JRC TECHNICAL REPORTS

Updated Guidelines for Applying Common Criteria to Identify Agricultural Areas with Natural Constraints

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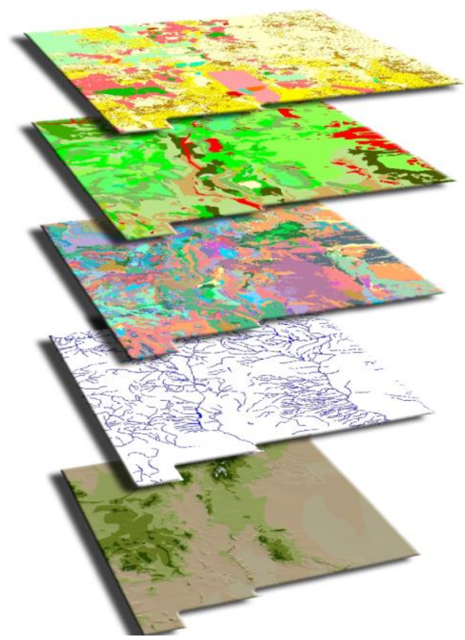

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Foreword

This document provides updated guidelines for mapping the proposed common soil, climate and terrain criteria to define agricultural Areas with Natural Constraints (ANC), as set out in the EU Regulation 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005.

These enhanced guidelines build on the previous JRC Technical Report by Böttcher et al. (2009).

These guidelines are written for technical staff in the Member State (MS) administrations, technical departments and organisations contracted to compute biophysical criteria for ANC and map the delimitation of areas under Article 32 of EU Regulation 1305/2013. They have been prepared by the European Commission Joint Research Centre as part of its technical support to the Directorate-General for Agriculture and Rural Development regarding the implementation of the new delimitation of ANC.

The document provides information on each criterion (including its definition, threshold and description) and how it should be applied. It also proposes ways of aggregating the classified agricultural ANC.

This report is not a detailed description of precise steps and procedures to follow as, due to the diversity of national/regional datasets and classification systems, there is no single answer that fits all. Instead, the recommendations should guide MS on their ANC delineation process, with the aim of making the best use of their capacities and data characteristics.

These guidelines draw on feedback from discussions with experts and meetings with MS, taking into account MS experiences regarding data availability and accuracy; and on experience in applying 'in-house' the common biophysical criteria on pan-European databases. They are intended to be a 'living document' as they could be updated to take into account situations encountered in MS and technically discussed with the Commission's services.

This document is limited to the tasks under the Joint Research Centre's responsibility, i.e. applying the common ANC biophysical criteria using geo-referenced databases, and does not include guidance on the fine tuning or other aspects such as the Natural Constraints Payment measure.

The report does not change the earlier recommendations from previous documents. Its aim is to provide updated guidance answering questions from MS during the ongoing delineations.

These updated guidelines are also used as references by the JRC when assessing MS delineation methods. In this sense, this document contributes to a transparent process.

Acknowledgements

This report has been prepared by Jean-Michel Terres and Tibor Toth with updated contributions from A. Wania, A. Hagyo, R. Koeble and L. Nisini from the European Commission's Joint Research Centre. The document has been reviewed by DG Agriculture and Rural Development.

The text has been kindly proof-read by G Mulhern.

These updated Guidelines build on former publications by Tibor Toth, Kristin Böttcher and Åse Eliasson (formerly of the Joint Research Centre), and on scientific factsheets prepared by a network of European experts.

Abstract

This document provides guidelines for mapping the proposed common soil, climate and terrain criteria for agricultural areas with natural constraints, as set out in the EU Regulation 1305/2013*.*

It is written for scientific and technical officers in the Member State administrations in charge of applying the common biophysical criteria for the delimitation of areas under natural constraints, as set out in Article 32 of EU Regulation cited above, and replacing the so-called "intermediate" Less Favoured Areas denomination.

Guidelines have been prepared by the European Commission's Joint Research Centre as part of its technical support to the Directorate-General for Agriculture and Rural Development on the redefinition of Areas with Natural Constraints. The report provides information and explanations on how to apply the common biophysical criteria within the Member States. It gives the definition, agronomic importance, threshold and description of how to assess each criterion, and describes how the classified agricultural areas with natural constraints can be aggregated. The guidelines draw on the experience from meetings with Member States and application of the common biophysical criteria on a pan-European level.

The report does not change the earlier recommendations from previous documents. Its aim is to provide updated guidance answering questions from MS during the ongoing delineations.

These updated guidelines are also used as references by the JRC when assessing MS delineation methods. In this sense, this document contributes to a transparent process.

List of abbreviations and definitions

AET	Actual evapotranspiration
ANC	Areas with Natural Constraints
COLE	Coefficient of Linear Expansion
DEM	Digital Elevation Model
DG AGRI	Directorate-General for Agriculture and Rural Development of the European Commission
EU-12	Member States that joined the European Union in 2004 and 2007
EU28	European Union of the 28 Member States
ECE	Electrical conductivity of the extract
ESP	Exchangeable sodium percentage
FAO	Food and Agriculture Organization of the United Nations
FC	Water content at field capacity
JRC	Joint Research Centre of the European Commission
LAU	Local Administrative Unit
LFA	Less Favoured Areas
LGP	Length of growing period
MS	Member States of the European Union
P	Precipitation
PERC	Percolation
PET	Potential evapotranspiration
PTF	Pedotransfer function
PTR	Pedotransfer rule
RD	Rooting depth
SAR	Sodium adsorption ratio
SAT	Water content at saturation
SMB	Soil moisture balance
SMD	Soil moisture deficit
SMU	Soil Mapping Unit
STU	Soil Typological Unit
SWAP	Soil water available to plants
Tavg	Average daily temperature
Tb	Base temperature
Tobs	Measured temperature
Tmax	Daily maximum temperature
Tmin	Daily minimum temperature
TS	Thermal-time Sum
UAA	Utilised Agricultural Area

WMO	World Meteorological Organisation
WP	Water content at wilting point
WRB	World Reference Base for Soil Resources

1. Introduction

1.1 Context

This document aims to provide guidance on the computation and mapping of common biophysical criteria by the EU Member States (MS) for delimiting Areas with Natural Constraints (ANC). These guidelines are intended to help officers in MS administrations, technical institutes and contractors dealing with the computation of the common biophysical criteria for delimitation of ANC. They describe concepts and provide information on ways to derive the indicators and how they can be aggregated.

The framework for developing the common biophysical criteria was built on objectives given by the Directorate-General for Agriculture and Rural Development (DG AGRI), an extensive review of internal and external scientific reports, recommendations from a panel of climate, soil and land evaluation experts, and from the results of technical meetings with MS on their ANC simulations.

These Guidelines provide an indication of how to map the criteria for designating ANC, with descriptions of recommended datasets and analyses. However, it is not a detailed description on the exact steps and procedures to be followed, as each Member State has different databases and tools and thus no single answer can fit all. Furthermore, it is not a compulsory methodology to be followed by MS. Instead, the recommendations must be adapted within each MS to soil, climate and terrain datasets, existing land evaluation methods and/or results from models. The aim of this exercise is to make the best use of existing capacities and available information sources in the MS, as well as to share knowledge based on experiences gained during the technical discussions between MS and Commission services.

MS are required to apply the criteria as described in EU Regulation 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005, using the most appropriate datasets available. The accuracy of applying the criteria to delineate constrained farming areas from other zones is data dependent, both in the semantic and the spatial dimensions. If the semantic resolution of the available observations, measurements or estimates is higher (more classes) or different (class boundaries) than what is requested, a reclassification is necessary. This can imply a certain loss of information and increased uncertainty. Furthermore, it is advisable to ensure that the spatial resolution of the soil, terrain and climate data is compatible with the size of the administrative unit to be designated.

This report is structured as follows:

- section 2, an overview of the biophysical criteria, definitions and thresholds;
- section 3, a description of the necessary information sources;
- section 4, a description of how to assess the individual criteria;
- sections 5 and 6, descriptions of the spatial data processing and their aggregation leading to the classification of administrative units.

Please see the Commission Document *Fine-tuning in areas facing significant natural and specific constraints* prepared by DG Agriculture and Rural Development (DG AGRI) for the fine tuning recommendations.

These guidelines are built on scientific factsheets of the criteria described in the EU report 'Updated common bio-physical criteria to define natural constraints for agriculture in Europe' (Van Orshoven, Terres, Toth, - 2014), EUR 26638 EN.

1.2 Boundary Conditions

The common biophysical criteria referred to in this document are based on the definition provided in Annex III of EU Regulation 1305/2013 for areas affected by natural constraints, other than mountain areas.

The following objectives and recommendations[1] were taken into account when developing common biophysical criteria for the delimitation of farming areas with natural constraints:

- Scientifically clear and understandable methodology: The application of the criteria should be transparent, straightforward and scientifically clear in order to enable translation into the policy framework.
- Key soil, climate and terrain characteristics within the EU-28: The criteria should be based on the most pertinent characteristics of land according to its suitability for generic agricultural activity, and should be applicable within the EU-28.
- Natural conditions: The classification should relate to areas that have severe limitations and natural constraints to agriculture, and not to how the land is used, i.e. it does not identify conditions to be met in order to reach optimal production for each type of crop.
- Classification of land: The classification relates only to areas with natural constraints and not to the payment mechanisms such as eligibility rules and level of payments.
- Agricultural areas: the criteria should focus on agricultural areas as defined in Article 4 of EU Regulation No 1307/2013 (establishing rules for direct payments to farmers under support schemes within the framework of the Common Agricultural Policy), which include permanent grasslands and permanent pastures, permanent crops and arable land. Forest land is not included.
- No crop specificity: The method should not be crop dependent. Constraints were considered for a European conventional, mechanised, farm unit of adapted grain crops or adapted grasses for hay, silage or grazing.
- No change during the policy programming period: The criteria should not change during the period of the programme. The climate variables should not be based on a particular year, but rather on probabilities based on reference time series meteorological data.

[1] Based on recommendations from the Court of Auditors' special report n° 4/2003 (Official Journal C151 of 27.06.2003), communication from DG Agriculture and Rural Development and recommendations from experts consulted by the Joint Research Centre.

2. Common Biophysical Criteria

The biophysical criteria developed for identifying significant natural constraints to agriculture in Europe are provided in Table **1** below.

The criteria originated from the agricultural "problem-land approach" (FAO, 1990a and Nachtergaele, 2006), whereas the threshold values have been derived from, and justified by, state-of-the-art scientific knowledge and expert consultation. The criteria are based on a selection of elementary soil, climate and terrain characteristics judged to be most pertinent for distinguishing land according to its suitability for generic agricultural activity in Europe.

In countries or regions for which particular criteria are not relevant, they do not need to be calculated. Some criteria are more absolute than others, and some are easier to overcome. However, each criterion, despite having a particular impact and threshold, does at a certain point present a severe natural handicap for agricultural activities. Hence the delimitation of areas is transparent across the whole of the Community.

The criteria applied here are for 'natural' soil and climate conditions. Therefore, when soil and/or climate conditions have been improved (e.g. through drainage, irrigation or other techniques), criteria cannot be applied in the same way, as a natural constraint has been overcome. The area delimitation should therefore be '*fine-tuned'* after this improvement (for further guidance, see Art. 32 paragraph 3 of EU Regulation 1305/2013, and Commission Document *Fine-tuning in areas facing significant natural and specific constraints* prepared by DG Agriculture and Rural Development (DG AGRI) for the fine tuning recommendations.).

The reasons for choosing the modified "Problem Land Approach" rather than a more elaborated Land Quality[2] approach for the ANC mapping exercise are its simplicity, robustness, transparency and the objectives pursued, i.e. to identify areas with constraints to agriculture and not to identify all necessary conditions to reach optimal production for each type of crop. The concept of length of growing period (the low temperature criterion) and the probability-based approach for climate-related characteristics have been adopted from the Agro-ecological zoning approach (FAO, 1978, 1996; and Fischer et al., 2002).

Table 1: ANC Soil, climate and terrain criteria as in Annex III of EU reg. 1305/2013

CRITERION	DEFINITION	THRESHOLD
CLIMATE		
Low Temperature	Length of growing period (number of days) defined by number of days with daily average temperature > 5°C (LGP_{t5}) OR	≤ 180 days
	Thermal-time sum (degree-days) for growing period defined by accumulated daily average temperature > 5°C.	≤ 1500 degree-days

[2] Land quality is defined as "A complex attribute of land which acts in a distinct way in its influence of land for a specific use. Examples are moisture availability, soil quality, erosion resistance, etc." (FAO, 1976).

Dryness	Ratio of the annual precipitation (P) to the annual potential evapotranspiration (PET)	P/PET ≤ 0.5
CLIMATE AND SOIL		
Excess Soil Moisture	Number of days at or above field capacity	≥ 230 days
SOIL		
Limited Soil Drainage	Areas which are water logged for significant duration of the year	Wet within 80cm from the surface for over 6 months, or wet within 40cm for over 11 months OR Poorly or very poorly drained soil OR Gleyic colour pattern[3] within 40cm from the surface
Unfavourable Texture and Stoniness	Relative abundance of clay, silt, sand, organic matter (weight %) and coarse material (volumetric %) fractions	≥ 15% of topsoil volume is coarse material, including rock outcrop, boulder OR
		Texture class in half or more (cumulatively) of the 100cm soil surface is sand, loamy sand defined as: silt% + (2 x clay%) ≤ 30% OR
		Topsoil texture class is heavy clay (≥ 60% clay) OR
		Organic soil (organic matter ≥30%) of at least 40cm OR
		Topsoil contains 30% or more clay and there are vertic properties within 100cm of the soil surface
Shallow Rooting Depth	Depth (cm) from soil surface to coherent hard rock or hard pan.	≤ 30cm
Poor Chemical Properties	Presence of salts, exchangeable sodium, excessive acidity	Salinity: ≥ 4 deci-Siemens per meter (dS/m) in topsoil OR
		Sodicity: ≥ 6 Exchangeable Sodium Percentage (ESP) in half or more (cumulatively) of the 100cm soil surface layer OR

[3] In the World Reference Base for Soil Resources 2014, 'gleyic colour pattern' is changed to 'gleyic properties'.

		Soil Acidity: pH ≤ 5 (in water) in topsoil
TERRAIN		
Steep Slope	Change of elevation with respect to planimetric distance (%).	≥ 15%

3. Data for the Common Criteria

3.1 General Considerations

Assessment of criteria

Criteria are assessed according to the agronomic law of the minimum (Liebig's law). As soon as one of the criteria considered has passed the threshold indicated in Table **1**, the corresponding land is judged to have a natural constraint regarding agricultural production. The criteria are not weighted or given a relative importance or priority.

Calculation of climate criteria

Climate criteria are treated in a probabilistic way. In order to account for inter-annual variability of the length of the growing season, temperature accumulation, dryness and excess soil moisture, these characteristics are classified as being natural constraints in a probabilistic approach: i.e. the probability of exceeding the threshold is greater than 20%.

Spatial calculation unit

The mapping should be carried out at a sufficient level of detail. The available resolution of biophysical datasets varies between and sometimes within countries, as does the size of the administrative unit to be designated. Therefore, it is advisable to ensure that the scales of the soil and climate data are compatible with the scale at which the area will be designated. For example, it is not appropriate to use a small scale soil map (e.g. 1/1 000 000) for characterising soil conditions of administrative units of a few km^2.

It is acknowledged that a criterion needs to be assessed only when it is present in the country, i.e. no mapping is needed if the criterion is not a natural constraint in the country (e.g. the criterion on dryness is not expected to be present in northern Member States).

3.2 Data Requirements

Data requirements for the mapping of the biophysical criteria are described in this section, which is organised by group of criteria: climate, soil moisture balance, soil, and terrain.

3.2.1 Data for Climate Criteria

The recommended WMO reference climatic period consists of 30 years, as it is long enough to filter out any inter-annual variation or anomalies. The current climate reference period in use by WMO is from 1 January 1961 to 31 December 1990.

(h*ttp://www.wmo.int/pages/themes/climate/climate_data_and_products.php*)

The question has raised about the representativeness of a period such as 1961-90 after some years in a non-stationary climate. Moreover some countries may have more meteorological observation data available in recent period than 40 years ago. Consequently, and as suggested by the WMO Commission for Climatology, it shall be possible to adapt the reference period to best fit the aim of the application and based on best available meteorological datasets along the following principles:

- The current reference period is from 1 January 1961 to 31 December 1990;
- Updating the reference period is possible following a 'rolling' set of 30 year, updated every 10 years (period starting on 1 January of a year ending with the digit 1, e.g. 1971, 1981) depending on best available datasets, with the duration of the 'rolling' period being 30 years;

Once, a reference period for meteorological assessment is chosen, it shall be used for the calculation of all climate related criteria (i.e. Low temperature, Dryness, Excess soil moisture).

Time series of daily meteorological data, is required to assess the probability of exceedance. It is strongly advised to use the reference period best suited according to best available meteorological datasets and following the principles above as recommended by the World Meteorological Organisation (WMO).

In case meteorological observations are unavailable, another possibility is to use data produced by meteorological models (re-analysis data), provided that the horizontal resolution is adequate for the geographical unit under assessment (typically a grid size of 10 x 10 or 20 x 20 km maximum when assessing LAU2 units) and that the duration of the data series follows the principles above.

3.2.2 Model and Data Requirements for the Excess Soil Moisture Criterion

Given the usual level of detail of hydrological and soil data in Europe, it is preferable to use simple models of soil water balance. As these are usually parsimonious models that provide estimates of soil moisture and related quantities based on a limited number of parameters, errors are relatively easy to track and results can be quickly obtained and evaluated.

The soil properties required to calculate the water content in the soil profile, which Thomasson (1995) defined as the Soil Water Available to Plants (SWAP), are:

- Amount or deficit of water held at saturation (SAT),
- Amount or deficit of water held at field capacity (FC),
- Amount or deficit of water held at the permanent wilting point (WP).

Rainfall and potential evapotranspiration should be available on a daily basis and expressed in the same units (generally mm/day).

The potential evapotranspiration (PET) should preferably be calculated using the Penman-Monteith methodology in relation to a living grass reference crop (Allen et al., 1998).

Soil water balance calculations must be validated in the field to some extent and yield the required information (e.g. a monthly soil water balance would not be sufficient to infer the number of days in a year during which a certain soil moisture condition prevailed).

3.2.3 Data for Soil Criteria

National soil data are less harmonised than climate data, and different classification systems of different properties of the soils are represented in various ways according to national and regional characteristics, needs and purposes of the respective countries (Jones et al., 2005). Therefore, it is not possible to provide one single answer on how to derive the soil criteria for all MS.

Soil map scale
It is recommended that MS use the most suitable soil and land data available, i.e. with homogeneous coverage, good resolution and a good level of accuracy. The advisable map scale for the assessment of soil criteria is 1/25 000 to 1/50 000. Some MS use the 1/5 000 scale, which is even better for assessing soil constraints at municipality level.

Pedo-transfer rule or function

Different approaches to deriving soil criteria recommend that the most suitable representation in the national/regional dataset be identified for each soil criterion. It is suggested to use direct information on soil properties, e.g. depth to a gleyed layer or Exchangeable Sodium Percentage, rather than using the soil classification.

If the requested soil characteristics are not present in the soil dataset, the soil variables can be derived by using pedo-transfer rules or functions (PTRs or PTFs). PTRs are simple relationships that express soil attributes in terms of properties that are shown, inferred from soil maps, and/or extracted from databases. They have evolved from PTFs that give statistical relationships between soil properties. PTFs were mainly developed for estimating the hydraulic properties of soils (e.g. Hall et al., 1977; Gupta and Larson, 1979; Wösten et al., 1995) and other soil properties that are difficult to measure. It should be pointed out that a given PTF or PTR should not be extrapolated beyond the geographic region or soil type from which it was developed.

PTRs use Boolean and other logic-based rules, which are applied to infer less easily quantified properties, or for predicting classes. A rule can be seen as a statement of the form:

IF <available information is> THEN <new information is>.

For example, the soil name summarises a great amount of information on soil properties, which might not be directly available in a database. Examples of how to infer soil properties from soil names based on the taxonomy of the World Reference Base (WRB) for Soil Resources (FAO-ISRIC-ISSS, 1998, FAO-IUSS-ISRIC, 2006) are given in section 4 for some soil criteria. The WRB is used as a reference system as it provides an easy means of communication to identify, characterise and name major types of soils, and it aims to act as common denominator by which national systems can be compared (Nachtergaele et al., 2000). Many of the same diagnostic features are used in the WRB and several national classification systems, but are often defined differently. Direct correspondence between classes is rare, but most books which define a classification include correspondence tables.

Soil mapping unit

The primary soil mapping unit in many soil maps consists of a group of soil types (Soil Typological Units, STU) that form soil associations, since the mapping delineation of STUs is not feasible at a given scale. In this case, it is suggested that each STU be considered for the calculation of the constraint, provided that data on the percentage of occurrence are available (see section 5 for the calculation of the share of constrained agricultural area from a soil association type database).

If the semantic resolution of the available observations, measurements or estimates is higher (more classes) or different (class boundaries), it is proposed to use the most appropriate class, taking care not to pass the threshold indicated in the regulation (conservative approach) or to perform a reclassification, if possible.

If this is applied, it is recommended to verify the accuracy of the reclassification by cross-analysing the derived information with an independent analytical dataset representative for the given area (soil profile data, laboratory measurements) containing the parameter to be mapped. Possibly, this should be done using quantitative statistical analysis; this quantitative analysis can then be the basis to establish a correction factor for the calculation of the share of the SMU fulfilling the threshold.

Soil parameters

The following soil characteristics are needed for the assessment of constrained agricultural land:

- Drainage (soil hydromorphic status or frequency and duration of wet periods)
- Stoniness (% volume of stones)
- Texture (% clay and silt) within 100 cm of the soil surface (and clay content (%) in topsoil)
- Soil organic matter content (%) and thickness of organic layers within 100 cm of the soil surface
- Vertic properties within 100 cm of the soil surface
- Rooting depth (cm)
- Salinity [Electrical Conductivity of the extract (EC_E) in deci-Siemens per metre (dS/m)]
- Sodicity [Exchangeable Sodium Percentage (ESP)[4] or as SAR (Sodium Adsorption Ratio)[5]]
- pH (value of the hydrogen ion activity as an indicator of soil acidity, measured at 1:5 soil to water ratio)

Some soil biophysical criteria (e.g. stoniness, heavy clay, or shallow rooting depth) refer to **topsoil** in their definitions and thresholds. Topsoil is defined as the upper part of a natural soil that is generally dark coloured and has a higher content of organic matter and nutrients when compared to the (mineral) horizons below, excluding the humus layer. This definition is based on ISO 11074 (Jones et al., 2008). For arable land it refers to the tilled soil depth (i.e. 25-30 cm); and for grassland to the soil layer with high root content.

3.2.4 Data for Terrain Criterion

Several instruments have been developed over time to determine slope. Topography has been estimated using photogrammetry. In current practice, high-resolution elevation datasets obtained from radar and satellite data are also used. Commonly, MS have elevation data with 10-20 m or finer resolution through their mapping agencies. For a given location, the estimation of the slope will be affected by the resolution of the digital elevation model (DEM). Coarse-resolution DEM will underestimate the real slope. It is therefore recommended to use a large-scale DEM (20-m horizontal resolution or higher).

[4] ESP=exchangeable Na* 100/CEC (Na and CEC in meq/100g soil)

[5] SAR = Na / $\sqrt{\frac{1}{2}(Mg^2 + Ca^2)}$

4. Guidance for the Derivation of each Criterion

This section provides guidance on how the biophysical criteria can be assessed by Member States, including the definition, agronomic importance and indications on how to calculate each criterion. For the scientific rationale behind each criterion, see the factsheets in the document 'Updated common bio-physical criteria to define natural constraints for agriculture in Europe' (Van Orshoven, Terres, Toth, - 2014), EUR 26638 EN.

4.1 Criterion: Low Temperature

Definition

Low temperature is defined as the condition in which crop performance or survival is compromised by temperatures during the growing period that are too low for the normal growth and development of plants. In the context of areas affected by natural constraints for agriculture in Europe, low temperature is considered to be a characteristic of land for which thermal-time accumulation or the sum of the conducive temperatures during the growing period is too low for plants to complete the production cycle.

Threshold

Temperature thresholds and thermal requirements for plant development vary among crop species and cultivars. For European conditions, thermal-time sum (TS) requirements can be used as a reference to delimit thresholds for the development of crops.

In general, the adequate thermal-time requirement for most agricultural crops is above a TS_5 of 1 500°Cd (degree day), above a base temperature (T_b) of 5°C (Boons-Prins et al., 1993).

Therefore, severely limiting low temperatures are said to occur if the TS above a base temperature of 5°C (TS_5) is lower than or equal to 1 500°Cd, or if the length of the growing period during which temperatures are above a base temperature (T_b) of 5°C (LGP_{t5}) is less than or equal to 180 days.

Assessment

The concepts of thermal-time sums (TS_b, degree days, °Cd) or length of the temperature growing period (LGP_t, days) are defined as follows:

- Thermal-time sums above a base temperature (Tb) of 5°C during the growing period (days within LGPt5, see how to define the growing period below), are calculated for each year of the time series by accumulating, on a daily basis, the difference between the daily average temperature (T_{avg}) and the base temperature (T_b = 5°C).
- The length of the temperature growing period (LGP_{t5}), i.e. the number of days during which daily average temperatures (T_{avg}) are above 5°C, is calculated on a daily basis for each year of the time series. The LGP_{t5} characterises the days during which temperatures are conducive to crop growth. The start and end of the growing period are defined as below.

The daily average temperature can be calculated with:

Minimum and maximum daily temperature ($Tavg = \frac{(T_{min} + T_{max})}{2}$, °C), or with

Daily temperature measured at regular intervals during the day (Tavg = ∑n Tobs / n, °C)

The total duration of the growing period is defined as: the growing season starts from the fifth of five consecutive days with daily average temperatures exceeding 5°C (first occurrence in the year); and ends on the fifth of five consecutive days with daily average temperatures below (or equal to) 5°C (first occurrence in the second half of the year). This is represented in orange in the figure below (Figure 1).

However, the length of the temperature growing period (LGPt5) should consider only those days within the total duration of the growing period when T_{avg} is above 5°C. Therefore, the LGPt5 ANC criteria to be calculated correspond to the period indicated in purple in Figure 1.

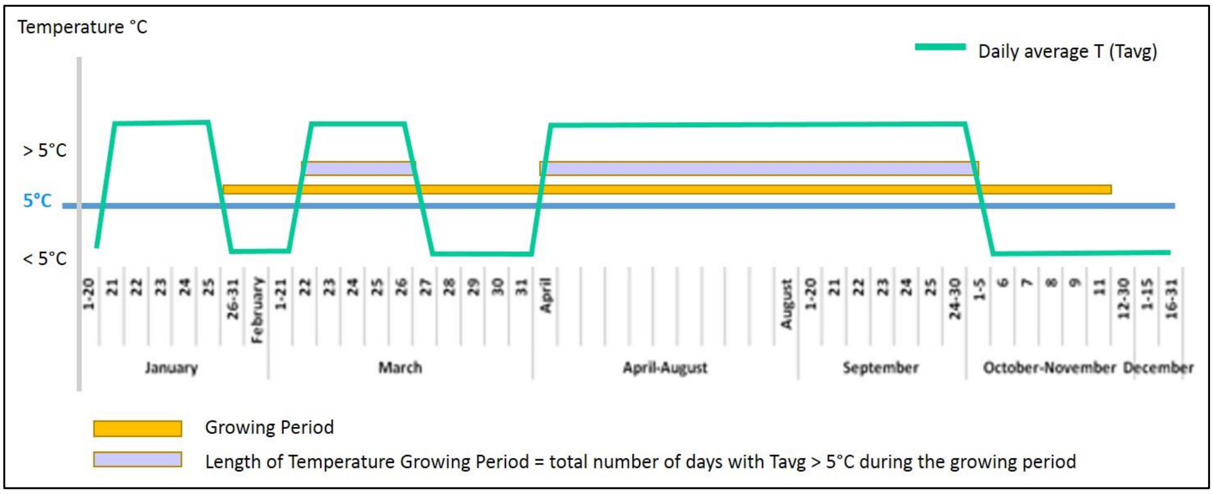


Figure 1: Illustrative example of the calculation of the Length of the Temperature Growing Period ($LGPt_5$).

The calculated values of LGP_{t5} and TS_5 are compared to the reference thresholds of EU Regulation 1305/2013 – Annex III.

Finally, the number of individual years with limiting conditions is counted. If limiting conditions occur in more than 20% of the years of the whole time series, the land is classified as being constrained with regard to this criterion.

If the temperature data used comes from meteorological stations, it is suggested to interpolate the daily temperature first and then to calculate the required indicators (TS_5, LGP_{t5}) for the resulting layers for each year. The following workflow is suggested:

i. To interpolate the daily average temperature data from stations for each year (the output is a series of 'daily' layers for each year), choosing an appropriate grid size according to the number and distribution of the meteorological stations, and taking into account the relevant characteristics of the studied area (e.g. mountain or plain area). It is advisable to test the interpolation method before full data processing. Some methods (e.g. co-kriging) take advantage of the covariance between two or more regionalized variables that are related as e.g. temperature and elevation. These methods may lead to better results especially if the main parameter (e.g. meteorological measurements) is scarce, while high resolution spatial data is available for the secondary parameter (elevation, distance to sea, physical barriers as mountains etc.).

ii. To test the accuracy of the interpolated surfaces (e.g. cross-validation). It is recommended to use several indicators to estimate the robustness and reliability of the interpolation method.

iii. When the interpolated surfaces are acceptable, the requested indicators, i.e. TS_5 and/or $LGPt_5$, should be calculated.

iv. The number of years during which the threshold is passed should be computed; for example by reclassifying each of the output layers of step iii. into binary [1/0] layers according to the threshold for the criterion (assign the value of 1 to TS_5 values ≤ 1 500 or to $LGPt_5$ values ≤ 180, and assign 0 to TS_5 values > 1 500 or $LGPt_5$ > 180), and then summing all of the output binary rasters. The output is a raster with the number of years during which the threshold has been passed.

v. The low temperature threshold must be passed in more than 20% of the years (e.g. at least in seven years out of 30) for the areas to be classified as being subject to natural constraints. From the output of step iv, the final layer for the areas subject to constraints can be obtained by reclassification, i.e. 1 is assigned to values of the output raster of step iv. (number of years) > 20% of the total number of years, and 0 assigned to its values ≤ 20% of the total number of years. The cells with a value of 1 are classified as areas subject to constraints due to low temperatures.

vi. The process shall be entirely documented, including the type and characteristics of the interpolation methods and the final map of the 'Low temperature' criteria.

4.2 Criterion: Dryness

Definition

Overly dry conditions are defined as the result of a permanent imbalance in water availability due to low precipitation and high evaporative water demand, resulting in overall low moisture and low carrying capacity of the ecosystems (Pereira, 2009).

Threshold

Severely limiting dryness conditions are established when the ratio of precipitation to potential evapotranspiration is less than or equal to 0.5 (i.e. P / ETP ≤ 0.5).

Assessment

The calculation needs to be carried out with the annual totals of precipitation (P, mm) and of potential evapotranspiration (PET, mm). Both quantities should be expressed in the same units (e.g. mm). The calculation should be made for each year of the available data time series.

The potential evapotranspiration (PET, mm) should be calculated using the Penman-Monteith formula in relation to a living grass reference crop (Allen et al., 1998).

To assess dryness, a time series of meteorological data is required to assess the probability of exceedance of the threshold at one location.

$AI_{UNEP} = P/PET,$

where AI stands for Aridity Index, *P* is the total annual precipitation and *PET* is the total annual potential evapotranspiration.

In order to account for interannual variability, the dryness index is classified as having a natural constraint in a probabilistic approach, i.e. if the probability of exceeding the threshold (dryness index value is less than or equal to 0.5) in an area is higher than 20%, then the area is considered to be affected by too dry conditions.

If data are provided by meteorological stations, it is recommended:

i. To interpolate annual precipitation data for each year (if there are data for 30 years, the output is a series of 30 layers), choosing an appropriate grid size according to the number and distribution of the meteorological stations, and taking into account the relevant characteristics of the studied area (e.g. mountain or plain area). For precipitation, the Inverse Distance Weighted (IDW) method should be discarded. Some methods (e.g. co-kriging) take advantage of the covariance between two or more regionalized variables that are related. These methods may lead to better results especially if the main parameter (e.g. meteorological measurements) is scarce, while high resolution spatial data is available for the secondary parameter.

ii. To test the accuracy of the interpolated surfaces (e.g. cross-validation). It is recommended to use several indicators to estimate the robustness and reliability of the interpolation method.

iii. To interpolate total annual PET data for each year (similar recommendations to precipitation, except for the IDW method which could be used). Precipitation and potential evapotranspiration should be interpolated separately because they are physical phenomena with different types of behaviour and spatial patterns.

iv. To test the accuracy of the interpolated PET surfaces similarly as in step ii.

When both precipitation- and PET-interpolated surfaces are acceptable, AI =P/PET can be calculated from the outputs of steps i and iii (if data is available for 30 years, 2 x 30 layers are used, and the result will be 30 layers).

v. The number of years during which the threshold is fulfilled is computed; for example by reclassifying each of the output layers of step iv into binary [1/0] layers according to the threshold for dryness criterion (assign the value of 1 to AI values ≤ 0.5, and assign 0 to AI values > 0.5), and then summing all of the output binary rasters. The output is a raster with the number of years during which the threshold is fulfilled.

vi. The dryness threshold must be fulfilled in more than 20% of the years for areas to be classified as being subject to the aridity constraint. From the output of step v, the final layer with the areas subject to dryness can be obtained by assigning 1 to values of the output raster of step v with number of years > 20%, and by assigning 0 to values ≤ 20%. The cells with a value of 1 are those areas subject to constraints due to dryness.

vii. The entire documentation of the process should be provided, including the type and characteristics of the interpolation methods and the final map with the 'Aridity' criteria.

4.3 Criterion: Limited Soil Drainage

Definition

Poor drainage reduces the space available for the gaseous phase activities, in particular gaseous oxygen, in the rooting zone. It increases the incidence and severity of soil-borne pathogens and can make it impossible to till the soil. An additional major effect of water-saturated soil on agriculture is that it can make the land inaccessible.

Threshold

The thresholds identify land areas that are waterlogged for significant periods during the normal growing season and that thus affect normal farming operations, crop yields or livestock husbandry management.

Soil is said to have limited drainage if it is classified as being:

- wet within 80cm (from the surface) for over 6 months, or wet within 40cm for over 11 months; or
- poorly drained (soils are commonly wet for considerable periods - ground water table commonly within 40cm from the surface, or classified as very poorly drained (wet at shallow depths for long periods - ground water table is commonly within 15cm from the surface; or
- soil with *gleyic colour pattern* within 40cm from the surface;

Assessment

Soil drainage characteristics can often be inferred from their name in the soil type classification system. Moreover, certain soil properties are also directly related to poor drainage. These are the more common approaches for assessing excess soil moisture related to drainage.

Soil morphology is commonly used to assess drainage status. Soils have observable morphological features which provide information on their general hydrodynamic behaviour. However, the use of hydromorphic features can be misleading, as colour and mottling are not always indicative of the water status of the soil, and it is not always possible to establish clear quantitative limits (which are based on expert judgement, the influence of the local and meteorological conditions at the moment of observation, etc.).

Most map classification systems and soil maps include criteria related to water regimes such as average, maximum or minimum values for (i) depth to saturated layers, (ii) length of time of saturation and / or (iii) depth or occurrence of oxydo-reduction mottles.

For example, the World Reference Base for Soil Resources - WRB (FAO-IUSS-ISRIC, 2006) - defines soil properties that are directly related to poor drainage, namely *gleyic* and *stagnic* features. These features define soil reference groups, such as Gleysols and Stagnosols. Other reference groups which are associated with poor internal drainage are, for example, (i) Solonchaks in low-lying areas with a shallow saline water table, (ii) Solonetz soils in flat lands with impeded vertical and lateral drainage, and (iii) Histosols with a shallow water table. However, there is not always a direct relationship between a taxonomic class (e.g. Gleysols) and actual drainage conditions. The WRB therefore gives only a broad indication of the soil characteristics, and the soil units identified by reference groups for the limited drainage often need to be confirmed by soil profile measurement datasets (Erdogan and Toth, 2014).

In other soil databases, the annual average soil water regime is an estimate of the soil moisture conditions throughout the year. It is based on time series of matrix suction profiles, or groundwater table depths, or soil morphological attributes, or a combination of these characteristics.

The annual soil water regime is expressed in terms of the duration of the state of soil wetness during the year. A soil is wet when it is saturated and has a matrix suction of less than 10 cm, or a matrix potential over -1 kPa. Time is counted in cumulative days and not as successive days of wet conditions. “Wet” means waterlogged.

The terminology ‘Poorly’ or ‘Very poorly drained’ refer to soil moisture conditions defined in the Soil Survey Division Staff (1993) document - see box below:

Definition of drainage classes from Soil Survey Division Staff (1993):

Poorly drained: Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season, or remains wet for long periods. The occurrence of internal free water is shallow or very shallow and common or persistent. Free water is commonly at or near the surface long enough during the growing season so that most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below plough-depth. Free water at shallow depth is usually present. This water table is commonly the result of low or very low saturated hydraulic conductivity of nearly continuous rainfall, or of a combination of these.

Very poorly drained: Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. The occurrence of internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly levelled or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients may be greater.

In many areas of Europe with natural drainage problems, soils have been artificially drained. If these drainage systems are operating correctly, the drained soil units should be evaluated as if they were better drained than they would have been without the installed drainage systems. Normally, artificial drainage systems improve the water regime by at least one class.

Member States/regions should identify the drainage/wetness representation in the national/regional dataset that corresponds best to the drainage criteria; it is not compulsory to test all three thresholds.

As an alternative, drainage conditions can also be assessed through a soil moisture balance calculation as the number of days during which the soil moisture content is at or above field capacity. This implies the use of soil hydraulic properties and weather data, and requires more parameters and more complex processes to be accounted for by the model. See the criterion on excess soil moisture (next section).

4.4 Criterion: Excess soil moisture

Definition

Excess soil moisture is the condition reached when the water content in the soil exceeds field capacity. For the purpose of the delimitation of ANC, the criterion is defined as the duration of the period (measured in days) during which soil moisture is at or above field capacity.

The 'field capacity' is defined as the maximum amount of water that a soil can retain solely under the force of gravity, and is effectively the condition of 'zero soil moisture deficit'.

Therefore, the calculation of the excess soil moisture criterion integrates soil criteria (such as texture, which relates to water retention, and rooting depth, which relates to the volume of the soil reservoir) and climate criteria (precipitation, potential evapotranspiration).

Threshold

Excess soil moisture is said to be severely limiting when the number of days with soil moisture content at or above field capacity is greater than or equal to 230 days.

Assessment

Soil moisture conditions are dependent on both weather conditions (rainfall, potential evapotranspiration) and soil hydraulic properties (water storable in the soil profile, maximum infiltration rate and hydraulic conductivity).

Consequently, the soil water-saturated period is derived from a soil moisture balance calculation with a daily time step, calculating soil moisture status from the cumulative balance of precipitation and soil water removal through evapotranspiration and percolation, taking into account antecedent soil moisture conditions.

The properties required to calculate the water content in the soil profile are:

- Amount or deficit of water held at saturation (SAT),
- Amount or deficit of water held at field capacity (FC),
- Amount or deficit of water held at permanent wilting point (WP).

Percolation occurs when the soil moisture content exceeds FC. The rate of percolation depends on the amount of water in excess of field capacity. The travel time of percolating water through the soil matrix is regulated by the hydraulic conductivity. This conductivity varies from near zero when the soil is at field capacity to a maximum value when the soil is at saturation. In the presence of a high water table, no percolation may occur, resulting in longer periods of soil water conditions above field capacity. It is generally accepted that any extra water added when the soil moisture level is at saturation point will be lost through run-off.

The potential evapotranspiration (PET) should be calculated using the Penman-Monteith methodology in relation to a living grass reference crop (Allen et al., 1998). Also see section 4.2 on interpolation.

If soil water retention properties have not been measured (from undisturbed cores) for an area of interest, they may be estimated from pedotransfer functions that relate water retention at saturation, field capacity and wilting point to other soil properties such as particle-size distribution, organic carbon and bulk density (e.g. Hall et al., 1977, for soils from England and Wales; Wösten et al., 1999, for European soils; Scheinost et al., 1997, for soils in Germany; Wösten et al., 2001, for a conceptual description).

The duration of the soil-saturated period will be the number of days during which soil moisture content is at or above field capacity, approximating the water content in the soil as either a water excess or a water deficit with regard to field capacity.

The start of the period during which soil moisture content is above field capacity (surplus) can be defined when five consecutive days fulfil the condition (during the second part of the year – after summer). Conversely, the end of the period will occur when soil moisture content is below field capacity (deficit) for at least five consecutive days (during the first part of the year – before summer).

A time series of daily meteorological data is required to assess the probability of exceedance: an area is classified as being constrained by 'Excessive soil moisture' if the probability of exceeding the threshold is higher than 20% of the number of years in the time series.

4.5 Criterion: Unfavourable Soil Texture and Stoniness

Definition

The texture of a soil refers to the relative proportions of different-sized soil particles in the bulk soil. It is more correctly called particle-size distribution. Conventionally, it is divided into two parts: coarse fragments, which are larger than 2 mm in diameter, and fine soil, which is smaller than 2 mm in diameter.

Threshold

Soil texture or stoniness is said to be a limiting constraint if any of the following conditions are met:

- coarse fragments (> 2 mm) of any kind make up more than 15% volume in the topsoil[6], including any proportion of rock outcrops, boulders, or
- texture class in half or more (cumulatively) of the soil within 100 cm of the surface is sand or loamy sand [defined as silt% + (2x clay%) ≤ 30%];
- the topsoil texture class is heavy clay (≥ 60% clay); or
- organic soil[7] defined as organic matter (≥30%) extends either 40 cm or more from the soil surface or taken cumulatively within the upper 100 cm of the soil; or

[6] The topsoil is the ploughed layer (designated Ap by the FAO soil description guidelines). It is defined as the upper part of a natural soil that is generally dark coloured and has a higher content of organic matter and nutrients than the (mineral) horizons below, excluding the humus layer. This definition is based on ISO 11074 (Jones et al., 2008). For arable land, it refers to the tilled soil depth (i.e. 25-30 cm), and for grassland, to the soil layer with high root content.

[7] Organic soils are very fragile ecosystems that can be drastically affected by improper management (mineralisation of organic matter). Moreover, they act as organic carbon pools and play an important role in carbon sequestration; therefore they should be properly treated, and preferably left in their natural condition.

- the topsoil contains 30% or more clay and there is a soil layer with *vertic* properties within 100 cm of the soil surface.

Assessment

Coarse fragments (> 2 mm) are described by their abundance (volume %), size, shape, state of weathering, and nature.

Fine earth (< 2 mm) is defined by the relative proportion (by weight) of sand, silt and clay as determined in the laboratory; the upper limits used here correspond to the FAO norms (FAO, 2006) and are 2 000, 63 and 2 micrometres, respectively. National systems may use different limits, but it is necessary to harmonise data using either transfer functions or soil profile datasets with measurements of particle size.

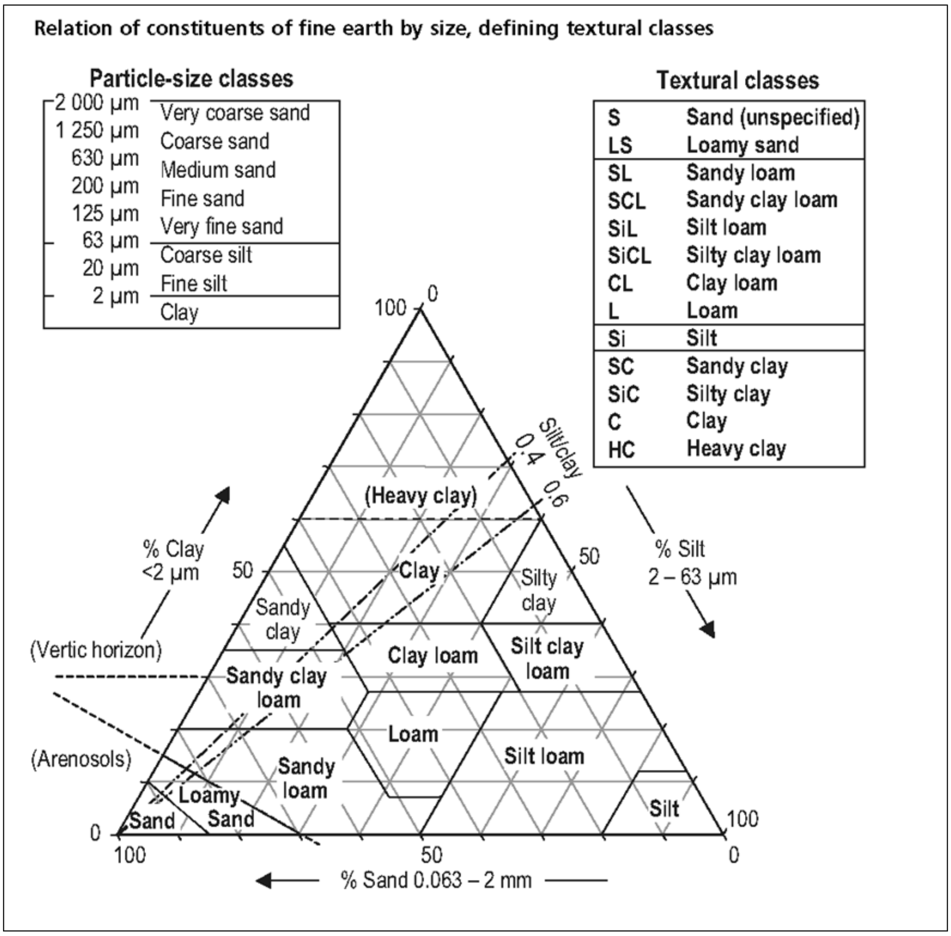


Figure 2: Texture classes are defined according to the FAO texture triangle (FAO, 2006)

Vertic properties, as defined by the WRB (FAO-IUSS-ISRIC, 2006)[8], have either:

- More than 30% clay throughout a thickness of at least 15 cm, and one or both of the following characteristics:
  - slickensides or wedge-shaped aggregates;
  - cracks ≥ 1-cm wide that open and close periodically;

or

[8] In the latest release of the WRB (IUSS Working Group WRB, 2014), this is defined as the Protovertic horizon

- a coefficient of linear expansion (COLE) of 0.06 or more, averaged over a depth of 100 cm from the soil surface.

Organic soil: The soil reference group Histosols of the WRB (FAO-IUSS-ISRIC, 2006) can generally be used as a proxy for the mapping of organic soils, although there are some differences in the definition. According to the definition used for delimiting ANC, Histosols with at least 20% organic carbon content (30% organic matter content) would qualify.

Not all soil classification are using the same textural class system and therefore it is proposed to use the most appropriate class, taking care not to pass the threshold indicated in the regulation (conservative approach) or to perform a reclassification, if possible.

If this is applied, it is recommended to verify the accuracy of the reclassification by cross-analysing the derived information with an independent analytical dataset representative for the given area (soil profile data, laboratory measurements) containing the parameter to be mapped. Possibly, this should be done using quantitative statistical analysis; this quantitative analysis can then be the basis to establish a correction factor for the calculation of the share of the SMU fulfilling the threshold.

4.6 Criterion: Shallow Rooting Depth

Definition

Rooting depth is the maximum depth from the soil surface to where most of the plant roots can extend. It is defined as the effective soil depth above any barrier to root extension.

Threshold

A soil is said to have limited physical rooting depth when the effective soil depth above any barrier to root extension is less than 30 cm.

Assessment

During routine field surveys, rooting depth is typically assessed using an auger. The observed depths are then interpolated with reference to the landscape structure to produce rooting depth estimates of land areas or mapped units.

If the soil classification system has classes with boundary values different from the 30cm threshold, then it may be necessary to perform a reclassification and applied a correction factor established with independent analytical dataset representative for the given area (soil profile data); similarly as described earlier.

4.7 Criterion: Poor Chemical Properties

Salinity

Definition

Salinity is the presence of soluble salt in the land surface, in soil or rocks, or dissolved in water. It can be a natural process that has been accelerated by human intervention that disturbs natural ecosystems. Soil salinity refers to the total amount of soluble salt in the soil.

Threshold

Salinity tolerance is influenced by plant physiology, soil and environmental factors and their interactions. Although crop response to soil salinity is crop specific, levels above 4 dS/m in topsoil severely affect many plants.

Assessment

Soil salinity is determined by measuring the electrical conductivity of a solution extracted from a water-saturated soil paste.

Soil names in the WRB that can be used for indicating severe salinity constraints of natural saline soils are Solonchaks and *salic* and *petrosalic* soils.

Sodicity

Definition

Sodicity refers to the presence of a high proportion of adsorbed sodium in the clay fraction of soils. Sodic soils are normally characterised by a dense, strongly structured, clay illuviation horizon that has a high proportion of adsorbed sodium ions. In the context of areas with natural constraints for agriculture in Europe, soil sodicity is a characteristic of land for which the proportion of adsorbed sodium in the soil clay fraction is too high for plants to perform or survive.

Threshold

The effect of Exchangeable Sodium Percentage (ESP) on the yield, chemical composition, protein and oil content and uptake of nutrients is severe when soil sodicity is at ESP ≥ 6 in the topsoil.

Assessment

Sodicity is determined by measuring the exchangeable sodium proportion of the cation exchange capacity, or by comparing the soluble Calcium and Magnesium in a soil solution (SAR – Sodium Adsorption Ratio).

According to the WRB classification, soils that have a high content of exchangeable Na are Solonetz, *natric* soils, or *sodic* soils, which can be used for indicating a severe sodicity constraint.

Soil acidity

Definition

Soil acidity is indicated by soil pH and is measured in pH units. The soil pH is defined as the negative decimal logarithmic value of the hydrogen ion activity (expressed in mol dm-3) in aqueous solutions. As the amount of hydrogen ions in the soil increases the soil pH decreases thus becoming more acidic. A neutral condition corresponds to pH = 7, above this value soils are considered to be alkaline.

Threshold

Severely acidic conditions occur when pH values are less than or equal to 5.0, impeding normal crop growth.

Assessment

Although the international standard (ISO 10390) permits the use of either water, or 0.01 mol dm-3 CaCl2 or 1 mol dm-3 KCl solutions for the measurement of pH. The computation of the pH criterion shall be made on pH values measured in 1:5 soil:water suspension (referred to as $pH_{1:5}\_H_2O$). The harmonization of the measurement method is important because there can be a difference of 1 or more pH units between measurements made using water or CaCl2 solutions.

4.8 Criterion: Slope

Definition

The slope is the angle between the soil surface and the horizontal. It can be expressed in degrees or as a percentage (45 degrees = 100%). Steep-slope farming requires specific / adapted equipment.

Threshold

Slopes greater than 15% pose severe problems for mechanised cultivation.

Assessment

The slope can be calculated from a DEM relatively simply. GIS software provide simple and straightforward tools for this. For example the maximum change in elevation over the distance between the cell and its 8 neighbours is a simple and straightforward method that can be applied.

5. Calculating the Share of Constrained Agricultural Area

5.1 Spatial data processing workflow

The assessment aims to identify areas currently under agricultural use that have natural constraints (regarding soil, climate, terrain). It is therefore important to exclude zones that are not under agricultural land use, so as to avoid overestimation of constrained areas. The application should estimate the percentage of agricultural area severely affected by one or more of the eight common criteria. The agricultural area is that area taken up by arable land, permanent grassland, permanent pasture or permanent crops, as defined in Article 4 of Regulation EU 1307/2013.

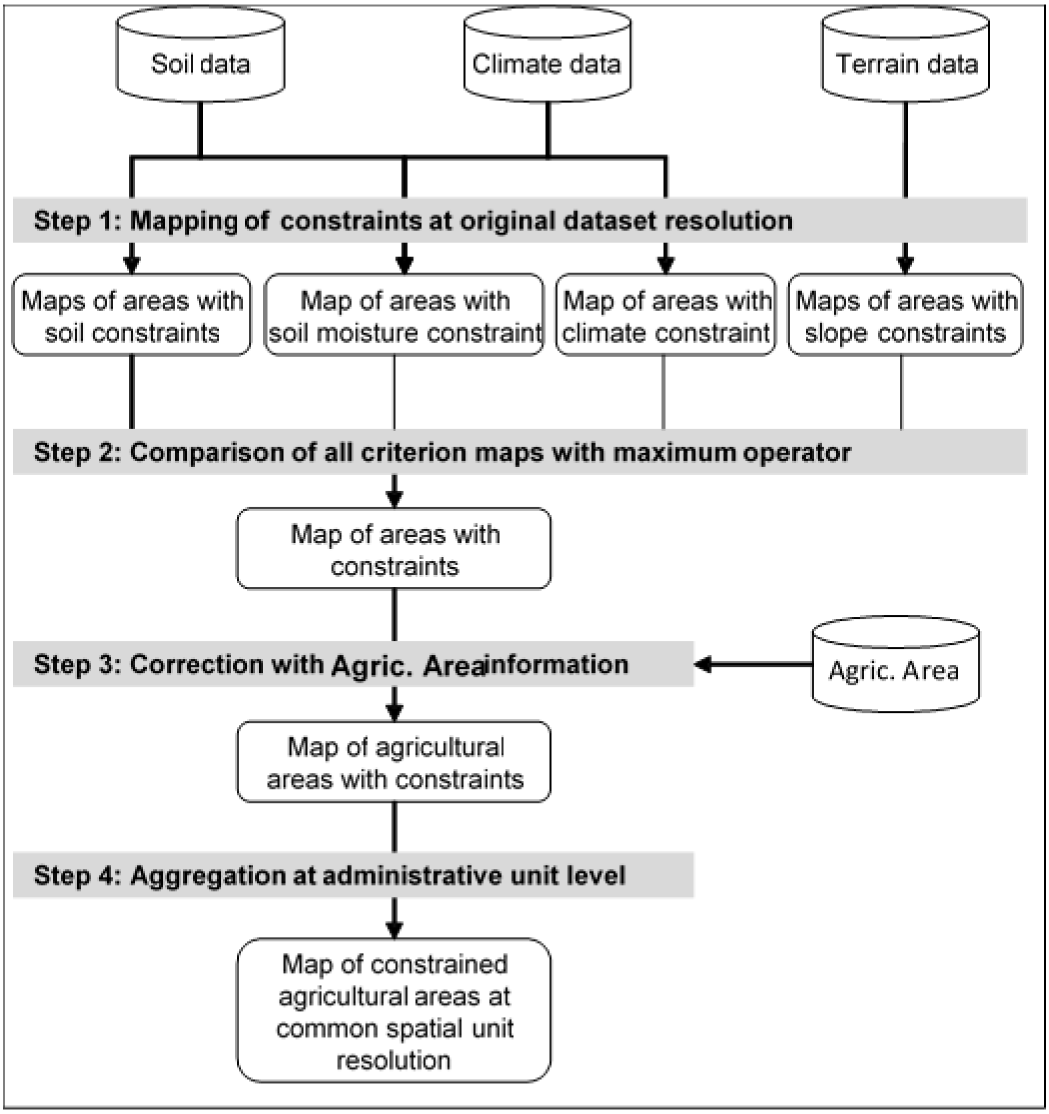


Figure 3: Workflow of the mapping of areas with natural constraints for agriculture

The data processing steps to be taken to derive the final map of agricultural areas constrained by biophysical criteria can be broken down into four main steps, as illustrated in Figure **3**. This is an example of a possible workflow, which depends on data format and sources in the Member States. The terms mapping and map are used in a general sense and refer to spatial analysis and spatial data layers.

Step 1: Mapping of the constraints at original dataset resolution

A map of constrained areas is derived for each criterion. The resolution of the map is chosen according to the original resolution of the datasets used to draw the map. Depending on the datasets available for processing, the information deduced could be expressed in a binary fashion (the calculation unit is either constrained or not) or using shares (percentage of the area of the calculation unit is constrained, or the calculation unit is constrained with a probability of x%).

Step 2: Comparison of the maximum operator of all criterion maps at the highest spatial resolution

A comparison of the individual criterion maps is performed. This comparison should be made at the highest resolution available for the different maps. Where there is resolution heterogeneity, maps at coarser resolution should be downscaled or disaggregated to finer levels of resolution. For each calculation unit[9], the outcome of this comparison is the value of the most limiting criterion (i.e. the highest % of constraint).

Step 3: Correction with agricultural area information

In order to avoid any spatial overestimation of areas constrained with regard to agriculture, it is necessary to exclude from the analysis those areas that are not under agricultural land use. Therefore, a mask of non-agricultural areas (or a correction of the share of constrained areas using information on agricultural areas) is applied to the map obtained in step 2. As a result, only areas subject to biophysical constraints on agricultural areas are retained. Depending on the dataset used, this masking / correction could be applied to each individual criterion map before step 2 is carried out.

Step 4: Aggregation at administrative unit level

The share of constrained agricultural area per unit obtained in step 3 is aggregated to administrative units.

5.2 Examples of soil information processing

5.2.1 Soil map with one soil type per mapping unit

The figure below gives an example of the workflow for mapping soil constraints where soil information is available in soil units which are defined by only one soil type (which is often the case with detailed soil maps). The processing steps are the same as those described in the general workflow.

[9] Common spatial unit for the comparison of the different data layers.

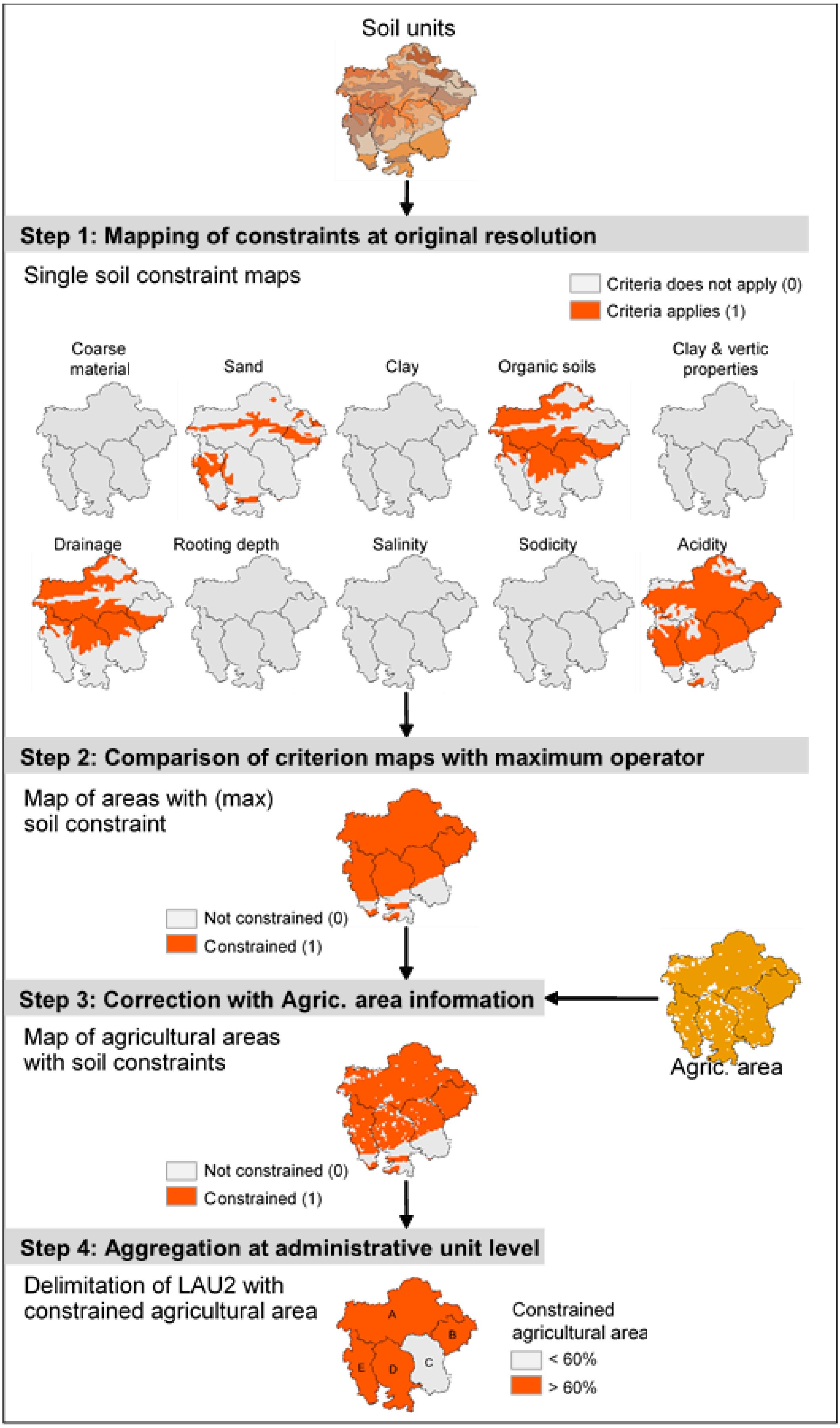


Figure 4: Example workflow for mapping soil constraints from soil units (defined by one soil type).

5.2.2 Soil map using Soil Association concept

When soil association maps are used, it is suggested that all soil types within the soil association (soil mapping unit) be considered, and not only the dominant soil type. This would allow for the calculation of the share of constrained area in each soil mapping unit, taking into account all its constituent soil types and all its soil constraints.

Calculation of share of constrained agricultural area using soil association maps

In order to illustrate the procedure, reference is made to the structure of a Soil Association Composition database.

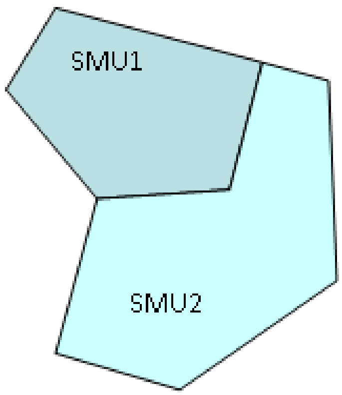
The Soil Association Composition Database is a digital soil map consisting of geometric and semantic datasets:

- Soil Mapping Units (SMUs), represented at least by one polygon;
- Soil Typological Units (STUs), which characterise distinct soil types that are described by attributes specifying the nature and properties of soils (texture, water regime, etc.).

The Soil Association type database does not provide a spatial representation of the STUs. STUs are grouped into SMUs to form soil associations and illustrate the functioning of pedological systems within landscapes.

Soil databases of some Member States may follow a similar concept and therefore show a similar structure, ideally at a more detailed mapping scale.

The procedure to calculate the share of agricultural areas that are severely constrained according to the biophysical criteria first considers the properties of the STUs on which the criteria and thresholds are applied. As mentioned above, STUs do not have a cartographic representation but they can be linked to the SMUs. The share of each STU per SMU as found in the soil database allows for the definition of the amount of constrained area for each criterion in each SMU. The procedure is illustrated in the figure below using a hypothetical example with two SMUs, each made up of three STUs.



SMU1	STU1	STU2	STU3	SMU1
Is constrained for criteria a	x			
Share in SMU	10%	50%	40%	
Constrained	10%			10%

SMU2	STU4	STU5	STU6	SMU2
Is constrained for criteria a	x	x		
Share in SMU	10%	65%	25%	
Constrained	10%	65%		75%

Figure 5: Schematic representation of the SMU / STU structure, showing how each SMU's level of constraint is calculated.

Areas which are not under agricultural use should be excluded from the next step to avoid spatially overestimating the agricultural areas constrained by the ANC biophysical criteria. This is illustrated in the figure below using the same hypothetical example.

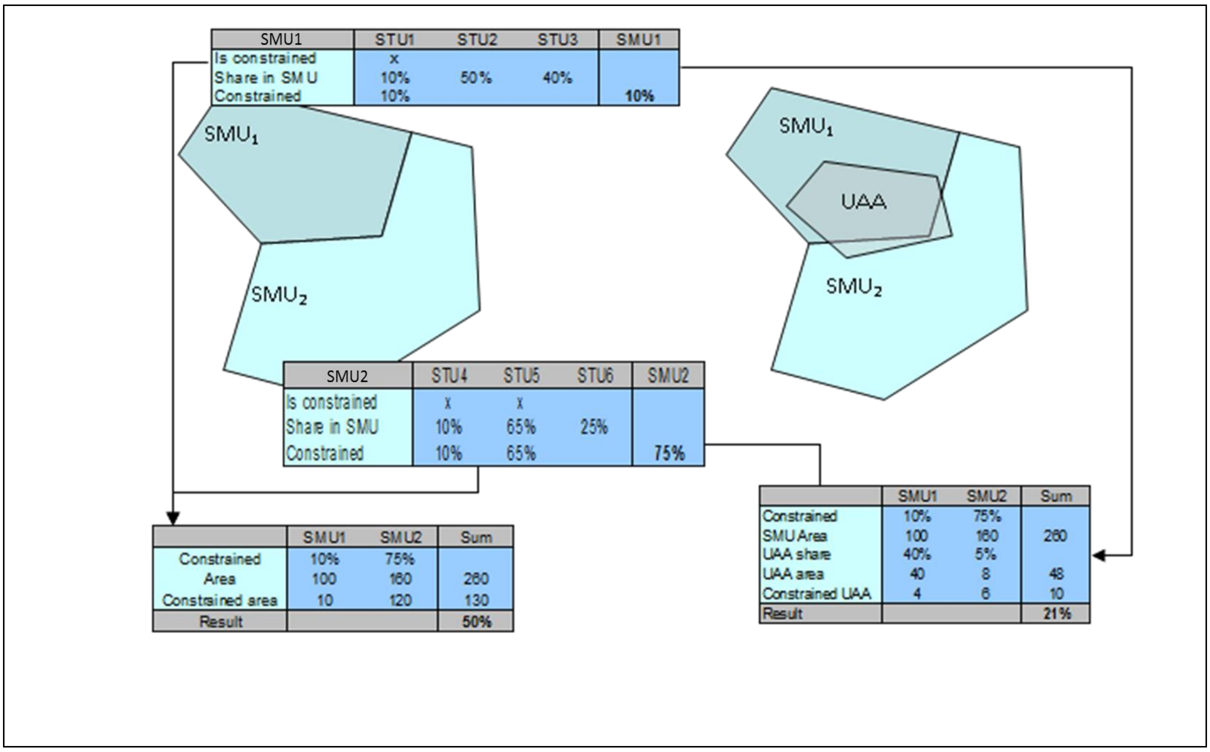


Figure 6: Illustrative example of how to calculate the constrained area of an SMU, incorporating information on the Agricultural Area.

On the left-hand side, SMU_1 includes one constrained STU, which covers 10% of the SMU_1 area, whereas SMU_2 includes two constrained STUs that account for 75% of the SMU_2 area. Summarising the two SMUs based on their area alone, without considering the Agricultural Area, gives the results in the table in the lower left corner, which estimate that a share of 50% of the area is constrained.

In the table on the right-hand side, the agricultural part of the area is considered by adding information about the location of the Agricultural Area. In the example, the Agricultural Area is mostly found in the SMU that is most favourable for agriculture (SMU_1), in which it covers 40% of the area. Assuming that SMU_1 is 100 ha, 10% of which is constrained, the constrained Agricultural Area of SMU_1 is 4 ha. Although SMU_2 is larger, only 5% is Agricultural Area. Given its size of 160 ha and the fact that 75% is constrained, the constrained Agricultural Area of SMU_2 is 6 ha. Summing up, the total constrained Agricultural Area is 10 ha out of the 48 ha total Agricultural Area (i.e. only 21% of Agricultural Area is constrained).

6. Aggregation procedure, diagnostic at administrative-unit level

6.1 For areas (other than mountain areas) facing significant natural constraints

Step 1*:* Every criterion present in the administrative unit should be mapped and overlaid with the agricultural area.

Step 2: The agricultural area that is constrained should be quantified; where two or more biophysical criteria apply to the same piece of agricultural land, they should only be counted once.

Step 3: If 60% or more of the total agricultural area of the administrative unit is constrained by the biophysical criteria, this administrative unit is classified as being affected by natural constraints (before the fine-tuning process).

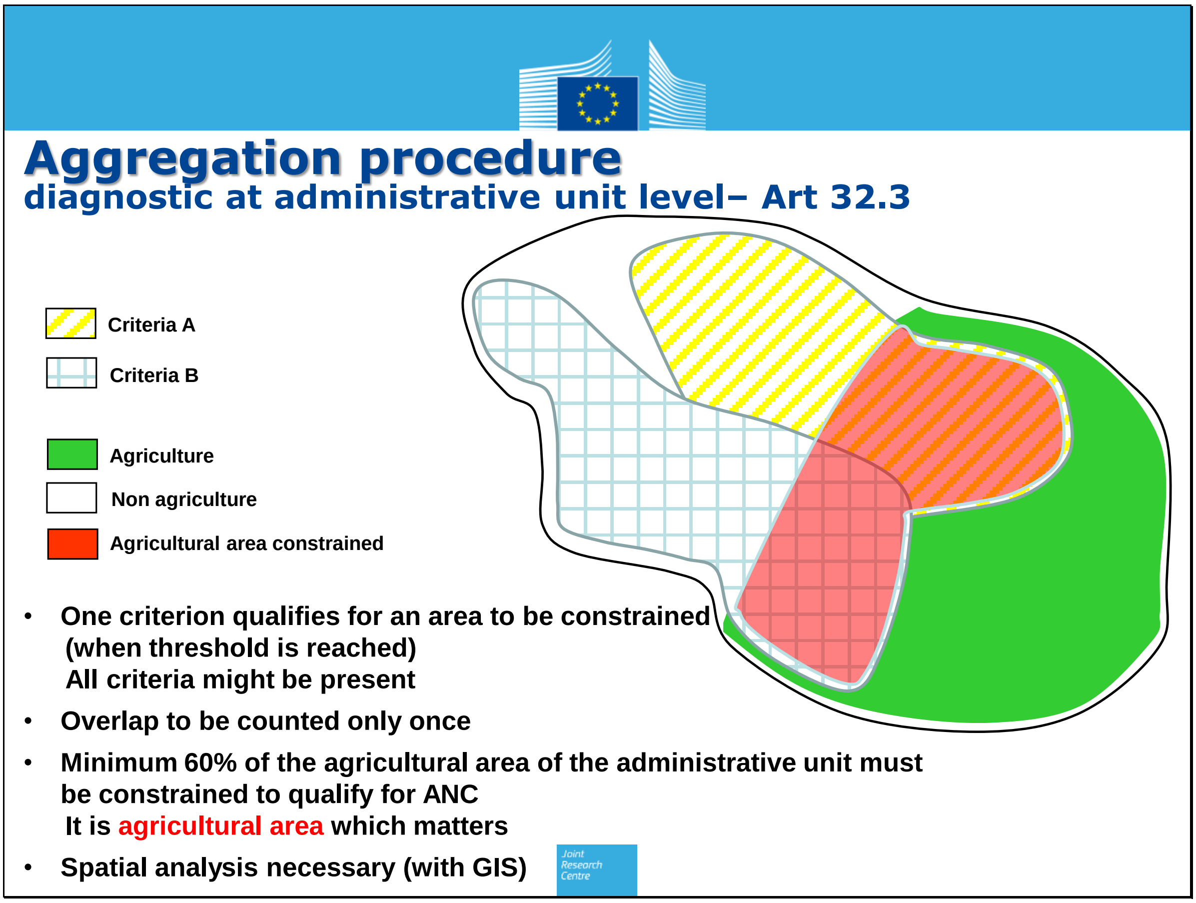


Figure 7: Spatial representation of the methodological guidelines for diagnosing an administrative unit as an ANC

6.2 For other areas affected by specific constraints

Step 1: Every criterion present in the administrative unit should be mapped and overlaid with the agricultural area.

Step 2*:* The agricultural area that is constrained should be quantified; when two or more biophysical criteria apply to the same piece of agricultural land, they should be counted only once.

Where there are at least two ANC criteria, each within a margin of not more than 20% of the threshold value, that are spatially overlapping, the constrained area to be considered is the spatial intersection between the two criteria and the Agricultural Area.

The Joint Research Centre, as the scientific body of the European Commission, has produced a guidance report (Terres et al., 2014) with recommendations on how to delineate 'Areas with Specific Constraints'. It is suggested that these recommendations be followed with regard to possible interactions and synergies when combining criteria.

Step 3*:* If 60% or more of the total agricultural area of the administrative unit is constrained by the biophysical criteria, then this administrative unit is affected by natural constraints (before the fine-tuning process).

This could take into account areas composed of ANC criteria at the threshold value indicated in Annex III of regulation 1305/2013 and combined ANC criteria, each within a margin of no more than 20% of the threshold value, if possible following the methodological framework described in the JRC guidance report (Terres et al., 2014).

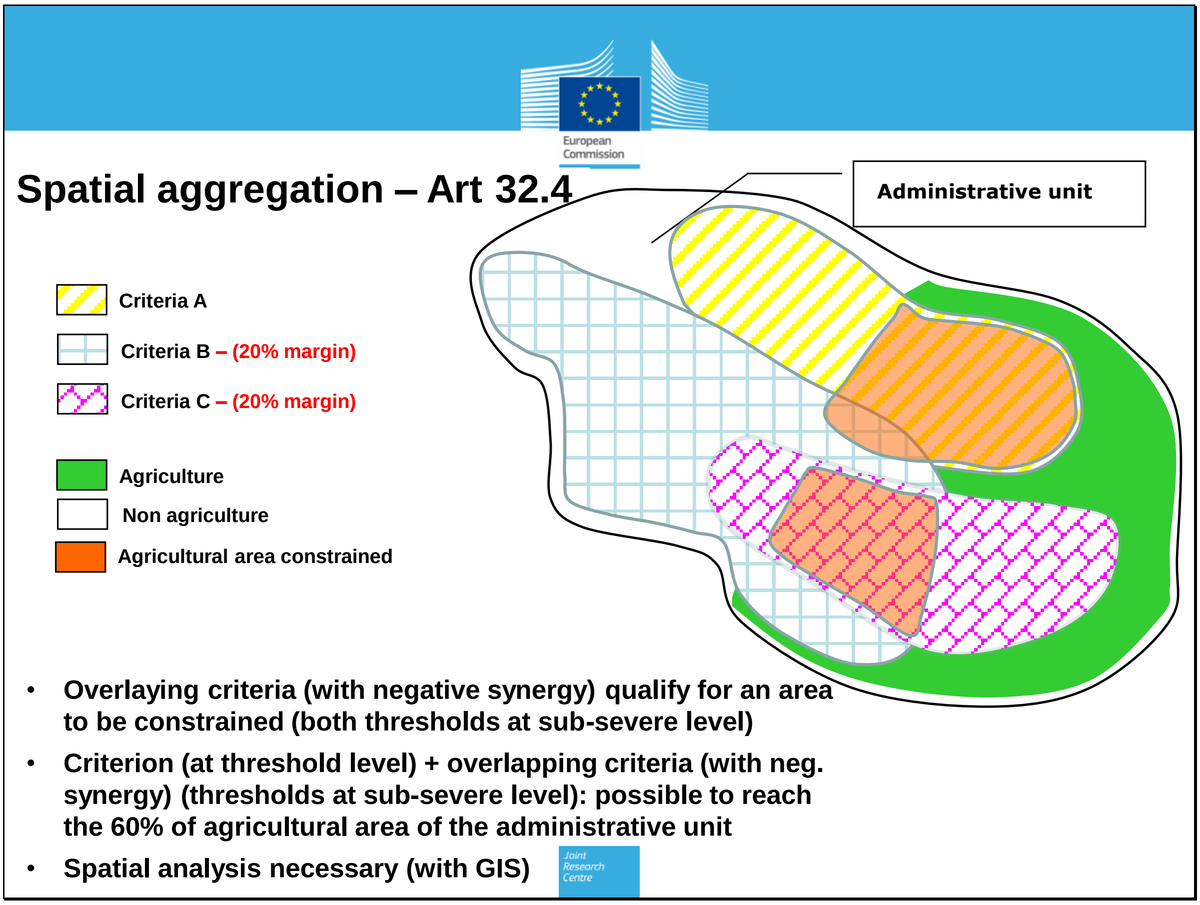


Figure 8: Spatial representation of the methodological guidelines for an administrative unit classified as an ANC (specific constraints)

Annex: Requested information on data and methodology for the use of biophysical criteria for delimitation of Areas with Natural Constraints

This section describes the minimum set of information and data that should be provided to the European Commission in the technical document describing the methodology used by the Member State to calculate the ANC criteria and to produce all intermediary and final results.

Information on meteorological datasets (temperature, precipitation, potential evapo-transpiration) and their use

- Number and spatial distribution of meteorological stations used (incl. maps)
- Time span (start date, end date, number of years) and time step (e.g. daily) of the data series used
- Method used for the criteria calculation (e.g. sum of temperature, average temperature, calculation of potential evapo-transpiration)
- If relevant: interpolation method, applied model, uncertainty assessment/validation method
- Description of the methodology used to account for the 20% probability rule related to the minimum number of years when the criterion should be fulfilled

Information on derivation of Excess soil moisture criterion

- Description of the meteorological and soil data used for the derivation of the criterion as described in this annex (in: Information on meteorological and soil datasets and their use)
- Method used for the calculation of the required meteorological and soil variables
- Applied soil water balance model and its general characteristics (time step, input variables,…)
- Model validation method and its results
- Description of the methodology used to account for the 20% probability rule related to the minimum number of years when the criterion should be fulfilled

Information on soil datasets and their use

- Description of the soil information used for the assessment along with the database structure, thematic content, classification and categorisation used. Spatial resolution, scale, date of survey types and spatial density of point (soil profile) data, and data coming from site description and laboratory analysis,
- Methodology to derive the parameters,
- Applied decision rules, thresholds,
- If relevant: interpolation method, applied model, uncertainty assessment/validation method.
- Specifically for criteria:

Unfavourable texture and stoniness:

- If soil texture classes are used for delineation: particle size classification (diameter limits of soil separates) and soil texture classification (definition of the used classes). The correspondence with the FAO standards (see in the Guidelines) and with ANC thresholds have to be demonstrated.
- If soil types are used for delimitation: demonstration of the correspondence with the ANC thresholds (definition or supporting analytical data, etc.) is needed, e.g. for organic soils information on the organic matter content and the depth of the organic soil layer.

Shallow rooting depth:

Definition and/or derivation method of rooting depth, showing the correspondence with the ANC definition (depth (cm) from soil surface to coherent hard rock or hard pan). If soil types are used for delimitation: demonstration of the correspondence with the ANC thresholds (definition or supporting analytical data) is needed.

Chemical properties (salinity, sodicity, acidity):

If soil types are used for delimitation: demonstration of the correspondence with the ANC thresholds (definition or supporting analytical data,) is needed. For *acidity*: pH measurement method: solution used, soil to water (or solution) ratio. If the available data is not in pH1:5_H2O (pH values measured at 1:5 soil to water ratio): recalculation method has to be shown.

For Coarse material, heavy clay, vertic properties, salinity and soil acidity: the definition/depth of topsoil is needed.

Information on terrain datasets and their use

- Characteristics of the applied database/model (DTM/DEM): data source, spatial resolution, grid size, horizontal and vertical accuracy
- Calculation method of slope: details of the calculation method (e.g. eight neighbours considered, mean or maximum slope etc.)

Information on agricultural area data

- Data source for agricultural areas (e.g.: LPIS/IACS)
- Methodology (spatial analysis) used to identify the agricultural areas affected by natural constraints

Information on criteria aggregation at administrative unit level

- Map of administrative units (used for ANC designation) with a unit code or name. The unit code or name needs to correspond with the one given in the result tables.
- Description of the applied aggregation methodology

Provision of intermediate and final results

- Individual maps of each criterion (and sub-criterion when relevant – e.g. unfavourable texture and stoniness has 5 sub-criteria),
- Maps of aggregated criteria with and without overlay of the agricultural area information,
- An overall table with the area (hectares) of agricultural area constrained by each criterion and by aggregated criteria (before and after fine-tuning),
- Final map of administrative units delineated as ANC,
- The exhaustive list of ANC administrative units and the area of agricultural area constrained
- Tables comparing the new ANC delimitation to the old 'LFA - Art19' delimitation such as:

Tables to be filled by Member State administration

Previous (LFA) delimitation [EC 1698(2005)]

	Art. 18	Art. 19	Art. 20	Not LFA
Agricultural area (ha)				

Calculated delimitation with bio-physical criteria (Areas with Natural Constraints) before Fine-tuning

	Art. 19 Agricultural area (ha)	Not Art. 19 (outside Art 18) Agricultural area (ha)	Total Agricultural area (ha)
ANC 'natural constraints other than mountain'			
Not ANC 'natural constraints other than mountain'			
Total			

Table with the ANC designation following regulation EU 1305/2013, Art.32 (after Fine-tuning)

ANC situation in the MS/Region

	ANC 'mountain' Art32.1.a)	ANC 'other than mountain' Art32.1.b)	ANC 'Specific' Art32.1.c)
Total Agricultural area (ha)			

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