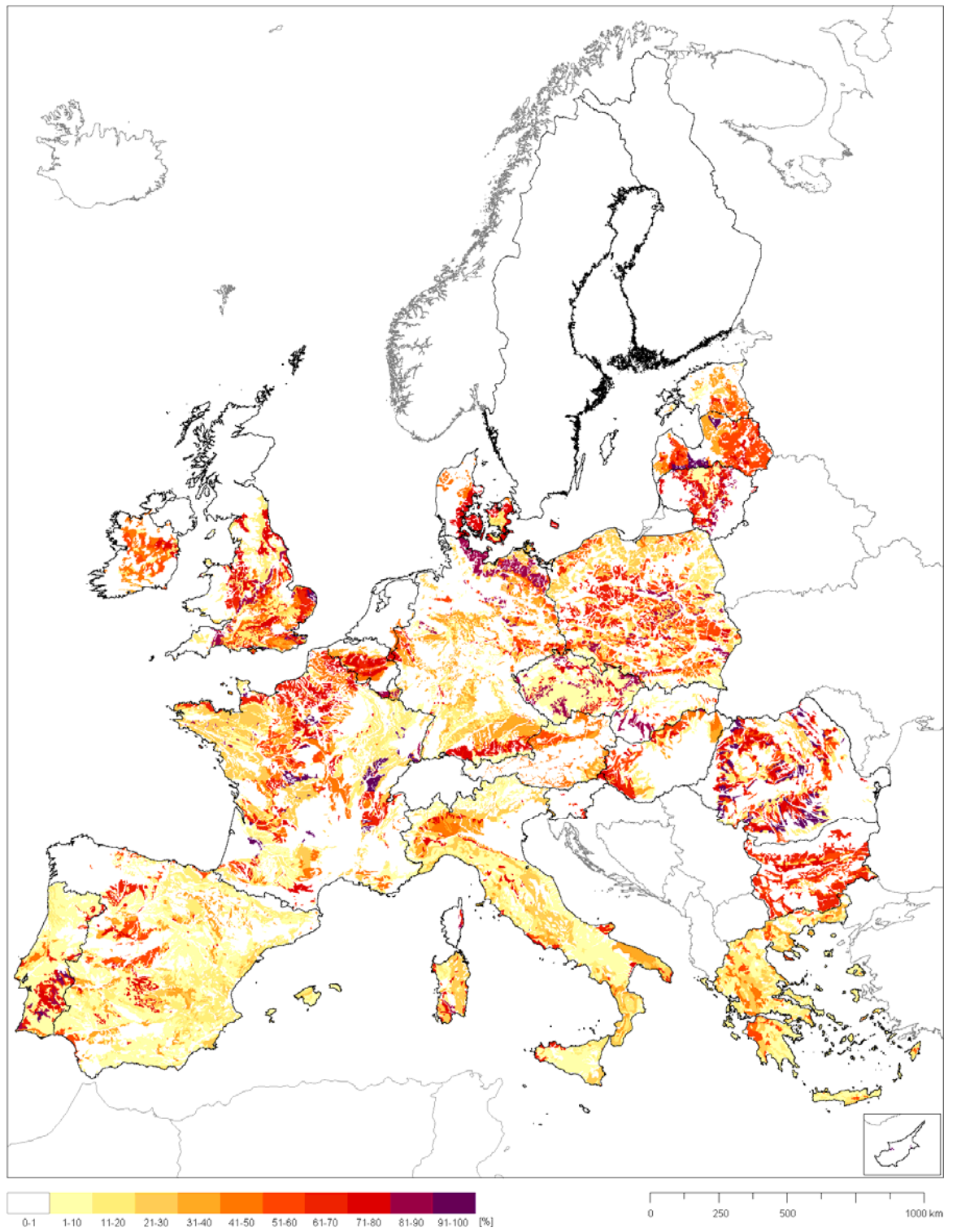
Luvisols show marked textural differences within the profile. The surface horizon is depleted in clay while the subsurface 'argic' horizon has accumulated clay. A wide range of parent materials and environmental conditions lead to a great diversity of soils in this Reference Soil Group.

Most Luvisols have favourable physical properties: these are porous and well aerated. Chemical properties and nutrient status varies with parent material and pedogenetic history that also determine the options of land utilization.

Other names used for this soil type include Pseudo-podzolic soil (Russia), sols lessivés (France), Parabraunerde (Germany) and Alfisols (Soil Taxonomy).

Map 4.15

LUVISOLS IN THE EUROPEAN UNION



4.16 Phaeozems

Geographical distribution

Phaeozems cover over 70,000 km² in the European Union (1.7%). The main areas of Pheozems are found in central and eastern Europe and Spain.

Five units of the Pheozem Reference Soil Group are present in the EU. Luvic type has the largest share while Sodic only a very minor one. (Table 4.16., Figure 4.16)

Table 4.16 Area of the second level units of Phaeozems

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcaric Phaeozem	PHca	15383
Gleyic Phaeozem	PHgl	14374
Haplic Phaeozem	PHha	15938
Luvic Phaeozem	PHlv	24734
Sodic Phaeozem	PHso	9

Calcaric Phaeozems have the highest spatial proportion in the Carpathian basin and the north-eastern third of Spain. **Gleyic Phaeozems** are present in nine countries with Hungary having the majority of them. **Haplic Phaeozems** are widespread in Hungary and Romania, but also present in France, Germany, Poland, Slovakia and the Czech Republic. The **Luvic** is the most common Pheozem unit in Bulgaria, Romania, Germany and (as inclusion) in Italy. These soils are also present in Poland and the Czech Republic. The only and very limited appearance of **Sodic Phaeozem** is at the eastern-Romanian border of the European Union.

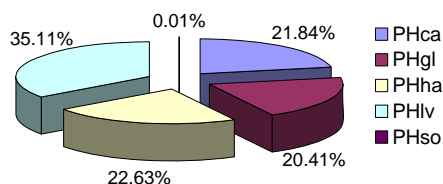


Figure 4.16 Share of the second level soil units in the area of Phaeozems

Global reference

Phaeozems are found in wet steppe (prairie) regions of the world, covering an estimated 1.9 million km² world-wide.

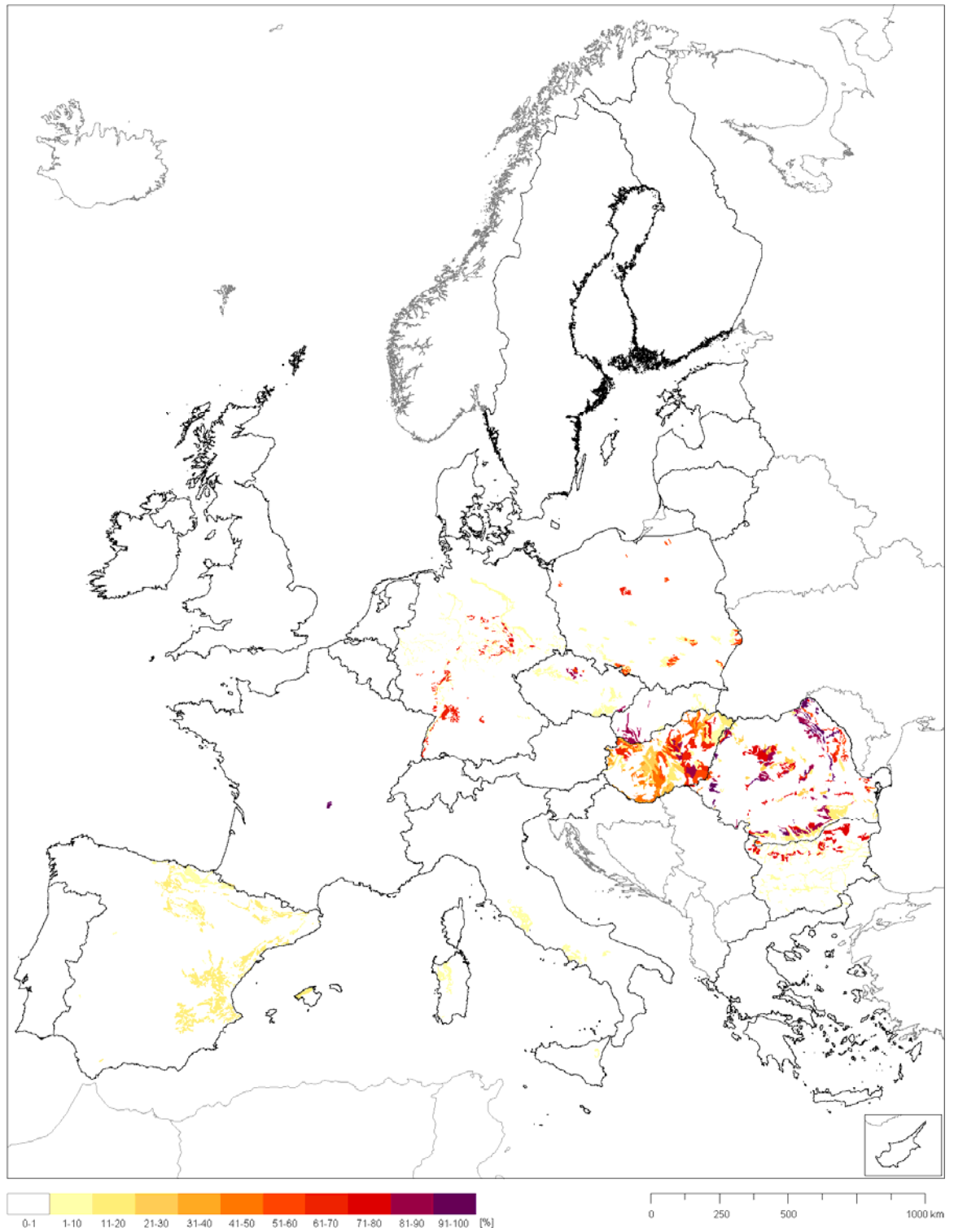
Phaeozems develop on loess, glacial till and other unconsolidated, predominantly basic materials on flat to undulating topography. These soils are much like Chernozems and Kastanozems but more intensively leached in wet seasons. Consequently, they have a dark, humus-rich surface horizon and have no secondary carbonates in the upper metre of soil.

Soils in this Reference Soil Group are porous, well-aerated soils with moderate to strong, very stable, crumb to blocky structures. The organic matter content of the surface layer of Phaeozems is typically around 5%. Phaeozems have good water storage properties but may still be short of water in dry seasons. Phaeozems are fertile soils, making excellent soil for agricultural production.

Commonly used international names are Brunizems (Argentina, France), Parabraunerde-Tsjernozems (Germany) and Aquolls in the order of the Mollisols (Soil Taxonomy).

Map 4.16

PHAEOZEMS IN THE EUROPEAN UNION



4.17 Planosol

Geographical distribution

Despite of their fairly widespread geographical distribution throughout the continent, Planosols have a relatively small share (< 0.5%; < 20,000 km²) among the soil types of the European Union.

Three different subgroups contribute to the Planosol coverage of the European Union. However, Haplic units only account for a very small area (Table 4.17, Figure 4.17)

Table 4.17 Area of the second level units of Planosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Dystric Planosol	PLdy	9379
Eutric Planosol	PLeu	9434
Haplic Planosol	PLha	167

Dystric Planosols are dominant in 56 soil units, associated to 150 and have inclusions in 48 throughout the continent. The most typical profiles can be found in Austria. Main areas of *Eutric Planosols* include regions in Estonia, Austria and Bulgaria but further eight counties contain this unit among their soil resources. *Haplic planosols* are inclusions in 40 soil associations, all in southern regions of England.

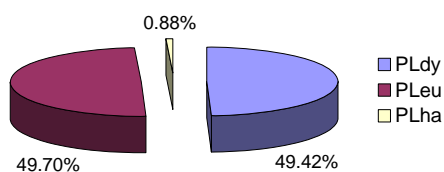


Figure 4.17 Share of the second level soil units in the area of Planosols

Global reference

Planosol areas of the earth can be found mainly in subtropical and temperate regions with clearly alternating wet and dry seasons. Their global coverage is estimated at around 1.3 million km².

Planosols are soils with bleached, light-coloured, eluvial surface horizons that show signs of periodic water stagnation and abruptly overly dense, slowly permeable subsoil with significantly more clay than the surface horizon. They develop mostly on clayey alluvial and colluvial deposits, predominantly in flat lands but can also be found in the lower stretches of slopes, in a strip intermediate between uplands, e.g. with Acrisols or Luvisols, and lowland (plain or basin) areas, e.g. with Vertisols.

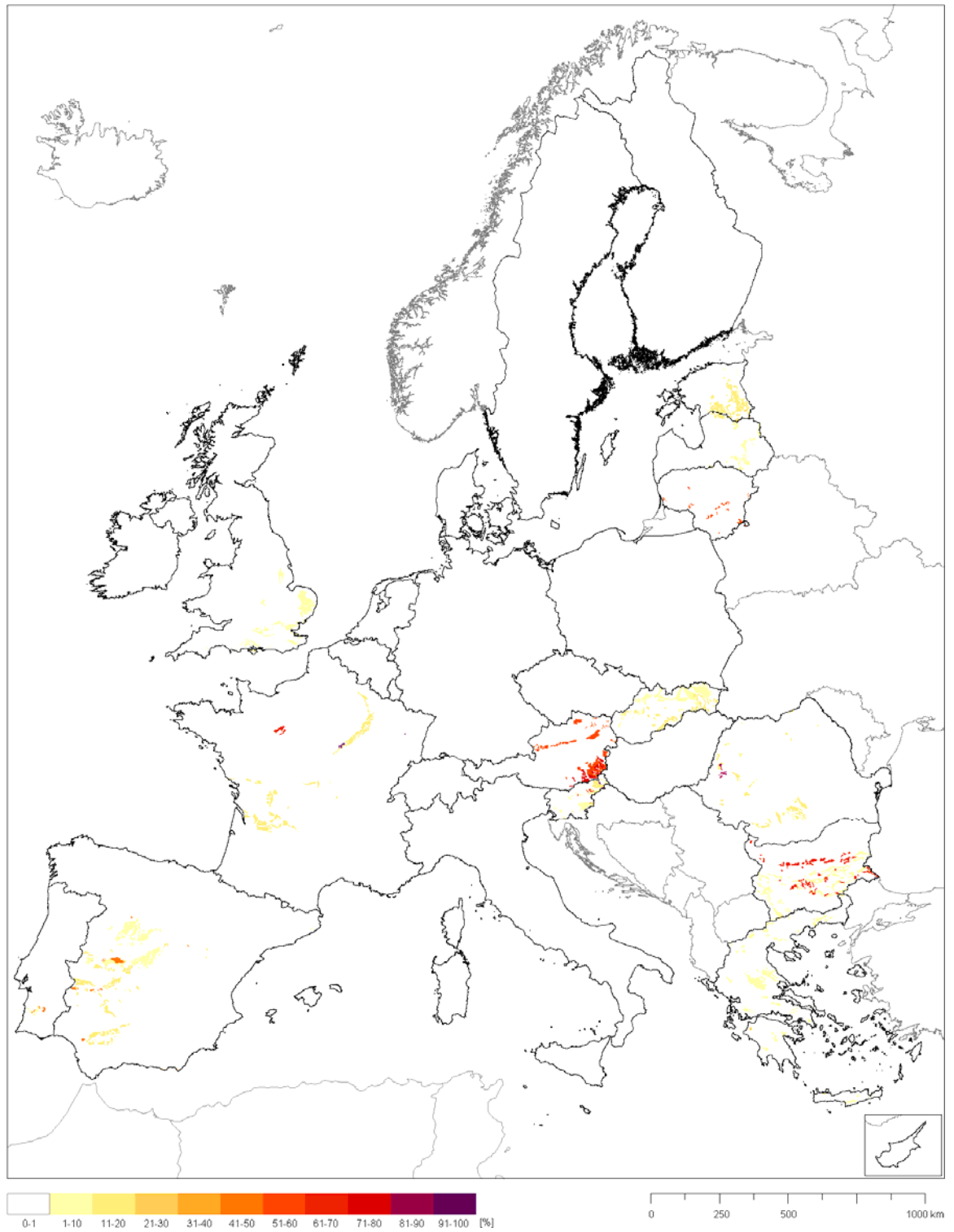
Planosols have typically a weakly structured surface horizon over a horizon showing evidence of stagnating water. The texture of these horizons is markedly coarser than that of deeper soil layers; the transition is sharp and conforms to the requirements of an 'abrupt textural change'. The finer textured subsurface soil may show signs of clay illuviation; it is only slowly permeable to water.

Most Planosols are poor soils and are therefore not used as cropland but utilized for extensive grazing and forestry.

Planosols were formerly known as pseudogley soils and today are dealt under different levels of classification hierarchies in national and international classification systems.

Map 4.17

PLANOSOLS IN THE EUROPEAN UNION



4.18 Podzols

Geographical distribution

The Podzol Reference Soil Group is the third most widespread in the European Union, covering more than 0.5 million km² or 13.66% of its total area. Podzols are dominant in 1,771 polygons, they are associated soils in 2,265 and inclusions in 1,960 associations. While vast areas of Podzols are found in the Scandinavian countries, this Reference Soil Group is present in twenty-two Member States of the EU and is only absent in Hungary, Slovenia, Bulgaria, Malta and Cyprus.

Five Podzol units are distinguished in the European Union. Haplic Podzols have the highest share of their areas. (Table 4.18, Figure 4.18)

Table 4.18 Area of the second level units of Podzols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Gleyic Podzol	PZgl	53836
Haplic Podzol	PZha	401332
Leptic Podzol	PZle	73945
Placic Podzol	PZpi	20146
Umbric Podzol	PZum	17616

The majority of *Gleyic Podzols* are located north of the 41° N latitude. However, some can be found in Austria and Portugal. The locations of *Haplic Podzols* show the general pattern of the Reference Soil Group. This is the major soil type of Finland, covering most of its area. *Leptic Podzols* are most frequent in Poland, but they represent large continuous areas in central-France and in the Carpathian Mountain as well. *Placic Podzol* is the major unit of the Reference Soil Group in the United Kingdom and Ireland. *Umbric Podzols* are the most characteristic for Belgium, but also found in nine EU Member States.

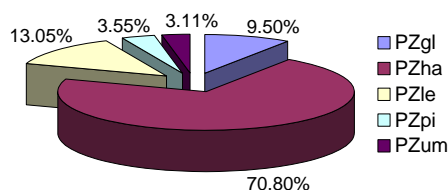


Figure 4.18 Share of the second level soil units in the area of Podzols

Global reference

Podzols cover 4.85 million km² globally, mainly in temperate and boreal regions on the Northern Hemisphere.

Most Podzols develop in humid, well drained areas, particularly, in the Boreal and Temperate Zones, on unconsolidated weathering materials of siliceous rock, prominent on glacial till, and alluvial and aeolian deposits of quartzitic sands. In the boreal zone Podzols occur on almost any rock. Podzols are associated with soils that have evidence of displacement of organic-iron/aluminium complexes but not strong enough to qualify as Podzols.

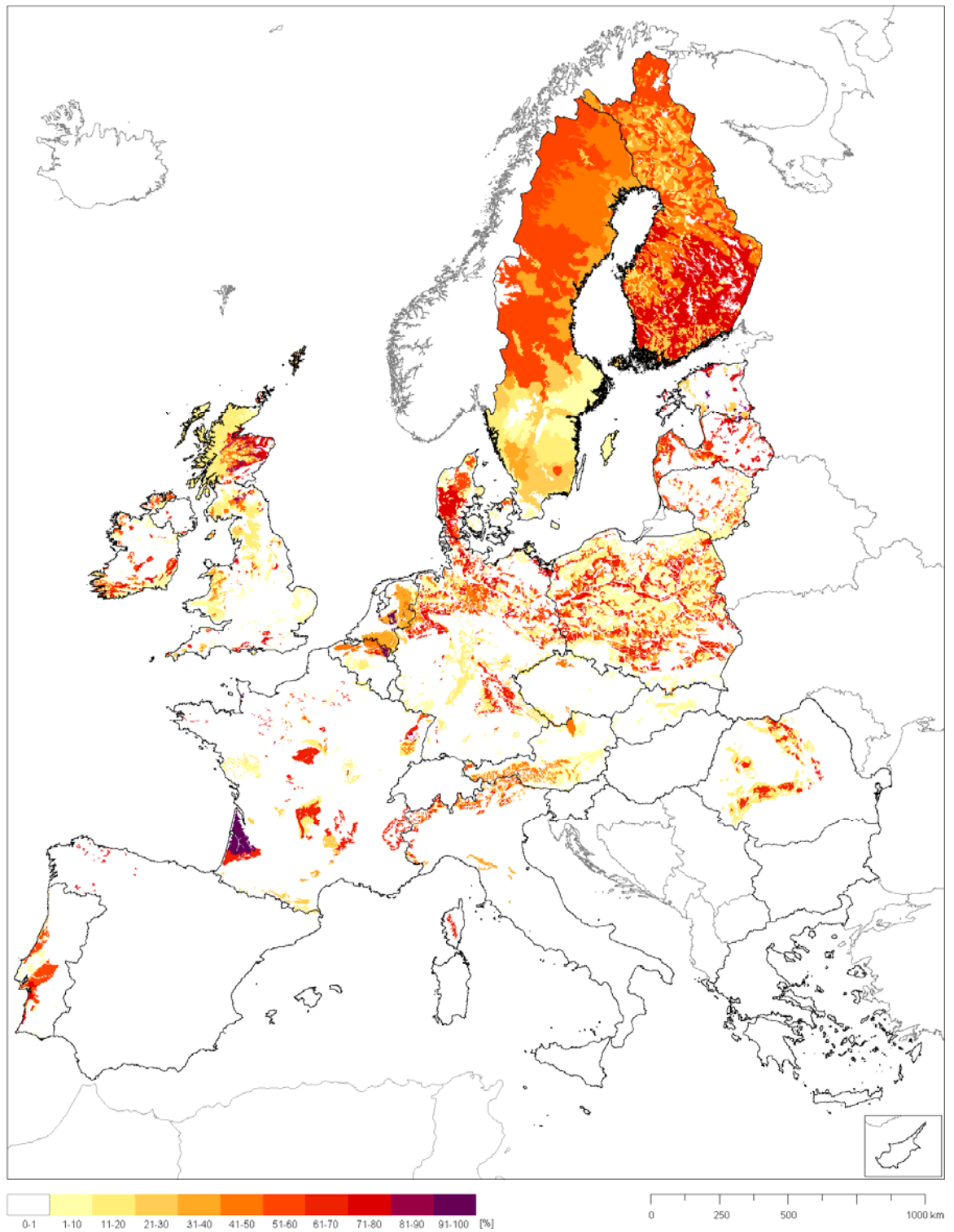
Main feature of podzol formation is the migration of aluminium, iron and organic compounds from the surface soil down to deeper layers with percolating rainwater. The humus complexes deposit in an accumulation (spodic) horizon while the overlying soil is left behind as a strongly bleached.

Due to the limiting climatic conditions Zonal Podzols generally have low suitability for agricultural production. Azonal podzols can be utilized for agricultural use after amelioration (e.g deep ploughing, liming).

The name Podzol is common to most national and international soil classification systems; the SoilTaxonomy refers to these soils as Spodosols.

Map 4.18

PODZOLS IN THE EUROPEAN UNION



4.19 Regosols

Geographical distribution

Regosol with an area of more than 220,000 km² belongs to the major soil types of the European Union. Most of the European Regosols are found in the Mediterranean region and the Balkan Peninsula. However, they can be found in nearly all Member States of the EU.

Three of the four units of the Reference Soil Group share 99% of the area, each having large spatial extensions. (Table 4.19, Figure 4.19)

Table 4.19 Area of the second level units of Regosols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Calcaric Regosol	RGca	70391
Dystric Regosol	RGdy	85733
Eutric Regosol	RGeu	63740
Haplic Regosol	RGha	2457

Calcaric Regosols are associated soils in most regions. However, this type is absent from Scandinavia, the Benelux states, France, Portugal and Poland. **Dystric Regosols** have their largest territories in Finland, Sweden, Portugal, Spain and the Benelux states. **Eutric Regosols** have a rather even distribution south-east of the Madrid-Warsaw line. **Haplic Regosols** can be found in Cyprus, Czech Republic and France.

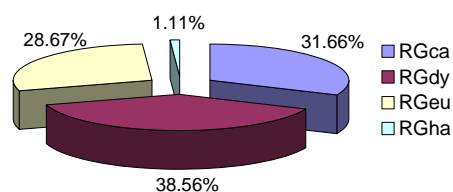


Figure 4.19 Share of the second level soil units in the area of Regosols

Global reference

Regosols are present at all climate zones without permafrost and at all elevations. Regosols are particularly common in arid areas, in the dry tropics and in mountain regions. Global coverage of this Reference Soil Group accounts to approximately 2.6 million km². Regosols are common inclusions in other map units on small-scale maps.

A Regosol is a very weakly developed mineral soil in unconsolidated materials with only a limited surface horizon having formed. Regosols form a taxonomic reference group containing all soil types that cannot be accommodated in any of the other WRB Reference Groups. Regosols are extensive in eroding lands

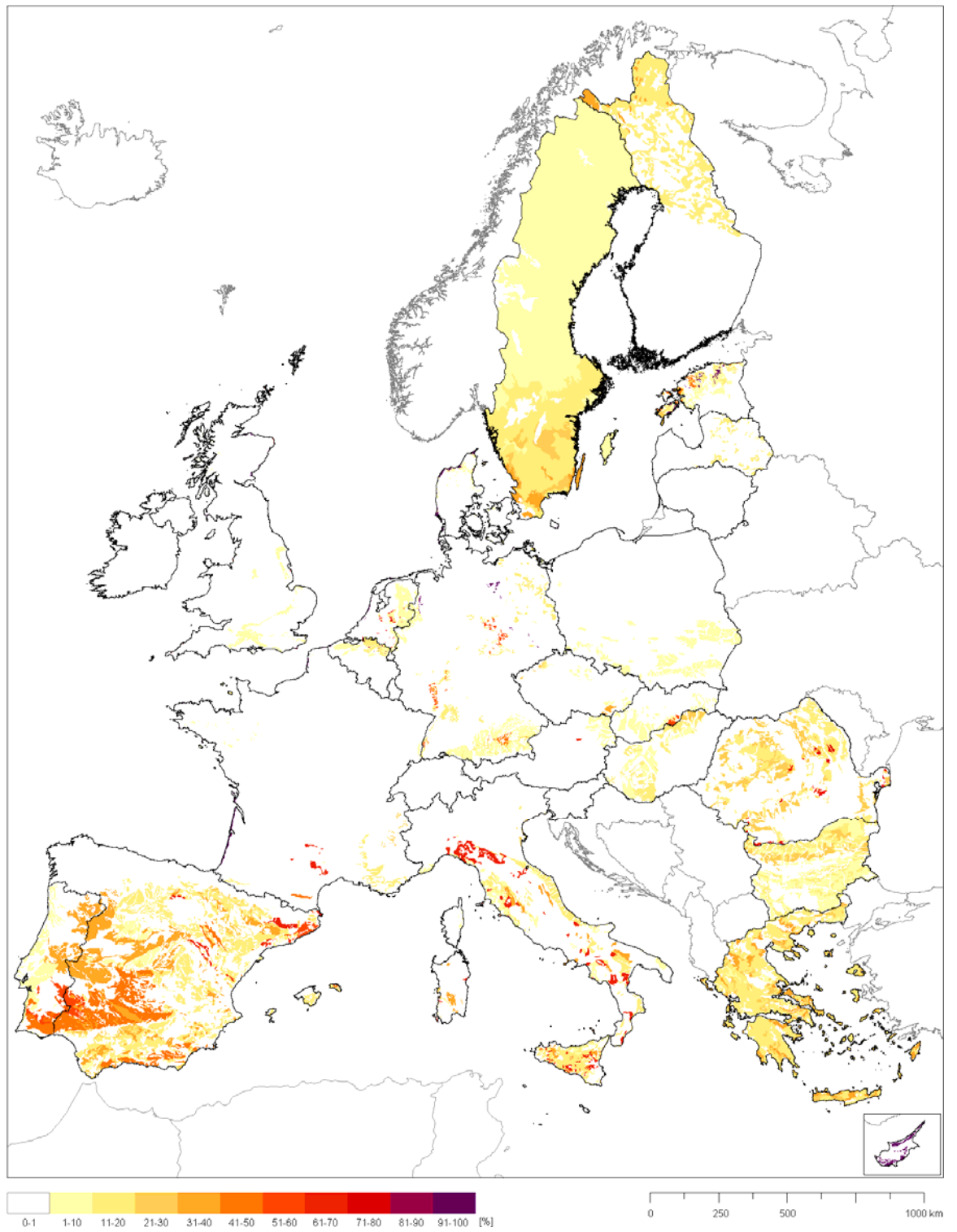
Limiting factors for the development of Regosols range from low soil temperatures and prolonged dryness to characteristics of the parent material or erosion.

The options for land use and management of these soils vary widely. Some Regosols are used for irrigated farming but generally they are kept for low volume grazing. In mountain areas Regosols are mostly forested.

Internationally, Regosols are similar to Entisols (USA), Skeletal Soil (Australia), *Rohböden* (Germany) and *Sols peu évolués régologiques d'érosion* (France).

Map 4.19

REGOSOLS IN THE EUROPEAN UNION



4.20 Solonchaks

Geographical distribution

Solonchaks cover approximately 1,000 km² from the surface of the European Union. This small share (0.28%) is divided between Portugal, Spain, Greece, Bulgaria, Romania, Hungary, Austria, Cyprus and France.

Three soil units of the Reference Soil Group can be found in the EU (Table 4.20, Figure 4.20). However, Takyric Solonchaks have the smallest share among the soil units of all Reference Soil Groups with only 5 km² area.

Table 4.20 Area of the second level units of Solonchaks

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Gleyic Solonchak	SCgl	4144
Haplic Solonchak	SCha	7579
Takyric Solonchak	SCty	5

Gleyic Solonchaks are present in all nine counties that have soils in this Reference Soil Group. They are dominant soil formations in 48 mapping units, are associated in 54 cases and are present as inclusions in further 7 soil associations. *Haplic Solonchak* is a soil type dominant in 16 mapping units in Spain and France and forming associations (34 mapping units) in Spain and inclusions in large areas (245 mapping units) of Spain, Hungary and some also in Greece. The only appearance of *Takyric Solonchak* in the EU is limited to a small area on the south-western coast of Spain.

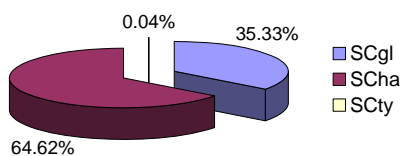


Figure 4.20 Share of the second level soil units in the area of Solonchaks

Global reference

Solonchaks are widespread in the arid and semi-arid climatic zones and coastal regions in all climates. The global extent of Solonchaks is estimated to be between 2.6 million and 3.4 million km². The level of salinity for diagnostic purposes cause the differences in the estimations.

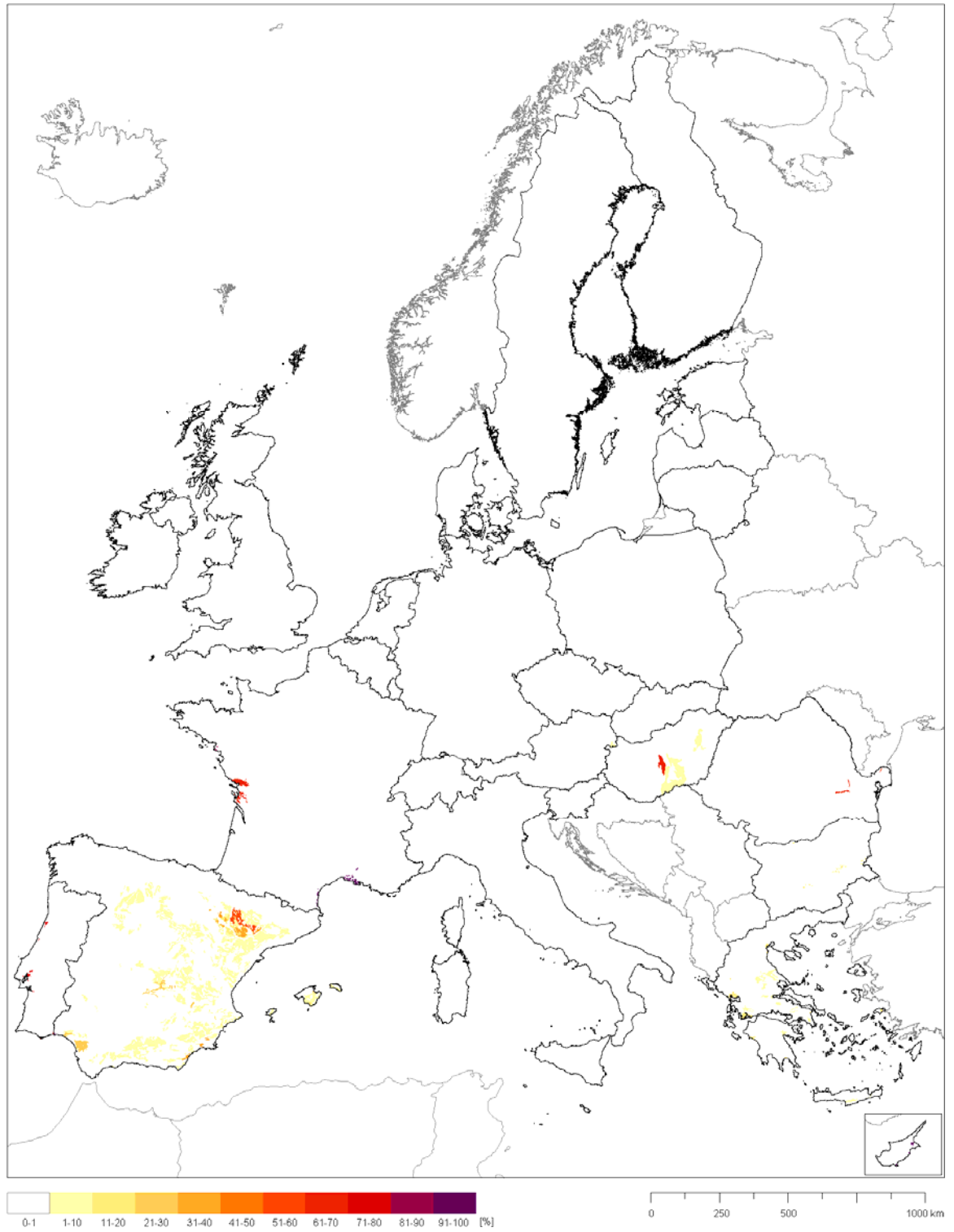
Solonchaks are a strongly saline soil types with high concentration of soluble salts. They occur where saline groundwater comes near to the surface or where the evapo-transpiration is considerably higher than precipitation, at least during a large part of the year. Salts dissolved in the soil moisture remain behind after evaporation of the water and accumulate at or near the surface. Their morphology, characteristics and limitations to plant growth depend on the amount, depth and composition of the salts.

Land use options on Solonchak soils are largely limited by the salt content. The salts magnify drought stress because dissolved electrolytes create an osmotic potential that affects water uptake by plants. A possible way of reclamation is to flush salts out from the soil. However, most Solonchaks can be used for extensive grazing. Solonchak soils in many cases form unique ecosystems worth protecting for their biodiversity and landscape values.

Solonchaks are often cited as saline soil and salt-affected soil in international nomenclatures.

Map 4.20

SOLONCHAKS IN THE EUROPEAN UNION



4.21 Solonetz

Geographical distribution

Areas of Solonetz soils are similar to those of Solonchaks in the European Union, covering nearly 10,000 km² (0.24%). However, the geographic extent is somewhat different: Solonetz are soils of the Charpatian Basin, Romania and Bulgaria.

Three units of the Reference Soil Group have coverage with the same order of magnitude (Table 4.21, Figure 4.21).

Table 4.21 Area of the second level units of Solonetz soils

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Gleyic Solonetz	SNgl	2749
Haplic Solonetz	SNha	2419
Mollic Solonetz	SNmo	4689

Gleyic Solonetz are characteristic for Romania and are the dominant soils in 13 polygons. (In a further 21 polygons they are associated and form inclusions in another 12.) **Haplic Solonetz** can be found in both on the Great Hungarian Plain (Nagyalföld) and in Bulgaria. They are dominant in 13 mapping units of the latter. **Mollic Solonetz** is the main type of salt affected soil in Hungary and it can be found close to the Lake Neusiedl in Austria.

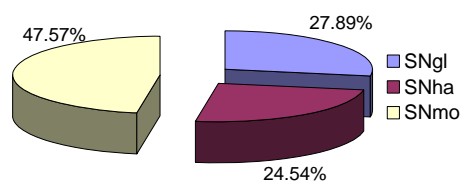


Figure 4.21 Share of the second level soil units in the area of Solonetz soils

Global reference

Solonetz are normally associated with flat lands in a climate with hot, dry summers or with former coastal deposits that contain a high proportion of salt. Global coverage of Solonetz soils accounts to approximately 1.35 million km².

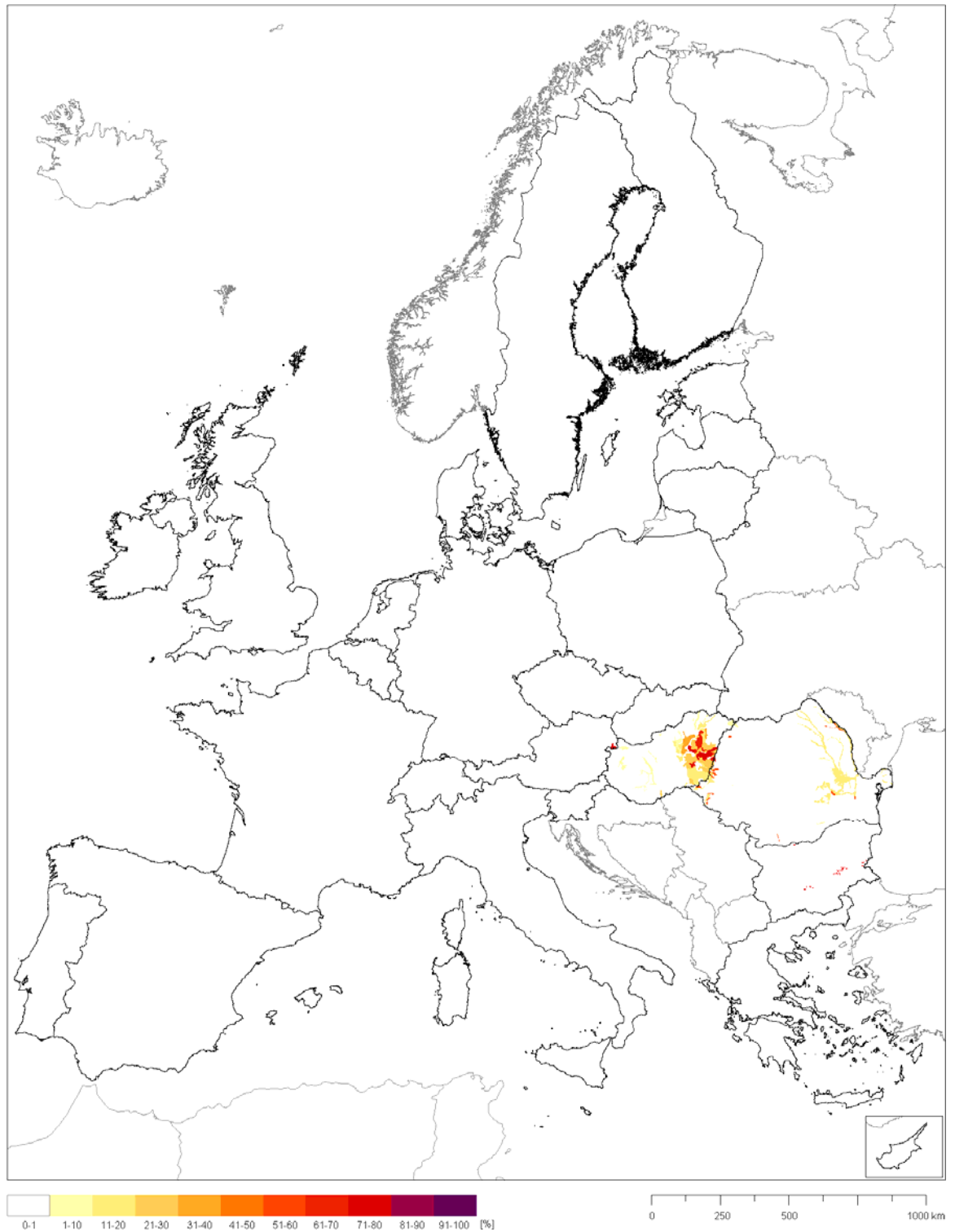
Solonetz soils are strongly alkaline with subsurface horizon of clay minerals, well developed columnar structure and high proportion of adsorbed sodium and/or magnesium ions. The presence of free soda in soil is associated with alkaline reaction (field-pH > 8.5). Under such conditions, organic matter has a tendency to dissolve and move through the soil body with moving soil moisture. The remaining mineral soil material is bleached and in the extreme case a clear eluvial horizon may form directly over the dense natric subsurface horizon. Black spots of accumulated organic matter can be seen in many Solonetz, at some depth in the natric horizon. The dense natric (clay) illuviation horizon poses an obstacle to water percolating downward by the dispersion of soil materials.

Land use options of Solonetz soils depend largely on the depth and properties of the surface soil. However, most Solonetz are problem soils when used for arable agriculture.

Internationally, Solonetz are referred to as alkali soil and sodic soil, Sols sodiques à horizon B et Solonetz solodisés (France), Natrustalfs, Natrustolls, Natrixeralfs, Natrargids or Nadurargids (Soil Taxonomy).

Map 4.21

SOLONETZES IN THE EUROPEAN UNION



4.22 Umbrisols

Geographical distribution

Umbrisols have the smallest share among all Reference Soil Groups of the European Union covering only 0.01% of the EU (329 km²). The only appearance of Umbrisols is limited to the coastal areas of northern Portugal, where they are associated with Cambisols.

Table 4.22 Area of the second level units of Umbrisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Arenic Umbrisol	UMar	329

Umbrisols areas are made up entirely by the *Arenic* unit (Table 4.22., Figure 4.22).

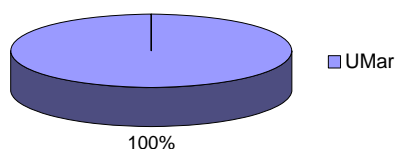


Figure 4.22 Share of the second level soil units in the area of Umbrisols

Global reference

The Umbrisol Reference Soil Group belongs to the set of mineral soils conditioned by a (sub)humid temperate climate. Soils in this Reference Soil Group occur in cool, humid regions, mostly mountainous and with little or no soil moisture deficit, on weathering material of siliceous rock; predominantly in late Pleistocene and Holocene deposits.

Umbrisols occupy about 1 million km² throughout the world.

The central concept of Umbrisols is that of deeply drained, medium-textured soils with a dark, acid surface with high organic matter content as the most distinguishing feature. Vegetation and climate influence the development of an umbric horizon (a dark colored horizon, with low base saturation). In some cases, an umbric horizon may form quite rapidly while concurrent development of an incipient, non-diagnostic, spodic or argic horizon is slow. This explains why umbric horizons are found in young, relatively undeveloped soils that lack any other diagnostic horizon, or have only a weak cambic horizon. Profile development is strongly dependent on deposition of (significant quantities of) organic material with low base saturation at the soil surface.

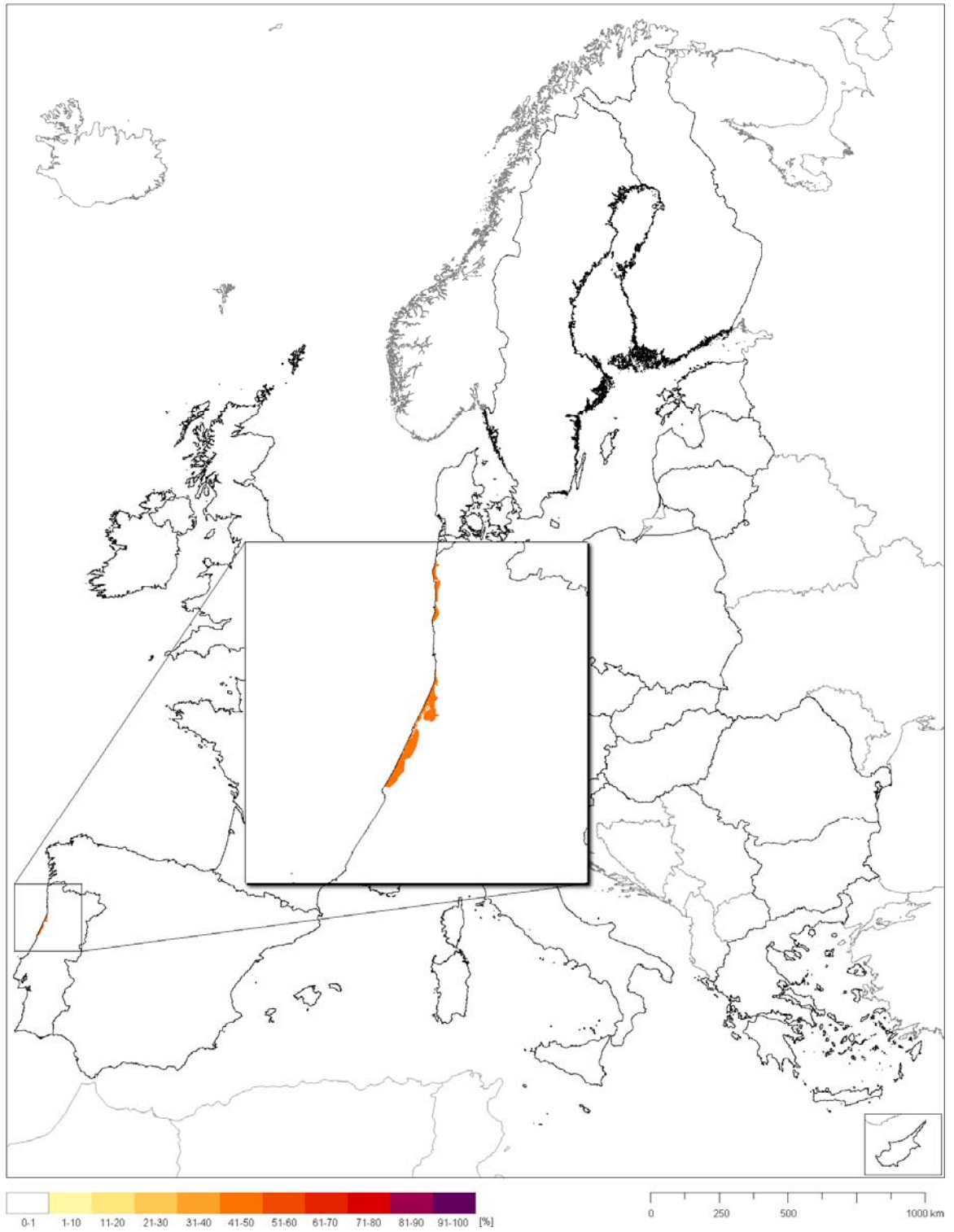
The organic material that characterises Umbrisols can comprise a variety of humus forms that have been variously described as acid or oligotrophic mull, moder, raw humus and mor. Organic matter could accumulate because of slow biological turnover of organic matter under conditions of acidity, low temperature, surface wetness, or a combination of these. However, Umbrisols were never cold and/or wet for sufficiently long periods to have developed a diagnostic histic horizon.

Many Umbrisols of the world are under a natural or near-natural vegetation cover. Umbrisols are predominantly suitable for forestry and extensive grazing. Under adequate management, Umbrisols may also be planted to cash crops such as cereals, root crops, tea and coffee.

Other national and international classification systems classify these soils as Umbrepts and Humitropepts (Soil Taxonomy), Humic Cambisols and Umbric Regosols (FAO), Sombric Brunisols and Humic Regosols (France).

Map 4.22

UMBRISOLS IN THE EUROPEAN UNION



4.23 Vertisols

Geographical distribution

Vertisols cover more than 36,000 km² (0.88%) of the European Union. Vertisols tend to be found in the southern countries of the EU. They form dominant soils in 160 polygons, associated soils in 54 cases and inclusions to 399 associations.

The Reference Soil Group has three soil units in the EU with Chromic and Haplic types accounting for 95% of their total area. (Table 4.23., Figure 4.23)

Table 4.23 Area of the second level units of Vertisols

Units in the Reference Soil Group in the EU	Codes of soil units	Area in the EU km ²
Chromic Vertisol	VRcr	12878
Haplic Vertisol	VRha	1823
Pellic Vertisol	VRpe	21746

Chromic Vertisol is characteristic for the Mediterranean and Balkan countries. **Haplic Vertisols** can be found in Cyprus (as dominant soils in their mapping units) and in Italy (in inclusions). The **Pellic** type is widespread throughout the countries with Vertisols, except in Cyprus. Largest Pellic Vertisol proportions are found in Hungary, Romania and Bulgaria.

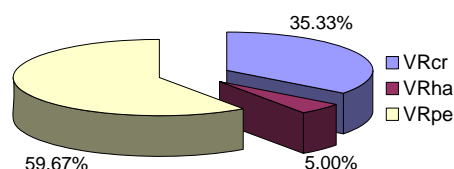


Figure 4.23 Share of the second level soil units in the area of Vertisols

Global reference

Vertisols develop within depressions, in level to undulating landscapes, mainly in tropical, semi-arid to (sub)humid and Mediterranean climates with an alternation of distinct wet and dry seasons. Sediments that contain a high proportion of smectitic clay or products of rock weathering that have the characteristics of smectitic clay are prerequisite of Vertisol formation.

Vertisols cover 3.35 million km² world-wide.

Vertisols shrink and swell upon drying and wetting. Deep wide cracks form when the soil dries out and swelling in the wet season and creates polished and grooved ped surfaces (slickensides) or wedge-shaped or parallel-sided aggregates in the subsurface vertic horizon. The landscapes of a Vertisol may have a complex micro-topography of micro-knolls and micro-basins called gilgai.

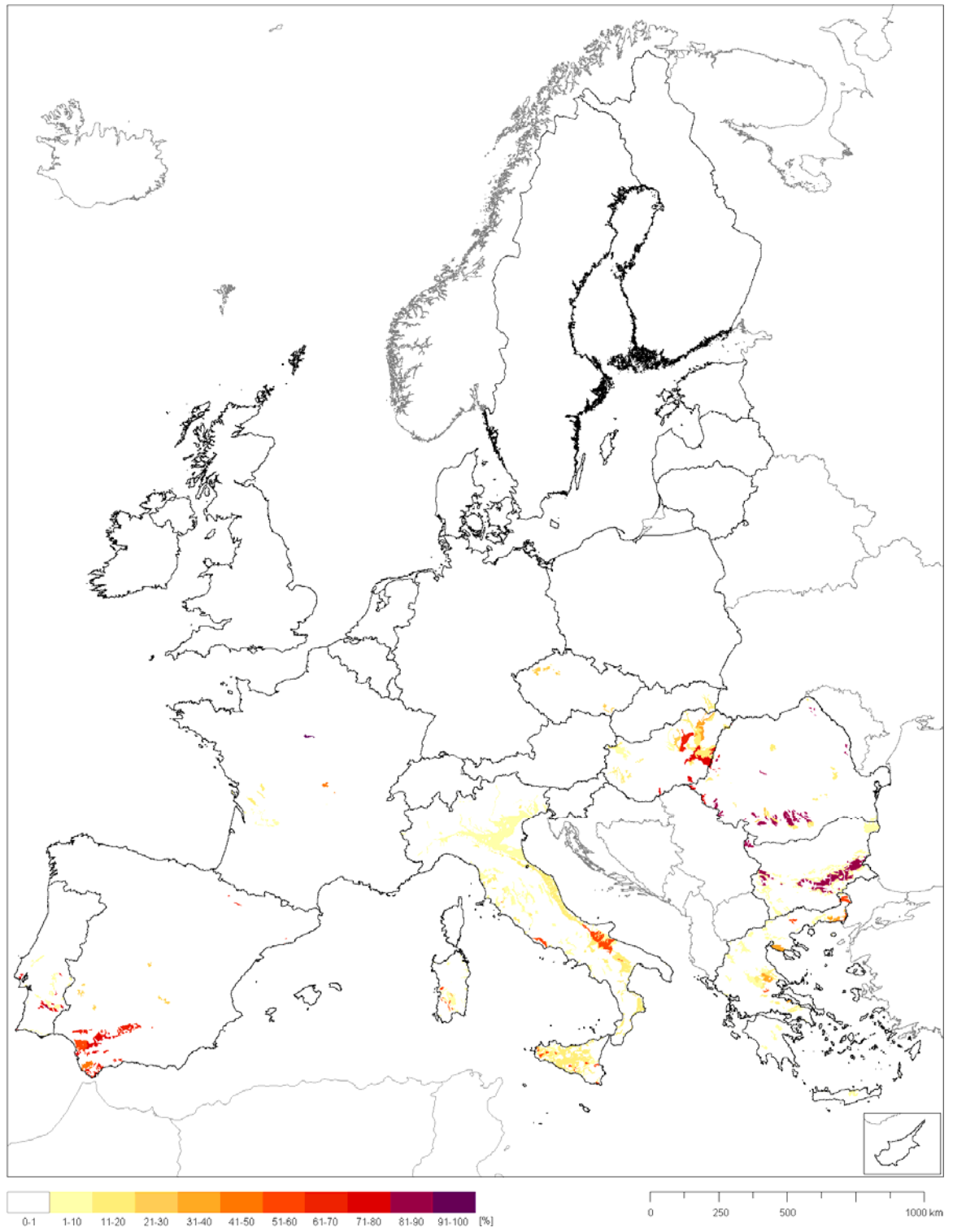
Vertisols with strong pedoturbation have a uniform particle size distribution throughout the profile but texture may change sharply where the substratum is reached. Dry Vertisols can be very hard, while wet Vertisols are very plastic and sticky.

The agricultural use of Vertisols is depending on their physical characteristics, and ranges from very extensive use through smallholder post-rainy season crop production to small-scale and large-scale irrigated agriculture. Cotton is known to perform well on Vertisols. Tree crops are generally less successful because roots find it difficult to establish themselves in the subsoil and are damaged as the soil shrinks and swells.

Vertisols of the world are also known as black cotton soil (USA), regur (India), vlei soil (South Africa) and margalites (Indonesia).

Map 4.23

VERTISOLS IN THE EUROPEAN UNION



5. Concluding remarks

A detailed inventory of the major soil types in the European Union, including their geographical distribution presented on soil maps has been prepared.

An adaptation of the formative elements of the second level units of the World Reference Base for Soil Resources (FAO 1998) as accepted by the European Soil Bureau Network to be shown at the scale of 1:1 million in the European Geographical Soil Database is presented. The information includes definitions relating to Reference Soil Groups, diagnostic horizons, properties materials and attributes.

Based on the analyses of the Soil Geographical Database of Eurasia the following main facts are highlighted:

- The information on soil coverage of the European Union sums up to 4,146,242 km², thus more than 95 % of the total surface area of the EU. Remaining areas include land cover types such as continuous built up areas, water bodies and glaciers.
- Twenty-three Reference Soil Group and ninety-three soil units can be found in the European Union. Soils of the EU represent a considerable share in the diversity of the world soil resources (global soil resources are described in the total of thirty Reference Soil Groups).
- Twenty-two Reference Soil Groups are dominant (occupying $\geq 50\%$ of the area) in some or in many mapping units.
- Geographical distribution of Reference Soil Groups varies between 0.01% of Umbrisols and 26.71% of Cambisols.
- Three main drivers dominate soil forming processes in the EU. More than 80% of the area of the EU is mainly influenced by the (sub-)humid temperate climate, the topography/physiography of the terrain or by the limited time of soil formation.
- The largest spatial extents (with over 30% of the land areas of the EU) have those mineral soils, of which the development is mainly conditioned by the climatic effects of the sub-humid temperate regions.
- The second most widespread set is that with less developed mineral soils (Cambisols), with 26.71% share from the total area.
- The dominating influence of topography on soil formation of mineral soils is characteristic on 26.52% of the land surface of the EU.
- Organic soils occupy 6.48%.
- The dominating influence of parent material is evident on 4.7%.

The figures published in this report might provide new input for a number of analyses in the fields of soil classification, land use studies, ecological and climate change research as well as the socio-economic aspects of soil resources utilization.

References

- EC 2001. Soil Map for Europe. Derived from the scale 1:1.000.000. European Soil Database. Joint Research Centre, European Commission
- EC 2003. European Soil Database (distribution version v2.0). European Commission Joint Research Centre, Italy
- EC 2006. COM 2006/231 2006. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - Thematic Strategy for Soil Protection. Commission of the European Communities. Brussels, 22.9.2006
- CEC. 1985. Explanatory text and map sheets of the 1: 1.000.000 soil map of the European Communities. Directorate-General for Agriculture. Office for official publications of the European Communities, Luxembourg, Luxembourg
- ESBN-EC (European Soil Bureau Network of the European Commission) 2005. Soil Atlas of Europe. Office for Official Publications of the European Communities. (Principal editors A. Jones, L. Montanarella, and R. Jones) Luxembourg. 128pp
- FAO. 1974. Soil map of the world, volume 1: Legend. Food and Agriculture Organization of the United Nations, Rome
- FAO. 1990. Soil map of the world: revised legend. World Soil Resources Report 60. Food and Agriculture Organization of the United Nations, Rome
- FAO 2001. Lecture notes on the major soils of the world. World soil resources reports 94. Edited by: Driessen, P., Deckers, J., Spaargaren, O. and Nachtergaele, F. Food and Agriculture Organization of the United Nations, Rome
- FAO 1998. World reference base for soil resources. World Soil Resources Report 84. Food and Agriculture Organization of the United Nations, Rome
- FAO 2006. World reference base for soil resources. A framework for international classification correlation and communication. World Soil Resources Report 103. Food and Agriculture Organization of the United Nations, Rome
- GISCO 2001. The GISCO Database manual. Eurostat, GISCO Project, Rue Alcide Gasperi, Batiment Bech D3/704, L-2920 Luxembourg, edition November, 2001. http://eussoils.jrc.it/gisco_dbm/dbm/p1ch3_5.htm
- Jones, R.J.A., Houšková, B., Bullock P. and Montanarella L. (eds) 2005. Soil Resources of Europe, second edition. European Soil Bureau Research Report No.9, EUR 20559 EN, 420pp. Office for Official Publications of the European Communities, Luxembourg
- JRC 2008. MEUSIS in the European Soil Portal: <http://eussoils.jrc.ec.europa.eu/projects/meusis/>
- Krasilnikov, P. (comp.) 2002. Soil Terminology and Correlation. Karelian Research Centre of the Russian Academy of Sciences. Petrozavodsk. 2nd Edition
- van Liedekerke, M., Panagos, P., Montanarella L., Filippi N. 2004. Towards a Multi-scale European Soil Information System. 13th EC-GIS Symposium. Porto.
- Panagos, P., Van Liedekerke, M., Filippi, N. and Montanarella, L., 2006. MEUSIS: Towards a new Multi-scale European Soil Information System. ECONGEO, 5th European Congress on Regional Geoscientific Cartography and Information Systems, Barcelona (Spain) June 13th-15th 2006. pp 175-177.

Appendix 1.

Correlation of soil types of the European Union according to different editions of the World Reference Base for Soil Resources (FAO 1998, 2006)

Reference Soil Groups / codes for soil units in WRB 1998	Name of soil unit in WRB 1998	Name of soil unit in WRB 2006
Albeluvisol		
ABeun	Endoeutric Albeluvisol	Haplic Albeluvisol
ABgl	Gleyic Albeluvisol	Gleyic Albeluvisol
ABha	Haplic Albeluvisol	Haplic Albeluvisol
Acrisol		
ACfr	Ferric Acrisol	Haplic Acrisol
ACgl	Gleyic Acrisol	Gleyic Acrisol
ACha	Haplic Acrisol	Haplic Acrisol
AChu	Humic Acrisol	Umbric Acrisol
ACpl	Plinthic Acrisol	Plinthic Acrisol
Andosol		
ANdy	Dystric Andosol	Aluandic Andosol
ANum	Umbric Andosol	Umbric Andisol
ANmo	Mollic Andosol	Mollic Andosol
ANvi	Vitric Andosol	Vitric Andosol
Arenosol		
ARab	Albic Arenosol	Albic Arenosol
ARha	Haplic Arenosol	Haplic Arenosol
ARpr	Protic Arenosol	Protic Arenosol
Anthrosol		
AT	Anthrosol	Anthrosol
ATpa	Plaggic Anthrosol	Plaggic Anthrosol
Chernozem		
CHcc	Calcic Chernozem	Calcic Chernozem
CHgl	Gleyic Chernozem	Gleyic Chernozem
CHha	Haplic Chernozem	Haplic Chernozem
CHlv	Luvic Chernozem	Luvic Chernozem
Calcisol		
CLad	Aridic Calcisol	Haplic Calcisol
Cambisol		
CMca	Calcaric Cambisol	Haplic Cambisol
CMcr	Chromic Cambisol	Haplic Cambisol
CMdy	Dystric Cambisol	Haplic Cambisol
CMeu	Eutric Cambisol	Haplic Cambisol
CMgl	Gleyic Cambisol	Gleyic Cambisol
CMha	Haplic Cambisol	Haplic Cambisol
CMmo	Mollic Cambisol	Haplic Umbrisol
CMvr	Vertic Cambisol	Vertic Cambisol

Appendix 1. continued

Reference Soil Groups / codes for soil units in WRB 1998	Name of soil unit in WRB 1998	Name of soil unit in WRB 2006
Fluvisol		
FLca	Calcaric Fluvisol	Haplic Fluvisol
FLdy	Dystric Fluvisol	Haplic Fluvisol
FLeu	Eutric Fluvisol	Haplic Fluvisol
FLgl	Gleyic Fluvisol	Gleyic Fluvisol
FLha	Haplic Fluvisol	Haplic Fluvisol
FLmo	Mollic Fluvisol	Mollic Fluvisol
FLti	Thionic Fluvisol	Haplic Fluvisol
Gleysol		
GLca	Calcaric Gleysol	Haplic Gleysol
GLdy	Dystric Gleysol	Haplic Gleysol
GLEu	Eutric Gleysol	Haplic Gleysol
GLha	Haplic Gleysol	Haplic Gleysol
GLhi	Histic Gleysol	Histic Gleysol
GLhu	Humic Gleysol	Haplic Gleysol
GLmo	Mollic Gleysol	Mollic Gleysol
GLti	Thionic Gleysol	Haplic Gleysol
Gypsisol		
GYad	Aridic Gypsisol	Haplic Gypsisol
Histosol		
HSdy	Dystric Histosol	Hemic Histosol
HSeu	Eutric Histosol	Hemic Histosol
Kastanozem		
KSec	Calcic Kastanozem	Calcic Kastanozem
KSha	Haplic Kastanozem	Haplic Kastanozem
KSlv	Luvic Kastanozem	Luvic Kastanozem
Leptosol		
LPca	Calcaric Leptosol	Haplic Leptosol
LPdy	Dystric Leptosol	Haplic Leptosol
LPeu	Eutric Leptosol	Haplic Leptosol
LPha	Haplic Leptosol	Haplic Leptosol
LPrz	Rendzic Leptosol	Rendzic Leptosol
Lpli	Lithic Leptosol	Lithic Leptosol
Luvisol		
LVab	Albic Luvisol	Albic Luvisol
LVar	Arenic Luvisol	Haplic Luvisol
LVcc	Calcic Luvisol	Calcic Luvisol
LVer	Chromic Luvisol	Haplic Luvisol
LVdy	Dystric Luvisol	Haplic Luvisol
LVfr	Ferric Luvisol	Haplic Luvisol
LVgl	Gleyic Luvisol	Gleyic Luvisol
LVha	Haplic Luvisol	Haplic Luvisol
LVvr	Vertic Luvisol	Vertic Luvisol

Appendix 1. continued

Reference Soil Groups / codes for soil units in WRB 1998	Name of soil unit in WRB 1998	Name of soil unit in WRB 2006
Phaeozem		
PHca	Calcaric Phaeozem	Haplic Phaeozem
PHgl	Gleyic Phaeozem	Gleyic Phaeozem
PHha	Haplic Phaeozem	Haplic Phaeozem
PHlv	Luvic Phaeozem	Luvic Phaeozem
PHso	Sodic Phaeozem	Haplic Phaeozem
Planosol		
PLdy	Dystric Planosol	Haplic Planosol
PLeu	Eutric Planosol	Haplic Planosol
PLha	Haplic Planosol	Haplic Planosol
Podzol		
PZgl	Gleyic Podzol	Gleyic Podzol
PZha	Haplic Podzol	Haplic Podzol
PZle	Leptic Podzol	Leptic Podzol
PZpi	Placic Podzol	Placic Podzol
PZum	Umbric Podzol	Umbric Podzol
Regosol		
RGca	Calcaric Regosol	Haplic Regosol
RGdy	Dystric Regosol	Haplic Regosol
RGeu	Eutric Regosol	Haplic Regosol
RGha	Haplic Regosol	Haplic Regosol
Solonchak		
SCgl	Gleyic Solonchak	Gleyic Solonchak
SCha	Haplic Solonchak	Haplic Solonchak
S Cty	Takyric Solonchak	Takyric Solonchak
Solonetz		
SNgl	Gleyic Solonetz	Gleyic Solonetz
SNha	Haplic Solonetz	Haplic Solonetz
SNmo	Mollic Solonetz	Mollic Solonetz
Umbrisol		
UMar	Arenic Umbrisol	Haplic Umbrisol
Vertisol		
VRcr	Chromic Vertisol	Haplic Vertisol
VRha	Haplic Vertisol	Haplic Vertisol
VRpe	Pellic Vertisol	Haplic Vertisol

Appendix 2.

Sets of Reference Soil Groups in the World Reference Base for soil resources

Based on the concept of dominant identifiers, i.e. the soil forming factors or processes that most clearly condition the soil formation Reference Soil Groups of the two consecutive version of WRB are aggregated in 10 sets (FAO 2001 and 2006). The structure and composition of sets defined on the basis of the first edition of the WRB (FAO 2001) was modified in the second edition (FAO 2006). Hereby we present both versions.

Table 1. is ready to use with the soil maps presented in this report. Table 2. is applicable in the context of the current soil maps of the EU together with the correlation tables of Appendix 1.

Table 1. Sets of Reference Soil Groups based on WRB 1998 (FAO 2001)

SET #1	Organic soils	HISTOSOLS*
SET #2	Mineral soils whose formation was conditioned by human influences (not confined to any particular region)	ANTHROSOLS*
SET #3	Mineral soils whose formation was conditioned by their parent material	ANDOSOLS*
	- Soils developed in volcanic material	ARENOSOLS*
	- Soils developed in residual and shifting sands	VERTISOLS*
	- Soils developed in expanding clays	
SET #4	Mineral soils whose formation was conditioned by the topography/physiography of the terrain	FLUVISOLS*
	- Soils in lowlands (wetlands) with level topography	GLEYSOLS*
	- Soils in elevated regions with non-level topography	LEPTOSOLS*
		REGOSOLS*
SET #5	Mineral soils whose formation is conditioned by their limited age (not confined to any particular region)	CAMBISOLS*
SET #6	Mineral soils whose formation was conditioned by climate: (sub-)humid tropics	PLINTHOSOLS
		FERRALSOLS
		NITISOLS
		ACRISOLS*
		ALISOLS
		LIXISOLS
SET #7	Mineral soils whose formation was conditioned by climate: arid and semi-arid regions	SOLONCHAKS*
		SOLONETZ*
		GYPSISOLS*
		DURISOLS
		CALCISOLS*
SET #8	Mineral soils whose formation was conditioned by climate: steppes and steppic regions	KASTANOZEMS*
		CHERNOZEMS*
		PHAEZEMS*
SET #9	Mineral soils whose formation was conditioned by climate: (sub-)humid temperate regions	PODZOLS*
		PLANOSOLS*
		ALBELUVISOLS*
		LUVISOLS*
		UMBRISOLS*
SET #10	Mineral soils whose formation was conditioned by climate: permafrost regions	CRYOSOLS

* Reference Soil Groups found in the EU.

Table 2. Sets of Reference Soil Groups in WRB 2006

SET #1 Soils with thick organic layers		HISTOSOLS
SET #2 Soils with strong human influence		
	Soils with long and intensive agricultural use:	ANTHROSOLS
	Soils containing many artifacts: Technosols	TECHNOSOLS
SET #3 Soils with limited rooting due to shallow permafrost or stoniness		
	Ice-affected soils	CRYOSOLS
	Shallow or extremely gravelly soils	LEPTOSOLS
SET #4 Soils influenced by water		
	Alternating wet-dry conditions, rich in swelling clays	VERTISOLS
	Floodplains, tidal marshes	FLUVISOLS
	Alkaline soils	SOLONETZ
	Salt enrichment upon evaporation	SOLOCHAKS
	Groundwater affected soils	GLEYSOLS
SET #5 Soils set by Fe/Al chemistry		
	Allophanes or Al-humus complexes	ANDOSOLS
	Cheluviation and chilluviation	PODZOLS
	Accumulation of Fe under hydromorphic conditions	PLINTHOSOLS
	Low-activity clay, P fixation, strongly structured	NITISOLS
	Dominance of kaolinite and sesquioxides	FERRALSOLS
SET #6 Soils with stagnating water		
	Abrupt textural discontinuity	PLANOSOLS
	Structural or moderate textural discontinuity	STAGNOSOLS
SET #7 Accumulation of organic matter, high base status		
	Typically mollic	CHERNOZEMS
	Transition to drier climate	KASTANOZEMS
	Transition to more humid climate	PHAEZEMS
SET #8 Accumulation of less soluble salts or non-saline substances		
	Gypsum	GYPSISOLS
	Silica	DURISOLS
	Calcium carbonate	CALCISOLS
SET #9 Soils with a clay-enriched subsoil		
	Albeluvisols	
	Low base status, high-activity clay	ALISOLS
	Low base status, low-activity clay	ACRISOLS
	High base status, high-activity clay	LUVISOLS
	High base status, low-activity clay	LIXISOLS
SET #10 Relatively young soils or soils with little or no profile development		
	With an acidic dark topsoil	UMBRISOLS
	Sandy soils	ARENOSOLS
	Moderately developed soils	CAMBISOLS
	Soils with no significant profile development	REGOSOLS

Appendix 3.

Adaptation of lower level units of WRB (FAO 1998) to the soils of the European Union

This appendix is based on the 1998 edition of the World Reference Base for Soil Resources (FAO 1998).

The information includes definitions of the formative elements for the second-level units relating to Reference Soil Groups, diagnostic horizons, properties and materials, attributes such as colour, chemical conditions, texture, etc. These formative elements are accepted by the European Soil Bureau Network to be shown at the scale of 1:1 million in the European Geographical Soil Database.

1. General principles for distinguishing lower level units

The general rules to be followed when differentiating lower level units are:

1. The diagnostic criteria applied at lower level are derived from the already established reference group diagnostic horizons, properties and other defined characteristics. They may, in addition, include new elements as well as criteria used for phase definitions at higher levels.
2. Lower level units may be defined, and named, on the basis of the presence of diagnostic horizons. In general, weaker or incomplete occurrences of similar features are not considered as differentiae.
3. Differentiating criteria related to climate, parent material, vegetation or to physiographic features such as slope, geomorphology or erosion are not considered. The same applies to criteria derived from soil-water relationships such as depth of water table or drainage. Substratum layers, thickness and morphology of solum or individual horizons, are not considered as diagnostic criteria for the differentiation of the lower level units.
4. There is one set of diagnostic criteria for the definition of the lower level soil units. This name contains in its definition the diagnostic criterion and functions at the same time as second and third level connotative. Each soil qualifier is given one unique meaning which should be applicable to all reference soil groups in which it occurs.
5. A single name should be used to define each lower level. However, these names can be used in combination with indicators of depth, thickness or intensity. If additional names are needed, these should be listed after the reference soil group names between brackets, e.g. Acric-Geric Ferralsol (Abruptic and Xanthic).
6. Definitions of the lower level units should not overlap or conflict with other soil subunits or with reference soil group definitions. For example, a Dystric-Petric Calcisol is a contradiction, whereas a Eutric-Petric Calcisol is an overlap in the sense that the name "eutric" does not give more information. New units can only be established after being documented by soil profile descriptions and supporting laboratory analyses.
7. Priority rules for the use of lower level soil names are to be followed strictly to avoid confusion. Precise ranking orders for each qualifier in each reference soil group are given later in the text.

Example

In Vertisols the following qualifiers have been recognized, in order of priority:

1. Thionic intergrade with acid sulphate Gleysols and Fluvisols
2. Salic intergrade with the Solonchak reference soil group
3. Natric intergrade with the Solonetz reference soil group
4. Gypsic intergrade with the Gypsisol reference soil group
5. Duric intergrade with the Durisol reference soil group
6. Calcic intergrade with the Calcisol reference soil group

7. Alic intergrade with the Alisol reference soil group
8. Gypsic containing gypsum
9. Pellic dark coloured, often poorly drained
10. Grumic mulched surface horizon
11. Mazic very hard surface horizon; workability problems
12. Chromic reddish coloured
13. Mesotrophic having less than 75 percent base saturation (occurs in Venezuela)
14. Hyposodic having an ESP of 6 to 15
15. Eutric having 75 percent or more base saturation
16. Haplic no specific characteristics

To classify a reddish coloured *Vertisol* with a calcic horizon one would follow the priority list and note that qualifiers 6 and 12 apply. Therefore, the soil is classified as Chromi-Calcic Vertisol. If more information on depth and intensity of the calcic horizon is available, e.g. Occurring near to the surface, one may specify this by classifying the soil as Chromi-Epicalcic Vertisol, indicating the occurrence of the calcic horizon within 50 cm from the surface.

When more than two qualifiers are required, they can be added between brackets after the standard name. If, for instance, the Vertisol discussed also has a very hard surface horizon (qualifier 11), the soil would be named Mazi-Calcic Vertisol (Chromic).

2. Definitions of formative elements for lower level units

2.1 Qualifiers

Albic having an *albic* horizon within 100 cm from the soil surface.

Arenic having a texture of loamy fine sand or coarser throughout the upper 50 cm of the soil.

Aridic having aridic properties without a takyric or yermic horizon.

Calcaric calcareous at least between 20 and 50 cm from the soil surface.

Calcic having a *calcic* horizon or concentrations of secondary carbonates between 50 and 100 cm from the soil surface.

Chromic having a B horizon which in the major part has a Munsell hue of 7.5YR and a chrome, moist, of more than 4, or a hue redder than 7.5YR.

Dystric having a base saturation (by 1 M NH₄OAc) of less than 50 percent in at least some part between 20 and 100 cm from the soil surface, or in a layer 5 cm thick directly above a lithic contact in Leptosols.

Eutric having a base saturation (by 1 M NH₄OAc) of 50 percent or more at least between 20 and 100 cm from the soil surface, or in a layer 5 cm thick directly above a lithic contact in Leptosols.

Ferric having a *ferric* horizon within 100 cm from the soil surface.

Gelic having *permafrost* within 200 cm from the soil surface.

Gleyic having *gleyic* properties within 100 cm from the soil surface.

Haplic having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization).

Histic having a *histic* horizon within 40 cm from the soil surface.

Humic having a high organic carbon content; in *Ferralsols* and *Nitisols* more than 1.4 percent (by weight) organic carbon in the fine earth fraction as weighted average over a depth of 100 cm from the soil surface, in *Leptosols* more than 2 percent (by weight) organic carbon in the fine earth fraction to a depth of 25 cm from the soil surface, and in other soils more than 1 percent (by weight) organic carbon in the fine earth fraction to a depth of 50 cm from the soil surface.

Leptic having continuous hard rock between 25 and 100 cm from the soil surface.

Lithic having continuous hard rock within 10 cm from the soil surface.

Luvic having an *argic* horizon which has a cation exchange capacity equal to or more than 24 cmolc kg⁻¹ clay throughout, and a base saturation by 1 M NH₄OAc) of 50 percent or more throughout the horizon to a depth of 100 cm from the soil surface.

Mollic having a *mollic* horizon.

Pellic having in the upper 30 cm of the soil matrix a Munsell value, moist, of 3.5 or less and a chroma of 1.5 or less (*in Vertisols only*).

Placic having within 100 cm from the soil surface a subhorizon of the *spodic* horizon which is 1 cm or more thick and which is continuously cemented by a combination of organic matter and aluminium, with or without iron ("thin iron pan") (*in Podzols only*).

Plaggic having a *plaggic* horizon; in *Anthrosols* 50 cm or more thick, in other soils less than 50 cm thick.

Plinthic having a *plinthic* horizon within 100 cm from the soil surface.

Protic showing no appreciable soil horizon development (*in Arenosols only*).

Rendzic having a *mollic* horizon which contains or immediately overlies calcareous materials containing more than 40 percent calcium carbonate equivalent (*in Leptosols only*).

Sapric having less than one-sixth (by volume) of the *organic* soil material consisting of recognizable plant tissue (after rubbing) (*in Histosols only*).

Sodic having more than 15 percent exchangeable sodium or more than 50 percent exchangeable sodium plus magnesium on the exchange complex within 50 cm from the soil surface.

Takyric having a *takyric* horizon.

Thionic having a *sulfuric* horizon or *sulfidic* soil material within 100 cm from the soil surface.

Umbric having an *umbric* horizon.

Vertic having a *vertic* horizon within 100 cm from the soil surface.

Vitric having a *vitric* horizon within 100 cm from the soil surface and lacking an andic horizon overlying a vitric horizon.

2.2 Diagnostic horizons

Albic horizon

General description. The albic horizon (from L. *albus*, white) is a light coloured subsurface horizon from which clay and free iron oxides have been removed, or in which the oxides have been segregated to the extent that the colour of the horizon is determined by the colour of the sand and silt particles rather than by coatings on these particles. It generally has a weakly expressed soil structure or lacks structural development altogether. The upper and lower boundaries are normally abrupt or

clear. The morphology of the boundaries is variable and sometimes associated with albeluvic tonguing. Albic horizons usually have coarser textures than the overlying or underlying horizons, although this difference with respect to an underlying spodic horizon may only be slight. Many albic horizons are associated with wetness and contain evidence of gleyic or stagnic properties.

Diagnostic criteria.

An albic horizon must have:

1. Munsell colour, dry:
 - a. value of either 7 or 8 and a chrome of 3 or less; or
 - b. value of 5 or 6 and a chrome of 2 or less; and
2. Munsell colour, moist:
 - a. a value 6, 7 or 8 with a chrome of 4 or less; or
 - b. a value of 5 and a chrome of 3 or less¹; or
 - c. a value of 4 and a chrome of 2 or less. A chrome of 3 is permitted if the parent materials have a hue of 5YR or redder, and the chrome is due to the colour of uncoated silt or sand grains; and
3. thickness: at least 1 cm.

Field identification. Identification of albic horizons in the field is based on Munsell soil colours. In addition to the colour determination, checks can be made using a x10 hand-lens to verify if coatings on sand and silt-sized particles are absent.

Additional characteristics. The presence of coatings around sand and silt grains can be determined using an optical microscope for analysing thin sections. Uncoated grains usually show a very thin rim at their surface. Coatings may be of an organic nature, consist of iron oxides, or both, and are dark coloured under translucent light. Iron coatings become reddish in colour under reflected light, while organic coatings remain brownish-black.

Relationships with some other diagnostic horizons. Albic horizons are normally overlain by humus-enriched surface horizons (mollic, umbric or ochric horizons) but may be at the surface due to erosion or artificial removal of the surface layer. They can be considered as an extreme type of eluvial horizon, and usually occur in association with illuvial horizons such as an argic, natric or spodic horizon, which they overlie. In sandy materials albic horizons can reach considerable thickness, up to several metres, especially in humid tropical regions, and associated diagnostic horizons may be hard to establish.

Andic horizon

General description. The andic horizon (from Japanese *An*, dark, and *Do*, soil) is a horizon resulting from moderate weathering of mainly pyroclastic deposits. However, they may also be found in association with non-volcanic materials (e.g. loess, argillites and ferralitic weathering products). Their mineralogy is dominated by short-range-order minerals, and they are part of the weathering sequence in pyroclastic deposits (tephric soil material (r) vitric horizon (r) andic horizon). Andic horizons may be found both at the surface and in the subsurface. They also often occur as layers, separated by non-andic layers. As a surface horizon, andic horizons generally contain a high amount of organic matter (more than 5 percent), are very dark coloured (Munsell value and chrome, moist, is 3 or less), have a fluffy macrostructure and often a smeary consistence. They are light in weight (have a low bulk density), and have mostly silt loam or finer textures. Andic surface horizons rich in organic matter may be very deep, reaching often a thickness of 50 cm or more (pachic characteristic). Andic subsurface horizons are generally somewhat lighter coloured. Andic horizons may have different properties, depending on the type of dominant weathering process acting upon the soil material. They may exhibit thixotropy, i.e. the soil material changes, under pressure or by rubbing, from a plastic solid into a liquified stage and back into the solid condition. In perhumid climates, humus-rich andic horizons may contain more than 100 percent water (by volume) compared to their oven-dry volume (hydric characteristic). Two major types of andic horizons are recognized, one in which allophane and similar minerals are predominant (the sil-andic type), and one in which aluminium complexed by organic

¹ Colour requirements have been slightly changed with respect to those defined in FAO (1988) and Soil Survey Staff (1996) to accommodate albic horizons, which show a considerable shift in chrome upon moistening. Such albic horizons occur frequently in, for example, the southern African region.

acids prevails (the alu-andic type). The sil-andic horizon has an acid to neutral soil reaction, while the alu-andic horizon varies from extremely acid to acid.

Diagnostic criteria. An andic horizon must have the following physical, chemical and mineralogical properties (Shoji et al, 1996; Berding, 1997):

1. bulk density of the soil at field capacity (no prior drying) of less than 0.9 kg dm^{-3} ; and
2. 10 percent or more clay and an $\text{Al}_{\text{ox}} + 1/2\text{Fe}_{\text{ox}}^2$ value in the fine earth fraction of 2 percent or more; and
3. phosphate retention of 70 percent or more; and
4. volcanic glass content in the fine earth fraction of less than 10 percent; and
5. thickness of at least 30 cm.

Sil-andic horizons have an acid oxalate (pH 3) extractable silica (Si_{ox}) of 0.6 percent or more while alu-andic horizons have a Si_{ox} of less than 0.6 percent (or, alternatively, an $\text{Al}_{\text{py}}^3/\text{Al}_{\text{ox}}$ ratio of less than 0.5 and 0.5 or more, respectively).

Field identification. Andic horizons may be identified using the pH NaF field test developed by Fieldes and Perrott (1966). A pH NaF of more than 9.5 indicates an abundant presence of allophanic products and/or organo-aluminium complexes. The test is indicative for most andic horizons, except for those very rich in organic matter. However, the same reaction occurs in spodic horizons and in certain acid clayey soils, which are rich in aluminium interlayered clay minerals. Sil-andic horizons generally have a field pH (H_2O) of 5 or higher, while alu-andic horizons mainly have a field pH (H_2O) of less than 4.5. If the pH (H_2O) is between 4.5 and 5, additional tests may be necessary to establish the 'alu-' or 'sili-' characteristic of the andic horizon.

Relationships with some other diagnostic horizons. Vitric horizons are distinguished from andic horizons by their lesser rate of weathering. This is evidenced by a higher volcanic glass content in vitric horizons (> 10 percent of the fine earth fraction) and a lower amount of noncrystalline or paracrystalline pedogenetic minerals, as characterized by the moderate amount of acid oxalate (pH 3) extractable aluminium and iron in vitric horizons ($\text{Al}_{\text{ox}} + 1/2\text{Fe}_{\text{ox}} = 0.4\text{-}2.0$ percent), by a higher bulk density (BD of vitric horizons is between 0.9 and 1.2 kg dm^{-3}), and by a lower phosphate retention (25 - < 70 percent). To separate andic horizons rich in organic matter from histic and folic horizons, andic horizons are not permitted to contain more than 20 percent organic carbon, while histic horizons with an organic carbon content between 12 and 20 percent are not permitted to have properties associated with andic horizons. Spodic horizons, which also contain complexes of sesquioxides and organic substances, can have similar characteristics to andic horizons rich in alumino-organic complexes. Sometimes only analytical tests can discriminate between the two. Spodic horizons have at least twice as much $\text{Al}_{\text{ox}} + 1/2\text{Fe}_{\text{ox}}$ than an overlying umbric, ochric or albic horizon. This normally does not apply to andic horizons in which the alumino-organic complexes are virtually immobile.

Argic horizon

General description. The argic horizon (from L. *argilla*, white clay) is a subsurface horizon which has a distinctly higher clay content than the overlying horizon. The textural differentiation may be caused by an illuvial accumulation of clay, by predominant pedogenetic formation of clay in the subsoil or destruction of clay in the surface horizon, by selective surface erosion of clay, by biological activity, or by a combination of two or more of these different processes. Sedimentation of surface materials which are coarser than the subsurface horizon may enhance a pedogenetic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic horizon. Soils with argic horizons often have a specific set of morphological, physico-chemical and mineralogical properties other than a mere clay increase. These properties allow various types of 'argic' horizons to be distinguished and to trace their pathways of development (Sombroek, 1986). Main subtypes are lixi-, luvi-, abrupti- and plan-argic horizons, and natric and nitic horizons. The argic B horizon as defined in the Revised Legend of the Soil Map of the World (FAO, 1988) is taken as a reference, with one modification. The requirement to observe in the field '... at least 1 percent clay skins on ped surfaces and in pores...' is changed into 5 percent. This change is based on the notion that there is no 1:1 correspondence between the amount of clay skins on ped surfaces and in pores, and the percentage of the thin section occupied by oriented clay.

² Al_{ox} and Fe_{ox} are acid oxalate extractable aluminium and iron, respectively (method of Blakemore et al., 1987).

³ Al_{py} : pyrophosphate extractable aluminium.

Even if 100 percent of the ped surfaces are covered by clay skins, the thin section will in its major part be occupied by the matrix of the soil and voids.

Diagnostic criteria. An argic horizon must have:

1. texture of sandy loam or finer and at least 8 percent clay in the fine earth fraction; and
2. more total clay than an overlying coarser textured horizon (exclusive of differences which result from a lithological discontinuity only) such that:
 - a. if the overlying horizon has less than 15 percent total clay in the fine earth fraction, the argic horizon must contain at least 3 percent more clay; or
 - b. if the overlying horizon has 15 percent or more and less than 40 percent total clay in the fine earth fraction, the ratio of clay in the argic horizon to that of the overlying horizon must be 1.2 or more; or
 - c. if the overlying horizon has 40 percent or more total clay in the fine earth fraction, the argic horizon must contain at least 8 percent more clay; and
3. an increase in clay content within a vertical distance of 30 cm if an argic horizon is formed by clay illuviation. In any other case the increase in clay content between the overlying and the argic horizon must be reached within a vertical distance of 15 cm; and
4. autochthonous rock structure is absent in at least half the volume of the horizon; and
5. thickness of at least one tenth of the sum of the thickness of all overlying horizons and at least 7.5 cm thick. If the argic horizon is entirely composed of lamellae, the lamellae must have a combined thickness of at least 15 cm. The coarser textured horizon overlying the argic horizon must be at least 18 cm thick or 5 cm if the textural transition to the argic horizon is abrupt (see abrupt textural change, in diagnostic properties).

Field identification. Textural differentiation is the main feature for recognition of argic horizons in the field. The illuvial nature may be established in the field using a x10 hand-lens if clear clay skins occur on ped surfaces, in fissures, in pores and in channels. An 'illuvial' argic horizon should at least in some part show clay skins on at least 5 percent of both horizontal and vertical ped faces and in the pores. Clay skins are often difficult to detect in soils with a smectitic mineralogy as these are destroyed regularly by shrink-swell movements. The presence of clay skins in 'protected' positions, e.g. in pores, should be sufficient to meet the requirements for an 'illuvial' argic horizon.

Additional characteristics. The illuvial character of an argic horizon can best be established using thin sections. Diagnostic 'illuvial' argic horizons must show areas with oriented clays that constitute on average at least 1 percent of the entire cross-section. Other tests involved are particle size distribution analysis, to determine the increase in clay content over a specified depth, and the fine clay⁴/total clay analysis. In 'illuvial' argic horizons the fine clay/total clay ratio is larger than in the overlying horizons, caused by preferential eluviation of fine clay particles. If the soil shows a lithological discontinuity over or within the argic horizon, or if the surface horizon has been removed by erosion, or if only a plough layer overlies the argic horizon, the illuvial nature must be clearly established. A lithological discontinuity, if not clear from the field (data), can be identified by the percentage of coarse sand, fine sand and silt, calculated on a clay-free basis (international particle size distribution or using the additional groupings of the USDA system or other), or by changes in the content of gravel and coarser fractions. A change of at least 20 percent (relative) of any of the major particle size fractions can be regarded as diagnostic for a lithological discontinuity. However, it should only be taken into account if it is located in the section of the profile where the clay increase occurs and if there is evidence that the overlying layer was coarser textured. Although this is a simplified way of treating lithological discontinuities, not much more can be done with the data commonly available. On the other hand, particle size discontinuities are of main interest for the argic horizon and will show if the overlying material was very much different and coarser, even without considering clay loss due to eluviation or other processes. Relationships with some other diagnostic horizons. Argic horizons are normally associated with and situated below eluvial horizons, i.e. horizons from which clay and iron have been removed. Although initially formed as a subsurface horizon, argic horizons may occur at the surface as a result of erosion or removal of the overlying horizons. Some clay-increase horizons may have the set of properties which characterize the ferralic horizon, i.e. a low CEC and ECEC (effective CEC), a low content of water-dispersible clay and a low content of weatherable minerals, all over a depth of 50 cm. In such cases a ferralic horizon has preference over an argic horizon for classification purposes. However, an argic horizon prevails if it overlies a ferralic horizon and it has, in its upper part over a depth of 30 cm, 10 percent or more water-dispersible clay, unless the soil material has geric properties or more than 1.4 percent organic carbon. Argic horizons also lack the structure and sodium saturation characteristics of the natric horizon.

⁴ Fine clay: <0.2 μm.

Calcic horizon

General description. The calcic horizon (from L. *calx*, lime) is a horizon in which secondary calcium carbonate (CaCO_3) has accumulated either in a diffuse form (calcium carbonate present only in the form of fine particles of 1 mm or less, dispersed in the matrix) or as discontinuous concentrations (pseudomycelia, cutans, soft and hard nodules, or veins). The accumulation may be in the parent material, or in subsurface horizons, but it can also occur in surface horizons as a result of erosion. If the accumulation of soft carbonates becomes such that all or most of the pedological and/or lithological structures disappear and continuous concentrations of calcium carbonate prevail, the horizon is named a hypercalcic horizon (from Gr. hyper, superseding, and L. calxis, lime).

Diagnostic criteria. A calcic horizon must have:

1. calcium carbonate equivalent content in the fine earth fraction of 15 percent or more (for hypercalcic horizons more than 50 percent calcium carbonate equivalent in the fine earth fraction); and
2. thickness at least 15 cm, also for the hypercalcic horizon.

Field identification. The presence of calcium carbonate can be identified in the field using a 10% HCl solution. The degree of effervescence (audible only, visible as individual bubbles, or foam-like) is an indication of the amount of lime present. This test is important if only diffuse distributions are present.

Other indications for the presence of a calcic or hypercalcic horizon are:

1. soil colours which are more or less white, pinkish to reddish, or grey; and
2. a low porosity (inter-aggregate porosity in the (hyper-)calcic horizon is usually less than that in the horizon immediately above and possibly also less than in the horizon directly underneath).

Calcium carbonate content may decrease with depth, but this is often difficult to establish, particularly if the calcic horizon occurs in the deeper subsoil. Accumulation of secondary lime is therefore sufficient to diagnose a (hyper-)calcic horizon.

Additional characteristics. Determination of the amount of calcium carbonate (by weight) and the changes within the soil profile of the calcium carbonate content are the main analytical criteria for establishing the presence of a calcic horizon. Determination of the pH (H_2O) enables distinction between accumulations with a basic ('calcic') character (pH 8.0 - 8.7) due to the dominance of CaCO_3 , and those with an ultrabasic ('non-calcic') character (pH > 8.7) because of the presence of MgCO_3 or Na_2CO_3 . In addition, microscopical analysis of thin sections may reveal the presence of dissolution forms in horizons above or below a calcic horizon, evidence of silicate epigenesis (isomorphous substitution of quartz by calcite), or the presence of other calcium carbonate accumulation structures, while clay mineralogical analyses of calcic horizons often show clays characteristic of confined environments, such as montmorillonites, attapulgites and sepiolites. Relationships with some other diagnostic horizons. When hypercalcic horizons become indurated, transition takes place to the petrocalcic horizon, the expression of which may be massive or as platy structures. In dry regions and in the presence of sulphate-bearing soil- or groundwater solutions, calcic horizons occur associated with gypsic horizons. Calcic and gypsic horizons usually occupy different positions in the soil profile because of the difference in solubility of calcium carbonate and gypsum, and normally they can be clearly distinguished from each other by the difference in morphology. Gypsum crystals tend to be needle-shaped, often visible with the naked eye, whereas pedogenetic calcium carbonate crystals are much finer in size.

Ferric horizon

General description. The ferric horizon (from L. *ferrum*, iron) is a horizon in which segregation of iron has taken place to such an extent that large mottles or concretions have formed and the inter-mottle/inter-concretionary matrix is largely depleted of iron. Generally, such segregation leads to poor aggregation of the soil particles in iron-depleted areas and compaction of the horizon.

Diagnostic criteria. A ferric horizon must have:

1. many (more than 15 percent of the exposed surface area) coarse mottles with hues redder than 7.5YR and chrome more than 5, or both; or
2. discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with iron and having redder hues or stronger chrome than the interiors; and
3. thickness of at least 15 cm.

Relationships with some other diagnostic horizons. If the amount of nodules reaches 10 percent or more (by volume) and the nodules harden irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access of oxygen, the horizon is considered to be a plinthic horizon. Therefore, ferric horizons may, in tropical or subtropical regions, grade laterally into plinthic horizons. The transition between the two is often not very clear.

Histic horizon

General description. The histic horizon (from Gr. *histos*, tissue) is a surface horizon, or a subsurface horizon occurring at shallow depth, which consists of poorly aerated organic soil material. Diagnostic criteria. A histic horizon must have:

1. either - 18 percent (by weight) organic carbon (30 percent organic matter) or more if the mineral fraction comprises 60 percent or more clay;
or - 12 percent (by weight) organic carbon (20 percent organic matter) or more if the mineral fraction has no clay;
or - a proportional lower limit of organic carbon content between 12 and 18 percent if the clay content of the mineral fraction is between 0 and 60 percent. If present in materials characteristic for andic horizons, the organic carbon content must be more than 20 percent (35 percent organic matter); and
2. saturation with water for at least one month in most years (unless artificially drained); and
3. thickness of 10 cm or more. A histic horizon less than 20 c

Mollic horizon.

General description. The mollic horizon (from L. *mollis*, soft) is a well structured, dark coloured surface horizon with a high base saturation and a moderate to high content in organic matter.

Diagnostic criteria. A mollic horizon must have:

1. soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms (prisms larger than 30 cm in diameter) are included in the meaning of massive if there is no secondary structure within the prisms; and
2. both broken and crushed samples have a Munsell chrome of less than 3.5 when moist, a value darker than 3.5 when moist and 5.5 when dry. If there is more than 40 percent finely divided lime, the limits of colour value dry are waived; the colour value, moist, should be 5 or less. The colour value must be at least one unit darker than that of the C horizon (both moist and dry), unless the soil is derived from dark coloured parent material, in which case the colour contrast requirement is waived. If a C horizon is not present, comparison should be made with the horizon immediately underlying the surface horizon; and
3. an organic carbon content of 0.6 percent (1 percent organic matter) or more throughout the thickness of mixed horizon. The organic carbon content is at least 2.5 percent if the colour requirements are waived because of finely divided lime, or 0.6 percent more than the C horizon if the colour requirements are waived because of dark coloured parent materials; and
4. a base saturation (by 1 M NH₄OAc) of 50 percent or more on a weighted average throughout the depth of the horizon; and
5. the following thickness:
 - a. 10 cm or more if resting directly on hard rock, a petrocalcic, petroduric or petrogypsic horizon, or overlying a cryic horizon; or
 - b. at least 20 cm and more than one-third of the thickness of the solum where the solum is less than 75 cm thick; or
 - c. more than 25 cm where the solum is more than 75 cm thick.

The measurement of the thickness of a mollic horizon includes transitional horizons in which the characteristics of the surface horizon are dominant - for example, AB, AE or AC.

The requirements for a mollic horizon must be met after the first 20 cm are mixed, as in ploughing.

Field identification. A mollic horizon can easily be identified by its dark colour, caused by the accumulation of organic matter, well developed structure (usually a granular or fine subangular blocky structure), an indication for high base saturation, and its thickness.

Relationships with some other diagnostic horizons. The base saturation of 50 percent separates the mollic horizon from the umbric horizon, which is otherwise similar. The upper limit of organic carbon content varies from 12 percent (20 percent organic matter) to 18 percent organic carbon (30 percent organic matter) which is the lower limit for the histic horizon or 20 percent, the lower limit for a folic horizon. A special type of mollic horizon is the chernic horizon. It has a higher organic carbon content (1.5 percent or more), a specific structure (granular or fine subangular blocky), a very dark colour in its upper part, a high biological activity, and a minimum thickness of 35 cm. Limits with high base-saturated fulvic and melanic horizons are set by the combination of the intense dark colour, the high organic carbon content, the thickness and the characteristics associated with andic horizons in these two horizons. Otherwise, mollic horizons frequently occur in association with andic horizons.

Plaggic horizon

General description. Plaggic horizon (from Dutch *plag*, sod) is one of the Anthropogenic horizons (from Gr. anthropos, human, and pedogenesis) which result from long-continued cultivation. The characteristics and properties of these horizons depend much on the soil management practices used. Anthropogenic horizons differ from anthropogenic soil materials, which are unconsolidated mineral or organic materials resulting largely from land fills, mine spoil, urban fill, garbage dumps, dredgings, etc., produced by human activities. These materials, however, have not been subject to a sufficiently long period of time to have received significant imprint of pedogenetic processes.

Diagnostic criteria. A plaggic horizon has a uniform texture, usually sand or loamy sand. The weighted average organic carbon content is more than 0.6 percent. The base saturation (by 1 M NH₄OAc) is less than 50 percent while the P₂O₅ content extractable in 1 percent citric acid is high, at least more than 0.025 percent within 20 cm of the surface, but frequently more than 1 percent.

Field identification. The plaggic horizons show evidence of surface raising, which may be inferred either from field observation or from historical records. The horizons are thoroughly mixed and usually contain artifacts such as pottery fragments, cultural debris or refuse, which are often very small (less than 1 cm in diameter) and much abraded. Plaggic horizons are built up gradually from earthy additions (compost, sods or soddy materials mixed with farmyard manure, litter, mud, beach sands, etc.) and may contain stones, randomly sorted and distributed. The plaggic horizon has brownish or blackish colours, related to the origin of source materials and its soil reaction is slightly to strongly acid. It shows evidence of agricultural operations such as spade marks as well as old cultivation layers. Plaggic horizons often overlie buried soils although the original surface layers may be mixed. The lower boundary is usually clear.

Plinthic horizon

General description. The plinthic horizon (from Gr. *plinthos*, brick) is a subsurface horizon which constitutes an iron-rich, humus-poor mixture of kaolinitic clay with quartz and other constituents, and which changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access of oxygen.

Diagnostic criteria. The plinthic horizon must have:

1. 25 percent (by volume) or more of an iron-rich, humus-poor mixture of kaolinitic clay with quartz and other diluents, which changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access of oxygen; and
2.
 - a. 2.5 percent (by weight) or more citrate-dithionite extractable iron in the fine earth fraction, especially in the upper part of the horizon, or 10⁵ percent in the mottles or concretions; and
 - b. ratio between acid oxalate (pH 3) extractable iron and citrate-dithionite extractable iron of less than 0.10; and
 - c. less than 0.6 percent (by weight) organic carbon; and
 - d. thickness of 15 cm or more.

⁵ Estimated from data given by Varghese and Byju (1993).

Field identification. A plinthic horizon commonly shows red mottles, usually in platy, polygonal, vesicular or reticulate patterns. In a perennially moist soil, the plinthic material is usually not hard but firm or very firm and can be cut with a spade. The plinthic material does not harden irreversibly as a result of a single cycle of drying and rewetting. Only repeated wetting and drying will change it irreversibly to an ironstone hardpan or to irregular aggregates, especially if it is also exposed to heat from the sun.

Additional criteria. Micromorphological studies may reveal the extent of impregnation of the soil mass by iron. In addition penetration resistance measurements and total amount of iron present may give an indication.

Spodic horizon

General description. The spodic horizon (from Gr. *spodos*, wood ash) is a dark coloured subsurface horizon which contains illuvial amorphous substances composed of organic matter and aluminium, with or without iron. The illuvial materials are characterized by a high pH-dependent charge, a large surface area and high water retention.

Diagnostic criteria. A spodic horizon must have:

1.
 - a. either- a Munsell hue of 7.5YR or redder with value of 5 or less and chrome of 4 or less when moist and crushed; or - a hue of 10YR with value of 3 or less and chrome of 2 or less when moist and crushed; or
 - b. a subhorizon which is 2.5 cm or more thick and which is continuously cemented by a combination of organic matter and aluminium, with or without iron ('thin iron pan'); or
 - c. distinct organic pellets between sand grains; and
2. 0.6 percent or more organic carbon; and
3. pH (1:1 in water) of 5.9 or less; and
4.
 - a. at least 0.50 percent $Al_{ox} + \frac{1}{2}Fe_{ox}$ ⁶ and have two times or more $Al_{ox} + \frac{1}{2}Fe_{ox}$ than an overlying umbric, ochric, albic or anthropogenic horizon; or
 - b. an optical density of the oxalate extract (ODOE) value of 0.25 or more, which also is two times or more the value of the overlying horizons; and
5. thickness of at least 2.5 cm and an upper limit below 10 cm of the mineral soil surface, unless permafrost is present within 200 cm depth.

Field identification. A spodic horizon normally underlies an albic horizon and meets the brownish black to reddish brown colours. Spodic horizons can also be characterized by the presence of a thin iron pan, or by the presence of organic pellets when weakly developed.

Relationships with some other diagnostic horizons. Spodic horizons can have similar characteristics as andic horizons rich in aluminio-organic complexes. Sometimes only analytical tests can positively discriminate between the two. Spodic horizons have at least twice as much the $Al_{ox} + \frac{1}{2}Fe_{ox}$ percentages than an overlying umbric, ochric, albic or anthropogenic horizon. This criterion normally does not apply to andic horizons in which the aluminio-organic complexes are hardly mobile.

Sulfuric horizon

General description. The sulfuric horizon (from L. *sulfur*) is an extremely acid subsurface horizon in which sulphuric acid is formed through oxidation of sulphides.

Diagnostic criteria. A sulfuric horizon must have:

1. pH < 3.5 in a 1:1 water suspension; and
- 2.

⁶ Al_{ox} and Fe_{ox} : acid oxalate (pH 3) extractable aluminium and iron, respectively.

- a. either- yellow/orange jarosite $[\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6]$ or yellowish-brown schwertmannite $[\text{Fe}_{16}\text{O}_{16}(\text{SO}_4)_3(\text{OH})_{10}\cdot 10\text{H}_2\text{O}]$ mottles; or - concentrations with a Munsell hue of 2.5Y or more and a chrome of 6 or more; or
 - b. superposition on sulfidic soil materials; or
 - c. 0.05 percent (by weight) or more water-soluble sulphate; and
3. thickness of 15 cm or more.

Field identification. Sulfuric horizons generally contain yellow/orange jarosite or yellowish brown schwertmannite mottles. Moreover, soil reaction is extremely acid; pH (H₂O) of less than 3.5 is not uncommon.

Relationships with some other diagnostic horizons. The sulfuric horizon often underlies a strongly mottled horizon with pronounced redoximorphic features (reddish to reddish brown iron hydroxide mottles and a light coloured, iron depleted matrix).

Takyric horizon.

General description. A takyric horizon (from Uzbek *takyr*, barren land) is a heavy textured surface horizon comprising a surface crust and a platy structured lower part. It occurs under arid conditions in periodically flooded soils.

Diagnostic criteria. A takyric horizon must have:

1. aridic properties; and
2. a platy or massive structure; and
3.
 - a. a surface crust which has all of the following properties:
 - a. enough thickness so that it does not curl entirely upon drying;
 - b. polygonal desiccation cracks extending at least 2 cm deep when the soil is dry;
 - c. sandy clay loam, clay loam, silty clay loam or finer texture;
 - d. very hard dry consistence and very plastic and sticky wet consistence; and
 - e. an electrical conductivity (EC) in the saturated paste of less than 4 dS m⁻¹, or less than that of the horizon immediately below the takyric horizon.

Field identification. Takyric horizons are found in depressions in arid regions, where surface water, rich in clay and silt but relatively low in soluble salts, can accumulate and leach the upper soil horizons. Periodic salt leaching causes dispersion of clay and the formation of a thick, compact, fine-textured crust, which forms prominent polygonal cracks upon drying. Clay and silt often make up more than 80 percent of the crust material.

Relationships with some other diagnostic horizons. Takyric horizons occur in association with many diagnostic horizons, the most important ones being the salic, gypsic, calcic and cambic horizons. The low electrical conductivity and low soluble salt content of takyric horizons set them apart from the salic horizon.

Umbric horizon.

General characteristics. The umbric horizon (from L. *umbra*, shade) is a thick, dark coloured, base-desaturated surface horizon rich in organic matter.

Diagnostic criteria. An umbric horizon must have:

1. soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms; and
2. Munsell colours with a chrome of less than 3.5 when moist, a value darker than 3.5 when moist and 5.5 when dry, both on broken and crushed samples. The colour value is at least one unit darker than that of the C horizon (both moist and dry) unless the C horizon has a colour value darker than 4.0, moist, in which case the colour contrast requirement is waived. If a C horizon is not present, comparison should be made with the horizon immediately underlying the surface horizon; and

3. base saturation (by 1 M NH₄OAc) of less than 50 percent on a weighted average throughout the depth of the horizon; and
4. organic carbon content of 0.6 percent (1 percent organic matter) or more throughout the thickness of mixed horizon (usually it is more than 2 to 5 percent, depending on the clay content). The organic carbon content is at least 0.6 percent more than the C horizon if the colour requirements are waived because of dark coloured parent materials; and
5. the following thickness requirements:
 - a. 10 cm or more if resting directly on hard rock, a petroplinthic or petroduric horizon, or overlying a cryic horizon; or
 - b. at least 20 cm and more than one-third of the thickness of the solum where the solum is less than 75 cm thick; or
 - c. more than 25 cm where the solum is more than 75 cm thick.

The measurement of the thickness includes transitional AB, AE and AC horizons. The requirements for an umbric horizon must be met after the first 20 cm are mixed, as in ploughing.

Field identification. The main field characteristics used to identify the presence of an umbric horizon are its dark colour and its structure. In general, umbric horizons tend to have a lesser grade of soil structure than mollic horizons. As a guide, most umbric horizons have an acid soil reaction (pH (H₂O, 1:2.5) of less than about 5.5) which represents a base saturation of less than 50 percent. An additional indication for the acidity is a rooting pattern in which most of the roots tend to be horizontal, in the absence of a physical root restricting barrier.

Relationships with some other diagnostic horizons. The base saturation requirement sets the umbric horizon apart from the mollic horizon, which otherwise is very similar. The upper limit of organic carbon content varies from 12 percent (20 percent organic matter) to 18 percent (30 percent organic matter) which is the lower limit for the histic horizon, or 20 percent, the lower limit of a folic horizon. Limits with base-desaturated fulvic and melanic horizons are set by the combination of the intense dark colour, the high organic carbon content, the thickness and the characteristics associated with andic horizons in these two horizons. Otherwise, umbric horizons frequently occur in association with andic horizons. Some thick, dark coloured, organic-rich, base-desaturated surface horizons occur which are formed as a result of human activities such as deep cultivation and manuring, the addition of organic manures, the presence of ancient settlements, kitchen middens, etc. (cf. anthropogenic horizons). These horizons can usually be recognized in the field by the presence of artifacts, spade marks, contrasting mineral inclusions or stratification indicating the intermittent addition of manurial material, a relative higher position in the landscape, or by checking the agricultural history of the area. If hortic or plaggic horizons are present, either the 0.5 M NaHCO₃ P₂O₅ analysis (Gong et al., 1997) or the 1 percent citric acid soluble P₂O₅ analysis may give an indication.

Vertic horizon

General description. The vertic horizon (from L. *vertere*, to turn) is a clayey subsurface horizon which as a result of shrinking and swelling has polished and grooved ped surfaces ('slickensides'), or wedge-shaped or parallelepiped structural aggregates.

Diagnostic criteria. A vertic horizon must have:

1. 30 percent or more clay throughout; and
2. wedge-shaped or parallelepiped structural aggregates with a longitudinal axis tilted between 10° and 60° from the horizontal; and
3. intersecting slickensides⁷; and
4. a thickness of 25 cm or more.

Field identification. Vertic horizons are clayey, and have a hard to very hard consistency. When dry, vertic horizons show cracks of 1 or more centimetre wide. In the field the presence of polished, shiny ped surfaces ("slickensides") which often show sharp angles with each other, is very obvious.

⁷ Slickensides are polished and grooved ped surfaces which are produced by one soil mass sliding past another.

Additional characteristics. The coefficient of linear extensibility (COLE) is a measure for the shrink-swell potential and is defined as the ratio of the difference between the moist length and the dry length of a clod to its dry length: $(L_m - L_d)/L_d$, in which L_m is the length at 33 kPa tension and L_d the length when dry. In vertic horizons the COLE is more than 0.06. Relationships with some other diagnostic horizons. Several other diagnostic horizons may also have high clay content, viz. the argic, natric and nitic horizons. These horizons lack the characteristic typical for the vertic horizon; however, they may be laterally linked in the landscape with the vertic horizon usually taking up the lowest position.

Vitric horizon

General description. The vitric horizon (from L. *vitrum*, glass) is a surface or subsurface horizon dominated by volcanic glass and other primary minerals derived from volcanic ejecta.

Diagnostic criteria. A vitric horizon must have:

1. 10 percent or more volcanic glass and other primary minerals in the fine earth fraction; and either:
2. less than 10 percent clay in the fine earth fraction; or
3. a bulk density $> 0.9 \text{ kg dm}^{-3}$; or
4. $\text{Al}_{\text{ox}} + 1/2\text{Fe}_{\text{ox}}^8 > 0.4$ percent; or
5. phosphate retention > 25 percent; and
6. thickness of at least 30 cm.

Field identification. The vitric horizon can be identified in the field with relative ease. It can occur as a surface horizon, however, it may also occur buried under some tens of centimetres of recent pyroclastic deposits. It has a fair amount of organic matter and a low clay content. The sand and silt fractions are still dominated by unaltered volcanic glass and other primary minerals (may be checked by x 10 hand-lens).

Relationships with some other diagnostic horizons. Vitric horizons are closely linked with andic horizons, into which they may eventually develop. The amount of volcanic glass and other primary minerals, together with the amount of non-crystalline or paracrystalline pedogenetic minerals mainly separates the two horizons. Vitric horizons may overlap with several diagnostic surface horizons, viz. the fulvic, melanic, mollic, umbric and ochric horizons.

Yermic horizon.

General description. The yermic horizon (from Sp. *yeremo*, desert) is a surface horizon which usually, but not always, consists of surface accumulations of rock fragments ("desert pavement") embedded in a loamy vesicular crust and covered by a thin aeolian sand or loess layer.

Diagnostic criteria. A yermic horizon must have:

1. aridic properties; and
2.
 - a. a pavement which is varnished or includes wind-shaped gravel or stones ("ventifacts"); or
 - b. a pavement and a vesicular crust; or c. a vesicular crust above a platy A horizon, without a pavement.

Field identification. A yermic horizon comprises a vesicular crust at the surface and underlying A horizon(s). The crust, which has a loamy texture, shows a polygonal network of desiccation cracks, often filled with inblown material, which extend into the underlying horizons. Crust and the A horizon(s) below have a weak to moderate platy structure.

Relationships with some other diagnostic horizons. Yermic horizons often occur in association with other diagnostic horizons characteristic for desert environments (salic, gypsic, duric, calcic and cambic horizons). In very cold deserts (e.g. Antarctica) they may occur associated with cryic horizons. Under these conditions coarse cryoclastic material dominates and there is little dust to be deflated and deposited by wind. Here a dense pavement with varnish, ventifacts, aeolian sand layers and soluble mineral accumulations may occur directly on loose C horizons, without a vesicular crust and underlying A horizons.

⁸ Al_{ox} and Fe_{ox} are acid oxalate (pH 3) extractable aluminium and iron, respectively (method of Blakemore et al., 1987)

2.3 Diagnostic properties

Abrupt textural change

General description. An abrupt textural change is a very sharp increase in clay content within a limited depth range.

Diagnostic criteria. An abrupt textural change requires either:

1. doubling of the clay content within 7.5 cm if the overlying horizon has less than 20 percent clay; or
2. 20 percent (absolute) clay increase within 7.5 cm if the overlying horizon has 20 percent or more clay. In this case some part of the lower horizon should have at least twice the clay content of the upper horizon.

Albeluvic tonguing

General description. The term albeluvic tonguing (from L. *albus*, white, and *eluere*, to wash out) is connotative of penetrations of clay and iron-depleted material into an argic horizon. When peas are present, albeluvic tongues occur along ped surfaces. Redoximorphic characteristics and stagnic properties are not necessarily present.

Diagnostic criteria. Albeluvic tongues must:

1. have the colour of an albic horizon; and
2. have greater depth than width, with the following horizontal dimensions:
 - a. 5 mm or more in clayey argic horizons; or
 - b. 10 mm or more in clay loamy and silty argic horizons; or
 - c. 15 mm or more in coarser (silt loam, loam or sandy loam) argic horizons; and
3. occupy more than 10 percent of the volume in the first 10 cm of the argic horizon, estimated from or measured on both vertical and horizontal sections; and
4. have a particle size distribution matching that of the eluvial horizon overlying the argic horizon.

Aridic properties

General description. The term aridic properties combines a number of properties which are common in surface horizons of soils occurring under arid conditions and where pedogenesis exceeds new accumulation at the soil surface by aeolian or alluvial activity.

Diagnostic criteria. Aridic properties are characterized by all of the following:

1. organic carbon content of less than 0.6 percent⁹ if texture is sandy loam or finer, or less than 0.2 percent if texture is coarser than sandy loam, as a weighted average in the upper 20 cm of the soil or down to the top of a B horizon, a cemented horizon, or to rock, whichever is shallower; and
2. evidence of aeolian activity in one or more of the following forms:
 - a. the sand fraction in some subhorizon or in inblown material filling cracks contains a noticeable proportion of rounded or subangular sand particles showing a matt surface (use a x 10 hand-lens). These particles make up 10 percent or more of the medium and coarser quartz sand fraction; or
 - b. wind-shaped rock fragments ("ventifacts") at the surface; or
 - c. aeroturbation (e.g. crossbedding); or
 - d. evidence of wind erosion or deposition, or both; and
3. both broken and crushed samples have a Munsell colour value of 3 or more when moist and 4.5 or more when dry, and a chrome of 2 or more when moist; and
4. base saturation (by 1 M NH₄OAc) of more than 75 percent, but normally 100 percent.

Additional remarks. The presence of acicular ("needle-shaped") clay minerals (e.g. palygorskite and sepiolite) in soils is considered connotative of a desert environment, but it has not been reported in all desert soils. This may be due to the fact

⁹ The organic carbon content may be higher if the soil is periodically flooded, or if it has an electrical conductivity of the saturated paste extract of 4 dS m⁻¹ or more somewhere within 100 cm of the soil surface.

that under arid conditions acicular clays are not produced but only preserved, provided they exist in the parent material or in the dust that falls on the soil.

Continuous hard rock

Definition. Continuous hard rock is material underlying the soil, exclusive of cemented pedogenetic horizons such as a petrocalcic, petroduric, petrogypsic and petroplinthic horizons, which is sufficiently coherent and hard when moist to make hand digging with a spade impracticable. The material is considered continuous if only a few cracks 10 cm or more apart are present and no significant displacement of the rock has taken place.

Geric properties

General description. Geric properties (from Gr. *geraios*, old) refers to mineral soil material which has a very low effective cation exchange capacity or even acts as an anion exchanger.

Diagnostic criteria. Mineral soil material has geric properties if it has either:

1. 1.5 cmolc or less of exchangeable bases (Ca, Mg, K, Na) plus unbuffered 1 M KCl exchangeable acidity per kg clay; or
2. a delta pH (pHKCl minus pH_{water}) of +0.1 or more.

Gleyic properties

General description. Soil materials develop gleyic properties (from the Russian local name *gley*, mucky soil mass) if they are completely saturated with groundwater, unless 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), and show a gleyic colour pattern.

Diagnostic criteria. Reducing conditions¹⁰ are evident by:

1. a value of rH in the soil solution of 19 or less; or
2. the presence of free Fe²⁺ as shown by the appearance of either:
 - a. a solid dark blue colour on a freshly broken surface of a field-wet soil sample, after spraying it with a potassium ferric cyanide (K₃Fe(III)(CN)₆) solution; or
 - b. a strong red colour on a freshly broken surface of a field-wet soil sample after spraying it with a a,a, dipyriddy solution in 10% acetic acid; and
3. a gleyic colour pattern¹¹ reflecting oximorphic¹² and/or reductomorphic¹³ properties either:

¹⁰ The basic measure for reduction in soil materials is the rH. This measure is related to the redox potential (Eh) and corrected for the pH as shown in the following formula:

$$rH = \frac{Eh(mV)}{29} + 2pH$$

¹¹ A gleyic colour pattern results from a redox gradient between the 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 peas the oxides are either transformed into insoluble Fe/Mn(II) compounds or they are translocated both processes leading to the absence of colours with a Munsell hue redder than 2.5Y. Translocated iron and manganese compounds can be concentrated in oxidized form (Fe(III) Mn(IV)) recognizable by a 10% H₂O₂ test in the field on ped surfaces or in (bio)pores ("rusty root channels"), and towards the surface even in the matrix.

¹² Oximorphic properties reflect alternating reducing and oxidizing conditions as is the case in the capillary fringe and in the surface horizon(s) of soils with fluctuating groundwater levels. Oximorphic properties are expressed by reddish brown (ferrihydrite) or bright yellowish brown (goethite) mottles or as bright yellow (jarosite) mottles in acid sulphate soils. In loamy and clayey soils the iron (hydr)oxides are concentrated on aggregate surfaces and the walls of larger pores (e.g. old root channels).

¹³ Reductomorphic properties reflect permanently wet conditions and are expressed by neutral (white to black: N1/ to N8/) or bluish to greenish (2.5Y, 5Y, 5G, 5B) colours in more than 95 percent of the soil matrix. In loamy and clayey material blue-green colours dominate due to Fe (II,III) hydroxy salts (green rust). If the material is rich in sulphur blackish colours

- a. in more than 50 percent of the soil mass; or
- b. in 100 percent of the soil mass below any surface horizon.

Field identification. Iron and manganese (hydr)oxides in soils with gleyic properties are redistributed to the outside of the peas and towards the soil surface from where oxygen is derived. The resulting colour pattern (reddish, brownish or yellowish colours near the ped surface or in the upper part of the profile, together with grayish/bluish colours in the inside of the peas or deeper in the soil) indicates if gleyic conditions occur. Also, the dipyriddy test often gives a good indication if ferric iron is present in the soil solution.

Permafrost

Definition. Permafrost is a layer in which the temperature is perennially at or below 0°C for at least two consecutive years.

Secondary carbonates

General description. The term secondary carbonates refers to translocated lime, soft enough to be cut readily with a finger nail, precipitated in place from the soil solution rather than inherited from a soil parent material. As a diagnostic property it should be present in significant quantities.

Field identification. Secondary carbonates must have some relation to the soil structure or fabric. Secondary carbonate accumulations may disrupt the fabric to form spheroidal aggregates or 'white eyes', that are soft and powdery when dry, or lime may be present as soft coatings in pores or on structural faces. If present as coatings, secondary carbonates cover 50 percent or more of the structural faces and are thick enough to be visible when moist. If present as soft nodules, they occupy 5 percent or more of the soil volume. Filaments (pseudomycelia), which come and go with changing moisture conditions, are not included in the definition of secondary carbonates.

Stagnic properties

General description. Soil material has stagnic properties (from *L. stagnare*, to flood) if it is, at least temporarily, completely saturated with surface water, unless drained, for a period long enough to allow reducing conditions to occur (this may range from a few days in the tropics to a few weeks in other areas), and show a stagnic colour pattern¹⁴.

Diagnostic criteria. Reducing conditions are evident by:

1. a value of rH in the soil solution of 19 or less; or
2. the presence of free Fe²⁺ as shown by the appearance of either:
 - a. a solid dark blue colour on a freshly broken surface of a field-wet soil sample, after spraying it with a 1% potassium ferric cyanide (K₃Fe(III)(CN)₆) solution; or
 - b. a strong red colour on a freshly broken surface of a field-wet soil sample after spraying it with a 0.2% a,a, dipyriddy solution in 10% acetic acid; and
3. an albic horizon or a stagnic colour pattern either:
 - a. in more than 50 percent of the soil volume if the soil is undisturbed; or
 - b. in 100 percent of the soil volume if the surface horizon is disturbed by ploughing.

prevail due to iron sulphides. In calcareous material whitish colours are dominant due to calcite and/or siderite. Sands are usually light grey to white in colour and often also impoverished in iron and manganese. The upper part of a reductomorphic horizon may show up to 5 percent rusty colours mainly around channels of burrowing animals or plant roots.

¹⁴ A stagnic colour pattern shows mottling in such a way that the surfaces of the peas (or part of the soil matrix) are lighter (one Munsell value unit or more) and paler (one chrome unit or less) coloured, and the interior of the peas (or parts of the soil matrix) are more reddish (one hue unit or more) and brighter (one chrome unit or more) coloured than the non-redoximorphic parts of the layer, or of its mixed average. This mottling pattern may occur directly below the surface horizon or plough layer, or below an albic horizon.

Field identification. The distribution pattern of the redoximorphic features, with iron and manganese oxides concentrated in the inside of peas (or in the matrix if peas are absent) gives a good indication of stagnic properties.

2.4 Diagnostic materials

Anthropogeomorphic soil material

General description. Anthropogeomorphic soil material (from Gr. *anthropos*, human) refers to unconsolidated mineral or organic material resulting largely from land fills, mine spoil, urban fill, garbage dumps, dredgings, etc., produced by human activities. It has, however, not been subject to a sufficiently long period of time to find significant expression of pedogenetic processes.

Calcaric (calcareous) soil material

Definition. Calcaric soil material (from En. *calcareous*) shows strong effervescence with 10 percent HCl in most of the fine earth. It applies to material which contains more than 2 percent calcium carbonate equivalent.

Organic soil material

General description. Organic soil material consists of organic debris which 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. if saturated with water for long periods (unless artificially drained), and excluding live roots, either:
 - a. 18 percent organic carbon (30 percent organic matter) or more if the mineral fraction comprises 60 percent or more clay; or
 - b. 12 percent organic carbon (20 percent organic matter) or more if the mineral fraction has no clay; or
 - c. a proportional lower limit of organic carbon content between 12 and 18 percent if the clay content of the mineral fraction is between 0 and 60 percent; or
2. if never saturated with water for more than a few days, 20 percent or more organic carbon.

Sulfidic soil material

General description. Sulfidic soil material (from E. *sulphide*) is waterlogged deposit containing sulphur, mostly in the form of sulphides, and only moderate amounts of calcium carbonate.

Diagnostic criteria. Sulfidic soil material must have:

1. 0.75 percent or more sulphur (dry weight) and less than three times as much calcium carbonate equivalent as sulphur; and
2. pH (H₂O) of more than 3.5.

Field identification. Deposits containing sulphides often show in moist or wet condition a golden shine, the colour of pyrite. Forced oxidation with a 30 percent hydrogen peroxide solution lowers the pH by 0.5 unit or more. Oxidation also gives rise to the smell of rotten eggs.

2.5 Other diagnostic criterion

Cation exchange capacity

The cation exchange capacity (CEC), used as a criterion in the definition of diagnostic horizons or properties as well as in the key to the reference soil groups, is essentially meant to reflect the nature of the mineral component of the exchange complex. However, the CEC determined on the total earth fraction is also influenced by the amount and kind of organic matter present. Where low clay activity is a diagnostic property, it may be desirable to deduct CEC linked to the organic matter, using a graphical method¹⁵ for individual profiles (Bennema and Camargo, 1979; Brinkman, 1979; Klamt and Sombroek, 1988).

3. Literature

- Berding F.R. 1997. Third level modifiers for the major soil groups of Andosols, Phaeozems and Podzols. Working Paper. FAO/AGLS, Rome.
- Bennema J. and Camargo M.N. 1979. Some remarks on Brazilian Latosols in relation to the Oxisols. In: Proceedings of the Second International Soil Classification Workshop. Part I. Beinroth F.H. and Paramanathan S. (eds.) Malaysia, 28 August to 1 September 1978. Soil Survey Division, Land Development Department, Bangkok. pp. 233-261.
- Blakemore L.C., Searle P.L. and Daly. B.K. 1981. Soil Bureau Laboratory Methods. A method for chemical analysis of soils. N.Z. Soil Bureau Sci. Rep. 10A. DSIRO.
- Brinkman R. 1979. Ferrolysis, a Soil-forming Process in Hydromorphic Soils. Thesis. Agricultural University Wageningen. PUDOC, Wageningen, The Netherlands.
- FAO. 1988. Soil Map of the World. Revised Legend. Reprinted with corrections. World Soil Resources Report 60. FAO, Rome.
- FAO. 1990. Guidelines for Soil Profile Description. Third edition (revised). Soil Resources, Management and Conservation Service, Land and Water Development Division, FAO, Rome.
- FAO 1998. World reference base for soil resources. World Soil Resources Report 84. Food and Agriculture Organization of the United Nations, Rome
- Fieldes M. and Perrott K.W. 1966. The nature of allophane soils: 3. Rapid field and laboratory test for allophane. New Zeal. J. Sci. 9: 623 - 629.
- Gong Z., Zhang X., Luo G., Shen H. and Spaargaren O.C. 1997. Extractable phosphorus in soils with a fimic epipedon. *Geoderma* 75: 289 - 296.
- Klamt E. and Sombroek. W.G. 1988. Contribution of organic matter to exchange properties of Oxisols. In: Proceedings of the Eighth International Soil Classification Workshop. Classification, characterization and utilization of Oxisols. Part 1: Papers. Beinroth, F. H. Camargo M.N. Eswaran H. (eds.). Rio de Janeiro. pp 64-70.
- Shoji S., Nanzyo M. Dahlgren R.A. and Quantin. P. 1996. Evaluation and proposed revisions of criteria for Andosols in the World Reference Base for Soil Resources. *Soil Sc.* 161(9): 604-615.
- Soil Survey Staff. 1996. Keys to Soil Taxonomy. Seventh edition. United States Department of Agriculture, Washington D.C.
- Sombroek W.G. 1986. Identification and use of subtypes of the argillic horizon. In: Proceedings of the International Symposium on Red Soils. (Nanjing, Nov. 1983). Institute of Soil Science. Academia Sinica. Science Press, Beijing, and Elsevier, Amsterdam. pp 159-166.
- Varghese T. and Byju. G. 1993. Laterite soils. Their distribution, characteristics, classification. and management. Technical Monograph 1, State Committee on Science, Technology and Environment. Thiruvananthapuram, Sri Lanka.

¹⁵ The method involves regressing the amount of organic C (expressed in g) against the measured CEC (pH 7) expressed in cmolc kg⁻¹ clay. With the resultant equation tile contribution of the organic C to tile CEC can be calculated, and the corrected CEC of the clay be determined. Uniform clay mineralogy throughout tile profile should be assumed.

Appendix 4.

Attributes of the soil polygons in the elaborated GIS dataset based on the tables of SGBDE

Transmitted STU attributes from the EGSBE	Codes of attributes in the extended GIS dataset ⁽¹⁾		Description of attributes ⁽²⁾	
STU_SGDBE_ATTRIBUTES	STU01	.....	STU10	
stu	S01_stu	.....	S10_stu	Identification number of soil typological unit
wrbfu	S01_wrb	.....	S10_wrb	Full soil code of the STU from the World Reference Base (WRB) for Soil Resources
wrbfu_cl	S01_Wrbcl	.....	S10_Wrbcl	Confidence level of the attribute
fao90fu	S01_fao90	.....	S10_fao90	Full soil code of the STU from the 1990 FAO-UNESCO Soil Legend
fao90fu_cl	S01_fao90cl	.....	S10_fao90cl	Confidence level of the attribute
fao85fu	S01_fao85	.....	S10_fao85	Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend.
fao85fu_cl	S01_fao85cl	.....	S10_fao85cl	Confidence level of the attribute
slope_dom	S01_slope1	.....	S10_slope1	Dominant slope class of the STU
slope_sec	S01_slope2	.....	S10_slope2	Secondary slope class of the STU
zmin	S01_zmin	.....	S10_zmin	Minimum elevation above sea level of the STU (in metres)
zmax	S01_zmax	.....	S10_zmax	Maximum elevation above sea level of the STU (in metres)
parmado	S01_pm1	.....	S10_pm1	Code for dominant parent material of the STU
parmado_cl	S01_pm1_cl	.....	S10_pm1_cl	Confidence level of the attribute
mat1	S01_mat1	.....	S10_mat1	Dominant parent material code
parmase	S01_pm2	.....	S10_pm2	Code for secondary parent material of the STU
parmase_cl	S01_pm2_cl	.....	S10_pm2_cl	Confidence level of the attribute
mat2	S01_mat2	.....	S10_mat2	Secondary parent material code
use_dom	S01_lu1	.....	S10_lu1	Code for dominant land use of the STU
use_sec	S01_lu2	.....	S10_lu2	Code for secondary land use of the STU
aglim1	S01_aglim1	.....	S10_aglim1	limitation to agricultural use
aglim2	S01_aglim2	.....	S10_aglim2	limitation to agricultural use
textsrfdom	S01_tx1	.....	S10_tx1	Dominant surface textural class of the STU
textsrfsec	S01_tx2	.....	S10_tx2	Secondary surface textural class of the STU
textsubdom	S01_sutx1	.....	S10_sutx1	Dominant sub-surface textural class of the STU
textsubsec	S01_sutx2	.....	S10_sutx2	Secondary sub-surface textural class of the STU
textdepchg	S01_dpctx	.....	S10_dpctx	Depth class to a textural change of the dominant
roo	S01_roo	.....	S10_roo	Depth class of an obstacle to roots within the STU
il	S01_dp_il	.....	S10_dp_il	Code for the presence of an impermeable layer within the soil profile of the STU
wr	S01_wreg	.....	S10_wreg	Dominant annual average soil water regime class of the soil profile of the STU
wm1	S01_w_man1	.....	S10_w_man1	Code for normal presence and purpose of an existing water management system in agricultural land on more than 50% of the STU
wm2	S01_w_man2	.....	S10_w_man2	Code for the type of an existing water management system
cfl	S01_conf_1	.....	S10_conf_1	Confidence level in the STU description

Note:

(1) The maximum number of SMUs within a SMU is 10; this gives the 10 classes of joined attributes.

(2) More information about the value-set of attributes is on the following website:

http://eussoils.jrc.it/ESDB_Archive/raster_archive/sg_attr.htm

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Authors: Tóth, G., Montanarella, L., Stolbovoy, V., Máté, F., Bódis, K., Jones, A., Panagos, P. and van Liedekerke, M.

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Abstract

This book provides a detailed inventory of the major soil types in the European Union, including their geographical distribution presented on soil maps. An adaptation of the formative elements of the second level units of the World Reference Base for Soil Resources (FAO 1998) as accepted by the European Soil Bureau Network to be shown at the scale of 1:1 million in the European Geographical Soil Database is presented. The information includes definitions relating to Reference Soil Groups, diagnostic horizons, properties materials and attributes.

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