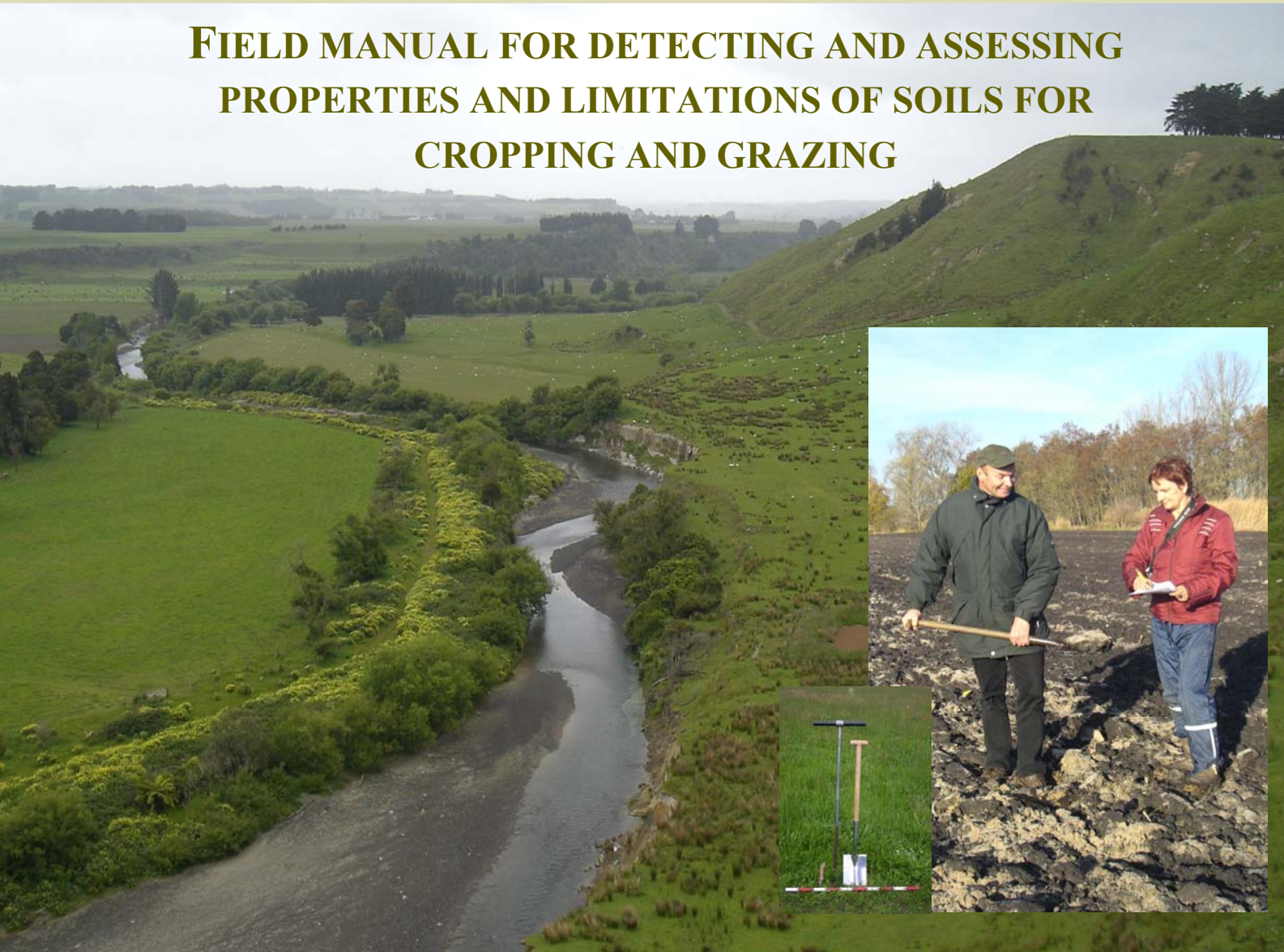


The Muencheberg Soil Quality Rating (SQR)

FIELD MANUAL FOR DETECTING AND ASSESSING PROPERTIES AND LIMITATIONS OF SOILS FOR CROPPING AND GRAZING



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1. Objectives

This manual shall provide guidance of soil quality (SQ) assessment for farming. Farmland is used to feed mankind in a sustainable manner. In this context, SQ may be characterised by the definition: "...the soil's fitness to support crop growth without becoming degraded or otherwise harming the environment" (Acton and Gregorich, 1995, in: Vigier et al., 2003).

During the past years many attempts have been undertaken to evaluate SQ in order to provide "*the soil's fitness or health*". They are focused on management induced aspects of SQ, mainly indicated by a favourable soil structure (INRA/ISTRO - report 2005).

However, "*fitness*" and "*health*" of a subject are not alone the result of a good management, but depend largely upon natural genetic constitution and age.

If common SQ ratings certify a fit and healthy looking soil to promise high yields, this may be erroneous. First is this rating not necessarily the result of proper management and second, the yield expectations may fail. A neighboured soil of more unfavourably looking soil structure and worse rating may possibly be higher in crop yield due to better crucial soil inherent properties like plant available water.

Soil inherent quality should also be taken into consideration when evaluating soil health. However, internationally comparable methods of the soil inherent quality assessment easy to handle are missing. Soil maps in different scales do exist, but they give only indirect hints on quality for cropping or grazing and for the crop yield potential.

The objective of this paper is to present a simple method for rating soil quality of farmland in the field - the Muencheberg SQR. The final result will be a semi-quantitative measure, e. g. a rating score between 1 and 100, of soil suitability for cropping or grazing.

This should provide comparative on-site assessment of the soil suitability for arable and grassland farming and estimation of the crop yield potential. In combination with methods of dynamic soil quality assessment, VSA (Shepherd, 2000), it will also provide recommendations for long-term sustainable use of soils and good agricultural practice. The frame of rating can further be utilised in decision support systems and scenarios of soil use.

Intended benefits of the method are:

- Reliable and fast field scoring of soil quality for farmland in terms of good, moderate, poor and very poor
- Field method, applicable for both extension and collegial contests
- Matching to procedures of dynamic soil quality assessment like VSA (Shepherd, 2000 or SoilPak (McKenzie, 2001)
- Valid for a range of soils over large regions
- Linkable with soil mapping units
- Correlation of final score with the crop yield potential within climatic sub-zones

Potential applications of the method are: Soil resource planning, guiding land purchase, and assessment of sustainability and environmental impacts of land use.

This manual is not valid for some extremely particular soil and cropping conditions:

- No paddy rice systems, no consideration of dual- or multi-cropping systems
- No consideration of direct climatic limitations and hazards of plant growth: frost, fire, wind
- No consideration of local typical risks for cropping like pests, weeds and diseases

Basic principles underlying the manual

- SQ ratings refer to current conditions of a soil pedon including the medium-term soil hydrological, thermal, geological and terrain conditions and the human impact (soil forming factors)
 - SQ ratings are performed in the field and will yield in a real-time judgement without delay due to laboratory analyses. However, those analyses are recommended or necessary to validate the results.
 - SQ ratings are restricted to soil's suitability for cropping and grazing. The focus is on rainfed cropping in temperate zones and rotations with dominance of cereals, mainly wheat.
- SQ ratings for grassland have less focus on particular vegetation or management systems. Grassland ratings assume a minimum level of accessibility and management.
- SQ ratings are grown up on a common description of a soil profile.
 - Matching tables will provide a fast orientation to commonly used current assessment of single indicators. These are mainly documented in: The FAO Guidelines for soil description (Guidelines for soil description, 2006) the German "Bodenkundliche Kartieranleitung"(AG Boden, 2005) and the U.S. National Soil Survey Handbook (USDA/NRCS (2005).
 - Overall ratings are compatible with internationally acceptable methods of dynamic SQ ratings. These are mainly: Visual soil assessment methods of Shepherd, 2000, Mc Kenzie, 2001 and Munkholm, 2000, (in: INRA/ISTRO - report 2005), and the method of Peerlkamp, mod. by Batey and Ball, 2006 (in: INRA/ISTRO - report 2005).
 - SQ indicators are ranked into an ordinal scale, empirically weighted and summarised. Such a procedure minimises, but does not eliminate, different individual judgement based on empirical appraisal. However, as the basis of assessment is documented, one can trace the evaluation back to soil characteristics and can evaluate the relevance of the ratings.
 - A growing number of sample ratings (Appendix 1) will provide a data basis for the adjustment of individual ratings and the perpetued improvement of the framework and thresholds

2. Concept

The Muencheberg SQR method shall result in a final score of a given pedon within a 100 point scale. This score is a measure of the long-term soil quality and will provide a rough estimate of the local crop yield potential. A set of indicators will be scored in terms of good, medium or poor, will be weighted and summarised. Indicators will be estimated based on a description of main soil profile features with consideration of the topographical and hydrological position of the pedon. The basic soil scoring procedure is compatible with the VSA method (Shepherd, 2000) for the evaluation of the dynamic soil quality and gives hints at management deficits.

Basic soil indicators (Fig. 2.-1, Table 3.2.0.-1) are scored by using scoring tables. Single scores are on a quasi 5-ball scale ranking from best conditions (2) to worst (0) with possible increments of 0.5, or 0.25 in very sensitive cases. Basic soil indicators will be completely estimated in the field. They can be backed by measurements of soil properties.

The final basic score ranges from 0 (theoretical minimum, practical is about 15) to 34. It is a measure of soil quality for farming. Values less than 20 indicate poor soils, values greater than 27 are typical of good soils.

In a second step (Fig. 2.-1) the rating system does also consider hazard soil properties and indicators. These properties are so critical for farming that they may limit the total soil quality. Hazard soil properties are the result of extremes of soil forming factors, either in excess or in a minimum. They are often determined by climatic factors. In many soils of the temperate zone the soil quality will not be limited by hazard soil factors. If the latter are present most of them can be identified by field methods or with simple field tool kits or by indicator vegetation.

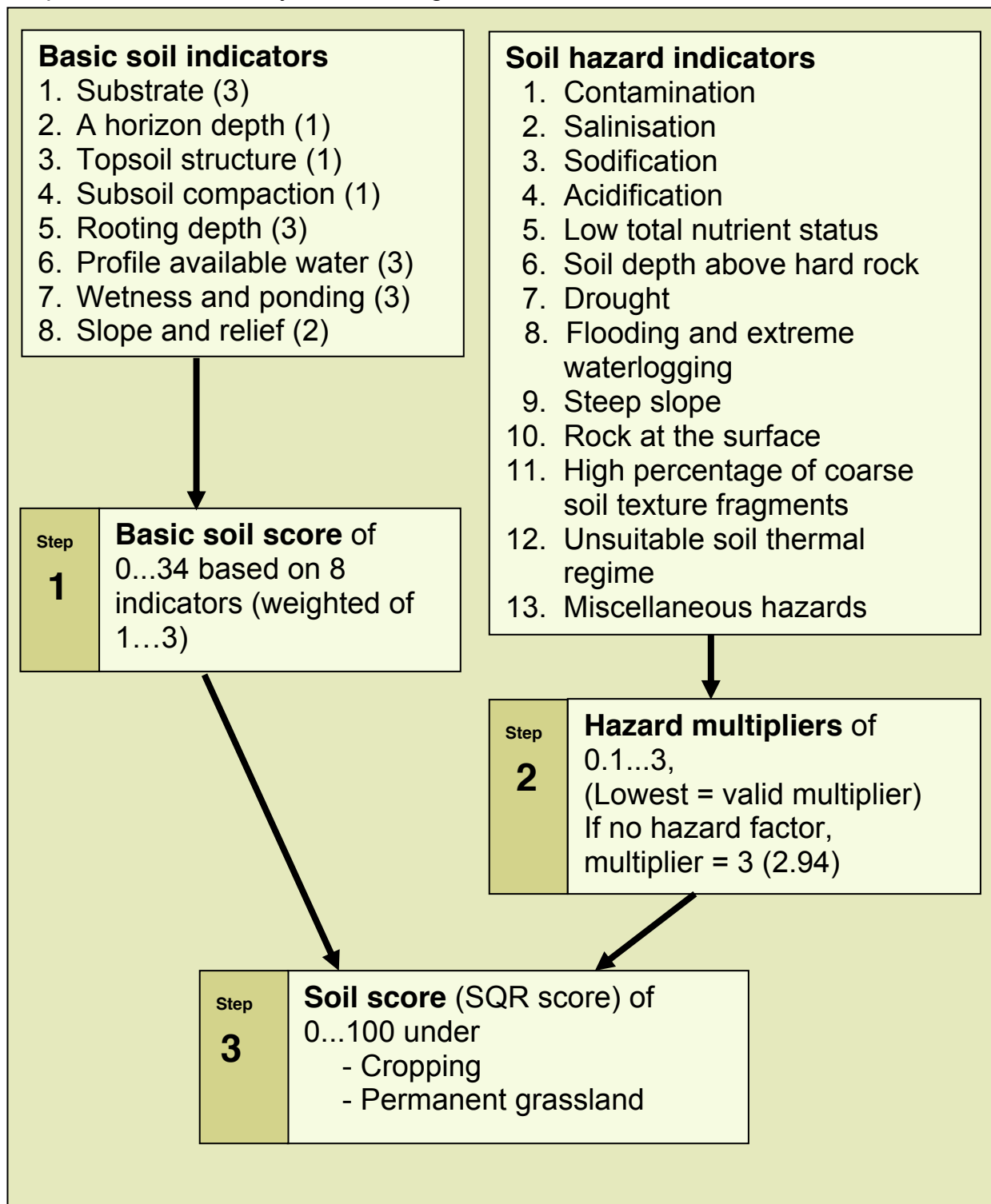


Fig. 2.-1: Scheme of the Muencheberg SQR

In SQR, hazard indicators are considered as multipliers for the basic soil score, ranging from about 0.01 (hazard properties do not allow farming) and 3 (no hazard properties). The lowest multiplier will be the valid one. The occurrence of more than one sub-optimum hazard indicators can be considered in such a way that the multiplier is set to a lower value within the range of scoring. In case of low ratings (< 1.5) of the slope gradient with sub-optimum (ratings < 2) of any further hazard indicator of Fig. 2.-1, the valid multiplier should be ranked into one score class lower than the minimum single lowest hazard indicator.

The rating system yields in a final score (SQR-score) ranging from about 0 to 100.

Classes of SQ are < 20 = **Very poor**, $20 - 40$ = **Poor**, $40 - 60$ = **Moderate**, $60 - 80$ **Good**, > 80 = **Very good**.

Pedon ratings are transferable to landscapes.

The Muencheberg SQR of farmland considers both direct soil properties like profile available water and the influence of other factors of soil directly influenced by climate like the soil thermal regime, flooding and drought risk or influenced by relief. As the final rating score is depending not only on the soil pedon, but also on topography and climate, the subject of rating could be commonly called “site” or “land”. Agricultural use of soils in a landscape can never be separated from these soil forming factors affecting soil quality permanently. Many authors consider soil quality as a subset of land quality (Singer and Ewing, 2000). We decided to prefer the term **soil** and consider the terms “soil”, “earth”, “ground”, “site” and “land” as synonyms in the context of this paper.

The land used by mankind for one of their basic needs, food production, is soil, a living natural body. Knowledge about the value of soil and recognising degradation risks may help to develop conservation strategies worldwide.

3. Procedure and scoring tables

3.1. Field procedure

Communication with the owner or manager of the land and having all permissions required for digging a soilpit or boring a hole is the basic precondition for fieldwork.

The field procedure requires a minimum of equipment. This consists of:

- Spade + borer + foot rule + knife + this field guide

Additionally some equipment can be useful to detect soil properties of particular interest and for documentation of the work. These are:

- A probe for pH (or pH test strips) and electrical conductivity if acidification, sodification or salinisation is being expected
- A photo camera and GPS for referencing the data
- A stable plastic box, a larger plastic bag and the field guide “Visual Soil Assessment” (Shepherd, 2000) to perform VSA analysis

In the field, the exact sampling point should be determined by using available information from soil maps, airborne data and current or former vegetation pattern.



Fig 3.1.-1: Before performing field tests, having permits and checking the ground for hidden dangers like cables or mines is important.



Fig 3.1.-2: Vegetation patterns are useful for pedon mapping and selection of representative sampling points.

Extreme variability of the soil quality over a few meters is typical of Holocene and Pleistocene soil landscapes in Central Europe. Differences are mainly due to layering of the soil substrate. Coarse and medium sand in the subsoil prevents rooting and has a low water capacity. Location Sophienthal, Germany.

A small soilpit of about 20*30 cm and 40 cm deep will be dug using a common spade. It is recommended to perform the SQR jointly with the VSA method acc. to Shepherd, 2000 to gather more information on the status of the topsoil structure.

To recognise the soil layering or a shallow watertable, an auger of about 7 cm diameter will be drilled from the bottom of the pit down to a depth of 1.6 m. If the soil is expected to be relatively uniform with depth and to have no shallow watertable, a rill soil probe pushed in (Bohrstock) will be an adequate alternative.

The method requires some experience in estimating soil texture class and organic matter content. Variation of soil texture and humus with depth (layering) is a main parameter of interest.



Fig 3.1.-3: Digging a small soilpit and performing the VSA drop scatter test according to Shepherd, 2000, gives information on texture and structure of the topsoil



Fig 3.1.-4: From the bottom of the soilpit a hole will be bored to detect soil layering and a shallow watertable.



Fig 3.1.-5: Examination of soil layering by a rill soil probe.

3.2. Scoring of basic indicators

3.2.0. What are basic indicators?

Basic indicators of Table 3.2.0.-1 characterise important aspects of soil quality for cropping or grazing. They are primarily based on properties and layering of the soil substrate, e. g. texture and soil organic matter (SOM). SQ of current farmland in the temperate zone can be described by those indicators. Most farmland in this zone is prime farmland. Basic soil indicators range only in certain limits, and a single indicator will not prevent farming in most cases. Thus their combination to a total basic SQR score is empirically additive. This kind of rating is completely compatible to the VSA method which is focussing on management induced SQ, mainly soil structure (Shepherd, 2000).

The total SQR basic score as a weighted sum of eight indicators is quite well correlated with the crop yield within a particular region of the temperate zone, for example in the region of Berlin, Germany (Mueller et al., 2005). The depth of the potential rooting zone and the available water within this zone are crucial parameters of soil quality in this sub-humid region.

Basic indicators are recognizable by the look on a soil profile and can be assessed with the aid of scoring tables below. As this kind of data is “soft”, the number of indicators has been set to eight. This makes the result of rating robust more than the use of a single indicator like the water capacity of the potential rooting zone (in: AG Boden, 2005).

Table 3.2.0.-1: Basic indicators of the SQR method

	Arable Land ¹⁾	Grassland
1	Soil substrate (3)	Soil substrate (3)
2	A horizon depth (1)	Depth of humic soil (2)
3	Topsoil structure (1)	Topsoil structure (1)
4	Subsoil compaction (1)	Subsoil compaction (1)
5	Rooting depth (3)	Biological activity (2)
6	Profile available water (3)	Profile available water (3)
7	Wetness and ponding (3)	Wetness and ponding (3)
8	Slope and relief (2)	Slope and relief (2)

¹⁾ The terms arable land and cropping land are used synonymously. Values in parentheses represent the weighting factor

Important criteria or further information for basic soil rating are as follows:

Soil substrate

- Soil texture class over the upper 80 cm (cropping land) or 50 cm
- Parent material of soil
- Strong gradients of texture within the upper 80 cm (layering)
- Content of coarse material > 2 mm over the upper 80 cm or 50 cm
- SOM of topsoil (upper 20 cm)
- Proportion of Carbonate, Gypsum, other concretions or artefacts

Depth of A- horizon and depth of humic soil

- A-horizon depth
- Depth of SOM content > 4 %
- Abrupt change from topsoil to subsoil

Aggregates and porosity

- Type and size of aggregates
- Structure ratings of Peerlkamp, Diez, Shepherd-VSA or others

Subsoil compaction

- Increased soil strength or density at 30-50 cm depth
- Redoximorphic feature in the topsoil and upper subsoil
- Structure ratings of Peerlkamp or others

Rooting depth and depth of biological activity

- Occurrence of roots
- Barriers to rooting and their intensity
- Effective rooting depth
- Zustandsstufe Bodenschaetzung

Profile available water

- Depth of watertable
- Water storage capacity of soil
- Grassland "Wasserstufe" (dry branch)

Wetness and ponding

- Depth of ground or perched water table
- Soil drainage class
- Degree of redoximorphic features in the subsoil
- Indicator values of vegetation
- Grassland "Wasserstufe" (wet branch)
- Soil position in a depression
- Wetness by suspended water (soils rich in silt and clay or muck)
- Ponding during soil assessment

Slope and relief

- Slope at the pedon position
- Microrelief and slope aspect at the pedon position

Single basic indicators will be described below.

A note on scoring tables of basic indicators:

Tables contain a score based on a description. To support scoring, prefixed explanatory text, some example photographs and orientation guides in the same or additional tables are given. This all shall support description but can never override it. Orientation guides come from different sources and do not necessarily match between different columns.

3.2.1. Soil substrate

Soil substrate, particularly that of the topsoil, largely controls all function of a soil. Soils of different texture may be advantageous for growing plants. Best soils for farming worldwide originate from loess. These soils are commonly deep, well drained and water storing. They have a large capacity to store nutrients because of their high cation-exchange capacity (CEC). Other soils like humic fine sands are very favourable for smallholder organic farming or for gardening. If soil depth is artificially restricted, for example in pot gardening, completely organic soil substrates are preferred.

Examples of unsuitable soils are those from coarse sand with low organic matter. They have a low storage capacity and tend to excessive leaching.

In the temperate zone of Western and Central Europe, in most soils of appropriate substrate the fertility status is not in a critical range due to a longer cultivation history in compliance with rules of crop rotation and nutrient cycling. This holds for the soil reaction and the content of stones largely too. Organic matter content is also correlated with the content of fine soil particles. For a given type of land use and climate, SOM is largely controlled by texture.

However, in dry regions, undesired components of soil substrate may occur. For example, high concentrations of calcium-sulphate or -carbonate (> 10 %) affect plant nutrition. In clayey soils they restrict root growth of most agricultural plants.

The dominant soil texture over the upper 80 cm (arable land) and 50 cm (grassland) will be scored by Table 3.2.1.-1.



Fig. 3.2.1.-1: Soil substrate from Loess and a well developed A horizon with a not too sharp boundary to the subsoil are features of high soil quality.

However, Loess of this soil is underlain by coarse material at 0.7 m, limiting the substrate score to a sub-optimum of 1.5. Rooting depth and water capacity of the rootzone in a sub-humid climate are also limited. Vermi-calcic Chernozem, location Voderady, Slovakia (Surina, 2001).



Fig. 3.2.1.-2: Soil substrate from Loess (substrate score at optimum of 2). However, climate is humid and soil has stagnant properties giving reason for artificial drainage. Stagnic Luvisol, location Ostinghausen, Germany.

Table 3.2.1.-1: Scoring of basic indicator 1: Soil substrate

Score	Characteristics ^{1, 2)}	Orientation guides		
		Texture classes and parent material of the German soil rating system (In: AG Boden, 2005, p. 318)	Texture classes of AG Boden, 2005, p. 142	Texture classes of FAO/USDA (Guidelines, 1990, 2006)
2	Loess, sandy loam, loam, optimum organic matter (SOM), all soils of SOM 8-20 %, free of coarse material (> 2 mm)	L-Loe, sL-Loe, SL-Loe, L-Al, L-V	lu, su, tu, sl, ll	silt loam, silt, loam, silty clay loam
1.5	Sandy loam, loam or loess of low SOM (< 2 %), sandy soils of SOM 4-8 %, lowland clay, peat of fens, coarse material < 5 %	L-D, sL-D, sL-Al, sL-V, SL-D, SL-Al, SL-V, IS-Loe, L-Vg, LT-Al, LT-V, T-Al	ut, tl	sandy loam, sandy clay loam, sandy clay, clay loam, sandy clay,
1	Sand and loamy sand, clay of low SOM, better soils with higher prop. of coarse material (5-10 %), dense clays, peat of bogs	IS-D, IS-Al, IS-V, sL-Vg, SL-Vg, LT-D, LT-Vg, T-D, T-V	ls, us, lt (exc. Tt)	loamy sand
0.5	Medium to fine textured sands, low to medium SOM, coarse material > 10 %, very stony clays, natural peatsoils without mucky topsoil	SI-D, SI-Al, SI-V, IS-Vg, T-Vg	fS, fSms, Tt	sand, clay
0	Coarse to medium textured sands, coarse material > 30 %	S-D, S-Al	Ss (exc. fS and fSms)	coarse sand

¹⁾ Presence of a significant textural gradient with depth above 0.8 m leads to a reduction by 0.5, possible maximum of score = 1.5

²⁾ If soil substrate is clearly chemically, biologically or physically degraded (for example contaminated or salinised), maximum score should be 0.5



Fig. 3.2.1.-3: Extreme stoniness in the soil profile (substrate score 0, drastic reduction of water capacity, score 0) Hyperskeletal Regosol. Location in Canterbury, New Zealand



Fig. 3.2.1.-4: Sandy soil of a coastal dune rangeland, substrate score 0.5. The iron bank (Ortstein) indicates extremely high leaching potential of the soil above. Location in Florianopolis, Brazil

3.2.2. Depth of A horizon and depth of humic soil

A well developed deep A-horizon is crucial for establishment of crops. It is an aspect of the long-term cultivation status. A-horizon contains the very most organic matter of the soil profile. This SOM plays a central role in maintaining key soil functions. It provides the binding and buffering capacity of soil and is an essential determinant of soil fertility. Intensive mechanisation of agriculture during the past decades has led to deep A-horizons of most soils in Western and Central Europe. Limitations with depth and SOM content and consecutive yield losses occurred mainly by water or tillage erosion (Den Biggelaar et al, 2003). Reduced topsoil thickness may limit crop yields (Al-Kaisi, 2001). In grassland (including rangeland) a deep humic layer is also advantageous like in arable land. Most grasslands of the humid temperate zone in Europe have a long cultivation history and have been converted from forest or re-converted from arable land. Thus the depth of the Aw-horizon is not a reliable indicator of soil quality. Instead of Aw depth the depth will be used as an indicator at which SOM will fall below a threshold.

Table 3.2.2.-1: Scoring of basic indicator 2, arable land: A horizon depth

Score	Depth	Remarks	Orientation guide degree of erosion acc. to AG Boden, 2005, p. 316
2	> 25 cm	If sharp border to lower horizon or the A horizon is diluted by subsoil, 0.5 score less If A horizon has very low SOM (< 2 %) or has gleyic or stagnic properties, 0.5 score less, and maximum score = 1	Eg0,1
1.5	20 - 25 cm		Eg2
1	15 - 20 cm		Eg3
0.5	10 - 15 cm		Eg4
0	< 10 cm		Eg5

Table 3.2.2.-2: Scoring of basic indicator 2, grassland: Depth of humic soil (d_h)

Score	Characteristic	Remarks
2	$d_h > 0.6$ m	Minimum SOM content of $h = 4$ %, if $h < 4$ %, d = depth of rooting zone or horizon, and maximum score = 1
1.5	d_h 0.3 - 0.6 m	
1	d_h 0.15 - 0.3 m	
0.5	d_h 0.05 - 0.15 m	
0	$d_h < 0.05$ m	

3.2.3. Topsoil structure

Soil structure is important for many soil properties like water and air flow, water storage, biotic activity and workability (Kay and Angers, 2000). The topsoil structure has to provide germination of seeds and employment of water and nutrients by the plants. Friable, porous topsoils provide suitable conditions for plant roots and soil fauna. They retain the moisture necessary for microbial activity and nutrient cycling. Fine aggregates, extensive porosity and presence of earthworms and intensive rooting are indicators of a good structure. Wormcasts and holes as well as birds behind tillage are further positive indirect indicators of a good structure. Soil structure is mainly influenced by soil management and can be assessed by VSA (Shepherd, 2000) or similar methods.

Structure is also related to soil substrate, e.g. texture and SOM, and changes with structure may be very persistent.

Large sharp-edged or platy aggregates, clods or massiveness are examples of poor structure. In grassland, some species of vegetation indicate insufficient topsoil structure due to compaction. Shell-shaped aggregates indicate former excessive stock trampling.

Table 3.2.3.-1: Scoring of basic indicator 3: Topsoil structure

Score	Characteristics	Orientation guides		
		Porosity score of VSA method (Shepherd, 2000)	Structure score acc. to Diez and Weigelt, 1997	Peerlkamp note (Peerlkamp, 1967)
2	Optimum aggregates and porosity, good rooted and aerated, many biopores, no sharp-edged aggregates	2	1, 2	=> 7
1.5	Between 2 and 1	1.5	2, 3	6
1	Markedly disturbed aggregate hierarchy, coarse sharp-edged blocky aggregates of clay soils, or platy aggregates, none or a few biopores, no mottles in topsoils	1, 0.5	3, 4	5
0.5	Like above, but mottling or anaerobic feature below grassland, no or few earthworm burrows or worms	0, 0.5	4	4
0	Massive, no aggregation or extremely large aggregates of hard platy structure, no or extremely hampered root penetration	0	5	=< 3

Note: If single grain structure is dominant, maximum score =1.



Fig. 3.2.3.-1: The arrangement of aggregates after performing the drop-shatter test of the VSA procedure (Shepherd, 2000) indicates differences of soil structure. The Manawatu soil (NZ: Weathered Fluvisol recent soil, FAO WRB: Eutric Fluvisol) shows moderate to good structure conditions (score 1.5) whilst the very clayey Kairanga soil (NZ: Typic Orthic Gley, FAO WRB: Eutric Gleysol) has a high proportion of large blocky aggregates (score 0). Performance of the VSA procedure is recommended in conjunction with the Muencheberg SQR.



Fig. 3.2.3.-2: At sub-optimum soil structure roots use interfaces of aggregates. Location: Oderbruch region, Germany

3.2.4. Subsoil compaction

Subsoil compaction occurs when soil is subject to deep mechanical pressure mainly through the use of heavy machinery. Soil compaction is potentially a major threat to agricultural productivity. It affects main aspects of soil quality adversely like restricting root growth, water storage capacity, fertility, biological activity and stability. Subsoil compaction is persistent as natural alleviation processes such as wetting/drying, freezing/thawing and biological activity including root growth decrease with depth. Wheel loads are still increasing and, in consequence, the extent and severity of subsoil compaction will increase too.

Compacted subsoil structure can also be a result of natural physical and chemical processes. High preconsolidation by former glaciation of the land or poor subsoil structure of sodic or dispersive clay are examples.

In cohesive soils sharp-edged large aggregates without any hierarchy are a sign of damaged subsoil.

In grassland, commonly the subsoil begins shallower. On meadows, machinery acts compacting. On pastures deep trampling in wet soil (pugging) can lead to unsuitable soil structure below the grassland. This is frequently combined with hydromorphic features of the subsoil and topsoil above. Sometimes in grassland reconverted from arable land, former subsoil compaction can be evident.

Table 3.2.4.-1 is valid both for arable land and grassland. Table 3.2.4.-2 is a supplement for grassland if unfavourable subsoil structure is combined with redoximorphic feature.

Table 3.2.4.-1 : Scoring of basic indicator 4: Subsoil compaction

Score	Characteristics	Orientation guides				
		Tillage pan score of VSA ¹⁾	Structure score of Diez and Weigelt, 1997	Peerlkamp note	Packing density acc. to Harrach et al., 1999	Increase of soil mechanical resistance ²⁾
2	No compaction, no sharp-edged aggregates	2	1, 2	=> 7	< 2	Only slight
1.5	Slightly compacted, between 2 and 1	1.5	2, 3	6	< 2	Slight to moderate
1	Moderately compacted, few sharp-edged aggregates, disturbed aggregate hierarchy, biopores	1.5	3, 4	5	2 - 3	Moderate
0.5	Compacted, sharp-edged aggregates, few vertical macropores	0, 0.5	4	4	3 - 4	Distinct
0	Clearly compacted, large sharp-edged aggregates of hard structure, none or very few macropores	0	5	=< 3	> 4	Very distinct

¹⁾ If depth of tillage pan > 20 cm

²⁾ Knife test or penetration resistance at comparable substrate and moisture status, below tillage layer related to topsoil and/or deeper subsoil

³⁾ Field assessment and/or estimate: PD = (DBD - 1.199 - 0.00204 sand) 0.1202⁻¹

Table 3.2.4.-2: Orientation guide of basic indicator 4, subsoil compaction, particularly under grassland

Score	Hydromorphic feature below grassland	Orientation guide
2	No redoximorphic feature ¹⁾ in the upper 30 cm	See sample photographs of VSA (Shepherd, 2000, p. 63)
1.5	Up to 10 % oximorphic feature	
1	Up to 20 % oximorphic feature, but only a few features of reduction	
0.5	Redoximorphic feature > 20 %, also above 15 cm	
0	Strong redoximorphic feature, > 50 %, reduction zones	

¹⁾ Includes oximorphic and reductomorphic features, oximorphic: mottles or concretions, reductomorphic: grey, blue, green or black coloured



Fig. 3.2.4.-1: Hydromorphic feature and coarse aggregates below meadow grassland prone to wetness and compaction (score = 0). Soil is a Gleyic Fluvisol (Arenic) Location: Oderbruch region, Germany

3.2.5. Rooting depth and depth of biological activity

A deep rooting system guarantees stable supply of crop water and nutrient requirements. It also minimises the risk of nutrient loss. Potential rooting depth limitation can be management-induced (compaction, water table control) but is often due to natural soil layering. Soils that are deep and have desirable texture and no structure limitations are suitable for most plants. Deep soils contain more plant nutrients and water than shallow soils. Shallow, stony, impervious soils, on the other hand, hold little nutrients and water. Crop yield is clearly correlated with soil rooting depth (Timlin et al., 2001, Sadras and Calvino, 2001), however, this effect can be compensated by irrigation (Timlin et al., 2001) or by climate. In many soils the rooting depth is restricted by physical or chemical barriers. Soil physical characteristics known to influence root development are penetration resistance, aeration, water retention, sharp contrasts in soil properties including fragipans and other compact horizons, cemented layers, lithic or paralithic contacts. Examples of extreme physical barriers are rock, a cemented hardpan, or particularly dense massive clay subsoil. A perched or permanent water table can also act as a barrier to root development. Changes in soil bulk density or mechanical soil resistance due to either compaction or naturally-occurring textural horizons, can significantly affect rooting depth. In terms of soil classification, root-limiting layers may be fragipans, duripans; petrocalcic, petrogypsic, and placic horizons; ortstein, and densic, lithic, paralithic, and petroferric contacts (Pedosphere.com., 2001). A very low pH of about 4.5 or less presents a chemical barrier to root growth. Medium and coarse textured sand may act as physical, chemical and biological barrier to rooting. Cone penetrometer resistance of more than 2 MPa inhibits root growth (Taylor and Gardner, 1963). Some soil types like Rendzinas, Rankers, or Lithic or Petroferric phase or soils in permafrost regions, have a limited potential rooting depth. Rooting depth is determined by both crop and soil properties. Inhibition of root development may also occur in early stages of crop establishment due to sealing of the soil surface.



Fig. 3.2.5.-1: A dense cemented layer of calcium carbonate can limit rooting depth for cropping (score 0.5). Soil is a Limnic Fluvisol (Calcaric, Drainic). Location Baerwinkel, Germany.

Under grassland, rooting depth is not a reliable soil quality indicator as shallow roots of grass cannot use the rooting potential of many soils. Deep digging organisms like anecic earthworms indicate the potential of soil to reclaim the resource of deeper soil. As earthworms, especially deep burrowing species avoid hydromorphic zones (Cannavacciuolo et al., 1998) both wormholes and hydromorphic zones seem to be suitable indicators of biological activity and deep rooting potential.



Fig. 3.2.5.-2: Haplic Luvisol from Pliocene parent material. The dark brown Bt horizon has clayey texture and stagnant properties in spring, limiting root development of cereals. Location Lovech, Bulgaria, (Penkov and Mueller, 2001).

Table 3.2.5.-1: Scoring of basic indicator 5, arable land: Rooting depth (RD)

Score	Characteristic	Barriers ^{1) 2)} to rooting
2	RD > 1.5 m	Water table, anoxic layers, SOM free sandy layers > 0.2 m, coarse SOM free sands > 0.1 m, rock or gravel underground, iron pans, compacted layers > 0.3 m, strongly acid, sodic or saline layers, permanently dry subsoil
1.5	RD 1.1 - 1.5 m	
1	RD 0.8 - 1.1 m, maximum of sandy soils	
0.5	RD 0.5 - 0.8 m	
0	RD < 0.5 m	

¹⁾ If barriers to seedling emergence exist like soil tending to surface crusting, water repellency or hardsetting, reduction by 0.5

²⁾ Rooting depth must be estimated based on visible roots or effective rooting depth. Barriers give an orientation to potential rooting depth (which is a maximum of current observed rooting depth or of potential rooting depth) if they are absolute barriers like uncracked hardrock. Intensity of most barriers may be very different.

Table 3.2.5.-2: Orientation guide of rooting depth (RD)

Score	Effective rooting depth AG Boden, 2005, p. 356, ¹⁾	Zustandsstufe German soil rating, in: AG Boden, 2005, p. 318	Classes of root-restricting depth (Soil Survey Manual, Chapter Three) ²⁾	
2	> 1.3 m	1 - 2	Very deep	> 150 cm
1.5	1 - 1.3 m	3	Deep	100-150 cm
1	0.8 - 1 m	4	Moderately deep	50-100 cm
0.5	0.5 - 0.8 m	5	Moderately deep	50-100 cm
0	< 0.5 m	6 - 7	Shallow and very shallow	> 50 cm

¹⁾ assuming field capacity moisture status at the begin of the vegetation period

²⁾ <http://soils.usda.gov/technical/manual/contents/chapter3e.html#54>

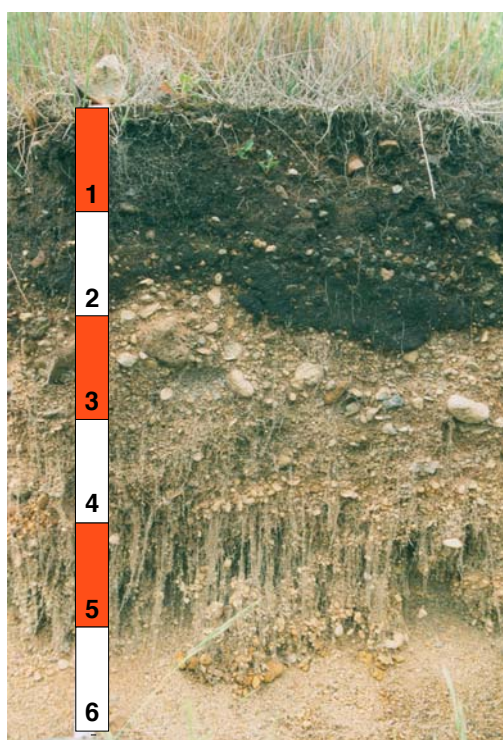


Fig. 3.2.5.-3: Soil from volcanic ash (Pumice soil) of extreme low density. Even roots of grass can penetrate this soil down to 0.6 m. Score of biological activity = 2. Location in Taupo region, New Zealand



Fig. 3.2.5.-4: Coarse or medium textured sandy subsoil is a barrier to rooting. Farmers tried to increase rooting depth by deep ploughing. Current rooting depth of cereals is about 0.7 m, rating score 0.5. Soil is a Gleyic Fluvisol (Anthric, Eutric, Arenic, Drainic). Location Sydowswiese, Oderbruch region, Germany.

Table 3.2.5.-3 : Scoring of basic indicator 5, grassland: Biological activity

Score	Characteristics
2	Indication of active bioporosity > 30 cm, mole activity or potential ¹⁾ , worm holes or worms of deep burrowing species like <i>Lumbricus terrestris</i> , numerous other species of soil fauna, intensive deep rooting of grasses > 60 cm
1.5	Active bioporosity > 20 cm, worm holes or worms of medium to deep digging species, numerous other species of soil macrofauna, rooting of grasses 40-60 cm
1	No indication of macrofauna or biogene pores deeper than 15 cm, moderate rooting of grasses (30-40 cm)
0.5	No indication of macrofauna or biogene pores deeper than 10 cm, restricted rooting of grasses (< 30 cm)
0	No indication of macrofauna or biogene pores deeper than 5 cm , extremely restricted rooting of grasses (< 20 cm)

¹⁾ e. g. moles or similarly living animals in the neighbourhood or at similar soil conditions at the same field

3.2.6. Profile available water

Profile Available Water (PAW) is the water capacity of a soil profile available for vegetation. PAW equals the water storage, commonly estimated as the difference in water content between field capacity and wilting point within the effective soil rooting depth. In case of a shallow watertable, this resource of potential groundwater consumption will be added according to the rules of the AG Boden, 2005. Stone content within the potential root zone diminishes the calculated value.

PAW is a crucial parameter of soil quality, in particular in regions of rain deficit during the vegetation period. It can buffer the effect of insufficient rainfall. Reliable estimation of this indicator is difficult as the stored amount of water at the beginning of the vegetation period can vary. This is mainly dependent on climate. In drier regions, many soils have high water storage capacity but this resource is not available as the store is not filled.

Estimates of Table 3.2.6.-1 are based on a filled store at the beginning of the vegetation period. This can be assumed for the temperate humid climate.

Local adaptations of field capacity related to the climate and the infiltration and depletion processes of different soils should be considered (Schindler et al., 2004). For example, the suction at field capacity could be varied between pF 1.8 (udic local field moisture regime, humid or per-humid climate), pF 2 (sub-humid climate) and pF 3 (aridic local field moisture regime).

On grassland, vegetation indicates the medium-term soil moisture status. Moisture numbers less than 4 of the Ellenberg scale (Ellenberg et al., 2001) or "Grasland-Wasserstufen" less than -2 are indicators of an ecologically dry soil moisture status.

Table 3.2.6.-1: Scoring of basic indicator 6: Profile available water

Score	Characteristics	Orientation guides	
		PAW in the effective rooting depth of AG Boden, 2005 ¹⁾	Grassland “Wasserstufe” (in AG Boden, 2005, p. 319/320)
2	No deficit of PAW, high water storage capacity of soil substrate (Loess, silty loam) or optimum or shallow water table	> 220 mm	1- (minus) or higher
1.5	Slight water deficit due to sub-optimum storage capacity, rooting depth or water table	160-220 mm	2-
1	Distinct water deficit	100-160 mm	3-
0.5	Strong water deficit, sandy soils and deep water table	60-100 mm	4-
0	Extreme water deficit, coarse sands or very shallow rooting depth	< 60 mm	5-

¹⁾ The orientation guide of Table 3.2.6.-1 refers to temperate humid conditions assuming the soil profile saturated to field capacity at the beginning of the vegetation period. It is related to differences in suction between -10 and -1500 kPa.

If the climate is sub-humid ($P < 500$ mm/yr) and the water table deeper than 1.2 m and the substrate score 1 or greater, 50 mm more are required to reach the same score. This is due to sometimes insufficient recovery of the soil water store during winter.

3.2.7. Wetness and ponding

Wetness and ponding (waterlogging) occurs when the soil profile is saturated with water or water appears above the soil and plants lack air. The severity of waterlogging depends on climatic, geomorphological and pedological site properties. Depressions and lowlands are more prone to waterlogging than higher land. The permeability of the soil, depth to water table and plant water use have an influence on the degree of waterlogging. Soils in per-humid regions and soils of impeded internal drainage are also subject to wetness and ponding. High and perched water tables limit the soil aeration status and root development of crops. Ponding reduces the topsoil nutrient status markedly. If the soil is cohesive, numerous days with topsoil water content higher than the plastic limit may delay soil management (technological wetness).

Rust-coloured mottles indicate wetness, but this is not a reliable criterion as the feature may be relictic. A soil profile with dominantly reductomorphic feature (grey, black, blue or green colours) at shallow depth indicates prolonged saturation with water. The water table commonly occupies this zone permanently.

Grasses and wetland plants are more tolerant to waterlogging than arable crops. On grassland, hydrophytic plants are reliable indicators of wetness.



Fig. 3.2.7.-1: Longer ponding on arable land is not tolerable for crops like winter wheat and causes soil compaction and management problems.

Location: Oderbruch region, Germany

Table 3.2.7.-1: Scoring of basic indicator 7: Wetness and ponding ¹⁾

Score	Characteristics	Remarks
2	No surface ponding or wetness	If soil position is in a depression, maximum score = 1.5, if soil suffers from wetness by suspended water (soils rich in silt and clay or muck), maximum score = 1.5
1.5	Surface ponding extremely rare, temporal wetness in the rootzone can occur for shorter periods	
1	Moderate surface ponding up to 3 days after heavy rainfall possible	
0.5	Significant wetness in the rootzone for longer periods, moderate ponding	
0	Significant surface ponding and wetness in the rootzone can occur for longer than 3 days after heavy rainfall	

Table 3.2.7.-2: Orientation guide of wetness and ponding

Score	Soil drainage class acc. to Soil Survey Manual, chapter three (USDA/NRCS, 2005)	Depth of ground or perched water table m ¹⁾	Degree of redoximorphic features in the subsoil, AG Boden, 2005, p. 315 ²⁾	Indicator values of vegetation ³⁾	Grassland "Wasserstufe" (in AG Boden, 2005, p. 319/320)
2	Well, Somewhat excessively, Excessively	> 1	Vn0	=> V, mF < 5.5	1+ (or lower)
1.5	Moderately well	0.8 - 1	Vn1	mF 5.5-6.5	2+
1	Somewhat poorly	0.6 - 0.8	Vn2	IV, mF 5.5-6.5	3+
0.5	Poorly	0.5 - 0.8	Vn3-4		3+ to 4+
0	Very poorly	< 0.5	Vn5-6	>= III, mF > 7	4+ to 5+

¹⁾ Temperate humid and sub-humid zones, if drainage is impeded by soil structure or indications of additional perched water, or clear technological wetness, 0.5 score less.

²⁾ Without consideration of wet humus accumulation, neglecting relictic oxymorphic feature

³⁾ Ecological degree of wetness acc. to AG Boden, 2005, p. 360-361, mF = mean wetness number of vegetation acc. to Ellenberg et al., 2001 on grassland



Fig. 3.2.7.-2: Rushes (*Juncus spec.*) are indicators of a poor aerated soil due to compaction and /or wetness. Location: Pohangina, Manawatu, New Zealand.

3.2.8. Slope and relief

Slope is a morphologic feature of the landscape and has a significant influence on soil formation, soil management and risk of degradation. Soils with slope gradients greater than 4 percent have risks of higher runoff and soil erosion and require management practices that protect the soil surface and minimise runoff. Worldwide, erosion is the most severe threat of sloped soils. On slopes of less than 7 % common agricultural machinery is applicable (Webb and Wilson, 1995).

Almost flat slopes are best suitable for cropping. Worldwide, in cases of high demand of farmland, very steep slopes (more than 30 %) are commonly used as grassland or even as arable land (Sun et al., 2006). However, the erosion risk is then very high.

Slope aspects and relief position are also important factors of soil quality. Their function is largely climate-dependent. In warm and dry climates on the Northern Hemisphere, southern aspects are more prone to drought, failure of crops and damage by erosion. In cool climates, northern aspects are indicated by late thawing and delay in the development of vegetation.

Slope is associated with soil types to a certain degree. For example, Fluvisols, Gleysols, Histosols, Planosols, Solonchaks, Solonetz and Vertisols are lowland soils (gradient < 8 %). Regosols, Rendsinas, Cambisols, Acrisols, and Nitosols are soils of sloping areas (gradient 8 - 30 %), and Andosols, Rankers and Lithosols are often associated with steep slopes (Fischer et al., 2002).

Table 3.2.8.-1: Scoring of basic indicator 8: Slope and relief ¹⁾

Score	Slope gradient characteristic	Gradient arable land	Gradient grassland	Orientation guide Inclination acc. to AG Boden, 2005, p. 58
2	No to very weak	< 2 %	< 4 %	N0
1.5	Weak	2 - 4 %	4 - 9 %	N1
1	Weak to moderate	4 - 9 %	9 - 14 %	N2
0.5	Moderate	9 - 12 %	14 - 30 %	N3.1
0	Distinct to steep	> 12 %	> 30 %	=> N3.2

¹⁾ Within the given score range of 0 to 2, a modification by 0.5 (one class) can be taken into account due to microrelief and slope aspect

Table 3.2.8.-2: Orientation guide for scoring slope gradient on the basis of soil description acc. to Guidelines, 2006, Table 7, p. 12

Slope gradient class	Slope gradient Percent	Orientation guide of rating scores	
		Arable land	Grassland
< 05	< 2 (Flat to very gently sloping)	2	2
05	2 - 5 (Gently sloping)	2	2
06	5 - 10 (Sloping)	1	1.5
07	10 - 15 (Strongly sloping)	0.5	1
08	15 - 30 (Moderately steep)	0	0.5
> 08	> 30 (Steep and very steep)	0	0



Fig. 3.2.8.-1: Distinctly sloped part within a field grown with winter rye. Slope is associated with loss of the A-horizon by water and tillage erosion. Soil is a Hypoluvisc Arenosol (Dystric). Location: Libbenichen, vicinity of Berlin, Germany

3.3. Scoring of hazard indicators

3.3.0. What are hazard indicators?

Hazard indicators characterise hazard properties of soils. Hazard properties of soils are capable of completely to superimpose other properties and to limit the quality of the total soil profile. For example, if a soil is too shallow or contaminated, no cropping will be possible. Some of the basic properties described above have this potential if their indicators reach extreme values. In this conception hazard properties, if occurring have been considered as multipliers and will clearly downgrade the total soil score. Multipliers in the tables below will provide a certain frame for scoring, depending on the risk of occurrence and the severity of the problem, e. g. possibilities and costs of soil rehabilitation, or dependent on climate.

Reliable scoring of hazard properties may require measurements in some cases. For example, if common indicators like vegetation are not enough sensitive to score acidification or sodification or salinisation, a field test kit for measuring pH and the electric conductivity may be very helpful.

Table 3.3.0.-1: Checklist of Hazard Indicators and thresholds for orientation

Indicator	Thresholds for orientation		
	Direct soil parameters	Indirect parameters of vegetation ²⁾ , climate or others	Soil reference groups (SRG) or <i>qualifiers</i> of WRB ¹⁾
1. Contamination	Specific for each pollutant acc. to international thresholds	High risk areas: cities, waste affected soils, floodplains	<i>Toxic, (Garbic, Spolic)</i>
2. Salinisation	EC > 2 mS/cm in topsoil	White crusts on soil surface, occurrence of halophytes, S-number acc. to Ellenberg > 3	<i>Salic, Hypersalic, Puffic, Chloridic</i>
3. Sodification	ESP > 15 % (SAR > 13), pH > 8.2 in topsoil	High pH indicating plants, R-number acc. to Ellenberg of 9	<i>Sodic, Alcalic, Natric</i>
4. Acidification	pH < 5.2 (cropping) or 4.5 (grassland) in topsoil	Low pH indicating plants, R-number acc. to Ellenberg of 3 or lower	<i>Hyperdystric, Hyperthionic</i>
5. Low total nutrient status	Clear deficit of nutrients, cannot be compensated by fertilisation within one year		<i>Hypergyptic, Hypercalcic</i>
6. Soil depth above hard rock	Hardrock or permafrost < 120 cm (arable land) or < 70 cm (grassland)		<i>Leptic, Lithic, Petric</i>
7. Drought	Water budget in the main vegetation period < 500 mm, ustic, xeric or aridic soil water regime,	Climatic water balance in the main vegetation period of 4 months < -100 mm, probability of the occurrence of a dry month > 10 %, aridity index acc. to De Martonne < 30, benefit of irrigation for cereals	<i>Aridic</i>
8. Flooding and extreme waterlogging	Flooding probability > 5 %, aquic or peraquic soil water regime	Delay of beginning of farming on cropping land > 20 d, Grassland mF (Ellenberg) > 8, clear benefit of land drainage	<i>Floatic, Gelistagnic, Subaquic, Tidalic</i>
9. Steep slope	Arable land gradient > 12 %, grassland gradient > 30 %		
10. Rock at the surface	Arable land > 0.01 % rock outcrop, grassland > 0.05 %		<i>Leptosols; Ekranic, Hyperskeletalic</i>

11. High percentage of coarse soil texture fragments	Arable land > 15 % by mass of coarse fragments (> 2 mm) in topsoil, grassland > 30 %		Leptosols; <i>Hyperskeletal</i> , <i>Skeletal</i>
12. Unsuitable soil thermal regime	Frigid, cryic or pergelic soil thermal regime	Tundra regions Duration of the frost free period < 140 d	Cryosols; <i>Cryic</i> , <i>Glacic</i>

¹⁾ SRG or qualifiers not in brackets are clear hazard indicators

²⁾ See examples of vegetation indicator species of drought, wetness, acidity, sodicity and salinity of Central Europe in Appendix 3. Region-specific values should be preferred if available (for example Bui and Henderson, 2003, Victorian Resources online. 2007. ELLENBERG'S INDICATOR VALUES FOR BRITISH PLANTS, 2007).

A note on scoring tables of hazard indicators:

Tables contain a score based on a description and thresholds if available. To support scoring, prefixed explanatory text, some example photographs and orientation guides in the same or additional tables are given. This information shall support the description but can never override it. Orientation guides come from different sources and do not necessarily match.

Based on the scores, a range of multipliers for the basic score is indicated. Within the given range of multipliers, an expert based individual adjustment of the multiplier will be possible.

3.3.1. Contamination

Commonly, agriculturally used soils are relatively clean. However, due to chemical or nuclear hazards or enhanced soil quality standards, content of detrimental substances can exceed thresholds. This means loss of soil quality and a risk for food quality. Many contaminated soils are relictic. Soil contamination can result in the damage of several soil functions and the contamination of surface water and groundwater. It belongs to the hot spots of soil degradation in Europe (EEA, 2000).

To detect and quantify contamination requires special analyses. However, pressure indicators like knowledge of frequent sewage sludge application or the location of the field in the vicinity of an industrial emitter can give first information on the risk. Artificial soils (Urban soils, Technosols acc. to WRB, 2006) show high risk of being contaminated. Besides that, most intensively human-induced and managed soils e. g. garden-like soils within or in the vicinity of big cities or bottomland soils of polluted rivers are prone to contamination.

A sensory analysis of the soil substrate on the basis of common criteria like kind of artefacts, colour and odour (Lichtfuss, 2004) of soil may provide important hints for contamination of soils.



Fig. 3.3.1.-1: Soils developed on debris or urban waste have a high risk of being contaminated. Soil is an Urbic Technosol (Reductic, Arenic). Location Buenos Aires, Argentina.

Table 3.3.1.-1: Scoring of contamination

Score	Characteristic	Multiplier
2	No contamination	3
1.5	Slight exceedance of thresholds, no risk for food safety	1.5 - 3
1	Slight exceedance of thresholds, minimum risk for food safety	1 - 1.5
0.5	Distinct exceedance of thresholds	0.5 - 1
0	Extreme exceedance of thresholds	0.01 - 0.5

3.3.2. Salinisation

Saline soils contain higher amounts of soluble salts that interfere with the growth of most plants. The physiological functions of the total plant, in particular the roots will be damaged (Vaughan et al., 2002). Salinisation is a typical problem of soils in drier regions with irrigation and may become more important in the currently temperate zone because of climate change. Even in the humid temperate zone salinisation may occur as a local phenomenon due to upward transport of water and diluted salts. Solonchaks are a type of soils having a salic horizon starting within 50 cm from the soil surface. If strong salinisation is manifested in soils, high efforts will be required of leaching the salts by irrigation and drainage. If not controlled, salinisation will result in completely unproductive soils. The electrical conductivity of the saturation extract is a proper measure of salinisation.



**Fig. 3.3.2.-1: Devastated soil by salinisation after long-term subsoil- irrigation in a semi-arid environment.
Location in Victoria, Australia**

Table 3.3.2.-1: Scoring of salinisation (in relation to Withers et al., 1978, p. 91 and Abrol et al., 1988, Soil Survey Manual, 1993 (USDA/NRCS, 2005), Kotuby-Amacher, et al., 1997, Department of Agriculture, Western Australia, 2005)

Score	Characteristics	Electric conductivity EC ¹⁾	Multiplier arable land	Multiplier grassland
2	No salinisation, no injury on all plants.	< 2	3	3
1.5	Low salinisation, sensitive plants and seedlings of others may show injury	2 - 4	1.5 - 3	2.6 - 3
1	Moderate salinisation, yields of most non-salt tolerant plants will be restricted, salt-sensitive plants will show severe injury	4 - 8	1 - 1.5	2 - 2.6
0.5	Strong salinisation, salt-tolerant plants will grow, most others show severe restrictions	8 - 16	0.5 - 1	1.5 - 2
0	Extreme salinisation, only very tolerant plants and halophytes will grow, salt crusts at the surface	> 16	< 0.5	< 1.5

¹⁾ Saturation extract of topsoil ($\text{mmho cm}^{-1} = \text{mS cm}^{-1} = \text{dS m}^{-1}$), if EC is measured in 1:5 solution, conversion is necessary according to Guidelines, 2006

3.3.3. Sodification

In the temperate zone, sodification is a phenomenon of drier regions due to the geological and climatic situation or irrigation with sodic water.

Sodicity is due to a high percentage of exchangeable sodium (ESP) of the total cation exchange capacity of the soil. This leads to soil dispersion, associated with clogging up the soil pores, reducing water and air permeability, limiting of root growth and slowing of drainage. The soil is more difficult to cultivate. Surface soil crusting, subsoil waterlogging, low nutrient efficiency and accelerated water erosion are consecutive problems of sodicity.

Sodicity is associated with alkalinity. In a certain range of alkalinity, micronutrients such as iron, zinc, copper, manganese and boron, but also macronutrients like phosphorus and potassium, are less available for plant use. Sodification and salinisation may occur in combination.

Solonetz is a type of soil having a natric horizon within 100 cm from the soil surface. An ESP of more than 15 percent or a sodium adsorption ratio (SAR) value of 13 are considered the threshold value for a soil classified as sodic (Abrol et al., 1988). This means that sodium occupies more than 15 percent of the cation exchange capacity (CEC).

In the field, a soil pH above 8.4 indicates a sodium problem. Sodic soils of high clay content show a typical columnar soil structure.



Fig. 3.3.3.-1: Coarse columnar structure of a Solonetz. Grassland vegetation is adapted to low to moderate sodification, score 1.5, multiplier 2.8. Location at Neusiedler See, Austria (Nelhiebel et al., 2001).

Table 3.3.3.-1: Scoring of sodification (related to Abrol et al., 1988)

Score	Characteristics	ESP ¹⁾	pH	Multiplier arable land	Multiplier grassland
2	No to slight sodification, very sensitive crops may be slightly adversely affected	< 15	< 8.2	3	3
1.5	Low to moderate sodification	15 - 30	8.2 - 8.4	2.5 - 3	2.7 - 2.9
1	Moderate to high sodification	30 - 50	8.4 - 8.6	2 - 2.5	2.5 - 2.7
0.5	High to very high sodification	50 - 70	8.6 - 8.8	1 - 2	2 - 2.5
0	Extreme sodification, plant growth is adversely affected, only extremely tolerant native grasses may grow	> 70	> 8.8	< 1	< 2

¹⁾ Saturation extract of topsoil

3.3.4. Acidification

Acid soils naturally occur in humid climates through processes of leaching and acid deposition. Soil acidity can vary according to geology, clay mineralogy, soil texture and buffering capacity. Acidification is a major land degradation issue (Bolan et al., 2003). Agricultural management like use of physiological acid fertilisers and nitrogen leaching can greatly accelerate the rate of acidification. When soil becomes more acidic the basic cations (Ca, Mg) are replaced by hydrogen ions or solubilised metals. The basic cations can be leached, and soils become less fertile and more acidic. Commonly, plant and crop growth are limited because of a reduction in the availability of nutrients (calcium, magnesium, boron, phosphorous, molybdenum and potassium) and/or an increase in toxic levels of aluminium, iron or manganese. Many plants can tolerate only small quantities of these elements before the soil becomes toxic and restricts plant growth. Acidity is measured by determining the pH of a soil. A result below pH 5.5 in water indicates growth limitations of acid-sensitive plants like some alfalfa, barley and canola. Acidification can properly be mitigated by liming.

Table 3.3.4.-1: Scoring of acidification (related to AG Boden, 2005, p. 367)

Score	Characteristics	pH ¹⁾	Multiplier arable land	Multiplier grassland
2	No significant acidification	> 5.2	3	3
1.5	Low to moderate acidification, sensitive crops may be adversely affected	4.5 - 5.2	2.5 - 3	3
1	Moderate to high acidification	4 - 4.5	2.2 - 2.5	2.7 - 3
0.5	High to very high acidification	3.3 - 4	2 - 2.2	2.5 - 2.7
0	Extreme acidification, plant growth is adversely affected, only extremely tolerant native grasses may grow	< 3.3	< 2	< 2.5

¹⁾ in 1:5 soil (air dried) : water extract



Fig. 3.3.4.-1: Rangeland consisting of *Corynephorus canescens* and lichens vegetation on an acid sandy soil (Umbric Podzol, pH 4, acidification score 0.5-1, multiplier 2.7), Location: Garnischberg, Oderbruch region, Germany

3.3.5. Low total nutrient status

Mainly due to climatic conditions and parent material, some soils may have an extreme low nutrient status. Also some soils which do not clearly meet criteria of salinisation/sodification or other hazards, may have an extremely low nutrient status. For example, de-salinised soils may maintain their low nutrient status for a long time. Low nutrient status will only act as a hazard indicator as common fertilisation will not counterveil against the soil nutrient deficiency.

Table 3.3.5.-1: Scoring of the soil nutrient status

Score	Characteristics	Multiplier arable land	Multiplier grassland
2	No lack of nutrients, or slight deficits can be compensated by single fertilisation	3	3
1.5	Moderate deficit of some nutrients, shortfall of soil-specific recommendation values	2.5 - 3	2.8 - 3
1	Clear deficit of some nutrients, compensation only by ameliorative fertilisation	2 - 2.5	2.5 - 2.8
0.5	Clear deficit of most nutrients, compensation possible over several years only	1.5 - 2	2.2 - 2.5
0	Extreme deficit of nutrients, high risk for food security, deficits can only be compensated by high doses of fertilisation over several years or not at all	1 - 1.5	2 - 2.2

3.3.6. Soil depth above hard rock

Hard rock or permanently frozen soil are extreme barriers to rooting and cannot be modified by common human cultivation activity. This is in contrast with the barriers described by the basic indicators above.

In terms of soil typology, Rankers or Rendsinas above rock or many Gelisols, e. g. soils with permafrost belong to soils having hazard of soil depth limitation. Hard rock at shallow depth seriously influences not only the root zone of plants, but also soil management.

Multipliers should be primarily adapted to the soil moisture regime and thus to climate. Applying higher values in case of humid climate and lower values in case of arid climate is recommended. In case of a per-humid climate or a humid climate of very even distribution of rain over the vegetation period, upgrading by 0.5 score is possible. In case of hardrock having clear cracks and fissures preventing stagnant water, upgrading by 0.5 is also possible.

Table 3.3.6.-1: Scoring of soil depth above hard rock ^{1, 2)}

Score	Characteristic	Multiplier ²⁾ arable land	Multiplier ²⁾ grassland
2	No depth limitations by hard rock ¹⁾ within 120 cm	3	3
1.5	Hard rock in 120-60 cm	2 - 3	2.7 - 3
1	Hard rock in 30-60 cm	0.5 - 2	1 - 2.7
0.5	Hard rock in 10-30 cm	0.1 - 0.5	0.5 - 1
0	Hard rock < 10 cm	< 0.1	< 0.5

¹⁾ Permafrost can also be considered as hard rock

²⁾ Consequent adjustment of multipliers (within the indicated range) to climate is recommended: Higher multipliers at deeper soil and perhumid/humid climate, lower multipliers at shallower soils and semiarid/arid climate

3.3.7. Drought

Lack of water for plants is the most severe limitation of soils for cropping and grazing worldwide (Hillel and Rosenzweig, 2002). Drylands cover more than 50 % of the global land surface (Asner and Heidebrecht, 2005). Negative impacts of global warming on crop yield are expected also for currently productive cropping areas (Lobell and Asner, 2003). There is also evidence of climatic change leading to serious drought in grassland ecosystems (WMO, 2004).

Reduction in precipitation over an extended period of time affects the soil moisture regime. Other climatic factors (such as high temperatures and low relative humidity) can increase the severity.

Drought is difficult to define. Sometimes it will be considered as a temporary aberration only, in contrast to aridity, which is described as a permanent feature of climate. However in a high precipitation area, a reduction of rain will not induce soil water deficits to the plant cover. Thus, agricultural drought should include aridity as a special case.

As drought influences plant growth via the soil water regime, effects of drought often accumulate slowly over a certain period of time.

For any particular site, the drought risk is depending on the probability of occurrence and the level of severity of deficit precipitation, as well as the profile available water (water supply in the effective rooting depth of AG Boden, 2005, see Table 3.2.6.-1). As a consequence of drought, affected soils are classified as suitable for irrigation. Thus, on the other hand, available classifications of irrigation benefit can be used as orientation guides of drought severity.

Within a climatic region, an unbalanced soil water budget over the vegetation period can be used as a measure of drought (Schindler et al., 2006). It is a sum of the profile available water of soil, the effective rainfall and the irrigation water within the vegetation period.

If the soil is not irrigated, climatic indices of drought including aridity have to be taken into consideration.

Examples of simple climatic indices are the Climatic water balance (AG Boden, 2005, p. 374) or the aridity index of UNEP (In: Rivas-Martínez, 2004). As the estimation of the potential evapotranspiration can lead to very different results in dependence on the method applied, diverse older indexes based on temperature and precipitation like the factors of Lang, de Martonne, Bagnouls/Gaussen or Emberger (In: Rivas-Martínez, 2004) also seem to be acceptable. Though these indices are very similar, classification results however may differ. For example, the climate in the region of Berlin, Germany ($P = 550 \text{ mm}$, $T = 9 \text{ °C}$) can fall into the following groups of classification:

Lang: Temperate warm to semiarid

De Martonne: Subhumid to humid

Emberger: Humid

Bagnouls/Gaussen: Axeric cold to axeric temperate

UNEP: Humid

Rating of drought is a very sensitive item of the SQR. Therefore, in Tables 3.3.7.-2 to 4, different orientation guides are given.

Note: Drought can also be rated 1.5 or less in case of PAW ratings of 2. Loess soil in a sub- humid or semi-arid climate (Chernozems, for example) may have 220-250 mm of PAW (optimum score of 2), but a drought risk score of 1.5.



**Fig. 3.3.7.-1: Soils prone to both flooding and drought are typical of many regions in semi-arid and arid zones.
Location in Queensland, Australia**

Long-term soil water regime and vegetation provide also potential indicators of drought, like the Grassland “Wasserstufe” of the German soil rating system (in AG Boden, 2005, p. 319). Wasserstufe values of 4- and 5- or Ellenberg values less than 4 indicate dry soils in Central Europe. If the climate is between humid and sub-humid conditions (many landscapes east of the Elbe river in Central Europe) and the profile available water (see basic indicator 6) is lower than 120 mm, a certain drought risk of score 1.5 can be expected.

Table 3.3.7.-1: Scoring of drought risk

Score	Characteristic	Multiplier arable land	Multiplier grassland
2	No risk of drought	3	3
1.5	Low risk of drought	2.5 - 3	2 - 3
1	Medium risk of drought	1 - 2.5	1 - 2
0.5	High risk of drought	0.1 - 1	0.5 - 1
0	Extreme high risk of drought	< 0.1	< 0.5

Table 3.3.7.-2: Orientation guide of drought risk

Score	Water budget mm ¹⁾	Climatic water balance in the main vegetation period of 4 months ^{2,3)}	Benefit of irrigation	Water regime classes of Soil Survey Manual ⁴⁾
2	> 500	> -100	None to low	Udic (or wetter)
1.5	350 - 500	-100... -200	Moderate	Ustic
1	200 - 350	-200... -300	High	Xeric
0.5	100 - 200	-300... -500	Very high	Aridic
0	< 100	< -500	Extremely high	Aridic

¹⁾ During the main vegetation period of 4 months, WB = Effective Precipitation (sum of daily P > 2 mm) plus PAW (storage capacity plus groundwater supply) plus irrigation

²⁾ Precipitation minus FAO-PM Grass reference ET (Allen et al., 1998)

³⁾ Climatic criteria of Table 3.3.7.-3 give orientation for rain-fed cropping and zonal soils, not for soils under irrigation and not for soils influenced by groundwater. In case of irrigation the actual water budget and its risk of deficiency have to be taken into consideration.

⁴⁾ USDA/NRCS, 2005

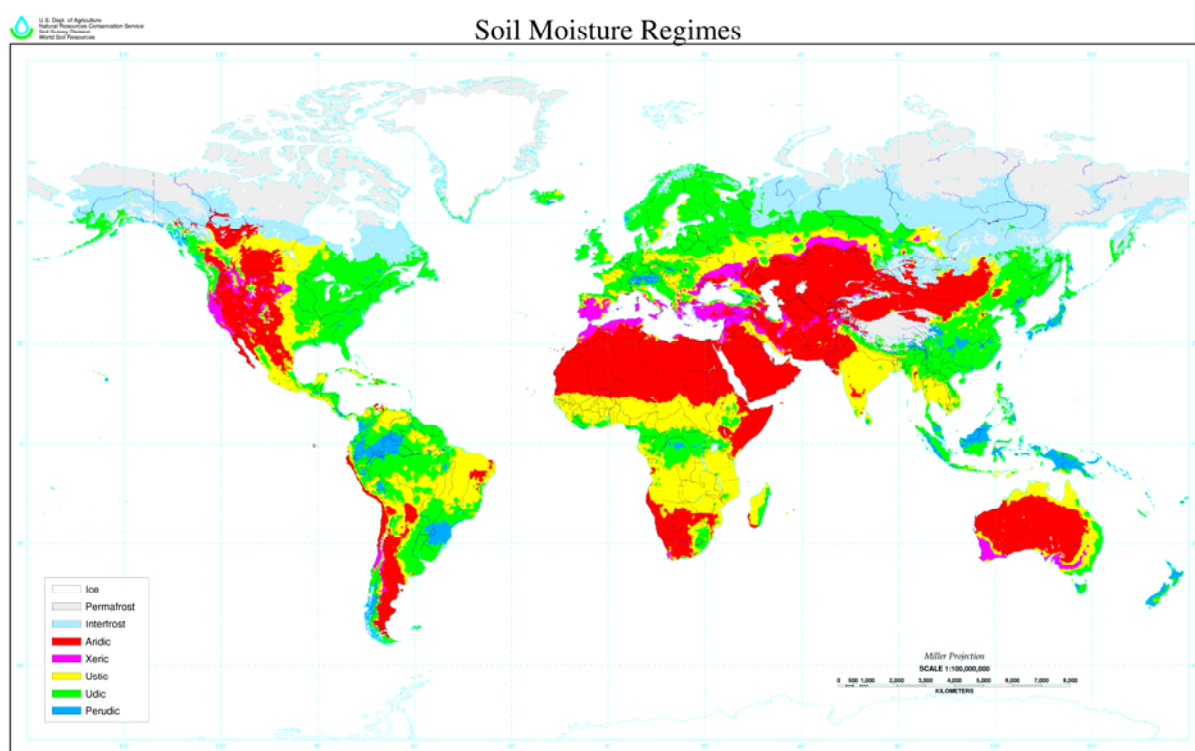


Fig. 3.3.7.-2 Global orientation of soil moisture regime classes, map adopted from USDA/NRCS (2007)

Table 3.3.7.-3: Orientation guide of drought risk, continuing ¹⁾

Score	Probability of the occurrence of a dry month ²⁾	Aridity index acc. to De Martonne ³⁾	Bailey moisture index ⁴⁾	Ombrothermic index lo ⁵⁾ of Rivas-Martínez, 1997
2	< 10 %	> 30 (humid)	> 8.7 (humid and perhumid)	>7 (humid and hyperhumid)
1.5	10 - 20 %	20 - 30 (subhumid)	6.4-8 (moist subhumid)	3.6-7 (subhumid)
1	> 20 %	15 - 20 (semiarid)	4.7-6.4 (dry subhumid)	2-3.6 (dry)
0.5	> 20 % and more than 1 month	5 - 15 (arid)	2.5-4.7 (semi-arid)	1-2 (semiarid)
0	> 50 % and more than 1 month	< 5 (extremely arid)	< 2.5 (arid)	< 1 (arid and hyperarid)

¹⁾ Climatic criteria only for rain-fed cropping and zonal soils, not for soils under irrigation and not for soils influenced by groundwater

²⁾ Dry month acc. to Bagnouls/Gaussen: $P < T/2$, where P = monthly sum of precipitation in mm and T = monthly mean temperature in °C, within the main vegetation period

³⁾ $AI = [P/(T + 10) + 12 p/(t + 10)]/2$, P = annual precipitation, T = mean annual temperature, p = precipitation of the driest month, t = temperature of the driest month

⁴⁾ Bailey moisture index $Si = \text{Sum of months } 1 \text{ to } 12 (0.18 p/1.045^{**t})$, where p = monthly precipitation, t = monthly temperature in °C

⁵⁾ $lo = Pp * 10/Tp$. The quotient resulting from the value of the yearly precipitation in mm of the months with average temperature higher than 0 °C divided by the value, expressed in centigrade degrees resulting from the total of the monthly average temperatures higher than 0 °C.

Table 3.3.7.-4: Orientation guide of drought risk, continuing

Score	Main biomes
2	Tundra, Alpine, Boreal forest (Taiga), Temperate forest, Tropical rain forest
1.5	Temperate Grassland
1	Mediterranean, Chaparral, Savanna
0.5	Desert-scrub
0	Desert

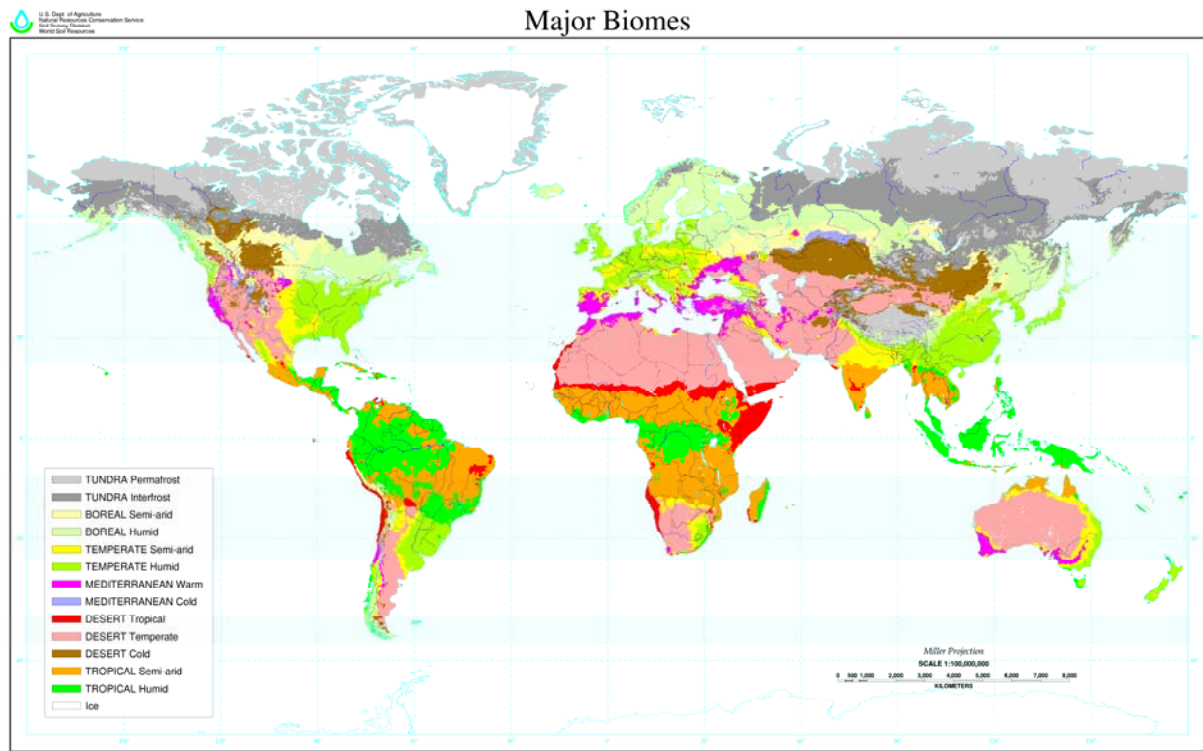


Fig. 3.3.7.-3 Global orientation of biomes, map adopted from USDA/NRCS (2007)



Fig. 3.3.7.-4: Spatial variability of drought. Growing of cereals in a local depression area by using surface recharge flow from adjacent hills. Recharge of > 100 mm/yr improves the water budget. Surrounding grassland without water surplus suffers from drought. „Brown soils“ from Colluvium. Location near Pune, state of Maharashtra, India



Fig. 3.3.7.-5: In case of irrigation the current soil moisture regime due to irrigation management determines the soil water capacity and the drought risk. Additionally the SQ without irrigation should be scored.

Location Niedergoersdorf, vicinity of Berlin, Germany.

Soils are Haplic Luvisols and Eutric Cambisols, texture loamy sand. At this location sprinkler irrigation eliminates the slight drought risk completely; the basic water capacity score is at

optimum of 2 and no more drought risk. As no further hazard occurs, the multiplier is at maximum of 3 (2.94). Without irrigation the basic score of water capacity is at sub-optimum of 1, the hazard score would be 1.5 and the multiplier would be lower, around 2.6. Total SQR-score of the soil is 80 with irrigation and 67 without irrigation.

Another very rough orientation for scoring drought risk related to Koeppen climatic zones is given in the later section 3.3.12.

3.3.8. Flooding and extreme waterlogging

Susceptibility to flooding (including inundation and extreme wetness due to permanent high water tables or perched water) imposes a serious limitation to farming, especially to cropping. Assessment of potential frequency, severity and duration of flooding is difficult and requires long-term knowledge about the site. In Western and Central Europe most rivers have intact constructed levees and the risk of flooding is mainly restricted to the recent floodplain. The flooding risk depends on the relative height of the soil above the river level.

Outside of floodplains, due to moderate rainfall distribution in the temperate climate, the inundation risk of soils in the landscape is limited to some lowlands and depressions.

Risk assessment includes both the flooding probability and the possible severity/damage.

Soils in bottomlands and/or in high rainfall areas may suffer from extreme waterlogging, which can farming affect very adversely or make impossible. A clear benefit of land drainage is an indirect parameter of extreme waterlogging.

The following Tables 3.3.8.-1 to 4 provide a frame for scoring hazard by flooding or extreme waterlogging. In case of occurrence of combinations of extreme waterlogging with flooding risk, the lowest score or a score of a class deeper is possible.

Table 3.3.8.-1 : Scoring of flooding hazard risk or extreme waterlogging ¹⁾

Score	Characteristics of flooding regime	Characteristics of extreme waterlogging	Multiplier arable land	Multiplier grassland
2	No or low risk of flooding (< 5 %)	Low or moderate level of waterlogging	3	3
1.5	Low risk of flooding (< 10 %) and/or short inundation (< 20 days) at the beginning of the vegetation period ²⁾	Occurrence of surface water (ponding) for longer time in the vegetation period, Ground or perched water dominating the topsoil for more than 20 days in the vegetation period	1 - 3	2.5 - 3
1	Medium risk of flooding (10-20 %) and/or longer inundation (20--40 days) at the beginning of the vegetation period	Very long period of wetness, ground or perched water occupying the topsoil for more than 60 days in the vegetation period	0.5 - 1	2 - 2.5
0.5	High probability of flooding (20-50 %) and/or longer inundation (40-90 days) at the beginning of the vegetation period	Very long wetness period	< 0.5	1 - 2
0	Extremely high probability of flooding (> 50 %) and/or longer inundation (> 90 days) at the beginning of the vegetation period	Extreme waterlogging, cropping impossible, only a short growing period for grassland	< 0.1	< 1

¹⁾ Flooding and extreme waterlogging should be rated independently. If both occur, the lowest rating or a score one class deeper is recommended

²⁾ If inundation occurs later in the vegetation period, inundation damage is higher and the allowable length for this score has to be cut in half for the next three months, for example: Vegetation period starts in March, and inundation is in March, then inundation of 20 days possible, if inundation is in April, only 10 days possible, if inundation is in May, only 5 days, June, July, August and September (end of main vegetation period) 2-3 days



Fig. 3.3.8.-1: Flooded Grassland meadow soils; WRB: Gleyic Fluvisols (Arenic); along the Oder river, (flood hazard risk score 0.5, multiplier 1.5), Location: Oderbruch region, Germany

Table 3.3.8.-2: Orientation guide of scoring flooding risk

Score	Inundation frequency and duration (based on Soil Survey Manual, chapter three ¹⁾)	Examples in floodplain areas
2	None or rare (Less than 5 times in 100 years) and brief (less than 2 days)	Soils outside of levees or highlevel terraces
1.5		Dune ridges, sand plains above general level of terrace plain
1	Occasional (5 to 50 time in 100 years) and long (1 week to 1 month)	Gullies, scoured drainage zones and prior stream channels within midlevel terraces
0.5		Low terraces including drainage zones and shallow ridges
0	Frequent (> 50 times in 100 years) and very long (> 1 month)	Immediate river margins, very low terraces

¹⁾ <http://soils.usda.gov/technical/manual/contents/chapter3c.html#28>

Table 3.3.8.-3: Orientation guide of scoring extreme waterlogging

Score	Water regime classes of Soil Survey Manual	Benefit ¹⁾ of land drainage
2	Udic or drier	None to low
1.5	Perudic	Moderate
1	Aquic	High
0.5	Peraquic	Very high
0	Peraquic	Extremely high

¹⁾ Benefit in terms of crop yield increase and better soil management

Table 3.3.8.-4: Orientation matrix of scoring extreme waterlogging by perched water (based on classes of the Soil Survey Manual, Chapter Three, Table 3-5) ¹⁾

Cumulative annual pattern / Depth	Very Shallow (SV) < 25 cm	Shallow (S) 25 to 50 cm	Moderately Deep (DM) 50 cm to 1 m	Deep (D) 1.0 to 1.5 m	Very Deep (DV) > 1.5 m
Absent (A) Not observed	2	2	2	2	2
Very Transitory (TV) Present <1 month	1	1.5	2	2	2
Common (C) Present 1 to 3 months	1	1	1	1.5	2
Transitory (T) Present 3 to 6 months	0.5	0.5	1	1	2
Persistent (PS) Present 6 to 12 months	0	0.5	0.5	1	2
Permanent (PM) Present Continuously	0	0	0.5	1	2

¹⁾ <http://soils.usda.gov/technical/manual/contents/chapter3c.html#28>

3.3.9. Steep slope

Slope is a landscape property of particular importance for agricultural land use. Considering good agricultural practice, low to moderate gradient can provide farming without hazard to soil, whilst steep slopes can lead to the complete loss of soil by erosion or landslide. This possible hazard is being considered in the second rating of the slope.

Loss of soil due to erosion by water or tillage is a major problem associated with slope. Erosion hazards are caused by a combination of climate, vegetation cover and agricultural practices (EEA, 2000, Eswaran et al., 2001). The risk of water erosion was considered indirectly by slope gradient rating (section 3.2.8).

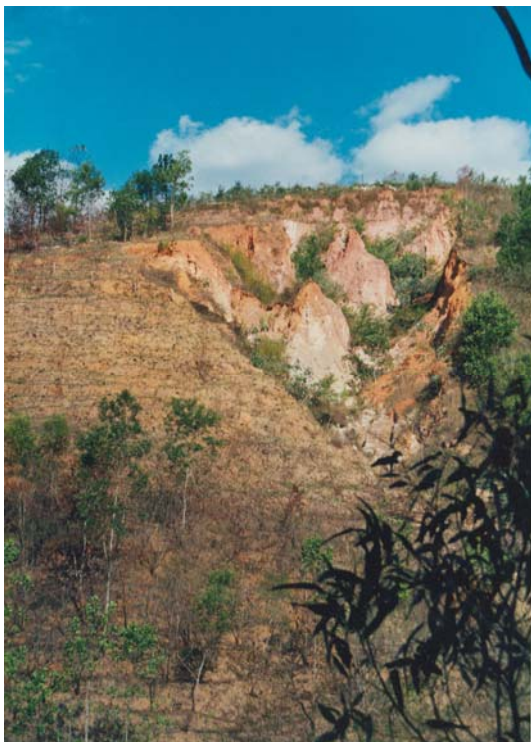


Fig. 3.3.9.-1: Gully erosion on steep land in a tropical humid environment. Acrisol soil landscape, Location Pinheiral, State of Rio de Janeiro, Brazil.



Fig. 3.3.9.-2: Farmland use of very steep slopes can lead to landslide (slip) erosion. Intact deep A-horizons at very different slope positions at this site show slip erosion appeared for the very first time since cultivation. Location: Pohangina, Manawatu, New Zealand.

Table 3.3.9.-1: Scoring of hazard from slope

Score	Arable land gradient %	Grassland gradient %	Multiplier
2	< 12	< 30	3
1.5	12 - 18	30 - 40	2.5 - 3
1	18 - 27	40 - 50	2 - 2.5
0.5	27 - 36	50 - 60	1 - 2
0	> 36	> 60	< 1

Table 3.3.9.-2: Recommendation values of multipliers for slope gradient classes acc. to Guidelines, 2006, Table 7, p. 12

Slope gradient class	Description	Slope gradient Percent	Multiplier arable land	Multiplier grassland
< 07	Sloping to flat	5-10	3	3
07	Strongly sloping	10-15	2-3	3
08	Moderately steep	15-30	1-2	3
09	Steep	30-60	< 1	1-3
10	Very steep	> 60	0	< 1

3.3.10. Rock at the Surface

Rock outcrops or stones and boulders at the surface create cultivation hazard. They hinder the agricultural use of soil for cropping in particular. The damage to pastoral grazing is much less.

Table 3.3.10.-1: Scoring of stones and boulders at the surface (related to Soil Survey Manual (USDA/NRCS, 2005) Chapter 3, Table 3-12.) ¹⁾

Score	Characteristic	Percentage	Orientation guide of Soil Survey Manual ¹⁾	Multiplier arable land	Multiplier grassland
2	No stones or boulders at the surface	< 0.01		3	3
1.5	Low to moderate stony or bouldery	0.01 - 0.1	Class 1	2 - 3	2.8 - 3
1	Very stony or very bouldery	0.1 - 3.0	Class 2	1 - 2	2 - 2.8
0.5	Extremely stony or extremely bouldery	3.0 - 15	Class 3	< 1	1.5 - 2
0	Very rubbly	> 15	Class 4 - 5	< 0.5	< 1.5

¹⁾ <http://soils.usda.gov/technical/manual/contents/chapter3e.html#54>



Fig. 3.3.10.-1: Left part: Extremely shallow soils and rock at the surface. Score 0, multiplier grassland < 1. Association of Nudilithic and Lithic Leptosols with Leptic and Colluvic Regosols, Location near Pune, state of Maharashtra, India



Fig. 3.3.10.-2: Extremely high proportion of stones at the surface limits SQ for grassland use (score 0, multiplier < 1). Hyperskeletal Leptosol. Location in Canterbury, New Zealand.

3.3.11. High percentage of coarse soil texture fragments (> 2 mm)

Coarse fragments limit the effective surface of soil particles and may diminish the storage of water and nutrients and the filtering and buffer function of soils. On cropping land, the total management may be hampered. Growing rootcrops may be difficult or impossible.

On the other hand, on very shallow soils, a certain proportion of coarse material may be advantageous to provide a minimum of rooting depth.

Table 3.3.11.-1: Scoring of coarse soil texture fragments (> 2 mm)

Score	Characteristics	Orientation guide % by mass ¹⁾	Multiplier arable land ²⁾	Multiplier grassland
2	Low percentage of coarse fragments	< 15	3	3
1.5	Moderate	15-40	2 - 3	2.5 - 3
1	High proportion of coarse fragments	40-60	1 - 2	2 - 2.5
0.5	Very high proportion of coarse fragments	60-85	0.5 - 1	1.5 - 2
0	Extremely high proportion of coarse fragments, mainly angular shape and fraction > 63 mm	> 85	< 0.5	< 1.5

¹⁾ Related to classes of AG Boden, 2005, Table 33, p. 150, values refer to the rooting zone

²⁾ Within a class, higher multipliers in case of smaller fractions, round aggregates and a more humid climate, and smaller multipliers if fraction is coarser, blocky or non-natural (e.g. construction waste), and climate is dry

3.3.12. Unsuitable soil thermal regime

The soil thermal regime is important for all physiological processes of plants. On grassland and rangeland, species were able to adapt to the thermal conditions. Cropping of annual plants requires critical minimum temperatures for all stages of development. Most grasses germinate at temperatures > 5 °C and many arable crops germinate and grow at temperatures > 10 °C. An upper limit of soil temperatures for adequate farming seems to exist with temperatures > 30 °C, exceeding this limit is thus detrimental for plant growth. High fluctuations of temperature in combination with other hazards which occur in semi-desert and desert regions are more important for the potential of soil for farming. Temperature recordings of the air thermal regime (e.g. climate data) are proper indicators of the soil thermal regime. The length of both the vegetation period and the frost free period are direct agro-climatic constraint for cropping, but also an indirect indicator of the soil thermal regime.

Modifications may be considerably determined by the snow cover in winter. Even under very harsh climate conditions snow can protect soils against deep freezing and provide acceptable conditions of cropping.

Table 3.3.12.-1: Scoring of soil thermal regime (related to Soil Survey Manual, USDA/NRCS, 2005, and Guidelines, 2006, p. 88-90.)

Score	Characteristics	Multiplier arable land	Multiplier grassland
2	Suitable or moderate regime, frost free period > 140 days	3	3
1.5	Slightly too cold or too hot	2.5- 3	3
1	Too cold or too hot	1-2.5	1.5-3
0.5	Very cold, very short vegetation period or too hot	0.5-1.5	1-1.5
0	Extremely cold, permafrost or extremely hot	< 0.5	< 1

Table 3.3.12.-2: Orientation guide of multipliers for temperature regime classes of Soil Survey Manual

Soil moisture regime	Multiplier arable land	Multiplier grassland
Pergelic	< 1	< 1.5
Cryic	1-2.5	1.5-3
Frigid	2.5-3	2.5-3
Isofrigid	2.5-3	3
Mesic	3	3
Isomesic	3	3
Thermic	3	3
Isothermic	3	3
Hyperthermic	3	3
Isohyperthermic	3	3

Table 3.3.12.-3: Orientation guide of scores for the soil thermal regime

Score	Duration of frost-free period (days) ¹⁾	Main biomes	Mean annual temperature for grassland in the temperate climate, ° C ²⁾
2	> 140	Tropical rain forest, Temperate forest, Mediterranean, Savanna, Temperate Grassland	> 8
1.5		Forest steppe in Asia	< 8
1	90-140	Boreal forest	< 5
0.5			< 3
0	< 90	Tundra	< 1

¹⁾ Within the 6 warmest months (vegetation period)

²⁾ Orientation for mountain regions within the temperate climate only

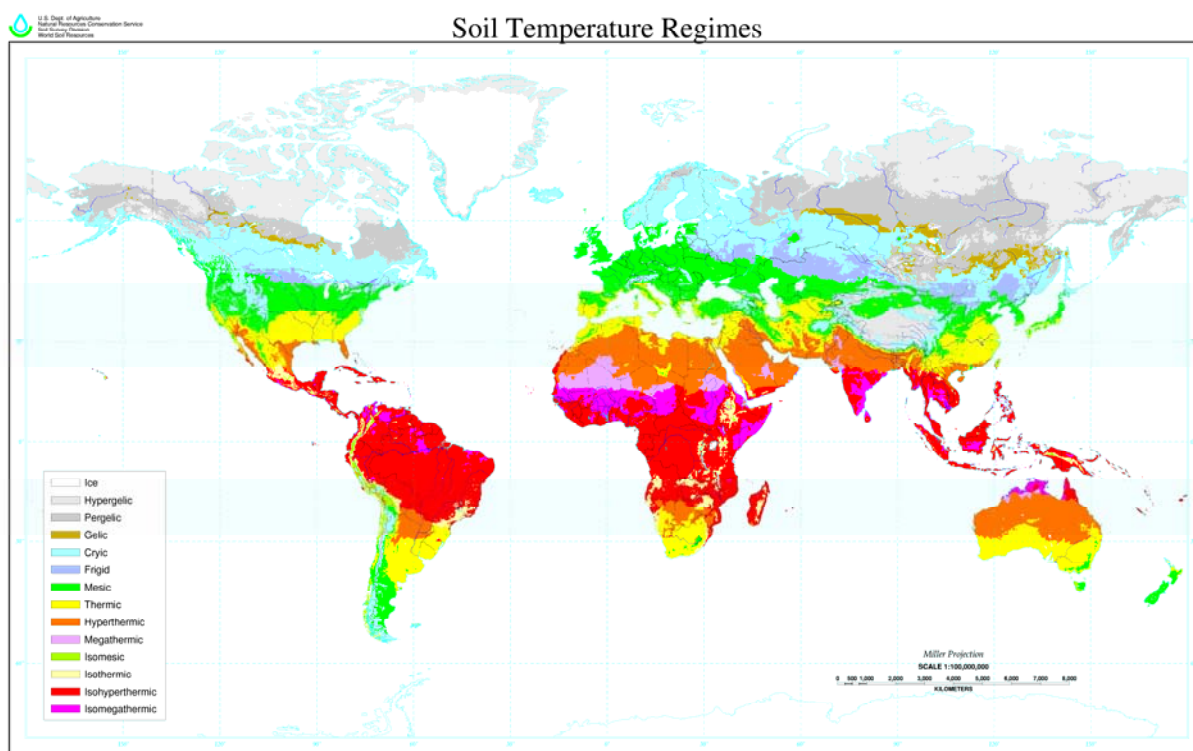


Fig. 3.3.12.1: Global orientation of the soil thermal regime, map adopted from USDA/NRCS (2007)

Table 3.3.12.-4: Orientation guide of drought and soil thermal regime scores for Koeppen climatic zones¹⁾

Climatic zone		Drought score		Thermal regime score	
		Arable land	Grass-land	Arable land	Grass-land
Tropical (Af) (tropical wet)		2	2	2	2
Monsoon (Am) (tropical monsoon)		1.5	1.5	2	2
Savanna	As	0.5	1	2	2
	Aw	1	1.5	2	2
Arid	BWh (desert hot)	0	0	1	1
	BWk (desert cold)	0	0	1	1
Semi-arid	BSh Subtropical (warm) Steppe	0	0.5	2	2
	BSk Midlatitude (cool) Steppe	0.5	1	1.5	1.5
Humid subtropical	Cfa Humid Subtropical Year-Round Wet	2	2	2	2
	Cwa (moist, dry winters, long hot summer) Humid Subtropical Winter-Dry	0.5	1	2	2

Oceanic	Cfb (maritime temperate moist all year, mild winters, long cool summers)	2	2	2	2
	Cwb	1.5	1.5	2	2
	Cfc subpolar oceanic (moist all year, mild winters, short cool summers)	2	2	1.5	1.5
Mediterranean	Csa (moist, mild winter, long hot dry summer)	0.5	1	2	2
	Csb (moist mild winters, long cool summers)	1	1.5	2	2
Humid continental	Dfa (moist all year, cold winters, long hot summers)	1	1.5	1.5	1.5
	Dwa Humid Continental Winter-Dry	1.5	1.5	1.5	2
	Dfb (moist all year, cold winters, long cool summers)	2	2	1.5	1.5
	Dwb	1.5	2	1.5	2
Subarctic	Dfc (moist all year, cold winters, short cool summers)	2	2	0.5	1
	Dwc	1.5	2	1.5	2
	Dfd	2	2	0.5	1
High-altitude Mediterranean	Dsa	0.5	1	1.5	2
	Dsb	1	1.5	2	2
	Dsc	1.5	1.5	2	2
Subarctic Winter-Dry Dwd		1	1.5	0.5	0.5
Polar	ET (polar tundra)	1.5	2	0	0
	EF (polar icecap)	1	1	0	0
Alpine (ETH)		1.5	2	0	0.5

¹⁾ For global orientation see also the World Map of the Koeppen-Geiger climate classification by Kottek et al., 2006

3.3.13. Miscellaneous hazards

Examples of further hazards to soils and farming are: Subsidence of organic soils, streambank erosion, frost action and gypsum at the surface (Muckel, 2004). They may be also rated according to the common criteria of Table 3.3.13.-1. Another hazard, wind erosion is a big concern to human and environment. The occurrence is more related to soil management and rating is thus part of the VSA method (Shepherd, 2000) which is recommended to be performed in combination with the SQR method. In case of serious deflation of the soil or deposition (dune formation with burying the current soil) this can be rated as a hazard acc. to Table 3.3.13.-1. A rule of thumb is that pure sandy soils (clay < 5%, silt < 10%) have a very high wind erosion risk if the annual average of windspeed at 10 above the ground is higher than 3 m/s. If soils are sandy-silty (clay < 8%, silt < 50%) the wind erosion risk is classified as very high at windspeeds > 5 m/s (Deutsche Norm, DIN 19706, 2004).

Also, common soil erosion by water can be scored if the slope gradient is less than 12 % (cropping land) or 30 % (grassland) and distinct soil erosion is evident. For example soils in “Thalways” are prone to erosion at very weak gradients.

Just water erosion risk assessments are scale-dependent and may extremely differ between nations and continents. For example, the classification of prime farmland (Soil Survey Staff, 1993, 2006) permits a criterion of erodibility $K \cdot S = < 2$ (K =soil factor, S =slope factor). In Germany, the potential risk of water erosion is classified as very high if $K \cdot S > 0.3$ (Deumlich et al, 2007). At a given Loess soil prone to erosion of $K = 0.5$ the acceptable slope gradient would be 22 % (prime farmland criterion) or 12 % (criterion in Germany, matching to Table 3.3.9.-1).

The list of hazard factors is extendable as from the conception the lowest multiplier will be valid.



Fig. 3.3.13.-1: Streambank erosion at 1999 flood. Location in Canterbury, New Zealand

Table 3.3.13.-1: Scoring of Miscellaneous hazards

Score	Characteristic	Multiplier arable land	Multiplier grassland
2	No	3	3
1.5	Low	2 - 3	2.5 - 3
1	Medium	1 - 2	2 - 2.5
0.5	High	0.5 - 1	1 - 2
0	Very high	< 0.5	< 1

3.4. Rules of final rating

In general, the lowest hazard multiplier will be multiplied with the basic score. If two or more hazard indicators are sub- optimum, final ratings should follow Table 3.4.1.

Table 3.4.-1: Rules of final rating

Number of sub-optimum Hazard Indicators (rating < 2)	Remarks	Rule
1		Basic score * hazard multiplier
2	Both have same rating	Basic score * multiplier of the most serious indicator, Multiplier less than average within the range

2	Both different	Basic score * lowest hazard multiplier
3	No steep slope	Basic score * multiplier of the most serious indicator, Multiplier at minimum of the range
3	Steep slope	Basic score * multiplier of the most serious indicator, Multiplier in the range of 1 rating class deeper
4 or more	No steep slope	Basic score * multiplier of the most serious indicator, Multiplier in the range of 1 rating class deeper
4 or more	Steep slope	Basic score * multiplier of the most serious indicator, Multiplier in the range of 2 rating classes deeper

3.5. Diagnostic check of the results

In a final stage of rating the results in terms of SQR score and classes of soil quality should experience a diagnostic check to avoid misclassifications (Table 3.5.1.).

Table 3.5.1: Diagnostic check of the final rating score (SQR score) of cropping land

SQR score	Soil quality assessment	Criteria to meet
< 20	Very poor	
20-40	Poor	- Save cropping of a main basic crop ⁴⁾
40-60	Moderate	- Criteria of unique farmland ¹⁾ - Save cropping of corn ³⁾
60-80	Good	- Criteria of farmland of statewide importance ¹⁾ - Save cropping of winter wheat in Eurasia and Northern America
> 80	Very good	- Criteria of prime farmland ¹⁾ - Acceptable risk of water and wind erosion ²⁾ - Save cropping of maize for corn

¹⁾ http://en.wikipedia.org/wiki/Prime_farmland, Soil Survey Staff (1993). Soil Survey Manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. Retrieved on 2006-08-30.

²⁾ Soil loss less than tolerable limit, for example methodics of water erosion risk assessment acc. to Deutsche Norm, DIN 19708 (2005) and Bavarian LfL (2004), wind erosion acc. to Deutsche Norm, DIN 19706 (2004)

³⁾ Cereal of highest local importance (maize, wheat, barley, rye, millet and others)

⁴⁾ Crop adapted to local conditions that provides subsistence farming (basic food of humans, for animal husbandry or a cash crop like potato, buckwheat or others)

4. Outlook

The Muencheberg SQR is an empirical rating system. The approach presented here has been developed and tested in the temperate climatic zone.

As the method includes the majority of soil hazard properties occurring worldwide, their validity should cover a larger range of soils suitable for cropping or grazing in different climatic zones and can thus provide a comparison of soil quality over large areas.

Sufficient correlations of the rating score with the crop yield potential are to be expected within climatic subzones and at a defined level of farming.



Fig. 4.-1: Extremely acid and sulphur-contaminated soil, not suitable for farmland. Only extremely adapted native brushes (*Leptospermum scoparium*, Manuka) can grow.

Basis score = 14, Hazard score = 0, Multiplier < 0.05 (0.01), Total SQR score = 1. Thionic Leptosol.

Location: Rotorua, New Zealand



Fig. 4.-2: Prime farmland soil for cropping. Haplic Chernozem (Siltic) from loess. Basic score 32, No hazard limitations, Multiplier= 2.94, Total SQR score 94. Location Rossdorf near Marburg, Germany

The approach has potential for modifications at different levels of evaluating soil properties.

Authors appreciate field tests on feasibility of this system worldwide. They are hopeful on applicability at different regions and spatial scales because of its simplicity, robustness and relatively fast handling.

A note on further orientation guides:

The World Resources Map index (USDA/NRCS, 2005, (<http://soils.usda.gov/use/worldsoils/mapindex/>)) gives a rough orientation on Global Soil Temperature Moisture Regimes, Soil Regions, Biomes and Risks of land use. The FAO has similar data available (FAO, 2000: Global Agro-Ecological Zones). If sites have been classified by WRB, 2006, Appendix 2 of this manual will provide a list of orientation scores according to soil reference groups and their qualifiers.

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Appendix 1: Examples of soil scoring


Examples of Muencheberg SQR: Seelow Silty Clay, Germany

Muencheberg Soil Quality Rating (SQR) Cropping land

Score card, Page 1: Basic soil data

Location name:	Seelow, Oderbruch region, Germany
Coordinates:	52°32'28.97"N, 14°26'35.99"E, elevation 7.4 m
Soil name:	Seelow Silty Clay, Profile G1/2
Land use:	Annual cropping (winter wheat, maize, sunflower)
Landform and topography:	River basin (former floodplain), flat
Date and Name of rating person:	22.11.04, L. Mueller

Soil profile data: Seelow Silty Clay

	m	Pedon field description				
		Texture class		Horizon	Humus %	Water table
		USDA/FAO	National			
	0.1					
	0.2	SIC ↓	Tu2 ↓	Sw-rAp	4.2	None↓
	0.3					
	0.4					
	0.5			Sd-rGo-M	3.1	
	0.6					High
	0.7			Sd-M-Go		
	0.8				2	
	0.9					
	1.0					Mean▽
	1.1					
	1.2					
	1.3					
	1.4					Low
	1.5					

Soil classification

Local	Pseudovergleyter Vega-Gley-Reliktglej aus Auenton
WRB	Gleyic Fluvisol
WRB 2006	Gleyic Fluvisol (Humic, Eutric, Clayic, Drainic)
US Taxonomy	
Remarks:	Former backwater area of the Oder river, drained polder, water table 0.7 to 1.4 m below surface, fluctuating, drainage class: Imperfect German soil assessment: LT 5 AI, 54/54

References to further data on soil profile and landscape: Excursion guide Oderbruch:
http://www.zalf.de/home_zalf/institute/blf/blf_e/mitarbeiter/mueller/pdf/exkurs.pdf

Examples of Muencheberg SQR: Seelow Silty Clay, Germany

Muencheberg Soil Quality Rating (SQR)

Cropping land

Score card, Page 2: Relevant criteria of Basic Rating

Indicator	Relevant criteria of Basic Rating	Pedon data
Soil substrate	Soil texture class over the upper 80 cm 50 cm	SiC
	Parent material of soil	Alluvium
	Strong gradients of texture within 80 cm (layering)?	None
	Content of coarse material > 2 mm over 80 cm (cropping) or 50 cm (grassland)	< 1 %
	SOM of topsoil (upper 20 cm)	4.2 %
	Proportion of concretions or artefacts	None
A horizon depth and depth of humic soil	A-horizon depth (cm)	20
	Depth of OM content > 4%	30
	Abrupt change from topsoil to subsoil ?	No
Topsoil structure	Type of topsoil aggregates	Angular to subangular blocky
	Size of topsoil aggregates	Medium
	Ratings of Peerlkamp, Diez, or Shepherd- VSA or other soil structure ratings	VSA structure and porosity ratings < 1 (medium to low)
Subsoil compaction	Increased soil strength or density at 30-50 cm depth?	Slight
	Redoximorphic feature in the topsoil and upper subsoil?	Slight
	Tillage pan score VSA	1.5 (slight)
	Other subsoil compaction features	Blocky structure
Rooting depth and biological activity	Abundance of roots	Few
	Barriers to rooting	Springtime watertable at 0.8 m
	Effective rooting depth AG Boden, 2005, p. 356	< 0.8 m
	Zustandsstufe Bodenschaetzung AG Boden, 2005, p. 318	V
	Abundance of deep burying earthworms (Grassland)	Few
	Abundance of moles (Grassland)	
Profile available water	Depth of watertable	0.8-1.5 m
	Water storage capacity of soil	Very high
	Grassland Wasserstufe	2-/2+
Wetness and ponding	Depth of ground or perched water table	0.8 (slight wetness)
	Soil drainage class	Imperfect
	Degree of redoximorphic features in the subsoil	Slight
	Indicator values of vegetation	
	Soil position in a depression ?	No, land is level
	Wetness by suspended water (soils rich in silt and clay or muck) ?	Yes
	Ponding during soil assessment	No
	Delay of begin of farming on cropping land (days)	< 7 days as compared with soils in the vicinity
Slope and relief	Slope at the pedon position	level
	Microrelief and slope aspect at the pedon position	

Examples of Muencheberg SQR: Seelow Silty Clay, Germany

Muencheberg Soil Quality Rating (SQR)

Cropping land

Score card, Page 3: Basic Rating

Basic indicators		Score	Weighting factor	Total	Remarks
1	Soil substrate	1.5	3	4.5	Clay soil, Table 3.2.1.-1
2	A horizon depth	1.5	1	1.5	20 cm, Table 3.2.2.-1
3	Topsoil structure	1	1	1	Unfavourable aggregate features, Table 3.2.3.-1
4	Subsoil compaction	1.5	1	1.5	Few signs of compaction, Table 3.2.4.-1
5	Rooting depth (RD)	1	3	3	RD 0.8-1.1 m, limited by water table, Table 3.2.5.-1
6	Profile available water (PAW)	2	3	6	> 220 mm due to capillary supply, Table 3.2.6.-1
7	Wetness and ponding	0.5	3	1.5	Moderate ponding and additional perched water, Table 3.2.7.-1
8	Slope and relief	2	2	4	Flat, no limitations, Table 3.2.8.-1
Total basic score				23	Medium score, maximum would be 34



Winter wheat on Seelow Silty Clay, *Phragmites australis* indicates wetness problems

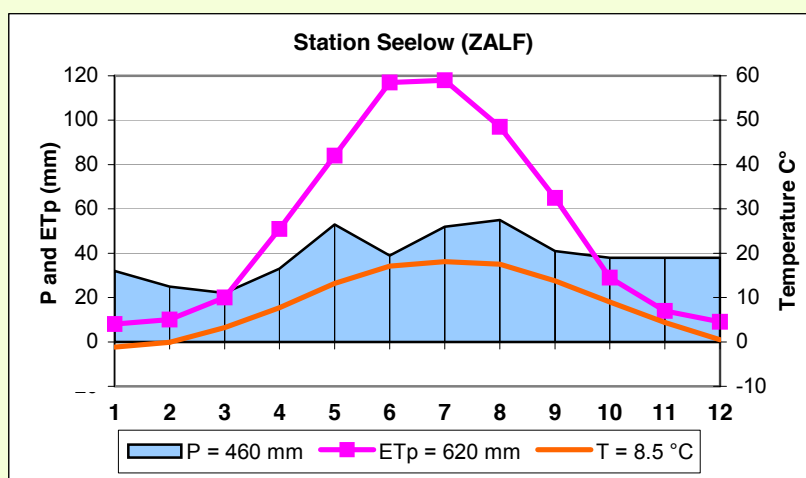
Examples of Muencheberg SQR: Seelow Silty Clay, Germany

Muencheberg Soil Quality Rating (SQR)

Cropping land

Score card, Page 4: Vegetation and climate data

Landuse	Cropping land, ploughless
Main species of vegetation	Cropping plants: winter wheat, maize, sunflower Weeds: <i>Agropyron repens</i> , <i>Phragmites australis</i>
Vegetation indicators	Ellenberg : F= 6-7 , Wasserstufe 2-/3+
Above ground biomass	8-12 t/ha*yr, 4-6.5 t/ha*yr grain of wheat
Main biome (potential natural vegetation)	Temperate forest



Climate:

Precipitation: 460 mm/a,
Temperature: 8-9° C,
Koeppen climatic zone: Cfb

Monthly temperature, °C

1	2	3	4	5	6	7	8	9	10	11	12	1-12
-1,2	-0,1	3,2	7,7	13,2	17,1	18,1	17,5	13,8	9	4,4	0,5	8,5

Agroecological data:

Latest/ first frost (p> 10 %)	May, 13 / Oct, 10
Begin of vegetation period (t> 5°C)	March, 25
Length of growing period (t>5°/ t> 10°)	250 / 190 days
Temperature sum (t>5°/ t> 10°)	3500 / 3000
Depth of soil freezing	40 cm
Snow days during winter	10-20 %

Examples of Muencheberg SQR: Seelow Silty Clay, Germany

Muencheberg Soil Quality Rating (SQR)

Cropping land

Score card, Page 5: Criteria of Hazard rating

Indicator	Relevant criteria of Hazard Rating	Pedon data
Contamination	Position in a risk area?	None
Salinization	Electric conductivity	
	Salt crusts or coatings	None
	Salt indicator vegetation	None
Sodification Acidification	pH	6.5
	SAR	
	ESP	
Low total nutrient status	Malnutrition features of crops ?	None
Soil depth above hard rock		> 50 m
Drought	Water budget mm/yr	> 500
	Climatic water balance in the main vegetation period of 4 months	
	Benefit of irrigation	
	Probability of the occurrence of a dry month	
	Aridity index acc. to De Martonne	
	Bailey moisture index	
	Ombrothermic index I _o of Rivas-Martínez (1997)	
Flooding and extreme waterlogging	Inundation frequency and duration	None
	Water regime class of Soil Survey Manual	Imperfect
	Benefit of land drainage	Moderate to low
Steep Slope	Slope %	0
Rock at the surface		None
Coarse soil texture fragments		None
Unsuitable soil thermal regime	Soil thermal regime	None
Miscellaneous hazards		None
Remarks		

Examples of Muencheberg SQR: Seelow Silty Clay, Germany

Muencheberg Soil Quality Rating (SQR) *Cropping land*

Score card, Page 6: Final rating

Hazard indicators		Score	Range of multipliers	Multiplier	Remarks
1	Contamination	2	3	3	No limitations by hazard factors
2	Salinisation	2	3	3	
3	Sodification	2	3	3	
4	Acidification	2	3	3	
5	Low total nutrient status	2	3	3	
6	Soil depth above hard rock	2	3	3	
7	Drought	2	3	3	
8	Flooding and extreme waterlogging	2	3	3	
9	Steep Slope	2	3	3	
10	Rock at the surface	2	3	3	
11	Coarse soil texture fragments	2	3	3	
12	Unsuitable soil thermal regime	2	3	3	
13	Miscellaneous hazards	2	3	3	
Lowest multiplier				3 (2.94)	

Final rating score (SQR score, rounded) = Total basic score* lowest multiplier

$$\text{SQR score} = 23 * 2.94 = \mathbf{68}$$

Cropland Soil quality assessment:

< 20= Very poor, 20 – 40 = Poor, 40 – 60= Moderate, 60 – 80 Good, > 80= Very good

Comment on final rating: Good cropping site, possible limitations due to temporary wetness and high clay content, associated with farm traffic induced sub-optimum soil structure, slight climatic drought risk can be compensated by capillary groundwater supply

Examples of Muencheberg SQR: Genschmar Sand, Germany


Muencheberg Soil Quality Rating (SQR)

Grassland

Score card, Page 1: Basic soil data

Location name:	Genschmar, Oderbruch, Germany
Coordinates:	52°37'43.50"N, 14°32'24.21"E, elevation 10 m
Soil name:	Genschmar Sand, Profile G1/3
Land use:	Grassland, Rangeland, nature conservation area, unfertilized pasture, grazing by cows and sheep
Landform and topography:	River floodplain, flat
Date and Name of rating person:	22.11.04, L. Mueller

Soil profile data: Genschmar Sand

	m	Pedon field description				
		Texture class		Horizon	Humus %	Water table
		USDA/FAO	National			
	0.1	IS	St2	Ah1	10	
	0.2			Ah2	6	
	0.3			ilCv	3	
	0.4	S (mS) ↓	fSms	fAh		
	0.5				< 1↓	
	0.6					
	0.7					
	0.8		mS	ailCv		
	0.9					
	1.0		mSfs ↓	aGo1		
	1.1					
	1.2					
	1.3					
	1.4					
	1.5			aGo2		2.5 m

Soil classification

Local	Regosol über Paternia aus Kippsand über Fluvisand
WRB	Dystric Fluvisol
WRB 2006	Haplic Fluvisol (Dystric, Arenic)
US Taxonomy	
Remarks:	Pedon in the floodplain near the Oder river, fluvial sand covered by shallow eolic and anthropogenic sand deposit, water table 1.8 to 3.5 m below surface, fluctuating, flooding probability < 2 %, drainage class: E, German soil assessment: IS II a 4(-), 33/30

References to further data on soil profile and landscape: Excursion guide Oderbruch: http://www.zalf.de/home_zalf/institute/blf/blf_e/mitarbeiter/mueller/pdf/exkurs.pdf

Examples of Muencheberg SQR: Genschmar Sand, Germany

Muencheberg Soil Quality Rating (SQR)

Grassland

Score card, Page 2: Relevant criteria of Basic Rating

Indicator	Relevant criteria of Basic Rating	Pedon data
Soil substrate	Soil texture class over the upper 80 cm 50 cm	S
	Parent material of soil	Alluvium
	Strong gradients of texture within 80 cm (layering)?	None
	Content of coarse material > 2 mm over 80 cm (cropping) or 50 cm (grassland)	< 1 %
	SOM of topsoil (upper 20 cm)	3 %
	Proportion of concretions or artefacts	None
A horizon depth and depth of humic soil	A-horizon depth (cm)	25
	Depth of OM content > 4%	25
	Abrupt change from topsoil to subsoil ?	No
Topsoil structure	Type of topsoil aggregates	Singular grain
	Size of topsoil aggregates	
	Ratings of Peerlkamp, Diez, or Shepherd- VSA or other soil structure ratings	VSA structure and porosity ratings < 1 (medium to low)
Subsoil compaction	Increased soil strength or density at 30-50 cm depth?	None
	Redoximorphic feature in the topsoil and upper subsoil?	None
	Tillage pan score VSA	2 (No pan)
	Other subsoil compaction features	None
Rooting depth and biological activity	Abundance of roots	Few
	Barriers to rooting	Sandy soil substrate
	Effective rooting depth AG Boden, 2005, p. 356	0.6 m
	Zustandsstufe Bodenschaetzung AG Boden, 2005, p. 318/319	II
	Abundance of deep burying earthworms (Grassland)	Few
	Abundance of moles (Grassland)	
Profile available water	Depth of watertable	1.8-3.5 m
	Water storage capacity of soil	Very low
	Grassland Wasserstufe	3-
Wetness and ponding	Depth of ground or perched water table	None
	Soil drainage class	Excessively drained
	Degree of redoximorphic features in the subsoil	None
	Indicator values of vegetation	
	Soil position in a depression ?	No, land is level
	Wetness by suspended water (soils rich in silt and clay or muck) ?	No
	Ponding during soil assessment	No
	Delay of begin of farming on cropping land (days)	No
Slope and relief	Slope at the pedon position	level
	Microrelief and slope aspect at the pedon position	

Examples of Muencheberg SQR: Genschmar Sand, Germany

Muencheberg Soil Quality Rating (SQR)

Grassland

Score card, Page 3: Basic Rating

Basic indicators		Score	Weighting factor	Total	Remarks
1	Soil substrate	0.5	3	1.5	Sand, Table 3.2.1.-1
2	Depth of humic soil	1	2	2	0.15- 0.3 m, Table 3.2.2.-2
3	Topsoil structure	1	1	1	Single grain, Diez score 3-4 Table 3.2.3.-1
4	Subsoil compaction	2	1	2	None, Table 3.2.4.-2
5	Biological activity	1	2	2	Less than 15 cm, Table 3.2.5.-3
6	Profile available water (PAW)	0.5	3	1.5	Strong deficite, Wasserstufe 4-, Table 3.2.6.-1
7	Wetness/ ponding	2	3	6	None, Table 3.2.7.-1
8	Slope and relief	2	2	4	Flat, Table 3.2.8.-1
Total basic score (TBS)				20	Medium score, maximum would be 34



Grazing cattle on Genschmar sand, elevated position in the floodplain of the Oder river

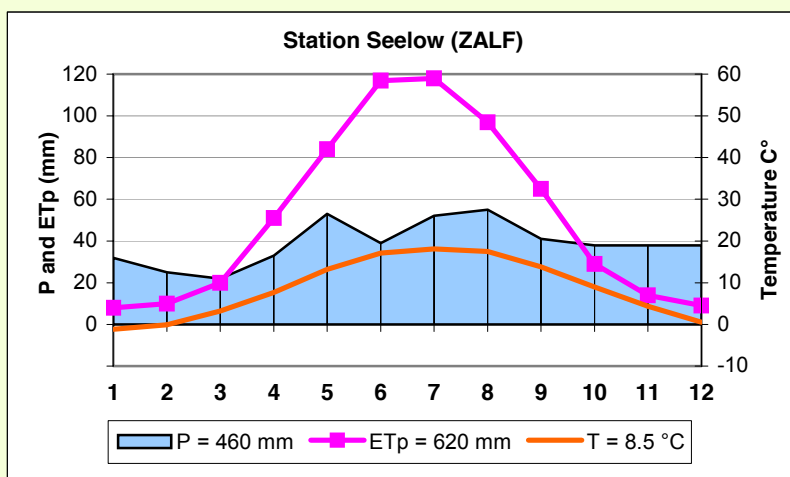
Examples of Muencheberg SQR: Genschmar Sand, Germany

Muencheberg Soil Quality Rating (SQR)

Grassland

Score card, Page 4: Vegetation and climate data

Landuse	
Main species of vegetation	<i>Agropyron repens</i> , <i>Calamagrostis epigejos</i> , <i>Rumex acetosa</i> , <i>Carex praecox</i> , <i>Alopecurus pratensis</i>
Vegetation indicators	Ellenberg :F= 4.6, Wasserstufe 3- to 4-
Above ground biomass	3-5 t/ha*yr
Main biome (potential natural vegetation)	



Climate:

Precipitation: 460-500

mm/a Temperature: 8-9° C

Koeppen climatic zone: Cfb

Monthly temperature, °C

1	2	3	4	5	6	7	8	9	10	11	12	1-12
-1,2	-0,1	3,2	7,7	13,2	17,1	18,1	17,5	13,8	9	4,4	0,5	8,5

Agroecological data:

Latest/ first frost (p> 10 %)	May, 13 / Oct, 10
Begin of vegetation period (t> 5°C)	March, 25
Length of growing period (t>5°/ t> 10°)	250 / 190 days
Temperature sum (t>5°/ t> 10°)	3500 / 3000
Depth of soil freezing	40 cm
Snow days during winter	10-20 %

Examples of Muencheberg SQR: Genschmar Sand, Germany

Muencheberg Soil Quality Rating (SQR)

Grassland

Score card, Page 5: Criteria of Hazard rating

Indicator	Relevant criteria of Hazard rating	Pedon data
Contamination	Position in a risk area?	Yes, located in a floodplain
Salinization	Electric conductivity	
	Salt crusts or coatings	None
	Salt indicator vegetation	None
Sodification	pH	4.6-5.6
Acidification	SAR	
	ESP	
Low total nutrient status	Malnutrition features of crops ?	None
Soil depth above hard rock		No hard rock
Drought	Water budget mm/yr	450
	Climatic water balance in the main vegetation period of 4 months	210 mm deficit
	Benefit of irrigation	
	Probability of the occurrence of a dry month	
	Aridity index acc. to De Martonne	
	Bailey moisture index	
	Ombrothermic index I _o of Rivas-Martínez (1997)	
Flooding and extreme waterlogging	Inundation frequency and duration	High position in the risk area, flooding probability < 2 times per 100 yrs
	Water regime class of Soil Survey Manual	Excessive
	Benefit of land drainage	None
Steep Slope	Slope %	0
Rock at the surface		None
Coarse soil texture fragments		None
Unsuitable soil thermal regime	Soil thermal regime	None
Miscellaneous hazards		None
Remarks		

Examples of Muencheberg SQR: Genschmar Sand, Germany

Muencheberg Soil Quality Rating (SQR)

Grassland

Score card, Page 6: Final rating

Hazard indicators		Score	Range of multipliers	Multiplier	Remarks
1	Contamination	2	3	3	Slight limitations by flooding, medium by drought, water budget about 450 mm, low risk of riverbank erosion
2	Salinisation	2	3	3	
3	Sodification	2	3	3	
4	Acidification	2	3	3	
5	Low total nutrient status	2	3	3	
6	Soil depth above hard rock	2	3	3	
7	Drought	1.5	2-3	2.2	
8	Flooding and extreme waterlogging	1.5	2.5-3	2.7	
9	Steep Slope	2	3	3	
10	Rock at the surface	2	3	3	
11	Coarse soil texture fragments	2	3	3	
12	Unsuitable soil thermal regime	2	3	3	
13	Miscellaneous hazards: Risk of riverbank erosion	1.5	2.5-3	2.7	
Lowest multiplier				2.2	
Final Multiplier acc. to Table 3.4.-1				2.0	

Final rating score (SQR score, rounded) = Total basic score* Lowest multiplier

$$\text{SQR score} = 20 * 2.0 = 40$$

Grassland Soil quality assessment:

< 20= Very poor, 20 – 40 = Poor, 40 – 60= Moderate, 60 – 80 Good, > 80= Very good

Comment on final rating: Poor to moderate grassland site, main limitations by drought

Appendix 2: Orientation guides of indicator scoring based on properties of Soil Reference Groups (SRG) and qualifiers of WRB, 2006

Note : Following Tables indicate only those limitations that are very highly probable to exist because of conflicting definitions of SRG and qualifiers with definitions and thresholds of Basic and Hazard soil rating tables.

Table A2-1: Limitations of Basic indicators based on SRG

Reference Soil Groups	Soil substrate	A horizon depth	Topsoil structure	Subsoil compact-ion	Rooting depth	Profile available water	Wetness and ponding	Slope and relief
Acrisol AC	≤1.5 (1)	(1)	(1)	(1)	≤1.5 (1)	(1)	(1.5)	(1)
Albeluvisol AB	(1)	(1.5)	(1)	(1.5)	(1)	(1)	(1.5)	(1.5)
Alisol AL	≤1.5 (1)	(1)	(1)	(1)	≤1.5 (1)	(1)	(1)	≤1.5 (1)
Andosol AN	(1.5)	(1.5)	(1.5)	(1.5)	(2)	(2)	(2)	≤1.5 (1)
Anthrosol AT	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)
Arenosol AR	≤1 (0.5)	(1)	(1)	(1)	≤1 (0.5)	(0.5)	(2)	(1.5)
Calcisol CL	≤1.5 (0.5)	(0.5)	(0.5)	(1)	≤1.5 (0.5)	(0.5)	(1.5)	(1.5)
Cambisol CM	(1)	(1.5)	(1.5)	(1)	(1.5)	(1.5)	(1.5)	(1.5)
Chernozem CH	≥0.5 (2)	(2)	(1.5)	(1.5)	(1.5)	(1.5)	(2)	(2)
Cryosol CR	(0.5)	(0.5)	(1)	(1)	≤1.5 (0.5)	(1.5)	≤1.5 (0.5)	(1.5)
Durisol DU	≤1.5 (0.5)	(0.5)	(0.5)	(0.5)	≤1.5 (0.5)	(1)	(2)	(1.5)
Ferralsol FR	≤1 (1)	(1)	(1)	(1)	(1.5)	≤1.5 (1)	(1.5)	(1)
Fluvisol FL	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	≥1 (2)
Gleysol GL	(1)	(1)	(1)	(1)	≤1.5 (1)	(2)	≤1.5 (0.5)	≥1 (2)
Gypsisol GY	≤1 (0.5)	(0.5)	(0.5)	(1)	≤1.5 (0.5)	(0.5)	(1.5)	(1)
Histosol HS	1-1.5 (1)	(1.5)	(1.5)	(1.5)	≤1.5 (1)	≥1 (2)	(0.5)	≥1 (2)
Kastanozem KS	(2)	(1.5)	(1.5)	(1.5)	(1.5)	(1)	(2)	(2)
Leptosol LP	≤1 (0.5)	≤1.5 (0.5)	(1)	(0.5)	≤1 (0.5)	(0.5)	(1.5)	(0.5)
Lixisol LX	≤1.5 (1)	(1.5)	(1)	(1)	(1)	(1)	(1.5)	(1)
Luvisol LV	(1.5)	(2)	(1)	(1)	(1.5)	(1.5)	(1.5)	(1.5)
Nitisol NT	≤1.5 (1)	(1.5)	(1.5)	(1.5)	(1.5)	(1)	(1.5)	(1)
Phaeozem PH	(2)	(1.5)	(1.5)	(1.5)	(2)	(1.5)	(2)	(2)
Planosol PL	≤1 (1)	(0.5)	(0.5)	≤1 (1)	≤1 (1)	≤1.5 (1)	≤1.5 (1)	≥1 (1.5)
Plinthosol PT	≤1.5 (1)	(1)	(0.5)	≤1.5 (0.5)	≤1.5 (0.5)	(1)	(1)	(1.5)
Podzol PZ	≤1.5 (1)	(1)	(0.5)	(1)	≤1.5 (1)	≤1.5 (1)	(1.5)	(1)
Regosol RG	(1)	(1)	(1)	(1)	(1)	(1)	(1.5)	(1)
Solonchak SC	≤1.5 (0.5)	(0.5)	(1)	(1.5)	≤1 (1)	(1)	≤1.5 (1)	≥1 (1.5)
Solonetz SN	≤1.5 (1)	(1)	(1)	(1.5)	≤1 (1)	(1)	≤1.5 (1)	≥1 (1.5)
Stagnosol ST	(1)	(1.5)	(1)	(1)	≤1 (1)	≤1.5 (1)	≤1.5 (0.5)	(1.5)
Technosol TC	≤0.5 (0.5)	(1)	(1)	(1)	(1)	(1)	(1)	(1.5)
Umbrisol UM	(1.5)	(1.5)	(1)	(1)	(1)	(2)	(1)	(0.5)
Vertisol VR	1	(1.5)	(1)	(1)	(1.5)	(1.5)	≤1.5 (1)	≥1 (1.5)

Table A2-2: Limitations of Basic indicators based on qualifiers

Qualifiers	Soil substrate	A horizon depth	Topsoil structure	Subsoil compact-ion	Rooting depth	Profile available water	Wetness and ponding	Slope and relief
Abruptic ap	≤1.5 (1)				≤1.5 (1)		≤1.5	
Aceric ae	≤1 (1)				≤1 (0.5)			
Aeric ac	≤1 (1)							
Acroxic ao	≤1.5 (1)							

Albic ab								
Alcalic ax	≤ 1 (0.5)				≤ 1 (0.5)			
Alic al	≤ 1 (1)							
Aluandic aa								
Thaptaluandic								
Alumic au	≤ 1 (0.5)				≤ 1 (0.5)			
Andic an								
Anthraquic aq			≤ 1 (1)	≤ 1 (0.5)	≤ 1 (0.5)			(2)
Anthric am	≥ 1	≥ 1 (2)						
Arenic ar	≤ 1.5 (1)				≤ 1.5 (1)	≤ 1.5 (1)		
Epiarenic arp	≤ 1 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Endoarenic arn	≤ 1.5 (1)				≤ 1.5 (1)	≤ 1.5 (1)		
Aric ai								
Aridic ad	≤ 1 (1)	≤ 1.5 (1)						
Arzic az	≤ 1 (0.5)				≤ 0.5 (0.5)		≤ 1.5 (0.5)	
Brunic br	≤ 1 (0.5)				≤ 1 (0.5)	≤ 1.5 (1)		
Calcaric ca								
Calcic cc								
Cambic cm								
Carbic cb	≤ 1.5 (1)							
Carbonatic cn	≤ 1.5 (0.5)				≤ 1.5 (1)			
Chloridic cl	≤ 1.5 (0.5)				≤ 1.5 (0.5)			
Chromic cr								
Clayic ce	≤ 1.5 (1)				≤ 1.5 (1)		(1)	
Epiclayic cep	≤ 1.5 (1)				≤ 1.5 (1)			
Endoclayic cen	≤ 1.5 (1)				≤ 1.5 (1)			
Colluvic co								
Cryic cy					≤ 1.5 (1)			
Cutanic ct								
Densic dn				≤ 0.5	0 (0)	≤ 1.5 (0.5)		
Drainic dr							≥ 0.5 (1)	
Duric du					≤ 1.5 (1)			
Endoduric nd	≤ 1.5 (1)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Hyperduric duh	≤ 1.5 (1)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Dystric dy	≤ 1.5 (1.5)							
Orthodystric dyo	≤ 1.5 (0.5)				≤ 1.5 (1)			
Ekranic ek	0	≤ 1.5 (0.5)	0	≤ 0.5 (0.5)	≤ 1 (1)	≤ 0.5 (0.5)		
Endodystric ny	≤ 1.5 (1.5)							
Endoeutric ne								
Endofluvic nf								
Endogleyic ng	≤ 1.5 (1)				≤ 1 (1)		≤ 1.5 (1.5)	
Endoleptic nl	≤ 1 (1)				≤ 1 (1)			
Endosalic ns					≤ 1 (1)			
Entic et								
Epidystric ed	≤ 1.5 (1)							
Epieutric ee								
Epileptic el	≤ 1 (0.5)				≤ 1 (0.5)			
Epigleyic eg	≤ 1.5 (1)				≤ 0.5 (0.5)		≤ 1.5 (0.5)	
Episalic ea	≤ 0.5 (0.5)				≤ 0.5 (0.5)			
Escalic ec								2
Eutric eu								
Orthoeutric euo					≤ 1 (1.5)			
Eutrosilic es								
Ferralic fl	≤ 1.5 (1)							
Hyperferralic flh	≤ 1.5 (1)				≤ 1.5 (1)			
Hypoferralic flw								
Ferric fr	≤ 1 (1)				≤ 1.5 (1)			
Hyperferric frh	≤ 1 (0.5)				≤ 1.5 (1)	≤ 1.5 (1)		
Fibric fi	≤ 1.5 (0.5)				≤ 1.5 (0.5)			

Floatic ft	≤1.5 (0.5)			2	≤0.5	2	0	2
Fluvic fv								
Folic fo	≤1 (0.5)		≤1.5 (1)					
Thaptofolic					≤1 (1)			
Fractipetric fp	≤1 (1)				≤1.5 (1)			
Fractiplinthic fa	≤1 (1)				≤1.5 (1)			
Fragic fg	≤1 (1)			≤1.5 (1)	≤1.5 (1)			
Fulvic fu								
Garbic ga	≤1.5 (1)							
Gelic ge					≤1.5 (1)			
Gelistagnic gt					≤0.5 (0.5)		≤0.5 (0.5)	
Geric gr	≤1.5 (1)		≤1.5 (1)		≤1.5 (1)			
Gibbsic gi								
Glacic gc	≤1 (0.5)				≤1 (0.5)		≤1.5 (0.5)	
Gleyic gl					≤1.5 (1.5)			
Glossalbic gb								
Glossic gs								
Greyic gz								
Grumic gm								
Gypsic gy	≤1.5 (1)				≤1 (0.5)	≤1.5 (1)		
Gypsic gp	≤1 (1)				≤1.5 (1)			
Haplic ha								
Hemic hm	≤1.5 (1)				≤1.5 (1)			
Histic hi	≤1.5 (1)				≤1.5 (1)			
Thaptohisthic hib	≤1.5 (1.5)				≤1.5 (1.5)			
Hortic ht	≥1 (1.5)	≥1 (1.5)						
Humic hu								
Hyperhumic huh	≥1.5 (2)	2						
Hydragric hg	≤1.5 (1)		≤1 (0.5)	≤1 (0.5)	≤0.5 (0.5)		≤1.5 (0.5)	
Hydric hy								
Hydrophobic hf	≤1.5 (0.5)		≤1 (0.5)		≤1.5 (1)			
Hyperalbic ha	≤1.5 (1)							
Hyperalbic hl	≤1.5 (1)				≤1.5 (1)			
Hypercalcic hc	≤1 (0.5)				≤1 (0.5)			
Hyperdystric hd	≤1.5 (0.5)				≤1 (0.5)			
Hypereutric he					≥1 (1.5)			
Hypergyptic hp	≤1 (0.5)				≤1.5 (0.5)			
Hyperochric ho	≤1.5 (0.5)		≤1 (0.5)		≤1.5 (0.5)			
Hypersalic hs	≤1 (0.5)				≤1 (0.5)	≤1 (0.5)		
Hyperskeletal hk	≤0.5 (0.5)	≤1 (0.5)	≤1.5 (1)		≤0.5 (0.5)	≤1.5 (0.5)		
Hypocalcic wc								
Hypogypsic wg					≤1.5 (1)			
Hypoluvic wl								
Hyposalic ws	≤1.5 (1)				≤1.5 (1)			
Hyposodic wn	≤1.5 (1)				≤1.5 (1)			
Irragric ir								
Lamellic ll								
Laxic la								
Leptic le	≤1.5 (1)				≤1 (0.5)			
Lignic lg	≤1 (1)				≤1.5 (0.5)			
Limnic lm								
Linic lc					≤1.5 (0.5)			
Lithic li	0	≤0.5 (0)		0	0	0		
Lixic lx								
Luvic lv								
Magnesian mg	≤1.5 (1)							
Manganiferrous mf	≤1 (1)				≤1.5 (1)			
Mazic mz	≤1.5 (0.5)		≤0.5 (0.5)		≤1.5 (0.5)			
Melanic ml								

Mesotrophic ms								
Mollic mo	≥ 1 (1.5)	≥ 1 (1.5)	≥ 1.5 (2)		≥ 1 (1.5)	≥ 1 (1.5)	≥ 1 (1.5)	
Molliglossic mi	≥ 1 (1.5)	≥ 1 (1.5)	≥ 1.5 (2)		≥ 1 (1.5)	≥ 1 (1.5)	≥ 1 (1.5)	
Natric na	≤ 1.5 (0.5)				≤ 1.5 (0.5)			
Nitic ni	≤ 1 (1)				≤ 1.5 (1.5)			
Novic nv								
Areninovic anv	≤ 1.5 (1)				≤ 1.5 (1)			
Nudilithic nt	0	0	0	0	0	0	0	
Omblic om	≤ 1 (1)				≤ 1.5 (0.5)	≥ 1 (2)	≤ 1 (0.5)	≥ 1 (2)
Ornithic oc								
Ortsteinic os	≤ 1 (0.5)			≤ 1.5 (0.5)	≤ 1 (0.5)			
Oxyaquic oa					≤ 1.5 (0.5)		≤ 1.5 (1)	
Pachic ph	≥ 1 (2)	≥ 1.5 (2)	≥ 1.5 (2)	≥ 1.5 (1.5)	≥ 1.5 (1.5)	≥ 1 (1.5)	≥ 1 (1.5)	
Pellic pe	≤ 1 (1)	≤ 1 (1)	≤ 1.5 (1)					
Petric pt	≤ 1.5 (1)				≤ 1.5 (1)			
Endopetric ptn	≤ 1 (1)				≤ 1 (1)	≤ 1.5 (1)		
Epipetric ptp	≤ 0.5 (0)				≤ 0.5 (0)	≤ 1 (0.5)		
Petrocalcic pc	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Petroduric pd	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Petrogleyic py	≤ 1.5 (0.5)				≤ 1.5 (1)		≤ 1.5 (0.5)	
Petrogypsic pg	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Petroplinthic pp	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Petrosalic ps	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Pisoplinthic px	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Placic pi	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Plaggic pa	≤ 1.5 (1)	≥ 1 (2)						
Plinthic pl	≤ 1.5 (0.5)				≤ 1.5 (1)	≤ 1.5 (0.5)		
Posic po								
Profondic pf	≤ 1.5 (1)							
Protic pr	≤ 1.5 (0)	≤ 1 (0)			≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Puffic pu	≤ 1.5 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Reductaquic ra	≤ 1 (0.5)				≤ 1.5 (0.5)		≤ 1.5 (0.5)	
Reductic rd	≤ 1.5 (0.5)				≤ 1.5 (0.5)			
Regic rg								
Rendzic rz	≤ 1 (1)		≥ 1 (1.5)		≤ 1.5 (1)			
Rheic rh	≤ 1.5 (1.5)				≤ 1.5 (1)	≥ 1.5 (2)	≤ 1.5 (1)	≥ 1 (2)
Rhodic ro								
Rubic ru								
Ruptic rp	≤ 1 (0.5)				≤ 1.5 (0.5)			
Rustic rs	≤ 1.5 (0.5)				≤ 1.5 (0.5)			
Salic sz	≤ 1.5 (1)				≤ 1.5 (1.5)	≤ 1.5 (1)		
Sapric sa	≤ 1.5 (1.5)				≤ 1.5 (1)			
Silandic sn								
Thaptosilandic	≤ 1.5 (1)							
Siltic sl	≥ 1 (1.5)				≥ 1 (1.5)			
Endosiltic sln	≥ 1 (1)				≥ 1 (1)			
Episiltic slp	≥ 1 (2)				≥ 1 (1.5)			
Skeletal sk	0				≤ 1.5 (0.5)	≤ 1.5 (0.5)		
Endoskeletal	≤ 1 (0.5)				≤ 1.5 (0.5)	≤ 1.5 (1)		
Episkeletic	0			≤ 1 (0.5)	≤ 1 (0.5)	≤ 1.5 (0.5)		
Sodic so	≤ 1.5 (0.5)				≤ 1.5 (0.5)			
Endosodic	≤ 1.5 (1)				≤ 1.5 (1)			
Solodic sc	≤ 1.5 (1)				≤ 1.5 (1)			
Somblic sm	≤ 1.5 (1)				≤ 1.5 (1)			
Spodic sd	≤ 1.5 (0.5)				≤ 1.5 (0.5)			
Spolic sp	≤ 1 (0.5)				≤ 1 (0.5)	≤ 1.5 (1)		
Stagnic st	≤ 1.5 (1)				≤ 1.5 (1)	≤ 1.5 (1)	≤ 1.5 (1)	
Endostagnic stn	≤ 1.5 (1)				≤ 1 (1)	≤ 1.5 (1)	≤ 1.5 (1)	
Epistagnic stc	≤ 1.5 (0.5)				≤ 0.5 (0)	≤ 1.5 (1)	≤ 0.5 (0.5)	

Subaquatic sq	0	0	≤0.5 (0)	0	0	2	0	2
Sulphatic su	≤1.5 (0.5)				≤1.5 (0.5)			
Takyric ty	0		0		≤1 (0.5)	≤1 (1)	≤1.5 (0.5)	≥1.5 (2)
Technic te	≤0.5 (0.5)		≤1.5 (1)		≤1.5 (1)	≤1.5 (1)		
Tephric tf	≤1.5 (1.5)							
Terric tr	≤0.5 (1)	≥1						
Thaptandic ba								
Thaptovitric bv	≤1.5 (1)							
Thionic ti	≤1.5 (0.5)				≤1.5 (1)			
Hyperthionic tih	≤1 (0)				≤1 (0)			
Orthothionic tio	≤1.5 (0)				≤1.5 (0.5)			
Protothionic tip	≤1.5 (1)				≤1.5 (1)			
Thixotropic tp	≤1 (0.5)		≤1				≤1.5 (0.5)	
Tidalic td	≤1.5 (0.5)	≤1 (1)	≤1.5 (1.5)		≥1.5 (0)	≥1.5 (1.5)	0	2
Toxic tx	0				≤1 (0)	≤1 (0)		
Anthrotoxic atx	0				≤1 (0)			
Ecotoxic etx	0				≤1 (0)			
Phytotoxic ptx	0				≤1 (0)			
Zootoxic ztx	0				≤1 (0)			
Transportic tn								
Turbic tu	≤1.5 (1)							
Umbric um	≤1.5 (1)		≤1.5 (1)					
Umbriglossic ug	≤1.5 (1)		≤1.5 (1)					
Urbic ub	0		≤1 (1)		≤1 (1)	≤1.5 (1)		
Vermic vm	≥1.5 (1.5)	≥1.5 (1.5)	≥1.5 (1.5)	≥1 (1.5)	≥1.5 (1.5)	≥1.5 (1.5)	≥1.5 (1.5)	
Vertic vr	≤1 (1)		≤1 (1)		≤1.5 (1)	≤1.5 (1)	≤1.5 (1)	
Vetic vt	≤1 (0.5)				≤1.5 (0.5)	≤1.5 (0.5)		
Vitric vi	≤1.5 (1)							
Voronic vo	≥1 (2)	2	2		≥1 (2)	≥1 (2)	≥1 (2)	≥1 (2)
Xanthic xa	≤1.5 (1)							
Yermic ye	0	0	0		≤1 (0.5)	≤1 (0.5)		

Table A2-3: Limitations of Hazard indicators based on SRG

1. Contamination
2. Salinisation
3. Sodification
4. Acidification
5. Low total nutrient status
6. Soil depth above hard rock
7. Drought
8. Flooding and extreme waterlogging
9. Steep slope
10. Rock at the surface
11. High percentage of coarse soil texture fragments
12. Unsuitable soil thermal regime
13. Miscellaneous hazards

Reference Soil Groups	1	2	3	4	5	6	7	8	9	10	11	12	13
Acrisol AC				≤1.5	≤1.5		≤1.5						
Albeluvisol AB													
Alisol AL							≤1.5						
Andosol AN													
Anthrosol AT													
Arenosol AR													
Calcisol CL							≤1.5						
Cambisol CM													
Chernozem CH							≤1.5						
Cryosol CR												≤1.5	
Durisol DU							≤1						
Ferralsol FR													
Fluvisol FL									2				
Gleysol GL									2				
Gypsisol GY					≤1.5		≤1						
Histosol HS									≥1				
Kastanozem KS							≤1.5						
Leptosol LP						≤1				≤1	≤1		
Lixisol LX							≤1.5						
Luvisol LV													
Nitisol NT													
Phaeozem PH													
Planosol PL									≥1.5				
Plinthosol PT													
Podzol PZ													
Regosol RG													
Solonchak SC		≤1.5					≤1.5		≥1.5				
Solonetz SN			≤1.5				≤1.5		≥1.5				
Stagnosol ST													
Technosol TC											≤1.5		
Umbrisol UM													
Vertisol VR									≥1.5				

Table A2-4: Limitations of Hazard indicators based on qualifiers

- 1 Contamination**
- 2 Salinisation**
- 3 Sodification**
- 4 Acidification**
- 5 Low total nutrient status**
- 6 Soil depth above hard rock**
- 7 Drought**
- 8 Flooding and extreme waterlogging**
- 9 Steep slope**
- 10 Rock at the surface**
- 11 High percentage of coarse soil texture fragments**
- 12 Unsuitable soil thermal regime**
- 13 Miscellaneous hazards**

Qualifiers	1	2	3	4	5	6	7	8	9	10	11	12	13
Abruptic ap													
Aceric ae													
Aeric ac													
Acroxic ao													
Albic ab													
Alcalic ax			≤1.5										
Alic al													
Aluandic aa													
Thaptaluandic													
Alumic au													
Andic an													
Anthraquic aq													
Anthric am													
Arenic ar													
Epiarenic arp													
Endoarenic arn													
Aric ai													
Aridic ad													
Arzic az													
Brunic br													
Calcaric ca													
Calcic cc													
Cambic cm													
Carbic cb													
Carbonatic cn													
Chloridic cl		≤1.5											
Chromic cr													
Clayic ce													
Colluvic co													
Cryic cy													
Cutanic ct													
Densic dn													
Drainic dr													
Duric du													
Endoduric nd													
Hyperduric duh													

Dystric dy													
Orthodystric dyo													
Ekranic ek												0	
Endoduric nd													
Endodystric ny													
Endoeutric ne													
Endofluvic nf													
Endogleyic ng													
Endoleptic nl							≤1.5						
Endosalic ns													
Entic et													
Epidystric ed					≤1.5								
Epieutric ee													
Epileptic el											≤1		
Epigleyic eg													
Episalic ea		≤1.5											
Escalic ec													
Eutric eu													
Orthoeutric euo													
Eutrosilic es													
Ferralic fl													
Hyperferralic flh													
Hypoferralic flw													
Ferric fr													
Hyperferric frh													
Fibric fi													
Floatic ft							0						
Fluvic fv													
Folic fo													
Thaptofolic													
Fractipetric fp													
Fractiplinthic fa													
Fragic fg													
Fulvic fu													
Garbic ga													
Gelic ge													
Gelistagnic gt							≤1.5				≤1.5		
Geric gr													
Gibbsic gi													
Glacic gc											≤1.5		
Gleyic gl													
Glossalbic gb													
Glossic gs													
Greyic gz													
Grumic gm													
Gypsic gy													
Gypsiric gp													
Haplic ha													
Hemic hm													
Histic hi													
Thaptohisthic hib													

Hortic ht													
Humic hu													
Hyperhumic huh													
Hydragric hg								≤ 1.5					
Hydric hy													
Hydrophobic hf													
Hyperalbic ha													
Hyperalbic hl													
Hypercalcic hc					≤ 1.5								
Hyperdystric hd				≤ 1.5									
Hypereutric he													
Hypergyptic hp					≤ 1.5								
Hyperochric ho													
Hypersalic hs		≤ 1.5											
Hyperskeletal hk											0		
Hypocalcic wc													
Hypogypsic wg													
Hypoluvic wl													
Hyposalic ws													
Hyposodic wn													
Iragric ir													
Lamellic ll													
Laxic la													
Leptic le													
Lignic lg													
Limnic lm													
Linic lc						≤ 1.5							
Lithic li						0							
Lixic lx													
Luvic lv													
Magnesian mg													
Manganiferriic mf													
Mazic mz													
Melanic ml													
Mesotrophic ms													
Mollic mo													
Molliglossic mi													
Natric na			≤ 1.5										
Nitic ni													
Novic nv													
Areninovic anv													
Nudilithic nt						0				0			
Ombric om													
Ornithic oc													
Ortsteinic os													
Oxyaquic oa													
Pachic ph						≥ 1	≥ 0.5	≥ 1	≥ 1	≥ 1			
Pellic pe													
Petric pt						≤ 1.5							
Endopetric ptn						≤ 1.5							
Epipetric ptp						≤ 1							
Petrocalcic pc						≤ 1.5							

Petroduric pd						≤ 1.5							
Petrogleyic py													
Petrogypsic pg						≤ 1.5							
Petroplinthic pp						≤ 1.5							
Petrosalic ps						≤ 1.5							
Pisoplinthic px													
Placic pi													
Plaggic pa													
Plinthic pl													
Posic po													
Profondic pf													
Protic pr													
Puffic pu		≤ 1.5											
Reductaquic ra						≤ 1							
Reductic rd													
Regic rg													
Rendzic rz						≤ 1.5							
Rheic rh													
Rhodic ro													
Rubic ru													
Ruptic rp													
Rustic rs													
Salic sz													
Sapric sa													
Silandic sn													
Thaptosilandic													
Siltic sl													
Endosiltic sln													
Episiltic slp													
Skeletal sk											≤ 1		
Endoskeletal											≤ 1.5		
Episkeletic											≤ 1		
Sodic so			≤ 1.5										
Endosodic			≤ 1.5										
Solodic sc													
Sombic sm													
Spodic sd													
Spolic sp													
Stagnic st													
Endostagnic stn													
Epistagnic stc													
Subaquatic sq								0					
Sulphatic su													
Takyrlic ty						≤ 1	≤ 1						
Technic te													
Tephric tf													
Terric tr													
Thaptandic ba													
Thaptovitric bv													
Thionic ti				≤ 1.5									
Hyperthionic tih				≤ 1.5									
Orthothionic tio													
Protothionic tip													
Thixotropic tp													

Tidalic td								≤ 0.5					
Toxic tx	≤ 0.5												
Transportic tn													
Turbic tu													
Umbric um													
Umbriglossic ug													
Urbic ub													
Vermic vm													
Vertic vr													
Vetic vt													
Vitric vi													
Voronic vo													
Xanthic xa													
Yermic ye										0			

Appendix 3: Orientation guides of indicator scoring based on vegetation in Central Europe
(Indicators of salinity, alkalinity, acidity, drought and wetness, vegetation data adopted from Ellenberg et al, 2001).

Note: In some regions, specific plant lists of Ellenberg values are available, they should be used. (For example: Australia: Victorian Resources online. 2007, England: ELLENBERG.S INDICATOR VALUES FOR BRITISH PLANTS, 2007).

Table A3-1: Hazard indicator 2, Salinisation

Score	Characteristic	Orientation, check species of S \geq 3 in list below
2	No salinisation	Most/dominant plants of S numbers =0 (not in list below), a few sub- dominant species may have S of 1-3
1.5	Low salinisation	Most/dominant plants of S numbers of 1 or higher, S > 4 largely missing
1	Moderate salinisation	Most/dominant plants of S numbers > 3, some plants of S numbers of 3, species having S=0 largely missing
0.5	Strong salinisation	Most/dominant plants of S numbers > 5, some plants of S numbers of 3, species having S \leq 1 largely missing
0	Extreme salinisation	Most/dominant plants of S numbers > 8, some plants of S numbers of 3-8, species having S \leq 3 largely missing

Table A3-1.1: Plant list of S numbers > 0

The S number is listed along with F and R numbers to check the possible combination of salinity with drought (F \leq 3), waterlogging (F \Rightarrow 9), alkalinity (R =9) or acidity (R \leq 3).

GENUS	Species	S number	F number	R number
Achillea	millefolium	1	4	.
Agropyron	junceiforme	7	6 =	7
Agropyron	pungens	6	5 ~	7
Alnus	glutinosa	1	9 =	6
Alopecurus	bulbosus	3	7 =	7
Alopecurus	geniculatus	2	8 =	7
Alopecurus	utriculatus	2	6 ~	8
Althaea	officinalis	2	7 =	8
Amaranthus	albus	1	2	.
Amaranthus	hybridus agg.	1	4	7
Amaranthus	powellii	1	4	8
Amaranthus	retroflexus	1	4	7
Ammocalamagrost	baltica	1	4	.
Ammophila	arenaria	1	4	7
Androsace	maxima	1	4	7
Angelica	archangelica	1	9 =	.

GENUS	Species	S number	F number	R number
Anthoxanthum	odoratum	1	.	5
Apium	graveolens	4	8	7
Apium	nodiflorum	1	10	.
Apium	repens	1	7 =	7
Armeria	maritima	6	6 =	5
Artemisia	maritima	5	5 =	.
Artemisia	rupestris	3	7	8
Aster	tripolium	8	. =	7
Atriplex	calotheca	1	6 =	7
Atriplex	glabriuscula	3	7 =	7
Atriplex	littoralis	7	. =	.
Atriplex	longipes	5	6 ~	.
Atriplex	oblongifolia	1	4	6
Atriplex	rosea	1	5	7
Baldellia	ranunculoides	1	10	.
Bassia	hirsuta	7	8 =	7
Berula	erecta	1	10	8
Beta	vulgaris	5	6 =	7
Blackstonia	acuminata	1	7 ~	6
Blysmus	compressus	1	8	8
Blysmus	rufus	5	7 =	7
Bolboschoenus	maritimus	2	10	8
Brassica	oleracea	3	5	.
Bromus	hordeaceus agg.	1	. ~	.
Bromus	hordeaceus ssp.	1	4	4
Bupleurum	tenuissimum	3	7 ~	8
Cakile	maritima	4	6 =	.
Calepina	irregularis	1	3	8
Callitriche	brutia	1	10	.
Callitriche	obtusangula	1	11	7
Callitriche	stagnalis	1	10	6
Carex	arenaria	1	3	2
Carex	distans	5	6 ~	8
Carex	extensa	6	7 =	.
Carex	flacca	1	6 ~	8
Carex	hordeistichos	2	7 =	7
Carex	nigra	1	8 ~	3
Carex	oederi	2	9	.
Carex	otrubae	1	8	7
Carex	panicea	1	8 ~	.
Carex	punctata	1	7 =	7
Carex	scandinavica	1	7 ~	7
Carex	secalina	2	7	.
Carum	carvi	1	5	.
Catabrosa	aquatica	1	9 =	7
Centaurium	littorale	2	7	8
Centaurium	pulchellum	1	. ~	9
Cerastium	dubium	2	8 =	7
Cerastium	holosteoides	1	5	.
Chenopodium	botryodes	1	7	7
Chenopodium	glaucum	3	6	.
Chenopodium	rubrum	1	7	7
Chenopodium	rubrum agg.	1	.	.
Cicendia	filiformis	1	8 =	3

GENUS	Species	S number	F number	R number
Cirsium	arvense	1	.	.
Cochlearia	anglica	8	8 =	7
Cochlearia	danica	4	8 =	8
Cochlearia	officinalis agg	2	7 =	7
Coronopus	squamatus	1	6 ~	7
Cotula	coronopifolia	5	7	7
Crambe	maritima	3	6 =	7
Crepis	nicaeensis	1	4	7
Datura	stramonium	1	4	7
Deschampsia	wibeliana	2	9 =	8
Eleocharis	multicaulis	1	10	.
Eleocharis	parvula	1	10	7
Eleocharis	quinqueflora	1	9	7
Eleocharis	uniglumis	5	9 =	7
Elymus	arenarius	1	6 =	7
Epilobium	hirsutum	1	8 =	8
Erysimum	repandum	2	4	8
Euphorbia	palustris	1	8 ~	8
Festuca	arundinacea	2	7 ~	7
Glaucium	flavum	2	6	8
Glaux	maritima	7	7 =	7
Gratiola	officinalis	1	8 ~	7
Halimione	pedunculata	7	8 =	7
Halimione	portulacoides	8	7 =	.
Holcus	lanatus	1	6	.
Honkenya	peplodes	5	6	7
Hordeum	jubatum	2	6	7
Hordeum	marinum agg.	6	8 =	7
Hordeum	secalinum	4	6	6
Hydrocotyle	vulgaris	1	9 ~	3
Hypochoeris	radicata	1	5	4
Inula	britannica	2	7 =	8
Inula	salicina	1	6 ~	9
Iris	spuria	2	7	8
Juncus	ambiguus	4	8	4
Juncus	anceps	3	7	7
Juncus	articulatus	1	9	.
Juncus	balticus	1	8	2
Juncus	compressus	1	8 =	7
Juncus	gerardii	7	. =	7
Juncus	inflexus	1	7 ~	8
Juncus	maritimus	6	7 =	7
Juncus	subnodulosus	2	8	9
Lactuca	saligna	1	4	8
Lactuca	tatarica	2	6 ~	8
Lathyrus	maritimus	1	4	7
Lavatera	thuringiaca	1	5	.
Lemna	gibba	1	11	8
Lemna	minor	1	11	.
Lemna	trisulca	1	12	7
Leontodon	saxatilis	1	6 ~	6
Lepidium	perfoliatum	2	6	6
Lepidium	latifolium	4	5 ~	7
Limonium	vulgare	8	7 =	7

GENUS	Species	S number	F number	R number
Linum	catharticum	1	.	7
Littorella	uniflora	1	10	7
Lotus	tenuis	4	7 ~	8
Lycopus	exaltatus	1	9 =	8
Lythrum	hyssopifolia	2	7 =	3
Lythrum	salicaria	1	8 ~	6
Malva	pusilla	1	4	5
Melilotus	altissima	2	7 ~	7
Melilotus	dentata	2	6 ~	7
Melilotus	indica	2	5 ~	7
Mentha	pulegium	1	7 =	7
Mentha	suaveolens	1	8 =	6
Najas	marina	1	12	9
Odontites	litoralis	4	7 =	7
Odontites	rubra	1	5	7
Oenanthe	conioides	2	10	7
Oenanthe	lachenalii	3	8 =	8
Oenanthe	silaifolia	2	8 ~	7
Oenothera	parviflora agg.	1	3	7
Oenothera	ammophila	1	3	8
Ononis	spinosa	1	4 ~	7
Ophioglossum	vulgatum	1	7	7
Orchis	palustris	1	9 ~	8
Parapholis	strigosa	5	7 =	7
Phleum	arenarium	1	3	7
Plantago	coronopus	4	7 =	7
Plantago	maritima	7	7 =	8
Poa	annua	1	6	.
Poa	subcoerulea	3	5	6
Poa	trivialis	1	7	.
Podospermum	laciniatum	1	3 ~	8
Polygonum	aviculare agg.	1	4	.
Polygonum	oxyspermum	1	7 =	7
Potamogeton	berchtoldii	1	12	7
Potamogeton	crispus	1	12	7
Potamogeton	pectinatus	1	12	8
Potamogeton	perfoliatus	1	12	7
Potamogeton	pusillus	1	12	6
Potamogeton	pusillus agg.	1	12	6
Potentilla	anserina	1	6 ~	.
Potentilla	supina	2	8 =	6
Puccinellia	capillaris	7	8 =	7
Puccinellia	distans	7	6 ~	7
Puccinellia	limosa	6	7	7
Puccinellia	maritima	8	8 =	7
Pulicaria	vulgaris	1	8 =	6
Ranunculus	baudotii	6	10	9
Ranunculus	circinatus	1	12	7
Ranunculus	flammula	1	9 ~	3
Ranunculus	repens	1	7 ~	.

GENUS	Species	S number	F number	R number
Ranunculus	sardous	1	8 =	.
Ranunculus	sceleratus	2	9 =	7
Rumex	maritimus	2	9 =	8
Rumex	stenophyllus	2	7 =	8
Ruppia	cirrrosa	9	12	8
Ruppia	maritima	9	10 =	8
Sagina	maritima	4	7 =	8
Sagina	nodosa	2	8 ~	8
Sagina	procumbens	2	5 ~	7
Salicornia	dolichostachya	8	9 =	7
Salicornia	europaea	9	8 =	8
Salicornia	fragilis	7	7 =	7
Salicornia	ramosissima	9	8 =	8
Salsola	kali	6	. =	7
Salsola	kali ssp.	2	4	8
Samolus	valerandi	4	8 =	7
Schoenoplectus	americanus	1	10	7
Schoenoplectus	carinatus	2	11	7
Schoenoplectus	lacustris	1	11	7
Schoenoplectus	tabernaemontani	3	10	9
Schoenoplectus	triqueter	2	10	7
Schoenus	nigricans	1	9 =	9
Sclerochloa	dura	1	4 ~	8
Scorzonera	parviflora	5	7	8
Sedum	acre	1	2	.
Senecio	vernalis	1	4	7
Sisymbrium	supinum	1	7 =	7
Sonchus	arvensis	1	5 ~	7
Sonchus	asper	1	6	7
Sonchus	palustris	1	8 ~	7
Spartina	townsendii agg.	8	9 =	8
Spergularia	media	8	7 =	7
Spergularia	salina	9	7 =	9
Spirodela	polyrhiza	1	11	6
Suaeda	maritima	8	8 =	7
Taraxacum	officinale agg.	1	5	.
Taraxacum	palustre agg.	1	8	8
Tetragonolobus	maritimus	1	.	9
Teucrium	scordium agg.	1	8 =	8
Trifolium	fragiferum	4	7 =	8
Trifolium	repens	1	5	6
Trifolium	resupinatum	2	6 ~	7
Trifolium	striatum	1	3	2
Triglochin	maritimum	8	7 =	.
Triglochin	palustre	3	9 =	.
Tripleurospermum	maritimum	6	6 =	7
Typha	angustifolia	1	10	7
Typha	latifolia	1	10	7
Verbascum	blattaria	1	3	7
Vicia	cracca	1	5	.
Vicia	lutea	1	4	7
Viola	tricolor ssp.	1	3	6
Xanthium	strumarium	1	5	7
Zannichellia	palustris	5	12	8
Zostera	marina	3	12	7
Zostera	noltii	3	12	7

Table A3-1.2: Legend S number acc. to Ellenberg:

Value	Description	Explanation
1	Salt tolerant	Plant mainly on soils free of salts or low-salt soils, partly on slightly salty soils (0-0.1% Cl ⁻)
2	oligohyalin (I)	Mainly on soils of very low chloride content (0,05-0,3% Cl ⁻)
3	β-mesohyalin (II)	Mainly on soils of low chloride content (0.3-0.5% Cl ⁻)
4	α/β-mesohyalin (II/III)	Mainly on soils of low to moderate chloride content (0.5-0.7% Cl ⁻)
5	α-mesohyalin (III)	Mainly on soils of moderate chloride content (0.7-0.9% Cl ⁻)
6	α-meso-/polyhyalin (III/IV)	On soils of moderate to high chloride content (0.9-1.2% Cl ⁻)
7	polyhyalin (IV)	On soils of high chloride content (1.2-1.6% Cl ⁻)
8	euhalin (IV/V und V)	On soils of very high chloride content (1.6-2.3% Cl ⁻)
9	euhalin bis hypersalin (V/VI)	On soils of very high, in dry periods extremely high chloride content (>2.3% Cl ⁻)

Table A3-2: Hazard indicator 3, Sodification ¹⁾

Score	Characteristic	Extremely rough orientation, check species of R= 9 in list below ¹⁾
2	No to slight sodification	Most/dominant plants of R numbers < 9 (not in list below)
1.5	Low to moderate sodification	
1	Moderate to high sodification	Many species of R numbers of 9
0.5	High to very high sodification	
0	Extreme sodification	Most/dominant plants of R numbers of 9

¹⁾ Plants in the list below characterize either the presence of lime than of sodium. They are thus no indicators of sodification, but give a hint for a possible high pH which could be associated with sodification

Table A3-2.1: Plant list of R numbers of 9

GENUS	Species	R number	GENUS	Species	R number
Achillea	clusiana	9	Himantoglossum	hircinum	9
Acinos	alpinus	9	Horminum	pyrenaicum	9
Adonis	flammea	9	Hornungia	petraea	9
Aethionema	saxatile	9	Hutchinsia	alpina	9
Aethusa	cynapium ssp.	9	Hydrilla	verticillata	9
Ajuga	chamaepitys	9	Hypericum	elegans	9

GENUS	Species	R number	GENUS	Species	R number
Alchemilla	hoppeana	9	Iberis	intermedia	9
Allium	suaveolens	9	Inula	salicina	9
Amaranthus	graecizans	9	Inula	spiraeifolia	9
Anacamptis	pyramidalis	9	Iris	sambucina	9
Anagallis	foemina	9	Juncus	subnodulosus	9
Androsace	chamaejasme	9	Kernera	saxatilis	9
Androsace	hausmannii	9	Koeleria	vallesiana	9
Androsace	lactea	9	Laser	trilobum	9
Anthemis	austriaca	9	Laserpitium	latifolium	9
Aquilegia	einseliana	9	Laserpitium	siler	9
Arabis	alpina	9	Lathyrus	bauhinii	9
Arabis	caerulea	9	Lathyrus	latifolius	9
Arabis	ciliata	9	Lathyrus	pannonicus	9
Arabis	pumila	9	Leontodon	incanus	9
Arabis	soyeri	9	Leontodon	montanus	9
Asperula	arvensis	9	Leucanthemum	halleri	9
Asperula	tinctoria	9	Linum	leonii	9
Asplenium	seelosii	9	Linum	perenne ssp.	9
Aster	amellus	9	Linum	tenuifolium	9
Astragalus	cicer	9	Liparis	loeselii	9
Astragalus	frigidus	9	Medicago	falcata	9
Astragalus	danicus	9	Mentha	longifolia	9
Astragalus	exscapus	9	Micropus	erectus	9
Astragalus	onobrychis	9	Minuartia	austriaca	9
Athamanta	cretensis	9	Moehringia	muscosa	9
Bifora	radians	9	Myagrum	perfoliatum	9
Blackstonia	perfoliata	9	Myosotis	alpestris	9
Bunium	bulbocastanum	9	Myosotis	rehsteineri	9
Bupleurum	falcatum	9	Myriophyllum	spicatum	9
Bupleurum	longifolium	9	Najas	intermedia	9
Bupleurum	ranunculoides	9	Najas	marina	9
Bupleurum	rotundifolium	9	Nigella	arvensis	9
Calamagrostis	pseudophragmite	9	Nigritella	miniata	9
Calamintha	nepeta agg.	9	Nonea	pulla	9
Carduus	crassifolius	9	Odontites	lutea	9
Carex	appropinquata	9	Onobrychis	arenaria	9
Carex	brachystachys	9	Onobrychis	montana	9
Carex	firma	9	Ophrys	apifera	9
Carex	lepidocarpa	9	Ophrys	holoserica	9
Carex	mucronata	9	Ophrys	insectifera	9
Carex	ornithopoda	9	Ophrys	sphecodes agg.	9
Carex	ornithopoides	9	Orchis	militaris	9
Carex	tomentosa	9	Orchis	tridentata	9
Caucalis	platycarpus	9	Orlaya	grandiflora	9
Centaurium	pulchellum	9	Orobanche	alba	9
Cerastium	latifolium	9	Orobanche	caryophyllacea	9
Chaerophyllum	aureum	9	Orobanche	flava	9
Chamorchis	alpina	9	Orobanche	teucrii	9
Chondrilla	chondrilloides	9	Oxytropis	jacquinii	9
Cirsium	eriphorum	9	Papaver	sendtneri	9
Cladium	mariscus	9	Pedicularis	oederi	9
Conringia	orientalis	9	Pedicularis	rostrato-capita	9
Coronilla	coronata	9	Pedicularis	rostrato-spicat	9
Coronilla	emerus	9	Petrocallis	pyrenaica	9

GENUS	Species	R number	GENUS	Species	R number
Coronilla	vaginalis	9	Peucedanum	alsaticum	9
Coronilla	varia	9	Pinus	nigra	9
Corydalis	lutea	9	Poa	compressa	9
Cotoneaster	tomentosus	9	Polygala	amarella	9
Crepis	kernerii	9	Polygala	calcareae	9
Crepis	praemorsa	9	Potentilla	brauneana	9
Crepis	terglouensis	9	Potentilla	heptaphylla	9
Cyclamen	purpurascens	9	Primula	farinosa	9
Cystopteris	dickieana	9	Prunella	laciniata	9
Cystopteris	montana	9	Pulsatilla	grandis	9
Cystopteris	sudetica	9	Ranunculus	baudotii	9
Doronicum	grandiflorum	9	Ranunculus	hybridus	9
Dorycnium	germanicum	9	Ranunculus	parnassifolius	9
Dorycnium	herbaceum	9	Rapistrum	perenne	9
Draba	aizoides	9	Reseda	luteola	9
Draba	ladina	9	Rhamnus	pumilus	9
Draba	sauteri	9	Rhamnus	saxatilis	9
Draba	tomentosa	9	Rorippa	anceps	9
Dryopteris	villarii	9	Rumex	palustris	9
Epilobium	dodonaei	9	Salix	reticulata	9
Epipactis	leptochila	9	Salix	serpillifolia	9
Erigeron	acris ssp.	9	Salvia	nemorosa	9
Erigeron	neglectus	9	Saponaria	ocymoides	9
Erigeron	polymorphus	9	Saxifraga	aphylla	9
Erophila	spathulata	9	Saxifraga	burserana	9
Erysimum	cheiri	9	Saxifraga	caesia	9
Erysimum	hieraciifolium	9	Saxifraga	mutata	9
Euphorbia	verrucosa	9	Schoenoplectus	tabernaemontani	9
Euphrasia	cuspidata	9	Schoenus	nigricans	9
Falcaria	vulgaris	9	Seseli	annuum	9
Festuca	alpina	9	Seseli	hippomarathrum	9
Festuca	norica	9	Sesleria	varia	9
Festuca	stenantha	9	Silene	pusilla	9
Fumana	procumbens	9	Spergularia	salina	9
Galium	glaucum	9	Spiranthes	aestivalis	9
Galium	megalospermum	9	Stachys	alpina	9
Galium	truniacum	9	Stachys	recta	9
Gentiana	clusii	9	Tetragonolobus	maritimus	9
Gentiana	utriculosa	9	Teucrium	montanum	9
Gentianella	aspera	9	Thesium	rostratum	9
Glaucium	corniculatum	9	Thlaspi	rotundifolium	9
Globularia	cordifolia	9	Thlaspi	montanum	9
Globularia	punctata	9	Torilis	arvensis	9
Gymnadenia	odoratissima	9	Trifolium	scabrum	9
Gypsophila	repens	9	Trisetum	distichophyllum	9
Helianthemum	alpestre agg.	9	Turgenia	latifolia	9
Helianthemum	canum	9	Vaccaria	hispanica	9
Helianthemum	grandiflorum ss	9	Valeriana	montana	9
Helianthemum	ovatum	9	Valeriana	pratensis	9
Helictotrichon	parlatorei	9	Valeriana	supina	9
Hieracium	bupleuroides	9	Valeriana	saxatilis	9
Hieracium	glaucum	9	Verbascum	pulverulentum	9
Hieracium	morisianum	9	Veronica	austriaca	9
Hieracium	scorzonerifolium	9	Veronica	fruticulosa	9
Hieracium	villosum	9	Viola	cenisia	9

Table A3-2.2: Legend R number acc. to Ellenberg

Value	Description	Explanation
9	Indicator of alkalinity and lime	Only on soils rich in lime (or high pH)

Table A3-3: Hazard indicator 4, Acidification

Score	Characteristic	Orientation, check species of R ≤ 3 in list below
2	No significant acidification	Most/dominant plants of R numbers > 3 (not in list below), a few sub-dominant species may have R of 1-3
1.5	Low to moderate acidification	
1	Moderate to high acidification	Most/dominant plants of R numbers of 1-3, a few sub-dominant species may have R > 3
0.5	High to very high acidification	
0	Extreme acidification	Most/dominant plants of R numbers of 1, some plants of R numbers of 2-3, species having R > 3 largely missing

Table A3-3.1: Plant list of R numbers ≤ 3

GENUS	Species	R number	GENUS	Species	R number
Achillea	moschata	3	Juncus	bufonius agg.	3
Agrostis	canina	3	Juncus	effusus	3
Agrostis	rupestris	2	Juncus	jacquinii	2
Agrostis	stricta	2	Juncus	squarrosus	1
Aira	praecox	2	Kalmia	angustifolia	1
Ajuga	pyramidalis	1	Koeleria	hirsuta	3
Alchemilla	alpina	2	Laserpitium	halleri	3
Alchemilla	pentaphyllea	3	Lathyrus	linifolius	3
Amelanchier	lamarckii	3	Ledum	palustre	2
Andromeda	polifolia	1	Leontodon	helveticus	3
Androsace	alpina	2	Ligusticum	mutellinoides	3
Androsace	obtusifolia	1	Linnaea	borealis	2
Antennaria	dioica	3	Listera	cordata	2
Anthoxanthum	alpinum	2	Loiseleuria	procumbens	3
Anthoxanthum	puelii	2	Lonicera	caerulea	2
Armeria	alpina	2	Lonicera	periclymenum	3
Arnica	montana	3	Luzula	campestris	3
Arnoseris	minima	3	Luzula	luzuloides	3
Asplenium	adiantum-nigrum	2	Luzula	nivea	3
Asplenium	alternifolium	3	Luzula	pallescent	3

GENUS	Species	R number	GENUS	Species	R number
Asplenium	septentrionale	2	Luzula	sudetica	3
Avenella	flexuosa	2	Luzula	sylvatica ssp.	2
Avenochloa	versicolor	3	Lycopodiella	inundata	3
Betula	carpatica	1	Lycopodium	annotinum	3
Betula	nana	1	Lycopodium	clavatum	2
Betula	pubescens	3	Lythrum	hyssopifolia	3
Blechnum	spicant	2	Maianthemum	bifolium	3
Botrychium	matricariifoliu	3	Melampyrum	pratense	3
Botrychium	simplex	1	Melampyrum	pratense ssp.	3
Bupleurum	stellatum	3	Melampyrum	sylvaticum	2
Calamagrostis	villosa	2	Meum	athamanticum	3
Calluna	vulgaris	1	Minuartia	recurva	3
Campanula	barbata	1	Minuartia	stricta	2
Cardamine	matthioli	3	Monotropa	hypopitys agg.	3
Cardamine	resedifolia	3	Montia	fontana ssp.	3
Cardaminopsis	halleri	3	Myrica	gale	3
Carex	arenaria	2	Nardus	stricta	2
Carex	bigelowii	1	Narthecium	ossifragum	2
Carex	binervis	1	Oreochloa	disticha	1
Carex	brunnescens	3	Ornithopus	perpusillus	2
Carex	curvula	2	Orobanche	rapum-genistae	3
Carex	echinata	3	Oxyria	digyna	3
Carex	fuliginosa	2	Pedicularis	sylvatica	1
Carex	leporina	3	Peplis	portula	3
Carex	ligerica	2	Phyteuma	betonicifolium	2
Carex	limosa	2	Phyteuma	hemisphaericum	3
Carex	nigra	3	Pinus	rotundata	2
Carex	pauciflora	1	Plantago	alpina	3
Carex	paupercula	3	Poa	chaixii	3
Carex	pilulifera	3	Poa	laxa	3
Carex	pseudobrizoides	2	Polygala	serpyllifolia	2
Carex	rostrata	3	Polygala	vulgaris	3
Carex	trinervis	3	Polypodium	vulgare agg.	2
Carlina	acaulis ssp.	3	Potamogeton	polygonifolius	3
Centaurea	nigra	3	Potentilla	argentea agg.	3
Cerastium	pedunculatum	3	Potentilla	aurea	3
Chamaedaphne	calyculata	3	Potentilla	collina	2
Cicendia	filiformis	3	Potentilla	frigida	2
Clematis	alpina	3	Potentilla	palustris	3
Coleanthus	subtilis	3	Potentilla	rhenana	2
Corallorhiza	trifida	3	Primula	glutinosa	2
Cornus	suecica	2	Primula	hirsuta	3
Corydalis	claviculata	3	Primula	integrifolia	3
Corynephorus	canescens	3	Primula	minima	1
Crepis	conyzifolia	2	Pseudorchis	albida	2
Cryptogramma	crispa	3	Pteridium	aquilinum	3
Cytisus	scoparius	3	Pulsatilla	alba	2
Dactylorhiza	maculata ssp.	2	Pulsatilla	apiifolia	3
Dactylorhiza	majalis ssp.	3	Pyrola	minor	3
Dactylorhiza	sphagnicola	3	Radiola	linoides	3
Danthonia	decumbens	3	Ranunculus	flammula	3
Deschampsia	setacea	2	Ranunculus	glacialis	3

GENUS	Species	R number	GENUS	Species	R number
Dianthus	deltoides	3	Ranunculus	grenieranus	2
Dianthus	seguieri	3	Ranunculus	hederaceus	3
Digitalis	purpurea	3	Ranunculus	pygmaeus	3
Digitaria	ischaemum	2	Rhododendron	ferrugineum	2
Diphasium	alpinum	2	Rhynchospora	alba	3
Diphasium	complanatum	1	Rhynchospora	fusca	1
Diphasium	issleri	1	Rubus	chamaemorus	2
Diphasium	tristachyum	1	Rumex	acetosella	2
Diphasium	zeilleri	1	Rumex	acetosella agg.	2
Drosera	anglica	3	Rumex	tenuifolius	2
Drosera	intermedia	2	Salix	herbacea	3
Drosera	obovata	2	Saxifraga	aspera	3
Drosera	rotundifolia	1	Saxifraga	bryoides	3
Dryopteris	expansa	2	Saxifraga	cotyledon	3
Elatine	hexandra	3	Saxifraga	cuneifolia	3
Elatine	hydropiper	2	Saxifraga	exarata agg.	2
Epilobium	collinum	2	Saxifraga	seguieri	3
Epilobium	lanceolatum	3	Scheuchzeria	palustris	3
Epilobium	nutans	3	Scleranthus	annuus	2
Epilobium	palustre	3	Scleranthus	polycarpus	3
Erica	cinerea	2	Scutellaria	minor	2
Erica	tetralix	1	Sempervivum	arachnoideum	2
Eriophorum	vaginatum	2	Sempervivum	montanum	2
Eritrichum	nanum	2	Senecio	incanus	1
Euphrasia	drosocalix	2	Sibbaldia	procumbens	2
Euphrasia	frigida	3	Silene	exscapa	2
Euphrasia	micrantha	2	Silene	rupestris	3
Euphrasia	minima	2	Soldanella	montana	2
Festuca	halleri	1	Soldanella	pusilla	2
Festuca	nigrescens	3	Solidago	virgaurea ssp.	2
Festuca	ovina	3	Sparganium	angustifolium	3
Festuca	supina	2	Spergula	arvensis	3
Festuca	tenuifolia	3	Spergularia	rubra	3
Festuca	varia	3	Stachys	arvensis	3
Galeopsis	segetum	3	Stellaria	longifolia	2
Galium	harcynicum	2	Subularia	aquatica	2
Genista	anglica	2	Tanacetum	alpinum	2
Genista	germanica	2	Teesdalia	nudicaulis	1
Genista	pilosa	2	Teucrium	scorodonia	2
Gentiana	acaulis	2	Thelypteris	limbosperma	3
Gentiana	annonica	1	Thesium	ebracteatum	2
Gentiana	punctata	2	Trichophorum	alpinum	2
Gentiana	purpurea	3	Trichophorum	cespitosum	1
Geum	montanum	2	Trichophorum	cespitosum agg.	1
Geum	reptans	2	Trichophorum	germanicum	1
Gnaphalium	supinum	3	Tridentalis	europaea	3
Gypsophila	muralis	3	Trifolium	alpinum	2
Hammarbya	paludosa	2	Trifolium	arvense	2
Hieracium	alpinum	1	Trifolium	spadiceum	3
Hieracium	fuscum	3	Trifolium	striatum	2
Hieracium	glaciale	1	Ulex	europaeus	3
Hieracium	glanduliferum	1	Utricularia	bremii	3
Hieracium	glaucinum	3	Utricularia	ochroleuca	3

GENUS	Species	R number	GENUS	Species	R number
Hieracium	laevigatum	2	Vaccinium	gaultherioides	3
Hieracium	pallidum	2	Vaccinium	macrocarpon	1
Holcus	mollis	2	Vaccinium	microcarpum	1
Huperzia	selago	3	Vaccinium	myrtillus	2
Hydrocotyle	vulgaris	3	Vaccinium	uliginosum	1
Hymenophyllum	tunbrigense	3	Vaccinium	vitis-idaea	2
Hypericum	elodes	2	Veronica	bellidioides	1
Hypericum	maculatum	3	Veronica	officinalis	3
Hypericum	pulchrum	3	Veronica	scutellata	3
Hypochoeris	glabra	3	Vicia	lathyroides	3
Illecebrum	verticillatum	3	Viola	canina	3
Isolepis	fluitans	3	Viola	epipsila	3
Jasione	laevis	3	Viola	palustris	2
Jasione	montana	3	Woodsia	ilvensis	3
Juncus	balticus	2			

Table A3-3.2: Legend R number acc. to Ellenberg

Value	Description	Explanation
1	Strong acidity	Plant ever on acid soils, never on weak acid to alkaline soils
2		
3	Acidity	Plant mainly on acid soils, only exceptional on neutral soils

Table A3-4: Hazard indicator 7, Drought

Score	Characteristic	Orientation, check species of F ≤ 3 in list below
2	No risk of drought	All plants of F numbers > 3 (not in list below), a few sub-dominant species may have 3
1.5	Low risk of drought	
1	Medium risk of drought	Most plants of F numbers > 3 (not in list below), some plants of F numbers of 3, species having 2 and 1 are missing
0.5	High risk of drought	
0	Extreme high risk of drought	Most plants of F numbers 2 or 1, some have 3, some sub-dominant species have 4 or higher

Table A3-4.1: Plant list of F numbers <=3

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Acer	monspessulanum	3	Lepidium	neglectum	3
Achillea	collina	2	Linum	austriacum	3
Achillea	pannonica	3	Linum	leonii	3
Achillea	setacea	2	Linum	perenne	3
Achnatherum	calamagrostis	3	Linum	tenuifolium	2
Acinos	arvensis	2	Lonicera	etrusca	3
Adonis	aestivalis	3	Lychnis	viscaria	3
Adonis	flammea	3	Medicago	falcata	3
Adonis	vernalis	3	Medicago	minima	3
Agropyron	intermedium	3 ~	Medicago	nigra	3
Agrostis	stricta	2	Melampyrum	cristatum	3 ~
Aira	caryophyllea	2	Melica	transsilvanica	3
Aira	praecox	2	Melica	ciliata	2
Ajuga	genevensis	3	Melilotus	alba	3
Allium	carinatum	3 ~	Melilotus	officinalis	3
Allium	montanum	2	Mibora	minima	3
Allium	oleraceum	3	Micropus	erectus	2
Allium	pulchellum	2	Minuartia	cherlerioides	3
Allium	sphaerocephalon	3	Minuartia	fastigiata	2
Allium	strictum	2	Minuartia	hybrida	3
Alyssum	alyssoides	3	Minuartia	rupestris	3
Alyssum	montanum	2	Minuartia	setacea	2
Amaranthus	albus	2	Minuartia	verna	3
Amaranthus	blitoides	3	Minuartia	viscosa	3
Amaranthus	graecizans	3	Moenchia	erecta	2
Ambrosia	psilostachya	3	Muscari	comosum	3
Amelanchier	ovalis	3	Muscari	neglectum	3
Anacamptis	pyramidalis	3	Muscari	racemosum	3
Anchusa	officinalis	3	Muscari	tenuiflorum	3
Androsace	elongata	2	Myosotis	ramosissima	2
Androsace	hausmannii	3 ~	Myosotis	stricta	3
Androsace	septentrionalis	2	Nardurus	halleri	2
Anemone	sylvestris	3	Nepeta	pannonica	2
Anthemis	austriaca	3	Nigella	arvensis	3
Anthemis	ruthenica	3	Nonea	pulla	3
Anthemis	tinctoria	3	Odontites	lutea	3
Anthericum	liliago	3	Odontites	viscosa	3
Anthericum	ramosum	3	Oenothera	ammophila	3
Anthyllis	vulneraria	3	Oenothera	parviflora agg.	3
Apera	interrupta	2	Onobrychis	arenaria	2
Arabis	auriculata	3	Onobrychis	viciifolia	3
Arabis	brassica	3	Ononis	natrix	3
Arabis	glabra	3	Onosma	arenarium	3
Arabis	turrita	3	Orchis	militaris	3
Arctostaphylos	uva-ursi	3	Orchis	simia	3
Armeria	alliacea	3	Orchis	tridentata	3
Armeria	elongata	3	Origanum	vulgare	3
Armeria	elongata ssp	3	Orlaya	grandiflora	3
Armeria	halleri	3	Ornithogalum	kochii	2
Artemisia	campestris	2	Ornithopus	perpusillus	3
Artemisia	mutellina	3	Orobanche	alba	3

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Artemisia	pontica	3	Orobanche	alsatica	3
Asparagus	officinalis	3 ~	Orobanche	amethystea	1
Asperula	cynanchica	3	Orobanche	arenaria	3
Asplenium	ruta-muraria	3	Orobanche	bartlingii	3
Asplenium	seelosii	3	Orobanche	caryophyllacea	3
Asplenium	septentrionale	3	Orobanche	coerulescens	2
Aster	linosyris	2	Orobanche	gracilis	3
Astragalus	arenarius	2	Orobanche	lutea	3
Astragalus	danicus	3 ~	Orobanche	mayeri	3
Astragalus	exscapus	3	Orobanche	teucarii	2
Astragalus	onobrychis	2	Oxytropis	pilosa	1
Atriplex	tatarica	3	Petrorrhagia	prolifera	3
Aurinia	saxatilis	2	Petrorrhagia	saxifraga	2
Avenochloa	pratensis	3 ~	Peucedanum	cervaria	3
Berteroa	incana	3	Peucedanum	oreoselinum	3
Bifora	radians	3	Phleum	arenarium	3
Bothriochloa	ischaemum	3	Phleum	phleoides	3
Bromus	erectus	3	Phyteuma	tenerum	2
Bromus	squarrosus	3	Pimpinella	nigra	2
Bromus	tectorum	3	Pimpinella	saxifraga	3
Bupleurum	falcatum	3	Pinus	nigra	3
Bupleurum	rotundifolium	3	Poa	badensis	3
Calamintha	nepeta agg.	3	Poa	bulbosa	3
Calepina	irregularis	3	Poa	compressa	3
Campanula	bononiensis	3	Podospermum	laciniatum	3 ~
Cardaminopsis	petraea	3	Polycarpon	tetraphyllum	3
Cardaria	draba	3	Polycnemum	arvense	3
Carex	arenaria	3	Polycnemum	verrucosum	2
Carex	hallerana	3	Polygala	calcareae	3
Carex	humilis	2	Polygala	chamaebuxus	3 ~
Carex	ligerica	3	Polygala	comosa	3
Carex	melchiorii	3	Polygonatum	odoratum	3
Carex	mucronata	3	Potentilla	arenaria	1
Carex	ornithopoda	3	Potentilla	argentea agg.	2
Carex	praecox agg.	3 ~	Potentilla	caulescens	3
Carex	supina	2	Potentilla	clusiana	3
Catapodium	rigidum	2	Potentilla	collina	2
Centaurea	diffusa	3	Potentilla	grandiflora	3
Centaurea	jacea ssp.	3	Potentilla	heptaphylla	3
Centaurea	paniculata agg.	2	Potentilla	inclinata	2
Centaurea	scabiosa	3	Potentilla	intermedia	3
Cephalanthera	rubra	3	Potentilla	neumanniana	3
Cerastium	arvense ssp.	3	Potentilla	pusilla	2
Cerastium	brachypetalum a	3	Potentilla	recta	3
Cerastium	pumilum agg.	2	Potentilla	rhenana	2
Cerastium	semidecandrum	3	Prunella	grandiflora	3
Ceterach	officinatum	3	Prunella	laciniata	3
Chamaecytisus	supinus	3	Prunus	fruticosa	3
Chondrilla	junccea	3	Prunus	mahaleb	3
Cirsium	acaule	3	Pulsatilla	grandis	3
Clematis	recta	3 ~	Pulsatilla	pratensis	2
Colutea	arborescens	3	Pulsatilla	vulgaris	2
Conringia	orientalis	3	Quercus	ilex	3
Corispermum	hyssopifolium a	3	Quercus	pubescens	3

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Coronilla	coronata	3 ~	Ranunculus	bulbosus	3
Coronilla	emerus	3	Rapistrum	perenne	3
Coronilla	vaginalis	3	Reseda	lutea	3
Corynephorus	canescens	2	Rhamnus	pumilus	3
Cotinus	coggygria	3	Rhamnus	saxatilis	3
Cotoneaster	integerrimus	3	Rosa	agrestis	3
Cotoneaster	tomentosus	3	Rosa	coriifolia	3
Crepis	praemorsa	3 ~	Rosa	elliptica	3
Danthonia	alpina	3	Rosa	jundzillii	3
Dianthus	carthusianorum	3	Rosa	micrantha	3
Dianthus	deltoides	3	Rosa	rubiginosa	3
Dianthus	gratianopolitan	2	Rosa	scabriuscula	3
Dictamnus	albus	3	Rosa	subcollina	3
Diploxaxis	tenuifolia	3	Rosa	villosa	3
Dorycnium	germanicum	2	Rumex	pulcher	3 ~
Dorycnium	herbaceum	3	Rumex	tenuifolius	3
Draba	aizoides	3	Rumex	thyrsiflorus	3 ~
Draba	dubia	3	Salvia	pratensis	3
Draba	tomentosa	2	Sanguisorba	minor	3
Epipactis	atrorubens	3	Sanguisorba	muricata	2
Epipactis	muelleri	3	Saponaria	ocymoides	3 ~
Eragrostis	megastachya	3	Saxifraga	caesia	3
Eragrostis	minor	3	Saxifraga	paniculata	3
Eragrostis	pilosa	3	Saxifraga	tridactylites	2
Erica	herbacea	3	Scabiosa	canescens	3
Erodium	ciconium	3	Scabiosa	columbaria	3
Erophila	praecox	2	Scabiosa	gramuntia	2
Erophila	spathulata	3	Scabiosa	ochroleuca	3
Erophila	verna	3	Scandix	pecten-veneris	3
Eryngium	campestre	3	Scleranthus	perennis	2
Erysimum	crepidifolium	2	Scleranthus	polycarpus	2
Erysimum	odoratum	2	Scleranthus	verticillatus	2
Euphorbia	chamaesyce	3	Scorzonera	austriaca	3 ~
Euphorbia	cyparissias	3	Scorzonera	purpurea	2
Euphorbia	polychroma	3	Sedum	acre	2
Euphorbia	seguierana	2	Sedum	album	2
Euphorbia	verrucosa	3	Sedum	annuum	3
Falcaria	vulgaris	3	Sedum	dasyphyllum	3
Festuca	alpina	3	Sedum	forsteranum	3
Festuca	amethystina	3 ~	Sedum	maximum	3
Festuca	cinerea	2	Sedum	rubens	3
Festuca	duvalii	1	Sedum	rupestre agg.	2
Festuca	hervieri	3	Sedum	sexangulare	2
Festuca	heteropachys	2	Sedum	spurium	3
Festuca	pallens	2	Sedum	vulgare	3
Festuca	polesica	3	Sempervivum	arachnoideum	2
Festuca	pseudovina	3	Sempervivum	montanum	3
Festuca	rupicola	3	Sempervivum	tectorum	2
Festuca	stenantha	3	Senecio	erucifolius	3 ~
Festuca	trachyphylla	3	Senecio	inaequidens	3
Festuca	valesiaca	2	Senecio	viscosus	3
Festuca	varia	3	Seseli	annuum	3
Filago	arvensis	3	Seseli	hippomarathrum	2
Filago	gallica	2	Seseli	libanotis	3

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Filago	lutescens	3	Silene	chlorantha	2
Filago	minima	2	Silene	conica	2
Filago	pyramidata	2	Silene	noctiflora	3 ~
Filago	vulgaris	3	Silene	nutans	3
Filipendula	vulgaris	3 ~	Silene	otites	2
Fragaria	viridis	3	Silene	rupestris	3
Fraxinus	ornus	3	Sisymbrium	irio	3
Fumana	procumbens	2	Sisymbrium	volgense	3
Gagea	bohemica	2	Solanum	sarrachoides	3
Galeopsis	angustifolia	2	Sorbus	danubialis	3
Galium	glaucum	2	Sorbus	mougeotii	3
Galium	lucidum	3	Spergula	morisonii	3
Galium	parisiense	3	Spergula	pentandra	2
Galium	tricornutum	3	Stachys	annua	3
Gentiana	cruciata	3	Stachys	germanica	3
Gentianella	ciliata	3	Stachys	recta	3
Geranium	sanguineum	3	Stipa	bavarica	1
Globularia	punctata	2	Stipa	capillata	2
Gypsophila	fastigiata	2	Stipa	eriocaulis	2
Helianthemum	apenninum	2	Stipa	eriocaulis ssp.	2
Helianthemum	canum	2	Stipa	joannis	2
Helianthemum	nummularium	3	Stipa	tirsa	3
Helianthemum	ovatum	3	Stipa	pulcherrima	1
Helichrysum	arenarium	2	Taraxacum	laevigatum agg.	3
Herniaria	glabra	3	Taraxacum	obliquum agg.	3
Herniaria	hirsuta	3	Teesdalia	nudicaulis	3
Hieracium	ambiguum	3	Teucrium	botrys	2
Hieracium	amplexicaule	3	Teucrium	chamaedrys	2
Hieracium	auriculoides	3	Teucrium	montanum	1
Hieracium	bauhinii	3	Thalictrum	minus	3
Hieracium	bifurcum	2	Thesium	bavarum	3 ~
Hieracium	calodon	3	Thesium	linophyllon	2
Hieracium	cymosum	3	Thesium	rostratum	3 ~
Hieracium	echioides	2	Thymus	praecox	3
Hieracium	fallax	2	Thymus	pulegioides ssp	2
Hieracium	franconicum	2	Thymus	serpyllum	2
Hieracium	peleterianum	3	Trifolium	alpestre	3 ~
Hieracium	rothianum	2	Trifolium	arvense	3
Hieracium	wiesbaurianum	3	Trifolium	montanum	3 ~
Hierochloe	australis	3 ~	Trifolium	ornithopoides	3
Himantoglossum	hircinum	3	Trifolium	retusum	3
Hippocrepis	comosa	3	Trifolium	rubens	3
Hirschfeldia	incana	3	Trifolium	scabrum	2
Holosteum	umbellatum	3	Trifolium	striatum	3
Hornungia	petraea	2	Tordylium	maximum	3
Hypericum	elegans	3 ~	Trinia	glauca	1
Hypochoeris	glabra	3	Tuberaria	guttata	2
Hyssopus	officinalis	2	Turgenia	latifolia	3
Inula	germanica	3	Vaccaria	hispanica	2
Inula	hirta	3	Ventenata	dubia	3
Inula	spiraeifolia	3	Verbascum	blattaria	3
Iris	aphylla	3	Verbascum	lychnitis	3
Iris	germanica	3	Verbascum	phoeniceum	3
Iris	sambucina	3	Verbascum	pulverulentum	3

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Iris	variegata	3	Veronica	austriaca	3
Isatis	tinctoria	3	Veronica	dillenii	2
Jasione	montana	3	Veronica	praecox	2
Jovibarba	sobolifera	2	Veronica	prostrata	2
Juniperus	sabina	3	Veronica	spicata	3
Jurinea	cyanoides	2	Veronica	teucrium	3
Kernera	saxatilis	3	Veronica	verna	2
Kochia	laniflora	2	Veronica	verna agg.	2
Koeleria	glauca	3	Veronica	vindobonensis	3
Koeleria	macrantha	3	Vicia	lathyroides	2
Koeleria	vallesiana	1	Vicia	tenuifolia	3
Laburnum	anagyroides	3	Vincetoxicum	hirundinaria	3
Lactuca	perennis	2	Viola	collina	3
Lactuca	viminea	3	Viola	hirta	3
Lappula	squarrosa	3	Viola	rupestris	3
Lathyrus	aphaca	3	Viola	tricolor ssp.	3
Lathyrus	niger	3	Vulpia	bromoides	3
Lathyrus	pannonicus	3 ~	Vulpia	myurus	2
Leontodon	incanus	3	Woodsia	ilvensis	3
Lepidium	graminifolium	3			

Table A3-4. 2: Legend F number acc. to Ellenberg

Value	Description	Explanation
1	Severe drought indicator	Plant ever on dry soils, viable on drying up soils
2		
3	Drought indicator	Plant mainly on dry soils, partly on moderate dry soils, missing on moist soils
~		Periodically dry and wet

Table A3-5: Hazard indicator 8, Flooding and extreme waterlogging

Score	Characteristic	Orientation, check species of F ≥ 9 in list below
2	No or low risk of flooding, low or moderate level of waterlogging	All plants of F numbers < 9 (not in list below), a few sub-dominant species may have 9 or 10, species having F ≥ 11 missing
1.5	Low risk of flooding, longer ponding and wetness	Some species of F=9 or higher, some flooding indicators (=), species having F ≥ 11 missing
1	Medium risk of flooding, very long period of wetness	Many plants of F = 9 or higher, some plants of F less than 9, species having F =12 largely missing, some flooding indicators (=)
0.5	High probability of flooding, very long period of wetness	Many plants of F ≥ 9 , many flooding indicators, some species of F less than 9
0	Extreme high probability of flooding, extreme waterlogging	Most plants of F > 9 or many flooding indicators, some sub-dominant species may have 9 or less, drought indicators F ≤ 3 missing

Table A3-5.1: Plant list of F numbers ≥ 9

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Acorus	calamus	10	Ludwigia	palustris	9 =
Agrostis	canina	9	Luronium	natans	11
Alchemilla	coriacea	9	Lycopodiella	inundata	9 =
Alchemilla	effusa	9	Lycopus	europaeus	9 =
Alchemilla	straminea	9	Lycopus	exaltatus	9 =
Aldrovanda	vesiculosa	12	Lysimachia	thyrsiflora	9 =
Alisma	gramineum	11	Marsilea	quadrifolia	10
Alisma	lanceolatum	10	Mentha	aquatica	9 =
Alisma	plantago-aquaticum	10	Menyanthes	trifoliata	9 =
Alnus	glutinosa	9 =	Mimulus	guttatus	9 =
Alopecurus	aequalis	9 =	Minuartia	stricta	9
Anagallis	tenella	9	Montia	fontana	9
Andromeda	polifolia	9	Myosotis	laxa	9 =
Angelica	archangelica	9 =	Myosotis	rehsteineri	10
Apium	inundatum	10	Myrica	gale	9
Apium	nodiflorum	10	Myriophyllum	alternifolium	12
Arabis	soyeri	9 =	Myriophyllum	spicatum	12
Armeria	purpurea	10	Myriophyllum	verticillatum	12
Azolla	caroliniana	11	Najas	flexilis	12
Azolla	filiculoides	11	Najas	intermedia	12
Baldellia	ranunculoides	10	Najas	marina	12
Berula	erecta	10	Najas	minor	12
Betula	humilis	9	Narthecium	ossifragum	9
Betula	nana	9	Nasturtium	officinale agg.	10

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Bidens	cernua	9 =	Nuphar	lutea	11
Bidens	connata	9 =	Nuphar	pumila	11
Bidens	radiata	9 =	Nymphaea	alba	11
Bidens	tripartita	9 =	Nymphaea	candida	11
Bolboschoenus	maritimus	10	Nymphoides	peltata	11
Butomus	umbellatus	10	Oenanthe	aquatica	10
Butomus	umbellatus var.	11	Oenanthe	conioides	10
Calamagrostis	canescens	9 =	Oenanthe	fistulosa	9 =
Calamagrostis	stricta	9 ~	Oenanthe	fluviatilis	11
Caldesia	parnassifolia	10	Oenanthe	peucedanifolia	9 ~
Calla	palustris	9 =	Orchis	palustris	9 ~
Callitriche	brutia	10	Pedicularis	palustris	9 =
Callitriche	cophocarpa	10	Peucedanum	palustre	9 =
Callitriche	hamulata	10	Phalaris	arundinacea	9 =
Callitriche	hermaphroditica	12	Phragmites	australis	10
Callitriche	obtusangula	11	Pilularia	globulifera	9 =
Callitriche	palustris	11	Pinguicula	leptoceras	9
Callitriche	platycarpa	11	Poa	palustris	9 =
Callitriche	stagnalis	10	Polygala	amarella	9
Caltha	palustris	9 =	Polygonum	amphibium	11
Calycocorsus	stipitatus	9	Potamogeton	acutifolius	11
Cardamine	amara	9 =	Potamogeton	alpinus	12
Cardamine	matthioli	9 ~	Potamogeton	angustifolius	12
Cardamine	palustris	9	Potamogeton	berchtoldii	12
Cardamine	rivularis	9 ~	Potamogeton	coloratus	11
Carex	acutiformis	9 ~	Potamogeton	compressus	12
Carex	appropinquata	9 =	Potamogeton	crispus	12
Carex	aquatilis	9 =	Potamogeton	filiformis	12
Carex	atherodes	9 =	Potamogeton	friesii	11
Carex	brunnescens	9 ~	Potamogeton	gramineus	12
Carex	canescens	9	Potamogeton	helveticus	12
Carex	cespitosa	9 =	Potamogeton	lucens	12
Carex	chordorrhiza	9 =	Potamogeton	natans	11
Carex	davalliana	9	Potamogeton	nitens	12
Carex	diandra	9 =	Potamogeton	nodosus	12
Carex	dioica	9	Potamogeton	obtusifolius	12
Carex	disticha	9 =	Potamogeton	pectinatus	12
Carex	elata	10	Potamogeton	pectinatus agg.	12
Carex	elongata	9 ~	Potamogeton	perfoliatus	12
Carex	flava	9	Potamogeton	polygonifolius	10
Carex	gracilis	9 =	Potamogeton	praelongus	12
Carex	heleonastes	9 =	Potamogeton	pusillus	12
Carex	hostiana	9	Potamogeton	pusillus agg.	12
Carex	juncifolia	9 =	Potamogeton	rutilus	12
Carex	laevigata	9 =	Potamogeton	trichoides	11
Carex	lasiocarpa	9 =	Potentilla	palustris	9 =
Carex	lepidocarpa	9	Ranunculus	aquatilis	11
Carex	limosa	9 =	Ranunculus	baudotii	10
Carex	microglochin	9	Ranunculus	circinatus	12
Carex	norvegica	9 ~	Ranunculus	flammula	9 ~
Carex	oederi	9	Ranunculus	fluitans	12
Carex	paniculata	9	Ranunculus	hederaceus	9 =
Carex	pauciflora	9	Ranunculus	lingua	10

GENUS	SPECIES	F number	GENUS	SPECIES	F number
Carex	paupercula	9	Ranunculus	ololeucos	10
Carex	pseudocyperus	9 =	Ranunculus	peltatus	12
Carex	pulicaris	9	Ranunculus	penicillatus	11
Carex	riparia	9 =	Ranunculus	reptans	10
Carex	rostrata	10	Ranunculus	sceleratus	9 =
Carex	trinervis	9	Ranunculus	trichophyllus	12
Carex	tumidicarpa	9	Ranunculus	tripartitus	10
Carex	vaginata	9	Rhynchospora	alba	9 =
Carex	vesicaria	9 =	Rhynchospora	fusca	9 =
Catabrosa	aquatica	9 =	Ribes	nigrum	9 =
Ceratophyllum	demersum	12	Rorippa	amphibia	10
Ceratophyllum	submersum	12	Rorippa	anceps	9 =
Chrysosplenium	oppositifolium	9 =	Rumex	hydrolapathum	10
Cicuta	virosa	9 =	Rumex	maritimus	9 =
Cladium	mariscus	10	Rumex	palustris	9 =
Cochlearia	pyrenaica	9 =	Ruppia	cirrrosa	12
Cucubalus	baccifer	9 =	Ruppia	maritima	10
Cyperus	longus	9 =	Sagittaria	sagittifolia	10
Dactylorhiza	majalis ssp.	9	Salicornia	dolichostachya	9 =
Dactylorhiza	praetermissa	9	Salix	cinerea	9 ~
Dactylorhiza	traunsteineri	9 =	Salix	myrtilloides	9
Deschampsia	litoralis	10	Salvinia	natans	11
Deschampsia	setacea	9 =	Saxifraga	aizoides	9 =
Deschampsia	wibeliana	9 =	Saxifraga	hirculus	9 =
Drosera	anglica	9 =	Saxifraga	oppositifolia s	9 =
Drosera	intermedia	9 =	Saxifraga	stellaris	9 =
Drosera	obovata	9	Scheuchzeria	palustris	9 =
Drosera	rotundifolia	9	Schoenoplectus	americanus	10
Dryopteris	cristata	9	Schoenoplectus	carinatus	11
Echinocystis	lobata	9 =	Schoenoplectus	lacustris	11
Elatine	alsinastrum	9 =	Schoenoplectus	mucronatus	10
Elatine	hexandra	9 =	Schoenoplectus	tabernaemontani	10
Elatine	triandra	9 =	Schoenoplectus	triqueter	10
Eleocharis	acicularis	10	Schoenus	nigricans	9 =
Eleocharis	mamillata	10	Scirpus	radicans	9 =
Eleocharis	multicaulis	10	Scolochloa	festucea	10
Eleocharis	palustris	10	Scrophularia	auriculata	9 =
Eleocharis	parvula	10	Scrophularia	umbrosa	9 =
Eleocharis	quinqueflora	9	Scutellaria	galericulata	9 =
Eleocharis	uniglumis	9 =	Scutellaria	minor	9
Elodea	canadensis	12	Sedum	villosum	9
Elodea	nuttallii	12	Senecio	congestus	9 =
Epilobium	alsinifolium	9	Senecio	fluviatilis	9 =
Epilobium	nutans	9	Senecio	paludosus	9 =
Epilobium	palustre	9	Silene	pusilla	9 =
Epilobium	parviflorum	9 =	Sium	latifolium	10
Epilobium	roseum	9 =	Sparganium	angustifolium	11
Epipactis	palustris	9 ~	Sparganium	emersum	10
Equisetum	fluviatile	10	Sparganium	erectum	10
Equisetum	variegatum	9	Sparganium	minimum	11
Eriophorum	angustifolium	9 =	Spartina	townsendii agg.	9 =
Eriophorum	gracile	9 =	Spiranthes	aestivalis	9
Eriophorum	latifolium	9	Spirodela	polyrhiza	11

GENUS F number	SPECIES		GENUS F number	SPECIES	
Eriophorum	scheuchzeri	9 =	Stellaria	crassifolia	9
Eriophorum	vaginatum	9 ~	Stellaria	palustris	9 ~
Galium	elongatum	9	Stratiotes	aloides	11
Galium	palustre	9 =	Subularia	aquatica	10
Galium	palustre agg.	9	Swertia	perennis	9
Gentiana	utriculosa	9 ~	Taraxacum	fontanum agg.	9
Glyceria	fluitans	9 =	Trapa	natans	11
Glyceria	nemoralis	9 =	Trichophorum	alpinum	10
Glyceria	maxima	10	Trichophorum	cespitosum	9
Glyceria	plicata	10	Trichophorum	cespitosum agg.	9
Groenlandia	densa	12	Trichophorum	germanicum	9
Hammarbya	paludosa	9 =	Triglochin	palustre	9 =
Hierochloa	odorata agg.	9	Typha	angustifolia	10
Hippuris	vulgaris	10	Typha	latifolia	10
Hottonia	palustris	12	Typha	minima agg.	9 =
Hydrilla	verticillata	12	Typha	shuttleworthii	10
Hydrocharis	morsus-ranae	11	Urtica	kioviensis	10
Hydrocotyle	vulgaris	9 ~	Utricularia	australis	12
Hypericum	elodes	9 =	Utricularia	bremii	12
Iris	pseudacorus	9 =	Utricularia	intermedia	12
Isolepis	fluitans	10	Utricularia	intermedia agg.	12
Isolepis	setacea	9	Utricularia	minor agg.	10
Isotes	echinospora	12	Utricularia	ochroleuca	12
Isotes	lacustris	12	Utricularia	vulgaris	12
Juncus	alpino-articula	9	Utricularia	vulgaris agg.	12
Juncus	articulatus	9	Vaccinium	microcarpum	9
Juncus	atratus	9 ~	Vaccinium	oxycoccus	9
Juncus	bulbosus	10	Vaccinium	oxycoccus agg.	9
Juncus	filiformis	9	Vallisneria	spiralis	12
Juncus	stygius	9 =	Veronica	anagallis-aquatica	9 =
Juncus	triglumis	9	Veronica	anagalloides	9 =
Kobresia	simpliciuscula	9	Veronica	beccabunga	10
Ledum	palustre	9	Veronica	catenata	9 =
Leersia	oryzoides	10	Veronica	scutellata	9 =
Lemna	gibba	11	Viola	epipsila	9 =
Lemna	minor	11	Viola	palustris	9
Lemna	trisolca	12	Wahlenbergia	hederacea	9
Leucojum	aestivum	9 =	Wolffia	arrhiza	11
Liparis	loeselii	9 =	Zannichellia	palustris	12
Littorella	uniflora	10	Zostera	marina	12
Lobelia	dortmanna	10	Zostera	noltii	12

Table A3-5.2: Legend F number acc. to Ellenberg

Value	Description	Explanation
9	Wetness indicator	Mainly on very wet soils
10		Water plant, viable without inundation for a longer period
11	Water plant	Roots in water, periodically above water
12	Submerged plant	Mainly below water
=		Flooding, inundation
~		Periodically dry and wet

To maintain soil quality for feeding coming generations with healthy agricultural products and ensuring prospering agricultural regions, soils should be used wisely.

This requires knowledge of their health in terms of comparable indicators of soil quality. In this paper an empirical approach of Soil Quality Rating is presented. It is based on the interpretation of a soil profile by simple scoring tables.

Soil deficiencies for cropping or grazing become apparent.

Finally, an empirical rating score ranging from 100 (prime farmland) to 0 (no farming possible) will allow to compare the quality of the soil in front of our eye with other soils on our planet.



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