Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance Climate Change Mitigation and Soil Health

A typology of farming systems, related soil management and soil degradation in eight European countries

D2.242

Renske Hijbeek, Joost Wolf & Martin van Ittersum with contributions from the CATCH-C research groups

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The CATCH-C project aims at identifying and improving the farm compatibility of sustainable soil management practices for farm productivity, climate-change mitigation, and soil quality. The project is carried out by a consortium of 12 partners, led by Stichting Dienst Landbouwkundig Onderzoek (DLO), The Netherlands.

Email: hein.tenberge@wur.nl
Internet: www.catch-c.eu

Authors of this report and contact details:

Name:	Renske Hijbeek	Partner acronym: WU-PPS
Address:	Group Plant Production Systems Wageningen University PO Box 430 6700 AK Wageningen The Netherlands	
E-mail:	renske.hijbeek@wur.nl	

Name:	Joost Wolf	Partner acronym: WU-PPS
Address:	Group Plant Production Systems Wageningen University PO Box 430 6700 AK Wageningen The Netherlands	
E-mail:	joost.wolf@wur.nl	

Name:	Martin van Ittersum	Partner acronym: WU-PPS
Address:	Group Plant Production Systems Wageningen University PO Box 430 6700 AK Wageningen The Netherlands	
E-mail:	martin.vanittersum@wur.nl	

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Contributions to this report from the CATCH-C Research groups:

The following persons have contributed to the farm type and agri-environmental zone typology:

- Anouk Cormont and Gerard Hazeu (Alterra research institute, Wageningen, The Netherlands)

The following persons have contributed to the interviews on current management and soil degradation problems:

- Hans-Peter Haslmayr and Norman Schlatter (AGES, Austria)
- Tommy D'Hose (ILVO, Belgium)
- Magdalena Werner (UGOE, Germany)
- Janine Krüger (IGZ, Germany)
- Juan Vicente Giráldez and Gema Guzmán (UCO, Spain)
- Ana Pedrera, Karl Vanderlinden and Antonio Gaitán (IFAPA, Spain)
- Nadia Guiffant and Eric Perret (Irstea, France)
- François Johany (INRA, France)
- Carlo Grignani, Laura Zavattaro and Chiara Costamagna (UNITO, Italy)
- Luca Bechini (UMIL, Italy)
- Bert Rijk (WUR, The Netherlands)
- Alina Syp (IUNG-PIB, Poland)

The following persons have written the overviews of the main soil degradation problems in their respective countries:

- P. Strauss, C. Krammer, and E. Murer (Federal Agency for Water management, Petzenkirchen, Austria)
- Tommy D'Hose and Greet Ruysschaert (ILVO, Belgium)
- Nadia Guiffant, Eric Perret and Nadine Turpin (Irstea, France)
- Janine Krüger and Jörg Rühlmann (Leibniz-Institute of Vegetable and Ornamental Crops, Grossbeeren, Germany)
- Luca Bechini, Chiara Costamagna, Carlo Grignani and Laura Zavattaro (University of Milano, University of Torino, Italy)
- Annette Pronk and Hein ten Berge (Plant Research International, Wageningen, The Netherlands)
- Grzegorz Siebielec, Artur Lopatka, Ewa Czyż and Alina Syp (Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy, Poland)
- Gema Guzmán, Tom Vanwalleghem and Juan Vicente Giráldez (UCO, Spain) and Karl Vanderlinden (IFAPA, Spain)

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General information

Task(s) and Activity code(s):	Tasks 2.2, 2.3 and 2.4
Input from:	N.A.
Output to:	Work packages 3, 4 and possibly 5
Related milestones:	MS221, MS231 and MS242

Executive summary

This report compiles the work carried out in Work package 2 (WP2). WP2 has developed an “agri-environment*farm type” typology, by combining soil and climate data (agri-environmental zones, AEZs) with farm specialisation data. The typology was used to select - within each of the eight partner countries - important combinations of farm type and biophysical setting. These are referred to as ‘major FTZs’ or ‘major farm types’, and provided the infrastructure for collecting specific information on Current Management Practices (CMPs) and soil degradation. This report describes, for each of the major FTZs, CMPs and related soil degradation problems. Both aspects were recorded through interviews with extension officers. In addition, this report summarizes the major soil degradation issues at national level, as compiled for each of the partner countries.

Beyond the work described here, the typology is used within the Catch-C project (a) to enable connecting the results from long term experiments (WP3) with geographical target areas; and (b) to carry out surveys of farmer perceptions on soil management in the major FTZ units (WP4).

As the typology covers almost the entire EU27 (with limited coverage only in Kroatia, Slovenia, and Romania), it can serve beyond the Catch-C project in studies that require a farm typology coupled to the biophysical context (climate, soil texture, slope).

The ***objectives*** *of the reported work* were:

• To develop and apply a typology that combines an agri-environmental zonation (AEZ) with information on farm type; the resulting intersections are called FTZ units. The typology is to be developed for the participant (Catch-C) countries;

• To make an inventory of the Current management Practices for the main FTZ Units in the participant countries;

• To make an inventory of the main soil degradation and emission problems for the main FTZ units in the participant countries;

• To record the main soil degradation problems for the FTZ Units in the participant countries, to compile information about the relationships between the soil degradation and management practices, and to list possible remedies.

We have applied the FTZ typology to the participant countries over Europe (***Task 2.2***). This typology has been developed to support the sampling of information about current management (***Task 2.3***) and main soil degradation problems (***Task 2.4***). In following Work Package 3 information on the effects of improved management practices from Long Term

Experiments (LTEs) can be linked to this FTZ typology. In Work Package 4 the FTZ typology can be used as a framework to collect information about farmer's perceptions on soil management.

Task 2.2 Development and application of typology

This task has resulted in the development of a typology for the Catch-C project, with specific attention to the participant countries and with almost complete EU27 coverage. (Limited data were available for Romania, Kroatia and Slovenia). This typology is a combination of the typical farming systems (FT) and the agri-environmental zonation (AEZ) per participant country. The resulting units (intersections of AEZ and FT) are referred to as FTZ units. The agri-environmental zonation is an aggregation of homogenous spatial mapping units (HSMUs) on the basis of slope, soil texture and climate zonation. The farm typology over Europe has been compiled, based on the farm type information over Europe from FADN, by overlaying information on farm specialisation and land use over Europe. Information about farm sizes and farm intensities is also available for all units. The main farm types are next spatially allocated to the HSMUs. This work has resulted in maps of the main agri-environmental zones in the EU27, maps of the major agri-environmental zones in each of the eight participant countries, and in tables and maps of the major farm types in each of the major agri-environmental zones in each of the eight countries.

Based on this compiled information and national expertise, a selection of the major FTZs in each of the eight participant countries was made. Note that this FTZ selection was required, because the labour-intensive inventories on current management can only be done for a limited number of FTZs.

Task 2.3 Inventory of current management practices

Current management practices were recorded for the major FTZs in each of the eight participant countries. For this task, a questionnaire on current management practices and related main soil degradation problems was compiled and tested. Next, the updated questionnaire about current management practices and main soil degradation problems was used by the CATCH-C colleagues to conduct interviews with experts (i.e. agricultural extension officers) for the selected FTZs in their country. Three interviews were conducted for each of the major FTZs selected per country.

The collected information about current management practices in the selected FTZs has been compiled and structured to produce a list of the main current management practices (e.g. crop rotation, crop protection, fertiliser application, land management) for the major FTZs in the participant countries.

Task 2.4 Inventory of the main degradation problems

Major soil degradation problems have been recorded for the selected FTZs in each of the eight participant countries. For this, the same questionnaire as described under Task 2.3, has been used by the CATCH-C colleagues to do interviews with experts for the selected FTZs in their country. Three interviews have been done for each of the FTZs, with 3 to 4 FTZs being selected in total per country.

Apart from these interviews, colleagues in the eight CATCH-C countries have also compiled information from other available sources to produce country reports on soil degradation with (a) a list of the main soil degradation problems, (b) a description of each of the main soil degradation problems and if available, (c) maps of the spatial distribution of the main soil degradation problems (see Appendix D).

Next, the information about soil degradation problems for the selected FTZs in the eight participant countries from both the interviews and the country reports has been analysed. This work has resulted in (a) a list of the main soil degradation problems in the major FTZs in each of the participant countries, and (b) information about the relationships between the main soil degradation problems for the major FTZs in the eight countries and the current management practices.

Main results and conclusions from the study

The main results and conclusions are given in the following about:
(a) FTZ selection procedure;
(b) Current management practices;
(c) Main soil degradation problems;
(d) Linking the main soil degradation problems to current management practices and Possible remedies. Details about this work are given in Sections II, III, IV and V.

FTZ selection procedure

The derived agri-environmental zonation comprises the main variables (i.e. climate, soil texture, and terrain slope) that determine the biophysical characteristics per zone and the related degree of risk for soil degradation under current management practices. Via a procedure adopted from Kempen et al. (2011) we allocated the main farm types to each of the agri-environmental zones in the eight participant countries.

Hence, this zonation is suitable as a basis to do inventories of current management practices and soil degradation problems for major FTZs per country. It can also enable trade-off analyses between the benefits of reduced soil degradation and the costs for improved management. However, note that the more homogeneous landscapes are in terms of soils and climates, the better results can be achieved with agri-environmental zonation.

We are confident, based on the overviews made of the main farm types in each of the agri-environmental zones in the eight participant countries and on the procedure for FTZ selection, that the three selected FTZs per country represent the main agri-environmental zones, main agricultural areas and the main farming systems in the eight CATCH-C countries. The selected FTZs provide the backbone to carry out inventories on farm management and soil degradation problems in these eight countries. The used farm typology is the same for the eight participant countries, which allows comparisons of compiled data (e.g. current management) between the eight countries; it is based on the classes from FADN, being the standard in European policy making.

While the major FTZs selected for further work cover only part of the total farm area per country (maps in Appendix A), we stress here that our numerical database specifies all other FTZ units across Europe, too, with the same level of detail. This information, however, cannot easily be represented in maps because of the small sizes of units, and the limited number of colours that the eye can distinguish on a map. Finally, note that some countries have made their own aggregations of AEZ classes. For example, three slope classes were merged in one particular FTZ in Spain. Such compromises were sometimes necessary to arrive at major FTZs representative for the country.

Current management practices

An overview of current management practices was compiled based on interviews with Agricultural Extension Officers (AEOs) in each of the participant countries. This was done for the major FTZs (see above) per country. Main conclusions from the compiled information on arable farming are : (a) green manures are applied on average on 20% of the total area, (b) conventional tillage is practised on average on 70% of the total area, non-inversion tillage on 30% of the total area, and minimum tillage is hardly applied, (c) animal slurry is applied on the main part (60 to 90%) of the total area in Belgium, Germany and the Netherlands and on a limited part of the total area (<20%) on FTZs in the other CATCH-C countries, and (d) crop residues are incorporated on average in half of the total area.

Main conclusions from the compiled information on livestock farming are: (a) green manures are applied on a small part (i.e. 0 to 20%) of the total area, (b) conventional tillage is practised on average on 85% of the total area, non-inversion tillage on 15% of the total area, and minimum tillage is practically not applied, (c) animal slurry is applied on the main part (>80%) of the total area on FTZs in all CATCH-C countries except for Poland where slurry is applied on less than 20% of the total area, (d) on FTZs in Belgium and Netherlands mainly animal slurry is applied, on FTZs in Austria, France and Italy both animal slurry and farm yard manure are applied, and in Poland mainly farm yard manure is applied.

Differences between FTZs in the occurrence of certain management practices can be explained from differences in farm type and farming intensity and from the cropping system and its biophysical conditions (e.g. minimum tillage is only applied in Spain and probably mainly in the dry and erosion-sensitive areas in southern Spain). However, part of these differences cannot be explained. We may assume that there are regional and national differences in farm structure and land ownership, historic development of agricultural sectors, protection of the environment and landscape, and main recommendations by agricultural extension services. These regional and national differences may cause differences between FTZs in the applied management practices.

Main soil degradation problems

Two approaches have been applied within this study to attain an overview of the main soil degradation problems in the participant countries: CATCH-C colleagues have prepared reports on the main soil degradation problems in their countries, based on documented sources available at national level (Set A; see Appendix D for country reports); and Interviews were held with extension officers, focussing on the selected FTZ units per country (Set B).

The overview (Set A) of the main soil degradation problems for the eight CATCH-C countries gives a number of insights: Water erosion, soil contamination (covering both excessive amounts of nutrients, heavy metals and biocides), sub-soil compaction and decrease in soil organic matter are problems in most countries. Salinization and desertification are mainly of importance in southern Europe (i.e. Spain, Italy). Low soil fertility is a problem in extensively managed areas in Spain. Floods and land slides do occur in the mountainous areas of France and Italy. Soil acidification can be problematic in France and Poland and mainly with soils developed in acidic parent material.

The overview of the main soil degradation problems shows that these problems can be partly explained from current soil management (e.g. sub-soil compaction due to the use of heavy machinery; decrease in soil organic matter due to short crop rotations with more root crops), but often too from unmanageable factors like climate (e.g. salinization and desertification in southern Europe), landscape (e.g. floods and land slides in hilly and mountainous areas), parent material of the soils (e.g. soil acidification) and location (e.g. salinization in coastal plains). These latter problems require governmental actions at the regional and/or national scale, such as improved water management, forest protection, and construction works.

Soil degradation problems that can be reduced by improving soil management on farm, are mainly sub-soil compaction and the resulting reduction in hydraulic permeability of the soil, decrease in soil organic matter and the resulting decrease in soil quality, structure and soil fertility, contamination with nutrients and pesticides and the resulting pollution of ground and surface waters, and wind erosion and possibly water erosion at the field scale and the resulting loss of soil fertility and soil organic matter.

The information collected from the AEOs through the interviews per FTZ (Set B) is largely consistent with the country reports (Set A). Extension officers mention largely the same soil degradation problems, but focus more on the field level and hence, mention more often problems, such as soil borne diseases, loss of biodiversity and wind erosion, whereas the country reports focus more on the wider (i.e. regional) scale and hence, mention much more often contamination as a problem.

Linking the main soil degradation problems to current management practices and possible remedies

Current soil degradation problems in each of the eight CATCH-C countries can be reasonably well explained from management practices in each of the countries. For example, Contamination does occur on most farms in Belgium, the Netherlands and Germany which can be explained from the animal slurry application on most farms in these countries. Mainly conventional tillage is applied in all CATCH-C countries, and both on arable and livestock farms, which partly (in addition to resp. topography and heavy machinery and wrong timing of farm operations) explains the water erosion and soil compaction problems on most farms.

Current management practices that are mainly responsible for the different soil degradation problems, have been derived from the information given by the AEOs in their interviews for each of the FTZs (Table IV.5). These practices appear to be the common practices in intensive and conventional farming with limited applications of organic matter and crop residues to the soil, monoculture, insufficient coverage of the soil, intensive tillage, use of heavy machinery with high wheel loads, high application levels of fertilisers and biocides, short rotations with intensive cultivation of tuber and root crops, high animal densities which often result in too high animal manure applications, and replacement of farm yard manure by slurry.

Ideas from the AEOs about possible remedies against each of the current soil degradation problems have been recorded, which gives a good overview of ways to improve soil management practices to limit the current soil degradation problems, such as for example: (a) Water and wind erosion can be limited by reduced tillage, increase of organic matter input into the soil, and better field coverage, (b) Contamination can be limited by fertiliser applications that are more adapted to crop demands and weather conditions, by better informed use of biocides and improved plant protection, and by decreased animal density and thus manure production, and (c) Compaction can be limited by reduction of wheel loads, use of low pressure tires, controlled traffic farming and reduced stocking densities.

Note that mainly qualitative relationships can be derived from this study: (a) between current management practices and soil degradation problems; and (b) between possible remedies (i.e. improved management practices) and the degree of reduction of these degradation problems. This is due to both the complex interactions between agri-environmental conditions (i.e. soil, landscape and climate) and the farm's characteristics with its specific current and historical management and input level and the approach used for data collection (interviewing the AEOs). Within Work package 3 of the project, more quantitative information about Best Management Practices and soil quality will be derived, whereas in Work package 4 farm compatibility with Best Management Practices will be investigated.

I. Introduction

Agriculture may potentially lead to or enhance soil degradation processes, like erosion, local and diffuse contamination (note that the term contamination as used in this study, covers both excessive amounts of nutrients, heavy metals and biocides), loss of organic matter, loss of biodiversity, compaction and other physical soil deterioration, salinization and landslides (Toth et al., 2008). Soil management practices can either enhance the quality of the soil or degrade this natural resource base, on which food production depends. The effects of soil management practices depend on the biophysical characteristics of the land, like slope, soil texture and climate and on the current degree of soil degradation.

One could expect that farmers use their soil as part of their capital, which is to be optimally used to optimize the profits from and sustainability of their farm. This means that they try to avoid soil degradation. Yet, soil resources in many parts of Europe are being degraded due to inappropriate land and soil management practices (Jones et al., 2012).

The overall aim of the CATCH-C project is to identify and improve the farm compatibility of sustainable soil management practices for farm productivity, CC-Mitigation and soil quality. To achieve this objective, we have developed and applied an "agri-environmental zone * farm type" typology for the eight EU countries that are involved in the CATCH-C project.

This report is the chief deliverable of WP2. The objectives of Work package 2 were:

• To develop and apply the farm typology (FT) and the agri-environmental zone (Z) typology to the participant countries;

• To make an inventory of the current management practices for the main FTZ Units (i.e. typical agri-environment and farm types) in the participant countries;

• To make an inventory of main soil degradation and emission problems for the main FTZ Units in the participant countries;

• To derive the main soil degradation problems for FTZ Units in the participant countries and to compile information about the relationships between the main soil degradation problems for the major FTZs in the eight countries and the current management practices and about the possible remedies against the main degradation problems.

Whereas these are the internal objectives of Work package2, the resulting typology itself sets a structure also for other work packages in the project. First, it allows to extrapolate the findings from Work package 3 (i.e., effects of Best management practises (BMPs) on production, climate and soil quality) to geographical target areas. Second, it defines the major farm types (FTZs) for the participant countries. These farm types are the basis for organising farm surveys (by way of interviews and questionnaires) in Work package 4.

II. Farm Type * Agri-environmental Zonation typology

1 Introduction

For the work envisaged in the different work packages of this project, a typology had to be developed with specific attention to the participant countries and preferably with EU27 coverage. This typology is needed to be able to focus on certain representative areas with the interviews and to up-scale and compare compiled information. Managements practices on a farm depend on both the biophysical conditions and on the economic characteristics of the farm. Therefore we need a typology which takes both aspects into account.

In a recent EU project (SEAMLESS) an integrated pan-European database on agricultural systems (Janssen et al., 2009) was compiled. This includes datasets on biophysical variables (climate, soils, land use, topography), farm management, crops and livestock, and socio-economic aspects (prices, employment, production data, trade flows, income, etc.). Important data sources are the European soil map (see http://eusoils.jrc.ec.europa.eu/), the climate data from the MARS (Monitoring Agriculture with Remote Sensing, see http://mars.jrc.ec.europa.eu/) database, the Farm Accountancy Data Network (FADN, see http://ec.europa.eu/agriculture/fadn/index_en.htm), and EuroStat (see http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/). The framework within the SEAMLESS project starts with administrative, so-called NUTS regions (http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction) which are then divided into climate zones, which are sub-divided into agri-environmental zones with homogenous soil characteristics. Farm type information – based on the Farm Accountancy Data Network (FADN) - is spatially allocated to these agri environmental zones (AEZs). More details on this integrated SEAMLESS approach are given by Van Ittersum et al.(2008), Andersen et al. (2007), and Hazeu et al. (2010, 2011).

In the Catch-C project, we followed a roughly similar approach, however, with the following differences: For the administrative level we used both the national (NUTS-0) and regional (NUTS-2) levels. First, the agri-environmental zones were composed from data on climate, slope and soil texture (instead of climate and soil organic matter as in SEAMLESS). NUTS-0 information was used to restrict AEZ zones to within-country units (i.e., AEZ units cannot cross territorial (national) boundaries. Next, farm types were defined based on farm specialization and land use. Unlike SEAMLESS, we disregarded farm size and farm intensity in defining our farm types (but we retained that information). Farm types were then spatially allocated to AEZs over Europe according to the procedure developed by Kempen et al. (2011). This allocation procedure uses FADN farm data at NUTS-2 level, to estimate the presence of certain farm types within agri-environmental zones. For this statistical procedure, information on regional land use areas, land use shares and yields is used. Hence, the resulting typology describes both the typical farming systems and the agri-environmental zones per participant country, and a homogeneous unit (one farm type in one AEZ) is referred to as an FTZ unit.

This work has resulted in maps of the main agri-environmental zones in the EU27, maps of the major agri-environmental zones in each of the eight participant countries (Appendix A), and in tables and maps of the major farm types in each of the major agri-environmental zones in each of the participant countries. Based on this compiled information, we have selected, after discussions with colleagues in the participant countries, the major FTZs in each of the eight participant countries.

2 Agri-environmental zonation

2.1 Approach and data used

The agri-environmental zonation is based on three variables: climate (environmental zones), soil texture and slope. These three variables are considered to be the most important determinants of the possibilities and limitations for soil management on a farm. Together they define the external (bio-physical) conditions.

Overlaying the three datasets results in spatial zones with similar biophysical characteristics. ArcMap 10 has been used to overlay the sets. Only European datasets have been used to ascertain uniformity in classes and methodology of data collection.

2.1.1 Environmental zones

Climate determines the length of the growing season, the temperature range during the growing season, the water availability and hence, the type of crops that can be grown and their yield potential. Different climates give different problems and risks for the soil, as dependent on the soil management. For example, in Southern Europe there is a rather high risk of erosion due to drier climates and limited field coverage, whereas in Northern Europe there is a relatively short growing season with more risk of soil compaction. Even though the climate gradually changes over space, regions can be classified with respect to their climate.

We have used the climate zonation for Europe from Metzger et al (2005), with 13 zones over Europe. This zonation is based on differences in climate data, ocean influence and geographical position. This climate zonation over Europe as a whole is given in Fig. II.1 (left) and for only the Catch-C countries in Fig. II.1 (right).

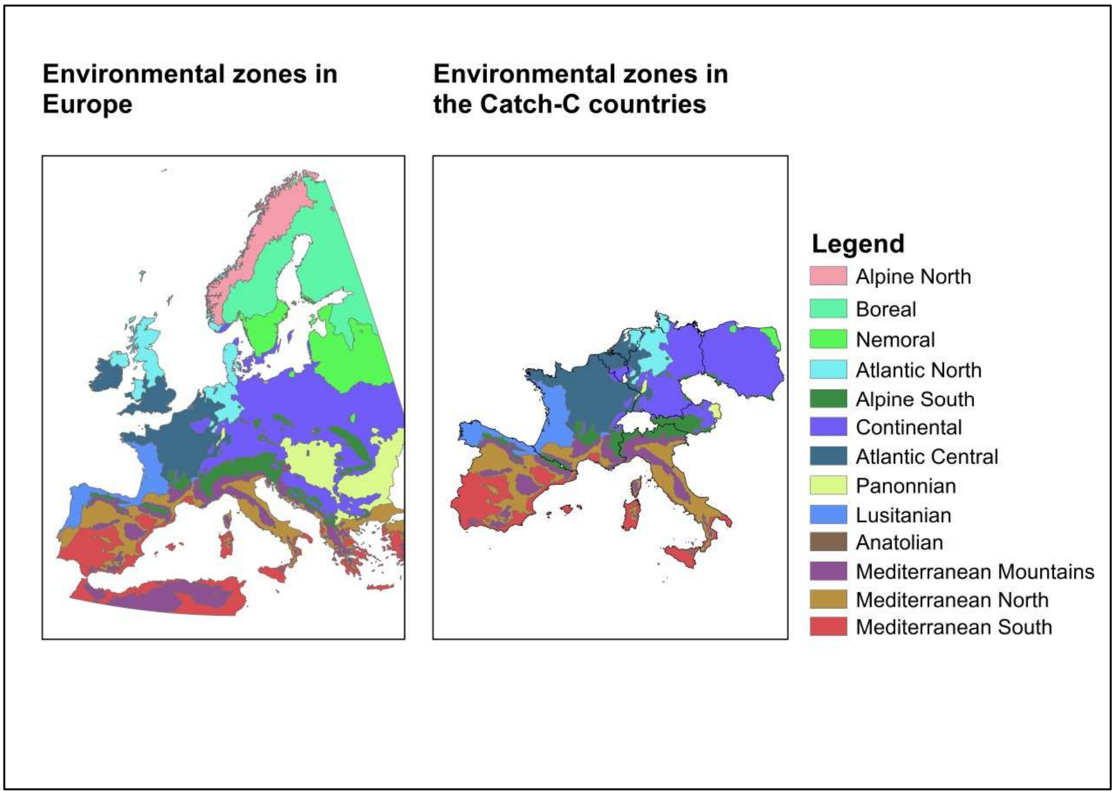

Figure II.1: Environmental zonation for the whole of Europe (left) and environmental zonation for the Catch-C countries only (right); Source Metzger et al. (2005)

2.1.2 Soil texture

Soil texture is important for soil management, because it influences the erodibility, risk of compaction, water holding capacity, workability and trafficability of the soil.

Soil texture can be described with different classes or parameters. Different countries in Europe appear to use different approaches. The European Soil database (JRC, 2006) gives a homogeneous dataset of soil texture across Europe with only the percentages of sand and clay fraction in the soil as variables. This European database was chosen to allow comparisons of soil texture data across the Catch-C countries.

In Fig. II.2 (left) a map of soil texture classes over Europe as a whole is given. The soil texture classes for only the Catch-C countries is shown in Fig. II.2 (right). Table II.1 gives explanation of the used texture classes.

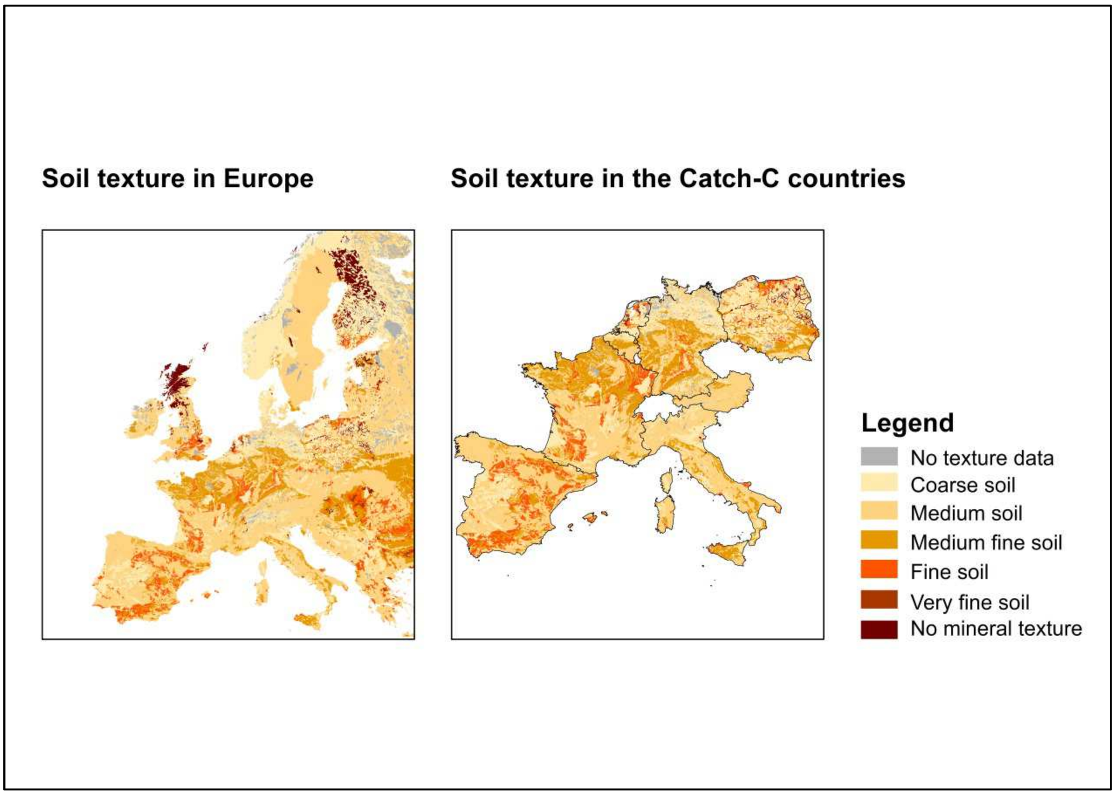

Figure II.2: Soil texture classes over Europe as a whole (left) and soil texture classes for the Catch-C countries (right) ; Source: European soil data base (JRC, 2006)

Table II.1 Soil texture classification

Description	Range
Coarse soil	Clay <18% and sand > 65%
Medium soil	18% < clay < 35% and sand >15% sand, or clay <18% and 15% < sand < 65%
Medium fine soil	clay < 35% and sand < 15%
Fine soil	35% < clay < 60%

Very fine soil	clay > 60 %
No mineral texture (Peat soils)	

2.1.3 Slope

Slope is important because an increasing slope angle results in more surface runoff and thus an increasing risk for water erosion of the topsoil and gully formation. The topsoil is important, because it is in general the most fertile part of the soil, has the highest amount or organic matter, and determines the infiltration rate of precipitation into the soil.

At the European scale, terrain slopes are determined with Digital Elevation Models (DEM). These slope estimates are done based on altitude differences. We have used slope data that were derived in a previous project, using a DEM called USGS GTOPO DEM (Klijn et al., 2005). This dataset contains 5 slope classes which are shown in Table II.2.

Table II.2 Slope classification

Class	Description	Slope in degrees	Slope in percentage
1	Level	0^0	0%
2	Nearly level	1^0	2%
3	Gentle slopes	$2\text{-}3^0$	3-6%
4	Moderate slopes	$4\text{-}7^0$	7-14%
5	Strong to steep slopes	$>8^0$	>14%

2.2 Combining the three variables into an agri-environmental zonation

The three described variables (environmental zones, slopes and soil texture) have been overlayed to obtain regions with similar biophysical characteristics. The result is an agri-environmental zonation for the eight CATCH-C countries. The homogeneous units of this zonation are called AEZs. This zonation is used as a basis to inventory the main farm types in each country (see, for example, Table II.5 for Austria). Fig. II.3 gives an overview of the agri-environmental zones in the eight Catch-C countries.

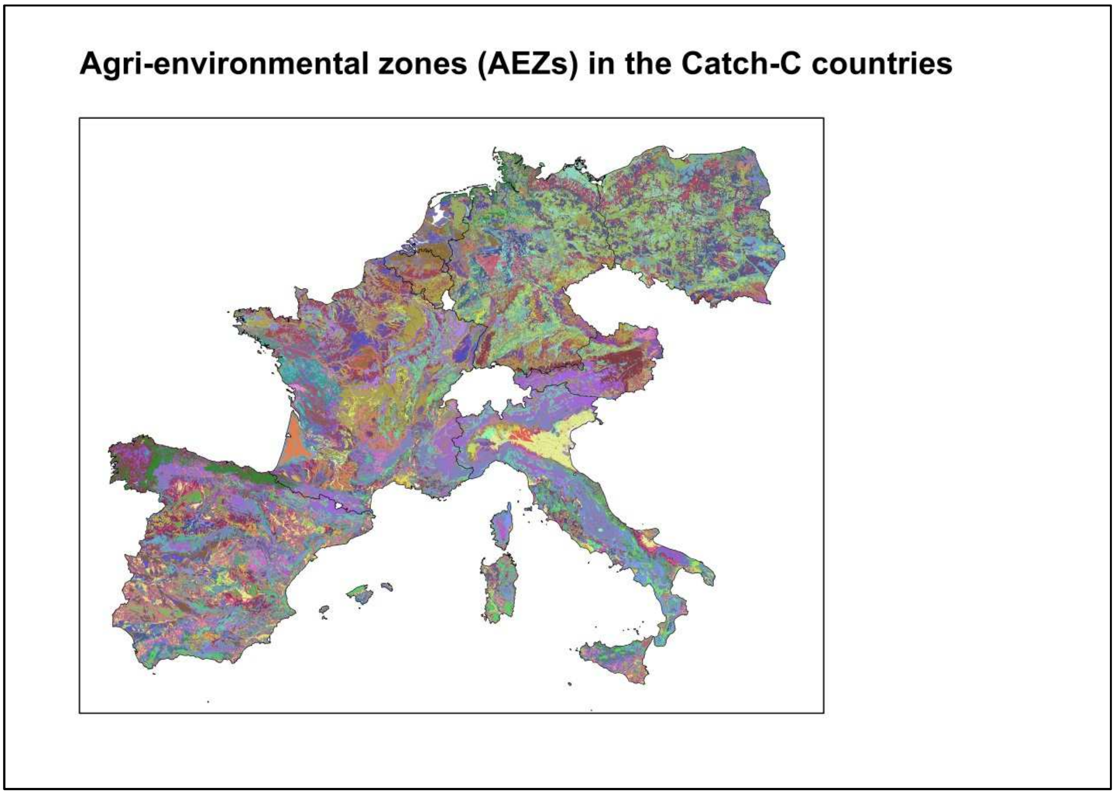

Figure II.3 Agri-environmental zones in the eight Catch-C countries over Europe, based on overlays of environmental zone (Fig. II.1), soil texture (Fig. II.2) and slope maps

2.3 Discussion

The derived agri-environmental zonation comprises the main variables (i.e. climate, soil texture, and terrain slope) that determine the biophysical characteristics per zone and the related degree of risk for soil degradation under current management practices. Hence, this zonation is suitable as a basis to do inventories of current management practices, soil degradation problems, and possible remedies.

The use of the agri-environmental zonation for the inventories of current management practices and soil degradation problems indicated a number of problems which could not always be entirely resolved: (a) the number of agri-environmental zones per country is often quite large (see Fig. II-3) which makes it difficult to compile reliable data on management and soil degradation per zone; hence, the resulting data are better for countries with more homogeneous landscapes and climates than for heterogeneous ones; (b) soil texture and slope angle may often change over short distances; we have used the dominant soil texture and slope classes in the zonation, however, this simplification is not always valid at the individual farm-scale; (c) soil texture classes as used in the zonation (from the European Soil database) are not always ‘recognized’ in the field (extension officers, farmers) and among researchers involved in the inventories; (d) the slope classes as used by extension officers (in our inventories of practices and problems), are often rather subjective and may not coincide with our numerical classes, as used in this zonation for the same zone.

3 Farm typology

3.1 Approach and data used

The biophysical characteristics as described in Section II.2, are not the only factors that determine the possibilities and limitations for improving soil management on a farm. Other farm characteristics (e.g. size, specialization) as located within an agri-environmental zone, may be equally important as the biophysical characteristics .

Andersen et al. (2007) have developed a farm typology to distinguish the main farm types over Europe with their most important characteristics. This farm typology has four dimensions: specialisation, land use, farm size and farm intensity. We adopted this typology, but used only the dimensions specialisation and land use, being most related to soil management and degradation issues. The specialisation of a farm indicates which activity generates the income for a farm (for example, dairy cattle or arable crops). The land use of a farm indicates which crops are grown (for example, permanent crops or cereals). Both the specialisation and land use of a farm determine the farming activities and required inputs and outputs.

The farm typology over Europe has been compiled, based on the farm type information from FADN at NUTS-2 level. The main farm types were spatially allocated over Europe, by defining the relative presence (area %) of the various farm types within each AEZ unit (note that the currently used AEZ units are different from those used in the SEAMLESS project, see Section II.1). This allocation was performed based on a procedure for Europe developed by Kempen et al. (2011). This work has resulted in tables and maps of the major farm types in each of the major agri-environmental zones in each of the eight participant countries (Section II.4 and Appendix A).

3.1.1 Farm specialisation

Most farms in Europe are specialised in one particular farming activity (like growing permanent trees or producing milk). In the applied farm typology the farming activity which contributes to more than two-third of a farm's economic size (i.e. farm gross margin) is designated as the 'specialisation' of that farm (see FADN information at http://ec.europa.eu/agriculture/rica/methodology1_en.cfm). The only exception is arable farming (here, more than one-third of a farm's economic size should be earned from arable crops). All other farm specializations are either mixed livestock or mixed farms. In Table II.3 an overview is given of all farm specialisation classes.

Table II.3 Classes and definitions of farm specialisation according to FADN, and as adopted in this project

Specialisation	**EU-code**	**Definition**
Arable systems (specialised field crops and mixed cropping)	1+6	- >1/3 of standard gross margin from general cropping (arable farming) - Or > 1/3 but ≤ 2/3 of standard gross margin from horticulture - Or > 1/3 but ≤ 2/3 of standard gross margin from permanent crops Combined with ≤ 1/3 of standard gross margin from meadows and grazing livestock and ≤ 1/3 from granivores
Permanent crops	3	> 2/3 of standard gross margin from permanent crops
Horticulture	2	> 2/3 of standard gross margin from horticultural crops
Dairy cattle	4.1	> 2/3 of standard gross margin from dairy cattle
Beef and mixed cattle	4.2 and 4.3	> 2/3 of standard gross margin from cattle and < 2/3 from dairy cattle
Sheep, goats and mixed grazing livestock	4.4	> 2/3 of standard gross margin from grazing livestock and < 2/3 from cattle
Pigs	5.1	>2/3 of standard gross margin from pigs
Poultry and mixed pigs/poultry	5.2	> 2/3 of standard gross margin from pigs and poultry and < 2/3 from pigs
Mixed livestock	7	> 1/3 and < 2/3 of standard gross margin from pigs and poultry and/or >1/3 and < 2/3 from cattle
Mixed farms	8	All other farms

3.1.2 Land use of a farm

The land use class of a farm indicates the most important usage of its farm land. In Table II.4 an overview is given of the different land use classes.

Table II.4 Classes and definitions of the land use of a farm, as adopted in this project

1	Land independent	UAA[1] = 0 or LU[2]/ha ≥ 5
2	Horticultural	Not 1 and ≥ 50% of UAA in horticultural crops
3	Permanent crops (not grassland)	Not 1 and 2 and ≥ 50% of UAA in permanent crops
4	Temporary grass	Not 1,2 or 3 and ≥ 50% of UAA in grassland and ≥ 50% of grassland in temporary grass
5	Permanent grass	Not 1,2,3 and ≥ 50% of UAA in grassland and < 50% of grassland in temporary grass
6	Fallow land	Not 1,2,3,4 or 5 and ≥ 50% of UAA in fallow
7	Cereal	Not 1,2,3,4,5 or 6 and ≥ 50% of UAA in cereals
8	Specialised crops	Not 1,2,3,4,5,6,7 and ≥ 25% in specialised crops[3]
9	Mixed crops (others)	Not 1,2,3,4,5,6,7 or 8

3.2 Example of the main farm types present in the agri-environmental zones of Austria

Farm types are spatially allocated over Europe according to the procedure as developed by Kempen et al. (2011). This allocation has resulted in estimates of the presence of the different farm types in each of the agri-environmental zones in the eight Catch-C countries. For example for Austria, an overview has been made of the main farm types in each of the agri-environmental zones. First, we produced a map (Fig. II.4) with the agri-environmental zones of Austria. Next, the farm types present in each of the agri-environmental zones were specified (Table II.5).

[1] UAA = Utilised Agricultural Area

[2] LU= Livestock Units

[3] Grain Maize, potatoes, sugar beet, hops, soya, tobacco, medicinal plants, sugar cane, cotton, fibre lax, hemp, mushrooms, vegetables in open, flowers in open, grass seeds, other seeds.

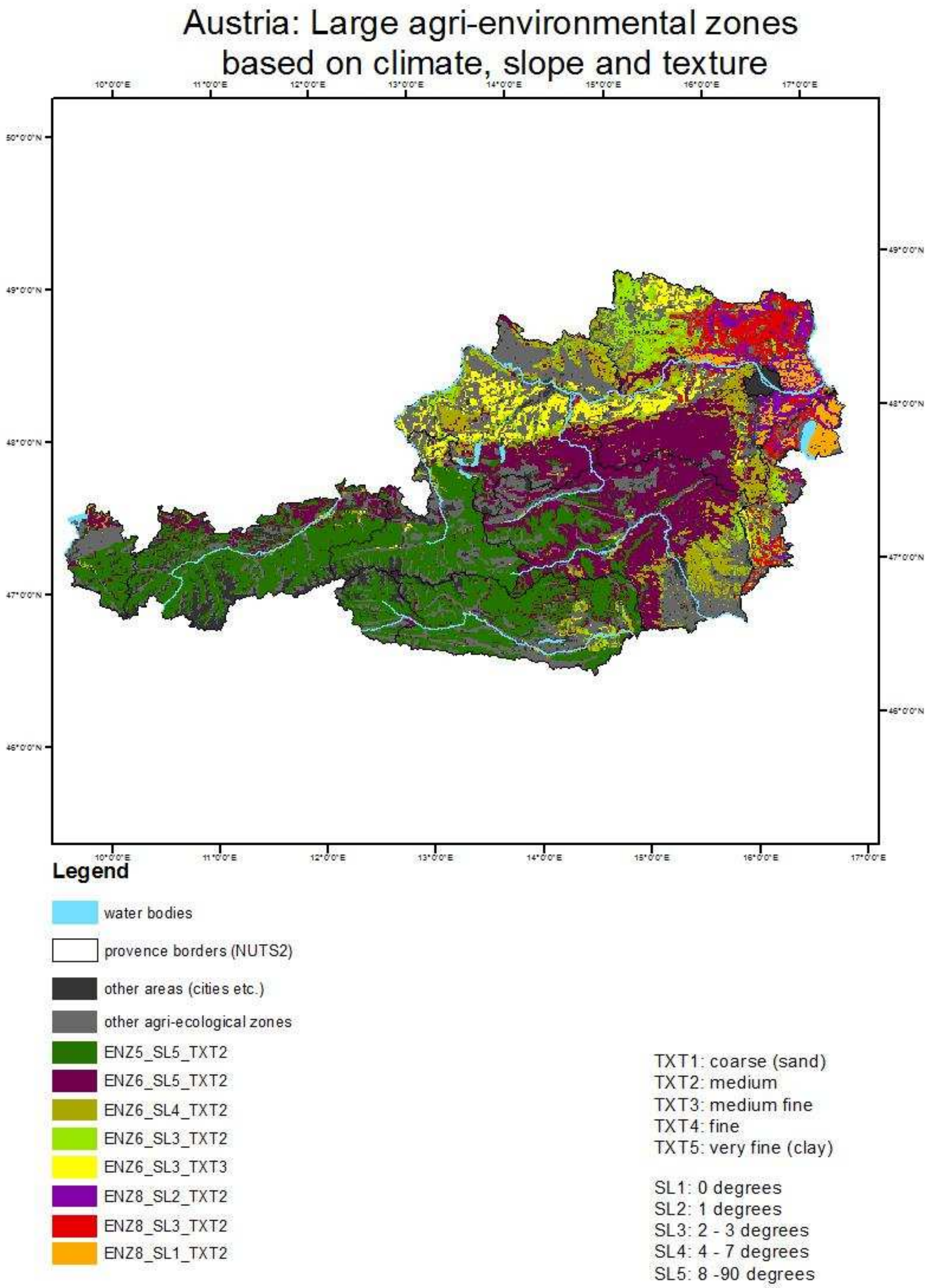

Figure II.4 Agri-environmental zones in Austria as based on over-laying climate, soil texture and terrain slope maps

Table II.5 Farm types present in each of the agri-environmental zones of Austria with their area fractions

AEZ (Austria)	**Land use and specialisation**	**Percentage of farm area in AEZ**
ENZ5_SL5_TXT2	Dairy cattle/Permanent grass	66.4%
	Beef and mixed cattle/Permanent grass	27.3%
total farm area (1000 ha)	Sheep and goats/Others	3.3%
364.42	Mixed livestock	0.9%
	Dairy cattle/Others	0.6%
	Beef and mixed cattle/Others	0.5%
	Poultry and mixed pigs/poultry	0.4%
ENZ6_SL5_TXT2	Dairy cattle/Permanent grass	57.8%
	Beef and mixed cattle/Permanent grass	21.0%
total farm area (1000 ha)	Dairy cattle/Others	6.4%
248.36	Mixed farms	3.8%
	Sheep and goats/Others	3.0%
	Beef and mixed cattle/Others	2.8%
	Mixed livestock	2.2%
ENZ6_SL4_TXT2	Dairy cattle/Permanent grass	33.7%
	Beef and mixed cattle/Permanent grass	12.8%
total farm area (1000 ha)	Mixed farms	10.7%
215.18	Beef and mixed cattle/Others	7.8%
	Dairy cattle/Others	7.3%
	Arable/Cereal	7.3%
	Mixed livestock	3.9%
ENZ6_SL3_TXT2	Arable/Cereal	20.9%
	Mixed farms	14.5%
total farm area (1000 ha)	Dairy cattle/Permanent grass	14.2%
166.44	Beef and mixed cattle/Permanent grass	7.3%
	Arable/Fallow	6.3%
	Permanent crops	5.8%
	Dairy cattle/Others	5.7%
ENZ6_SL3_TXT3	Arable/Cereal	23.3%
	Mixed farms	22.5%
total farm area (1000 ha)	Pigs/Others	11.9%
154.26	Beef and mixed cattle/Permanent grass	6.9%
	Beef and mixed cattle/Others	6.8%

	Dairy cattle/Permanent grass	5.6%
	Dairy cattle/Others	4.8%
ENZ8_SL2_TXT2	Arable/Cereal	44.7%
	Permanent crops	21.1%
total farm area (1000 ha)	Arable/Fallow	14.2%
132.42	Arable/Others	6.6%
	Arable/Specialised crops	4.7%
	Mixed farms	3.6%
	Beef and mixed cattle/Others	1.9%
ENZ8_SL3_TXT2	Arable/Cereal	51.3%
	Arable/Fallow	14.4%
total farm area (1000 ha)	Permanent crops	12.7%
124.35	Mixed farms	10.4%
	Arable/Others	4.8%
	Arable/Specialised crops	2.8%
	Beef and mixed cattle/Others	1.9%
ENZ8_SL1_TXT2	Arable/Cereal	43.7%
	Permanent crops	19.8%
total farm area (1000 ha)	Arable/Fallow	19.5%
91.11	Arable/Others	6.0%
	Mixed farms	3.9%
	Arable/Specialised crops	3.1%
	Mixed livestock	2.1%

3.3 Discussion

The applied procedure from Kempen et al. (2011) allows to allocate the main farm types to each of the agri-environmental zones in the eight participant countries. As soil and crop management practices (and associated soil degradation problems) are related to both the biophysical conditions and the farm's specialization and land use, inventories can now be done for these FTZ units.

The farm typology now offers a uniform basis across the eight participant countries. It enables (in Work package 2) the structured collection and compilation of data on current management (section III) and soil degradation (section IV) and gives the infrastructure for targeted work in other work packages, as was outlined at the end of Section I.

The used farm typology is based on the classes from FADN; as FADN classes can be considered as the standard in European policy making, the compiled information for the farm type classes in this project can be used in policy studies at the European level.

4 Selected Farm types and agri-environmental zones

4.1 Introduction

The number of farm types and agri-environmental zones within one country can be large (see Table II.5 for Austria), especially when the landscape is very heterogeneous. This makes it impossible to do inventories (see Sections III and IV) for all agri-environmental zone-farm type combinations (FTZ units). Hence, for each country three major farm types within specific agri-environmental zones have been selected.

4.2 Procedure for selection

The applied procedure for selecting the three major farm types per country was the following: (a) an overview was made of all farm types present in each of the agri-environmental zones (AEZ + FT --> FTZ) per country; (b) for each AEZ, the areas of the respective FTZs were calculated and the ten largest FTZs were listed (Table II.5 for Austria as example); (c) the CATCH-C participants per country were asked to review the economic importance and impacts on soil degradation of these ten largest FTZs.

In addition, the CATCH-C participants were asked if the FTZs designated for their country would be readily recognized ‘in the field’ (i.e., by farmers, extension officers, local researchers). Where this was not the case, participants were asked to aggregate some agri-environmental zones or farm types. Because we had used generic (European) classes, participants in some countries did not recognize the FTZs, and found it difficult to relate them to the farm classes normally used in their national studies. In such cases, re-combinations of FTZs were performed to arrive at FTZs which could be understood within the national context.

Concluding, the selection of the major farm types and agri-environmental zones was based on four criteria:

1. Their total area within the country
2. The economic importance
3. The impact on soil degradation
4. Recognisability within the national context

The results of this selection procedure are shown in the next paragraph.

4.3 Overview of selected farm types and agri-environmental zones

The three selected major FTZs (combinations of Farm type with agri-environmental zone) for each of the eight CATCH-C countries with their biophysical and farm characteristics are given in Table II.6. The spatial distributions over Europe of the agri-environmental zones, in which these selected FTZ combinations are located, are given in Figure II.5. Maps of the spatial distributions of the selected FTZs in each of the eight CATCH-C countries can be found in Appendix A.

Table II.6 Selected FTZs (combinations of Farm type with Agri-environmental zone) for the eight CATCH-C countries with their characteristics

Country[1]	**AEZ ID**	**FTZ ID**	**Climate**	**Land slope**	**Soil texture**	**Farm specialization**	**Land use**
AT	1	1A	Pannonian	gentle slopes	medium soils	arable	cereals
	2	2M	Continental	gentle slopes	medium soils	mixed	all land use types
	3	3C	Alpine South	strong to steep slopes	medium soils	dairy cattle	all land use types
BE	4	4A	Atlantic Central	nearly level	medium fine soils	arable	specialised crops
	5	5C	Atlantic Central	level	coarse soils	dairy cattle	permanent grass
	6	6M	Atlantic Central	level	medium soils	mixed	all land use types
DE	7	7A	Atlantic North	level	coarse soils	arable+mixed	specialised crops
	8	8A	Continental	level	coarse soils	arable+mixed	specialised crops
	9	9A	Continental	nearly level and gentle slopes	medium fine soils	arable+mixed	specialised crops
ES	10	10A	Mediterranean South	level to moderate slopes	fine soils	arable	cereals
	11	11P	Mediteranean South	nearly level to moderate slopes	medium fine soils	permanent crops	permanent crops
	12	12C	Mediteranean South and Mediteranean mountains	strong to steep slopes	medium soils	beef and mixed cattle + sheeps and goats	
FR	13	13A	Mediteranean North	gentle slopes	fine soils	arable	all land use types
	14	14C	Atlantic Central	nearly level	medium fine soils	dairy cattle	all land use types

	15	15A	Atlantic Central	nearly level	medium soils	arable	all land use types
IT	16	16A	Mediteranean North	level	coarse to medium fine soils	arable	cereals
	16	16C	Mediteranean North	level	coarse to medium fine soils	dairy cattle	temporary grass
	17	17A	Mediteranean North	gentle and moderate slopes	medium and medium fine soils	arable	cereals
NL	18	18A	Atlantic Central	level	medium and medium fine soils	arable	specialised crops
	19	19A	Atlantic North	level	medium and medium fine soils	arable	specialised crops and cereals
	20	20A	Atlantic North and Atlantic Central	level	coarse soils	arable	specialised crops
	20	20C	Atlantic North and Atlantic Central	level	coarse soils	dairy cattle	permanent grass
PL	21	21A	Continental	nearly level	medium fine soils	arable	cereals
	22	22M	Continental	nearly level	coarse soils	mixed	all land use types
	23	23C	Continental	level	coarse soils	dairy cattle	permanent grass

[1] AT= Austria, BE= Belgium, DE= Germany, ES= Spain, FR= France, IT= Italy, NL= Netherlands, PL= Poland

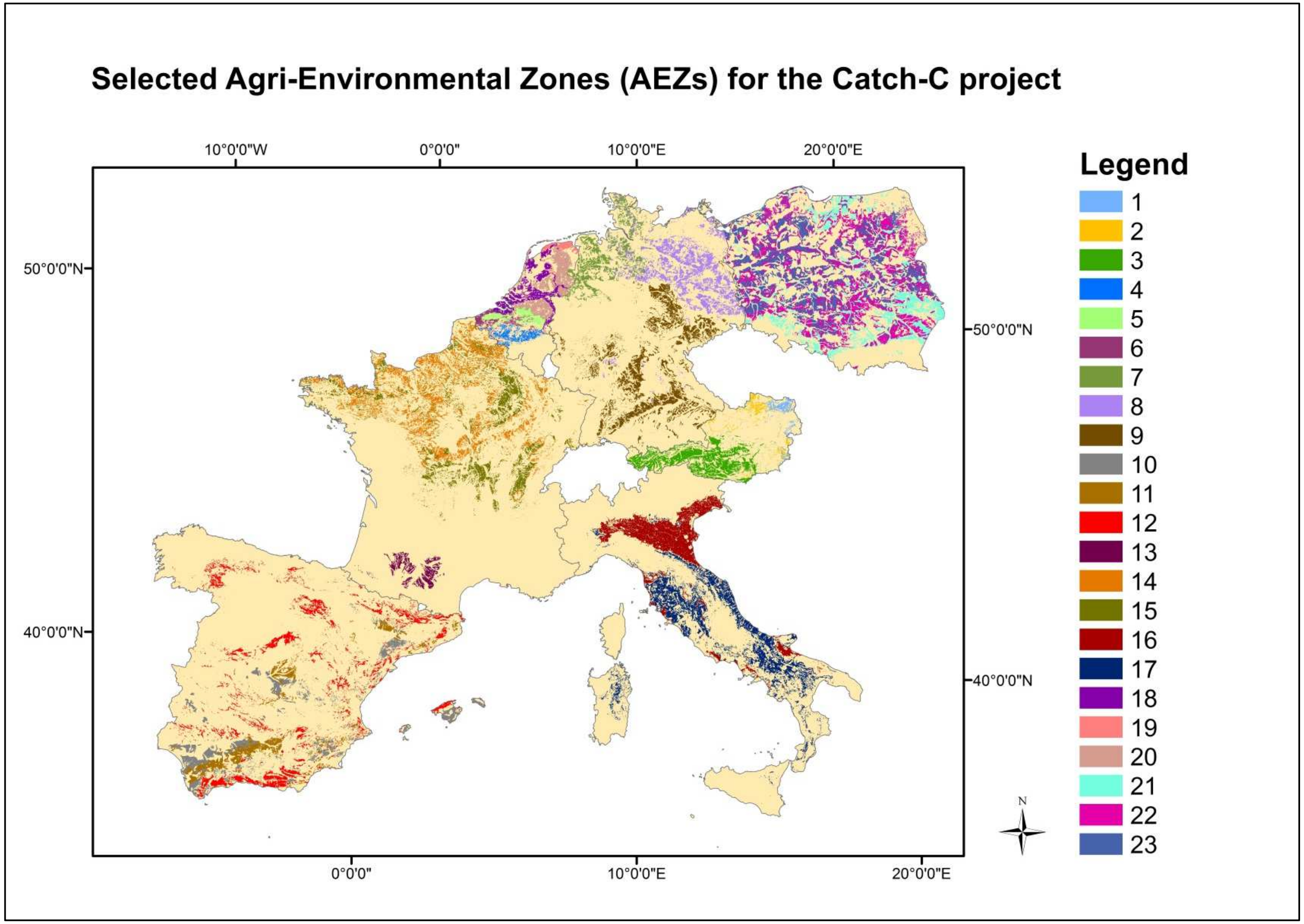

Figure II.5 Agri-environmental zones which have been selected within the Catch-C project. See Table II.6 for explanation of the AEZs and FTZs. Note that the areas of all FTZs in Europe have been determined but only the selection is shown in this map.

4.4 Discussion

We are confident, based on the overviews made of the main farm types in each of the agri-environmental zones in the eight participant countries and on the procedure for FTZ selection, that the three selected FTZs per country represent the main agri-environmental zones, main agricultural areas and the main farming systems in the eight CATCH-C countries. The selected FTZs provide the backbone to carry out inventories on farm management (Section III) and soil degradation problems (Section IV) in these eight countries. The used farm typology is the same for the eight participant countries, which allows comparisons of compiled data (e.g. current management) between the eight countries; it utilizes the classes from FADN, a common reference for European policy studies.

While the major FTZs selected for further work cover only part of the total farm area per country (maps in Appendix A), we stress here that our numerical database specifies all other FTZ units across Europe, too, with the same level of detail. This information, however, cannot easily be represented in maps because of the small sizes of units, and the limited number of colours that the eye can distinguish on a map. Finally, note that some countries have made their own aggregations of AEZ classes. For example, three slope classes were merged in one particular FTZ in Spain. Such compromises were sometimes necessary to arrive at major FTZs representative for the country.

III. Current management

1 Introduction

To evaluate the potential effects of best or alternative soil management practices, it is important to first compile information about the current management practices. There is currently a lack of data on current management practices across Europe (Louwagie et al., 2009; Toth et al., 2008). Therefore, we (i.e. all participants in the CATCH-C project) have performed inventories of current management practices in the selected FTZs (Section II.4.3).

2 Procedure for data collection

The Current Management Practices have been recorded for the major FTZs in each of the eight participant countries. For this task, a questionnaire about current management practices and main soil degradation problems has been compiled and tested. Next, the updated questionnaire about current management practices and main soil degradation problems has been used by colleagues in the participant countries to conduct interviews with experts (i.e. agricultural extension officers) for the selected FTZs in their country.

Three interviews have been done for each of the FTZs, with three to four FTZs being selected per country. The experts were asked to give estimates about the extent that some practices are currently applied and to inform us of what they advise to the farmers. The used questionnaire is given in Appendix B. The related glossary of management practices can be found in Appendix C..

3 Compiled information on current management practices

The collected information about current management practices on the selected FTZs is presented below. For more detailed information about the location and characteristics of the FTZs, see Table II.6 and figure II.5. Farm area fractions for arable and livestock farming in which green manures, different tillage practices and/or organic fertilisers are applied and crop residues are incorporated, are given in the following for the different FTZs in the CATCH-C countries. Note that the category Livestock farming includes both dairy cattle (C) farming and mixed farming (M).

3.1 Use of green manures

3.1.1 Arable farms

Green manure crops are mostly grown on arable farms in Belgium (4A; 50% of total area) and are also found on moderately large areas in arable farms in The Netherlands and Poland (18A, 20A and 21A; 20% of total area, see figure III.1).

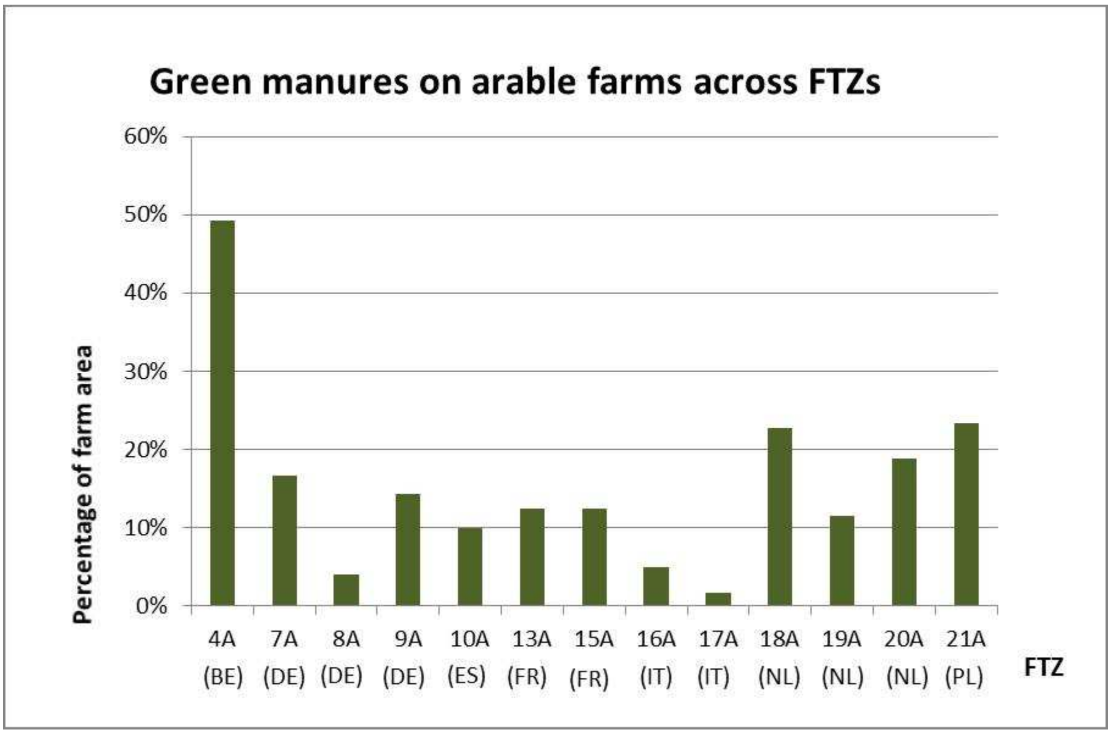

Figure III.1 Area fractions where green manures are applied, for FTZs in arable farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6.

3.1.2 Livestock farms

Green manures are moderately grown on mixed farms in Austria, dairy cattle farms in Belgium and France, and mixed farms in Belgium (2M, 5C, 6M and 14C ; 20 to 30% of total area) and little grown on dairy cattle farms in Italy and mixed farms in Poland (16C and 22M; 10% of total area, see figure III.2).

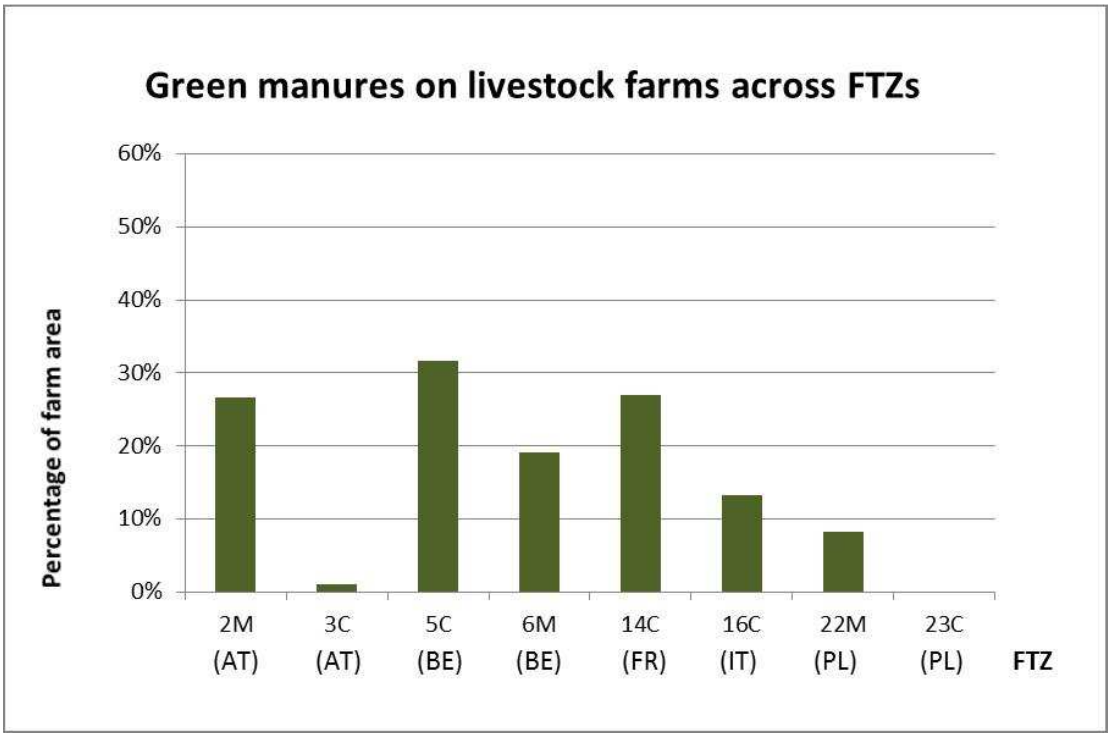

Figure III.2 Area fractions where green manures are applied, for FTZs in livestock farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

3.2 Tillage practices

3.2.1 Arable farms

Conventional tillage is the most common tillage practise in the CATCH-C countries. No tillage is practically not applied in these countries, except for moderate and limited application among permanent cropping and arable farms in Spain (11P and 10A). Non-inversion tillage is the most common tillage practice on arable farms in Austria, France, and Spain and arable and mixed farms in Germany (1A, 9A, 10A, and 15A) and is often applied on arable and mixed farms in Germany, permanent cropping in Spain, arable farms in Italy and Poland (8A, 11P, 16A, 17A and 21A ; about 30% of area, see figure III.3).

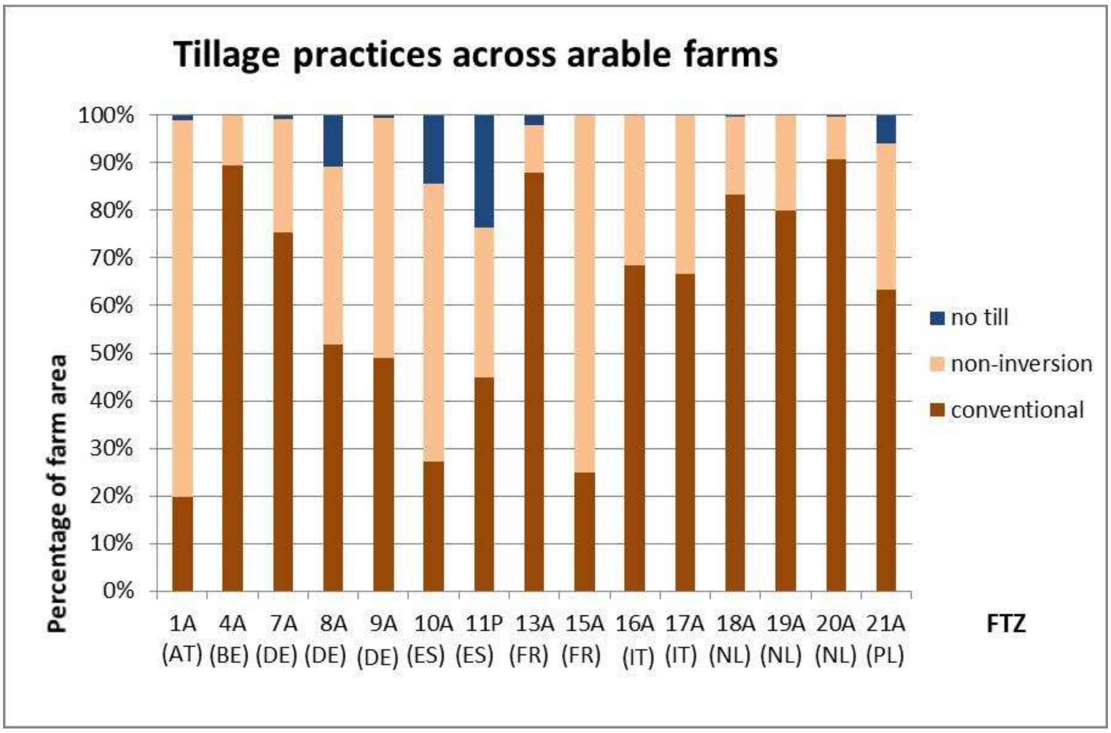

Figure III.3 Area fractions where different tillage practices are applied, for FTZs in arable farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

3.2.2 Livestock farms

As with arable farms, conventional tillage is most common on livestock farms in the CATCH-C countries. Non-inversion tillage is sometimes (20 to 30% of area) practised on mixed farms in Austria, dairy cattle farms in the Netherlands, and mixed farms in Poland (2M, 20C and 22M). No tillage is applied only on cattle farms in Spain (12C, see figure III.4).

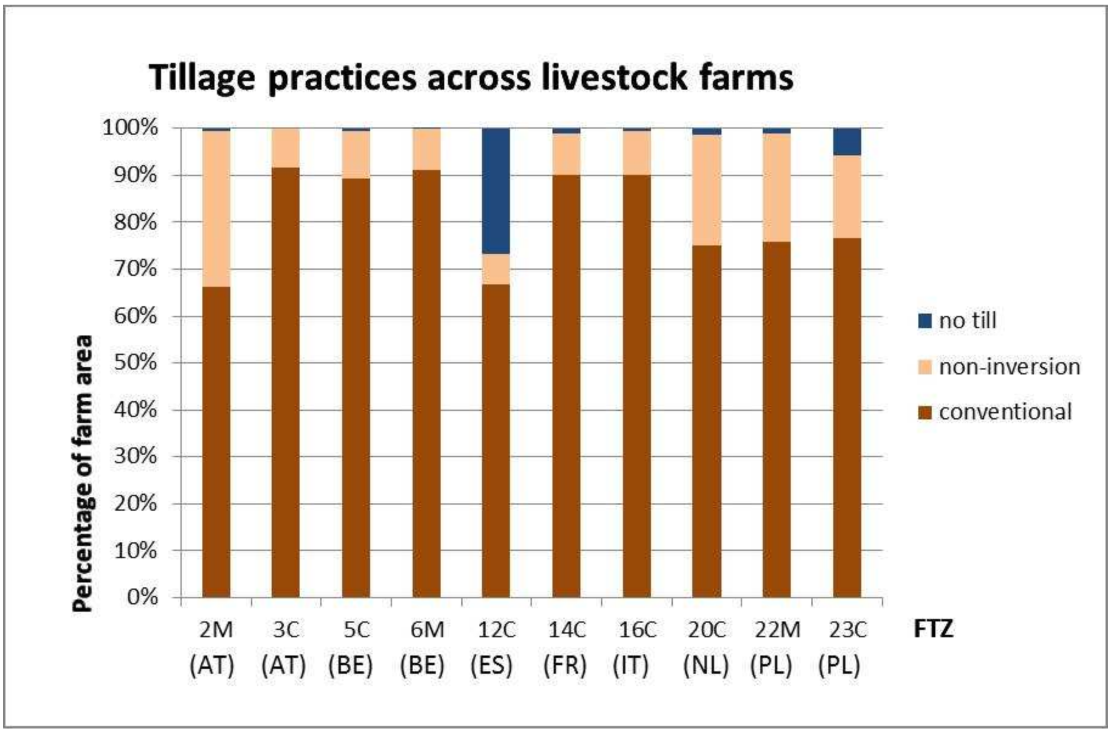

Figure III.4 Area fractions where different tillage practices are applied, for FTZs in livestock farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

3.3 Nutrient management

3.3.1 Arable farms

Mineral fertilisers are applied on the main part of the areas (70 to 100%) in all FTZs. Organic fertilisers and particularly animal slurry are applied on the main part (60 to 90%) of the areas in arable farming in Belgium, arable and mixed farming in Germany, and arable farming in the Netherlands (4A, 7A, 18A and 20A). Compost application appears to be of minor importance (Fig. III.5).

Note that in Germany farmers also use biogas slurry from biogas plants on 10 and 40% of the farm area. In Italy, farmers often use (up to 50% of the farm area) organo-mineral fertilisers which are a mixture of organic and inorganic fertilisers. The organic fraction may origin from animal manure but also from organic wastes from the livestock or crop processing industry.

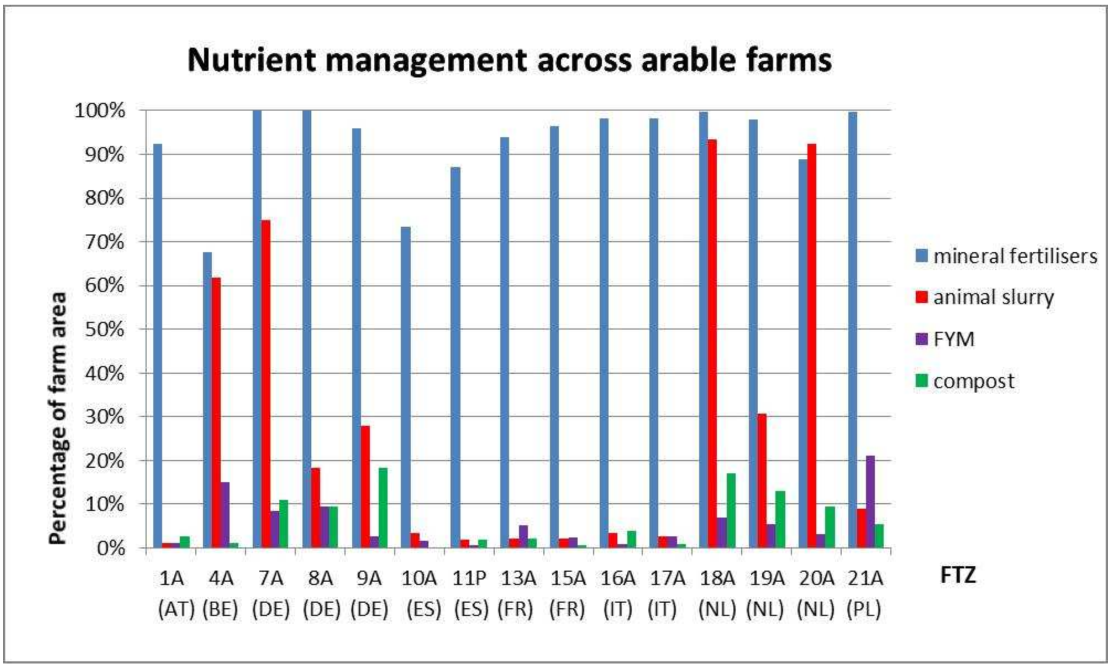

Figure III.5 Area fractions where organic fertilisers are applied, for FTZs in arable farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

3.3.2 Livestock farms

Animal slurry is applied on the main part (70 to 100%) of the livestock farm area. Exceptions are mixed and dairy cattle farms in Poland (22M and 23C), where slurry applications are limited and farm yard manure is applied to resp. 35 and 60% of the area.

Mineral fertilisers are also applied on the main part (70 to 100%) of the livestock farm area, except for dairy cattle farming in Austria and cattle farms in Spain (3C and 12C). Farm yard manure is applied on the main part of the farm area (80%) among cattle farming in Austria, on a moderate part of the area (40%) among cattle farms in France and Italy (14C and 16C), and on a limited to moderate part of the area (15 to 30%) on mixed farms in Austria, Belgium and Poland (2M, 6M and 22M).

In Belgium and The Netherlands (5C, 6M and 20C), animal manure consist mainly of slurry, while in Austria, France and Italy (2M, 3C, 14C and 16C) both animal slurry and farm yard manure are applied. Compost application appears to be of minor importance (see figure III.6).

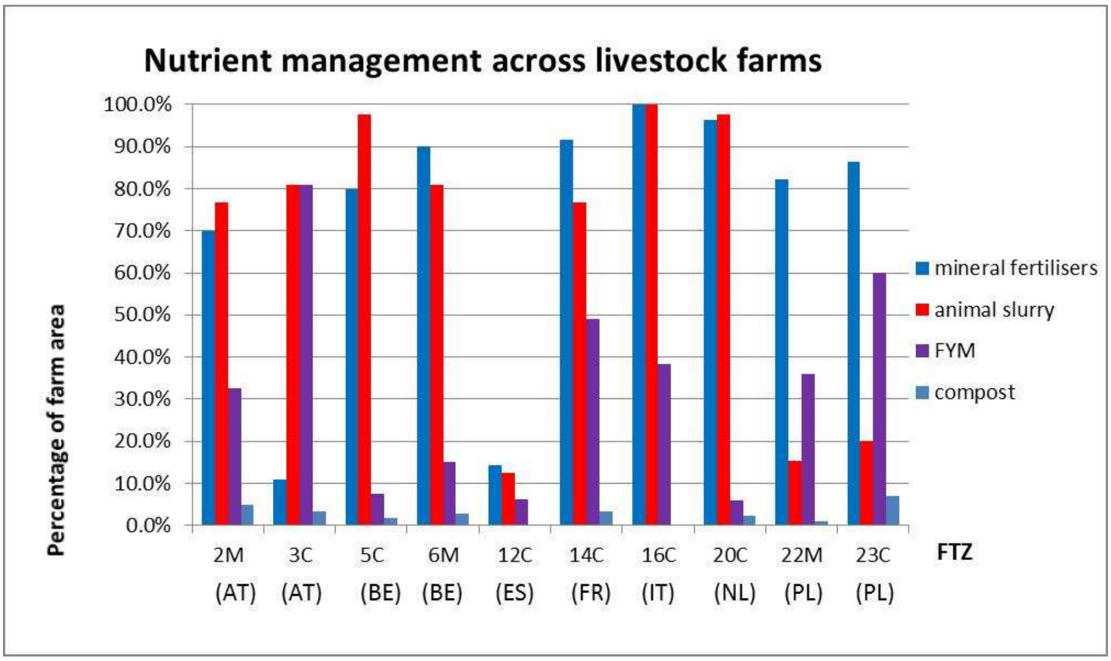

Figure III.6 Area fractions where organic fertilisers are applied, for FTZs in livestock farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

3.4 Incorporation of crop residues

3.4.1 Arable farms

Crop residues are incorporated in roughly half (40 to 60%) of the area in most FTZs. More incorporation (>70% of the area) of crop residues does occcur on arable farms in Austria, arable and mixed farming in Germany, and arable farming in France (1A, 8A, and 15A, see figure III.7).

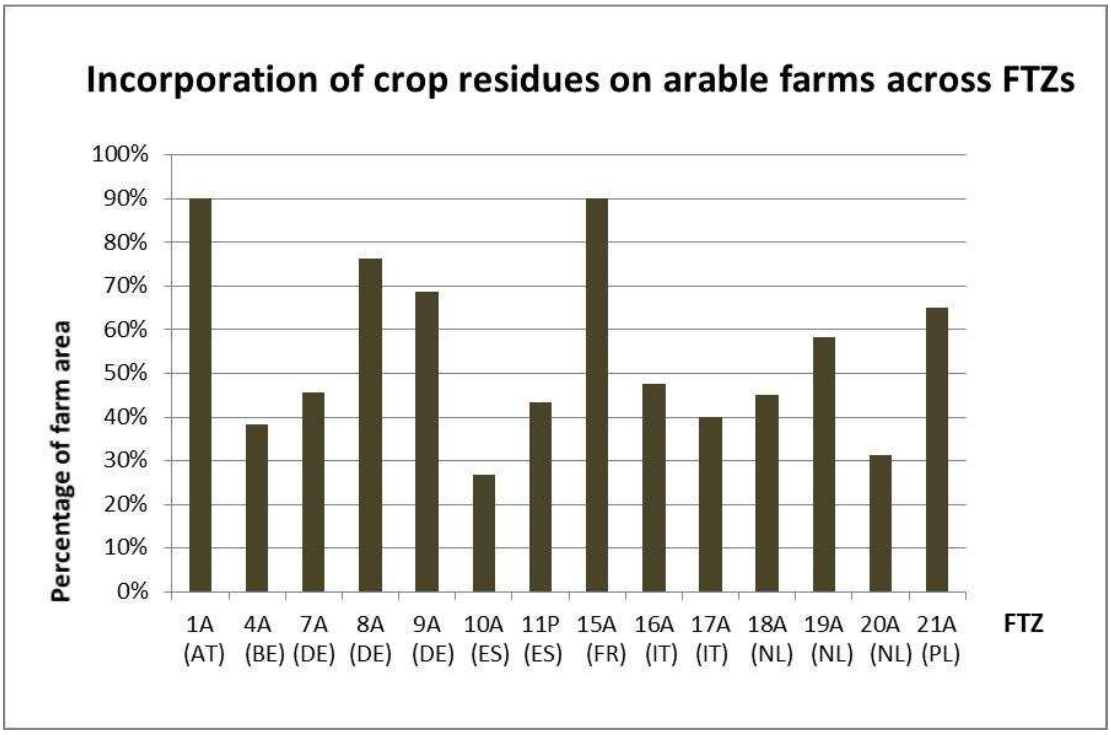

Figure III.7 Area fractions where crop residues are applied, for FTZs in arable farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

3.4.2 Livestock farms

Crop residues are incorporated in roughly one third (25 to 35%) of the area on cattle farms in Spain, dairy cattle farms in Italy, and Poland (12C, 16C and 23C). More incorporation (>70% of the area) of crop residues does occcur in mixed and dairy cattle farming in Austria, mixed farming in Belgium, dairy cattle farming in the Netherlands, and mixed farming in Poland (2M, 3C, 6M, 20C and 22M). Practically no incorporation of crop residues does occur on dairy cattle farms in Belgium and France (5C and 14C, see figure III.8).

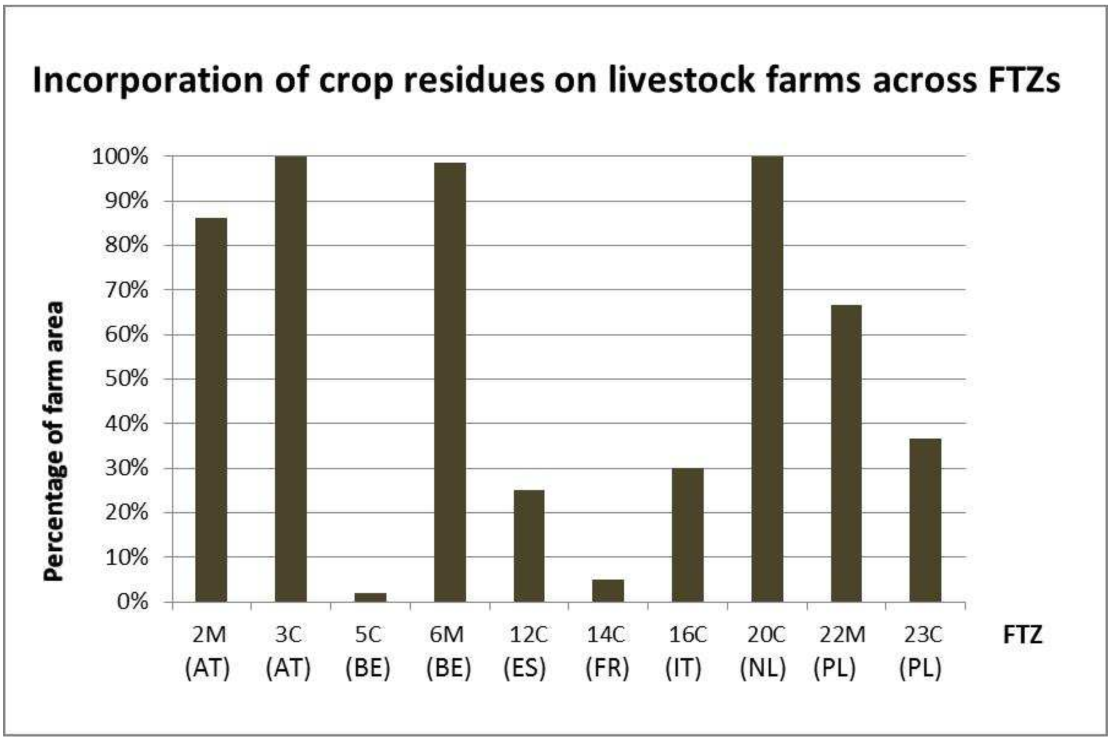

Figure III.8 Area fractions where crop residues are applied, for FTZs in livestock farming. FTZs with smaller area fractions are ignored. Information on the FTZs can be found in Table II.6

4 Discussion and main conclusions

Main conclusions from the compiled information on arable farming are : (a) green manures are applied on average on 20% of the total area, (b) conventional tillage is practised on average on 70% of the total area, non-inversion tillage on 30% of the total area, and minimum tillage is hardly applied, (c) manure as mainly animal slurry is applied on the main part (60 to 90%) of the total area in Belgium, Germany and the Netherlands and on a limited part of the total area (<20%) on FTZs in the other CATCH-C countries, and (d) crop residues are incorporated on average in half of the total area.

Main conclusions from the compiled information on livestock farming are : (a) green manures are applied on a small part (i.e. 0 to 20%) of the total area, (b) conventional tillage is practised on average on 85% of the total area, non-inversion tillage on 15% of the total area, and minimum tillage is practically not applied, (c) animal slurry is applied on the main part (>80%) of the total area on FTZs in all CATCH-C countries except for farming in Poland and beef and mixed cattle and sheep/goats farming in Spain where slurry is applied on less than 20% of the total area, (d) on FTZs in Belgium and Netherlands mainly animal slurry is applied, on FTZs in Austria, France and Italy both animal slurry and farm yard manure are applied, and in Poland mainly farm yard manure is applied.

The compiled information on current management practices and their occurrence depends on estimates by the agricultural extension officers. Some extension officers expressed that they found it difficult to provide good estimates for certain FTZs.

Differences between FTZs in the occurrence of certain management practices can be explained from differences in the farm type (e.g. nutrient management and tillage practices are different between arable and livestock systems). Further, the overall intensity of the farming (notably livestock density and hence the availability of manures) differs between countries. For example, very large area fractions receive animal manure in arable farming in Belgium, Germany and the Netherlands, in contrast to the other CATCH-C countries (Fig. III.5). Also, cropping systems and their biophysical context vary widely (e.g. minimum tillage is only applied in Spain and probably mainly in the dry and erosion-sensitive areas in southern Spain with arable and permanent cropping, as shown in Fig. III.3 and Fig. III.4).

Part of the differences between FTZs in the applied management practices, however, can not be explained from our classification. Variation may be caused by regional and national differences in the farm structure and land ownership, the historic development of agricultural sectors, the protection of the environment and landscape, and the main recommendations by agricultural extension services. These regional and national differences may cause differences between FTZs that are otherwise similar.

IV. Inventory of main soil degradation problems in the participant countries

1 Introduction

The partners in the CATCH-C project have compiled information on the main soil degradation problems in their country based on available sources and have produced country reports (see Appendix D). A compilation of the main soil degradation problems is given in the following. The main types of soil degradation are: (a) wind erosion, (b) water erosion, (c) contamination with biocides, heavy metals and excess nutrients, (d) decrease in soil organic matter, (e) loss of soil biodiversity and soil health, (f) soil physical problems like sub-soil compaction, reduced drainage and soil sealing, (g) salinization, (h) sensitivity to desertification, (i) floods and land slides, (j) soil borne diseases and (k) soil acidification. We refer to this information as ‘Set A’.

Besides, during the inventories of current management practices (Section III) the Agricultural Extension Officers (AEOs) have also been asked for information about the main soil degradation problems per FTZ. This rather qualitative information has been compiled in Table IV.5. We refer to this information as ‘Set B’.

2 Overview of the main soil degradation problems in the EU and participant countries (Set A)

An overview of the main soil degradation problems as reported (Set A) for the different CATCH-C countries, is given in Table IV.1. This shows that water erosion, contamination, soil physical problems (e.g. compaction) and decrease in soil organic matter are problems in most countries, that salinization is mainly of importance in southern Europe and in coastal plains (i.e. Spain, Italy and the Netherlands) and desertification in mainly southern Spain, that low soil fertility is a problem in extensively managed areas in Spain, that floods and land slides do occur in the mountainous areas of France and Italy, and that soil acidification can be problematic in France and Poland and mainly with soils developed in acidic parent material (e.g. granite).

Table IV.1 Reported soil degradation problems for the CATCH-C countries (see Appendix D for detailed information)

Country, Soil degradation problem	Austria	Belgium	France	Germany	Italy	Netherlands	Poland	Spain
Wind erosion	x	x		x				
Water erosion	x	x	x	x	x	x	x	x
Contamination		x	x	x	x	x	x	

Loss of soil organic C		x	x	x	x	x	x	
Loss of soil biodiversity			x	x		x		
Soil physical problems	x	x	x	x	x	x	x	x
Low/reduced soil fertility								x
Salinization					x	x		x
Desertification								x
Floods & land slides			x		x			
Soil borne diseases								
Soil acidification			x				x	

Next, for the selected and main FTZs in each of the eight participant countries the type and degree of the main soil degradation problem is given in Tables IV.2, IV.3, and IV.4. These estimates on the degree of soil degradation are mainly based the reported major soil degradation problems per country (Appendix D) and partly too on expert knowledge. This shows that in Austria water erosion is an important problem because of its mainly hilly and mountainous areas, and that soil physical problems (i.e. sub-soil compaction) do occur particularly in arable farming. Wind erosion does only occur with arable farming in the most Eastern parts of Austria (Table IV.2).

In Belgium, main soil degradation problems are related to nitrogen and phosphorus leaching which result in contamination of ground and surface waters. This is related to high animal densities and the resulting high animal slurry production and application per hectare in Belgium. Erosion by water and tillage operations does mainly occur on arable land in the central hilly and loamy area of Belgium (FTZ 4A, see Table II.6) Sub-soil compaction and decreasing amounts of soil organic carbon in the topsoil (mainly due to past land-use changes and recent decreases in organic matter inputs from manure (mainly as animal slurry), crop residue and cereal straw incorporation) are issues in all FTZs and may result in less favourable structure and permeability of the topsoil (Table IV.2). Wind erosion is mainly a problem in FTZ 5C, being particularly vulnerable due to the combination of open terrains and sandy soils. For more details about the soil degradation problems in Austria, Belgium and the six other CATCH-C countries, we refer to the respective country reports, as given in Appendix D.

Table IV.2 Main soil degradation problems for the selected and major FTZs in Austria and Belgium (see Appendix D for detailed information)[1]

Country, FTZ AEZ Specialization/ land use[2] Soil degradation problem	Austria 1A ENZ8_SL3_TXT2 Arable farms/ cereals	Austria 2M ENZ6_SL3_TXT2 Mixed farms	Austria 3C ENZ5_SL5_TXT2 Dairy cattle/ permanent grass	Belgium 4A ENZ7_SL2_TXT3 Arable farms/ specialised crops	Belgium 5C ENZ7_SL1_TXT1 Dairy cattle/ permanent grass	Belgium 6M ENZ7_SL1_TXT2 Mixed farms
Wind erosion	x	0	0	0	x	0
Water erosion	x	x	x	X	0	0
Contamination				X	X	X
Loss of soil organic C				X	X	X
Soil physical problems	x	0	0	x	x	x

[1] 0 = not of importance, x = weak to moderate problem, X = serious to very serious problem
[2] See Section II.2 for the AEZ classes used, see Section II.3 for the farm type classes used, see Fig. II.1 and II.2 for resp. the environmental zones and texture classes in the CATCH-C countries and Fig. II.4 for the texture and slope classes

In France, the main soil degradation problems do occur in arable farming, such as water erosion, floods and landslides in particularly the hilly and mountainous areas, soil acidification in mainly soils derived from acidic parent material (e.g. sandstone and granite), decreasing amounts of soil organic carbon in the topsoil due to changed crop rotations and soil physical problems due to increasing use of heavy machinery in field operations. These last two degradation problems may cause a loss of soil biodiversity. Contamination does occur on both arable and dairy cattle farming in France, both with nitrogen due to excess applications of animal manure and/or with heavy metals due to application of sludge from waste water treatment plants (Table IV.3).

In Germany wind erosion is a problem on the sandy soils, and water erosion and soil physical problems (i.e. soil compaction) in the hilly areas with loamy soils. On most farm types in Germany the amounts of soil organic carbon in the topsoil decrease due to changed crop rotations which may cause a loss of soil biodiversity. Lowest soil organic carbon contents are found on the sandy soils. Contamination with both nitrogen and heavy metals are a problem due to resp. excessive use of nitrogen in agriculture and both atmospheric deposition from industrial areas and application of sewage sludge. The problem with nitrogen eutrophication is most serious on the sandy soils in Northern Germany (Table IV.3).

In Spain the main soil degradation problem has to do with water erosion. This problem mainly occurs in the hilly and mountainous areas with a semi-arid climate with its limited vegetation cover and high rainfall intensity. On the arable farms decrease in the amounts of soil organic carbon in the topsoil, soil compaction and a low soil fertility are often a problem. In southern Spain with both arable and permanent cropping, salinization and desertification do occur (Table IV.3).

Table IV.3 Main soil degradation problems for the selected and major FTZ in France, Germany and Spain (see Appendix D for detailed information)[1]

Country, FTZ AEZ Specialization/ land use[2] Soil degradation problem	Germany 7A ENZ4_ SL1_ TXT1 Arable & Mixed farms/ specialised crops	Germany 8A ENZ6_ SL1_ TXT1 Arable & Mixed farms/ specialise d crops	Germany 9A ENZ6_ SL2&3_ TXT3 Arable & Mixed farms/ specialised crops	Spain 10A ENZ13_ SL1, 2,3&4_ TXT4 Arable farms/ cereals	Spain 11P ENZ13_ SL2, 3&4_ TXT3 Perma-nent crops	Spain 12C ENZ11&13_ SL5_ TXT2 Beef and mixed cattle/ permanent grass & Sheep and goats/ land based	France 13A ENZ12 _SL3_ TXT4 Arable farms	France 14C ENZ7_ SL2_ TXT3 Dairy cattle	France 15A ENZ7_ SL2_ TXT2 Arable farms
Wind erosion	x	x	0						
Water erosion	0	0	x	X	x	X	x	0	0
Contamination	X	x	x				x	x	x
Loss of soil organic C	x	x	x	x	0	0	x	0	x
Loss of soil biodiversity	x	x	x				x	0	x
Soil physical problems	0	0	x	x	0	0	x	0	x
Low/reduced soil fertility				x	0	x			
Salinization				x	x	0			
Floods & land slides							x	0	0
Soil acidification							0	x	x
Desertification				x	x	0			

[1] 0 = not of importance, x = weak to moderate problem, X = serious to very serious problem
[2] See Section II.2 for the AEZ classes used, see Section II.3 for the farm type classes used, see Fig. II.1 and II.2 for resp. the environmental zones and texture classes in the CATCH-C countries and Fig. II.4 for the texture and slope classes in Austria

In Italy, the main soil degradation problems are water erosion, floods and land slides with arable farming in the hilly and mountainous areas. On arable farms in general, both decreases in soil organic carbon in the topsoil and soil compaction and resulting reduction in hydraulic permeability do occur. Salinity problems mainly occur in small lowland areas along the coast. Some contamination of the soils with excess amounts of nitrogen, phosphorus, pesticides and heavy metals does occur (Table IV.4).

In the Netherlands the main soil degradation problem is the strong contamination with nitrogen, phosphorus, and pesticides and to a lesser extent with heavy metals. This can be explained from the present and particularly past high applications of both organic and inorganic fertilisers and pesticides in Dutch agriculture. Another and minor problem is sub-soil compaction which is due to the increased use of heavy machinery in arable farming (Table IV.4).

In Poland, soil acidification is a major problem (on more than 50% of agricultural area in Poland) and particularly on the soils derived from acidic parent material (i.e. sedimentary rocks with a light texture). Problems in arable farming are related to water erosion, decrease in soil organic carbon, and to soil compaction on particularly the loamy soils (Table IV.4).

Table IV.4 Main soil degradation problems for the selected and major FTZ in Italy, The Netherlands and Poland (see Appendix D for detailed information)[1]

Country,	Italy	Italy	Italy	Nether lands	Nether lands	Nether lands	Nether lands	Poland	Poland	Poland
AEZ	16A	16C	17A	18A	19A	20A	20C	23C	22M	21A
Specialization/ land use[2]	ENZ12_SL1_TXT1, 2&3	ENZ12_SL1_TXT1, 2&3	ENZ12_SL3&4_TXT 2&3	ENZ7_SL1_TXT2 &3	ENZ4_SL1_TXT2 &3	ENZ4 &7_SL1_TXT1	ENZ4 &7_SL1_TXT1	ENZ6_SL1_TXT1	ENZ6_SL2_TXT1	ENZ6_SL2_TXT3
Soil degradation problem	Arable farms/ cereals	Dairy cattle/ tempo-rary grass	Arable farms/ cereals	Arable farms/ specialised crops	Arable farms /specialised crops & cereals	Arable farms/ specialised crops	Dairy cattle/ permanent grass	Dairy cattle/ permanent grass	Mixed farms	Arable farms/ cereals
Water erosion	0	0	X	0	0	0	0	0	0	x
Contamination	x	x	x	X	X	X	x	0	x	0
Loss of soil organic C	x	0	x	0	0	0	0	0	0	x
Loss of soil biodiversity				0	0	0	0			
Soil physical problems	x	0	x	x	x	x	0	0	0	x
Salinization	0 to x	0 to x	0	0	0	0	0			
Floods & land slides	0	0	x							
Soil acidification	0	0	0					x	x	x

[1] 0 = not of importance, x = weak to moderate problem, X = serious to very serious problem
[2] See Section II.2 for the AEZ classes used, see Section II.3 for the farm type classes used, see Fig. II.1 and II.2 for resp. the environmental zones and texture classes in the CATCH-C countries and Fig. II.4 for the texture and slope classes in Austria

3 Examples of main soil degradation problems in two countries (i.e. the Netherlands and Poland)

Two main soil degradation problems are reported in more detail for two countries, i.e. contamination in the Netherlands and decrease in soil organic matter in Poland. For more information about the other major soil degradation problems in these countries and in the other six countries, see Appendix D.

3.1 Diffuse contamination in the Netherlands (by Annette Pronk)

- Heavy metals: up to 2005, the diffuse contamination by heavy metals is mainly caused by agricultural land use (www.emissieregistratie.nl), in particular by the use of fertilizers (synthetic and organic fertilizers). In 2005 the accumulation of heavy metals had slowed down compared to 1990 but eventually high concentrations above standard levels may occur.

- Pesticides: The objectives for 2010 for the environment and safe handling by workers (Ministerie van Landbouw Natuur en Voedselkwaliteit 2004) have not been achieved, although crop protection has become more sustainable (Van Eerdt, et al. 2012). Van Eerdt et al. (2012) conclude: " As a result of successful regulation, the use of plant protection products by farmers and growers has placed a considerably smaller burden on the environment over the 1998-2010 period. Two-thirds of the environmental benefits were found to be due to the implementation of emission reduction measures. However, surface waters still contain too large amounts of residues from plant protection products. This adversely affects aquatic organisms as well as drinking water. Moreover, growers to date still pay insufficient attention to risks related to plant protection products and their safe handling."

- Nutrients: Excess applications of fertilizers and manure increased nutrient amounts in the soils from 1960 to 2000 with 60-100 kg P_2O_5/ha/year, causing about 55% of the agricultural land to be saturated with phosphate (Fig. IV.1, left; source: Schoumans 2004). This is slightly lower than the amounts estimated by Römkens & Oenema (2004) due to a slightly different definition of phosphate saturation on clay soils. N-applications have induced N leaching to the surface and shallow groundwater (Fraters 2000) and are still forming a threat (Boumans and Fraters 2011). Most problems are found at this moment on the sandy soils in the South (Fig. IV.1, right) of the Netherlands (Schoumans, et al. 2012).

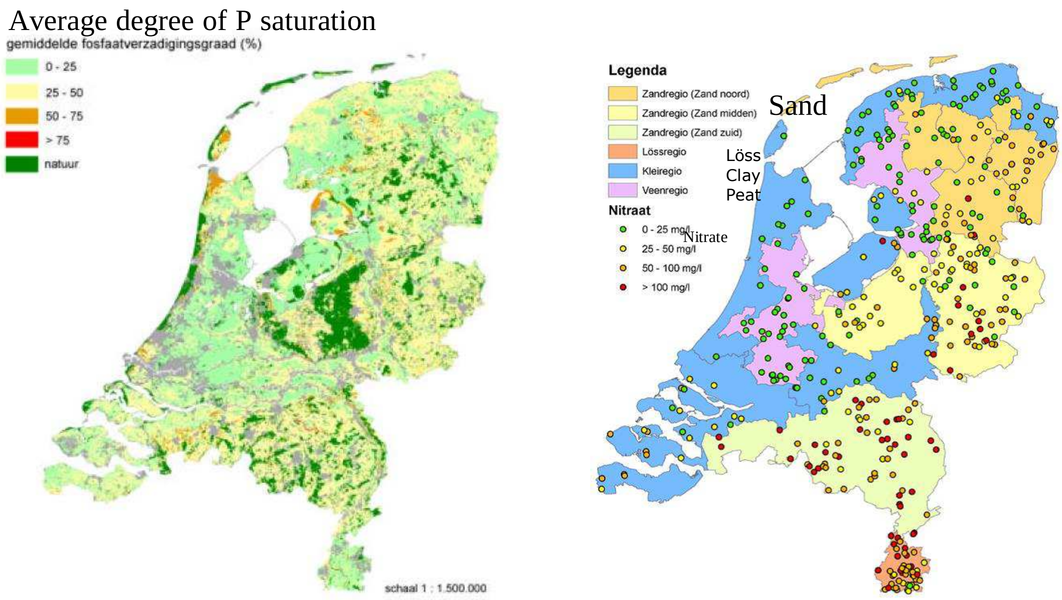

Figure IV.1 Left: Phosphate saturated soils in the Netherlands as measured in the period 1992-1998. For agricultural land, four classes have been distinguished that take into account a criterion for the degree of phosphate saturation for specific types of soil (Schoumans 2004). Right: Nitrate concentrations measured in the shallow ground water between 2007 and 2010 on farms of the LMM (nationwide monitoring network on the effects of the manure policy (Hooijboer and De Klijne 2012))

3.2 Decrease in soil organic matter in Poland (by Grzegorz Siebielec et al.)

Variations in soil organic matter (SOM) contents over Poland are strongly driven by natural factors such as texture, slope or water regime. Lowest SOM contents are found in light texture soils with low groundwater tables. The range of SOM in the arable soils of Poland is wide (0.5-10%), with the average SOM content equal to 2.2%. Organic soils are usually used for grasslands and not for arable cropping.

Area fraction of soils with extremely low SOM content (<1%) is 6%, whereas the area fractions of other SOM content groups are as follows: 50%, 33% and 11% for resp. 1-2%, 2-3.5% and >3.5% SOM contents. In 89% of the soils in Poland, the SOM content is below 3.5% (approx. 2% C), which can be considered within Europe as a low SOM content. This is specific for Polish soils which often have a light texture and low water holding capacity, resulting in unfavourable conditions for accumulation of organic matter in the soils.

In some regions of Poland the area of land that is only used for arable crop production, increases over time, whereas there is a limited animal production and thus manure application to these soils. This results in a negative balance of SOM at the farm level, as shown in a SOM map for Poland (Fig. IV.2). These balances of organic matter inputs and outputs are based on data on crop rotations and manure and organic matter applications. Positive changes in SOM over time are found in regions with intensive animal production and/or extensive grassland areas.

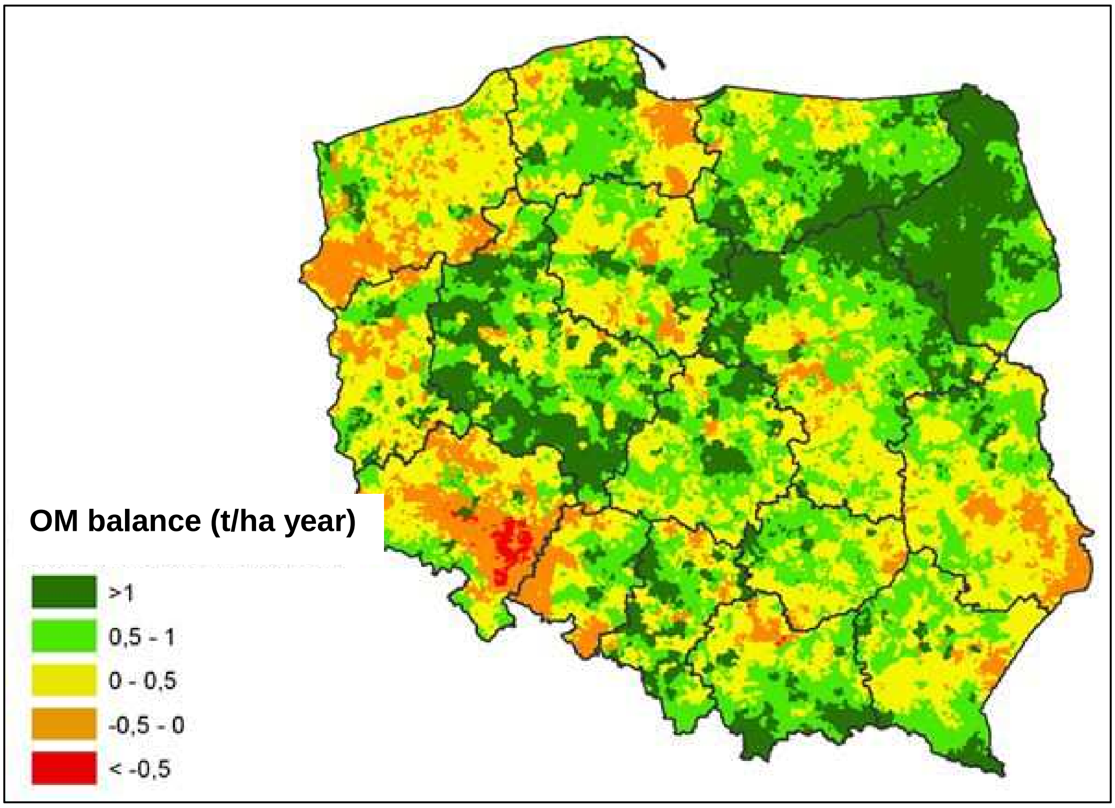

Figure IV.2 Change in soil organic matter (SOM) at farm level in Poland as based on organic matter input - output balances

4 Information on main soil degradation problems from inventories (Set B)

During the inventories of current management practices (Section III) the Agricultural Extension Officers (AEOs) were asked for information about the main soil degradation problems per FTZ. This qualitative information has been compiled in Table IV.5. We refer to this information (obtained from AEOs) as 'Set B'. Note that each of the soil degradation problems mentioned by AEOs is included here, even when this problem was only mentioned in only one out of the three interviews per FTZ.

The AEOs have been asked if one of the specified soil degradation problems were of importance in the selected FTZ: a) Water erosion, b) Wind erosion, c) Contamination, d) Negative soil organic matter balance, e) Loss of biodiversity, f) Soil borne diseases, g) Compaction, h) Floods and land slides, i) Desertification, and j) Salinization. Next, the AEOs were asked to describe which management practices cause or enhance the soil degradation problems mentioned (Table IV.5).

In the following paragraphs, we will compare the soil degradation problems as mentioned by the AEOs (Set B, Table IV.5) with those mentioned in the country reports (Set A, Tables IV.2, IV.3, IV.4). This is done to verify the consistency between both data sets on soil degradation problems.

Austria

According to Set A for Austria, water erosion is an important problem and compaction particularly does occur in arable farming. Wind erosion does only occur with arable farming in the most Eastern parts of Austria (Table IV.2). AEOs have mentioned the same major problems, but also some minor problems like contamination, negative soil organic matter balance, loss of biodiversity, and floods and land slides (Table IV.5).

Belgium

In Belgium, main soil degradation problems according to Set A are related to contamination of ground and surface waters with mainly nitrogen and phosphorus, water erosion, compaction, and decreasing amounts of soil organic matter in the topsoil (Table IV.2). Wind erosion is mainly a problem in FTZ 5C, being particularly vulnerable due to the combination of open terrains and sandy soils. AEOs have mentioned water erosion, negative soil organic matter balance, and compaction as major problems and also wind erosion (only on sandy soils), and soil borne diseases as a minor problem (Table IV.5). Hence, the same problems as in Set A were mentioned by the AEOs, but the contamination by nitrogen and phosphorus were not mentioned by AEOs.

Germany

In Germany (Set A) wind erosion is a problem on the sandy soils, and water erosion and soil physical problems (i.e. soil compaction) in the hilly areas. On most farm types the amounts of soil organic carbon in the topsoil decreases. Lowest soil organic carbon contents are found on the sandy soils. Contamination with both nitrogen and heavy metals are a problem, of which nitrogen eutrophication is most serious on the sandy soils in Northern Germany, and also the loss of soil biodiversity (Table IV.3). AEOs (Set B) have mentioned wind erosion on the coarse (sandy) soils and water erosion as the major problems and negative soil organic matter balance, loss of biodiversity, compaction, contamination and soil borne diseases as minor problems (Table IV.5). Hence, the same problems as in Set A were mentioned by the AEOs. In addition, they mentioned soil borne diseases.

Spain

In Spain the main soil degradation problem as documented in Set A, has to do with water erosion. This problem mainly occurs in the hilly and mountainous areas. On the arable farms, decrease in the amounts of soil organic carbon in the topsoil, soil compaction and a low soil fertility are often a problem. In Southern Spain with both arable and permanent cropping, salinization and desertification do occur (Table IV.3). AEOs (Set B) have also mentioned water erosion as the major problem and contamination, negative soil organic matter balance, loss of biodiversity, soil borne diseases, compaction, desertification, and salinization as minor problems (IV.5). Hence, the same problems as in Set A were mentioned by the AEOs except for low or reduced soil fertility. In addition, AEOs mentioned as problems contamination, loss of biodiversity, and soil borne diseases.

France

In France, the main soil degradation problems (Set A) do occur in arable farming, such as water erosion, floods and landslides in particularly the hilly and mountainous areas, soil acidification in mainly soils derived from acidic parent material, decreasing amounts of soil organic carbon and soil physical problems (e.g. compaction). Contamination does occur on both arable and dairy cattle farming in France, with nitrogen and/or with heavy metals (Table IV.3). AEOs have mentioned wind erosion, negative soil organic matter balance, compaction and loss of biodiversity as the major problems, mainly occurring in arable farming, and water erosion and floods and land slides as minor problems (Table IV.5). Hence, roughly the same problems as in Set A were mentioned by the AEOs, but they did not mention the contamination by nitrogen and heavy metals. AEOs gave wind erosion as an additional point.

Italy

In Italy, the main soil degradation problems (Set A) are water erosion, floods and land slides with arable farming in the hilly and mountainous areas. On arable farms in general, both decreases in soil organic carbon and soil compaction do occur. Salinity problems mainly occur in small lowland areas along the coast. Some contamination of the soils with excess amounts of nitrogen, phosphorus, pesticides and heavy metals does occur (Table IV.4). AEOs (Set B) have mentioned water erosion, negative soil organic matter balance, and compaction as major problems and loss of biodiversity and floods and land slides as minor problems (Table IV.5). Hence, the same problems as in Set A were mentioned by the AEOs except for salinity and contamination problems. In addition, AEOs mentioned as a problem loss of biodiversity.

The Netherlands

In the Netherlands the main soil degradation problem (Set A) is the strong contamination with nitrogen, phosphorus, and pesticides and to a lesser extent with heavy metals. Another and minor problem is compaction (Table IV.4). AEOs (Set B) have mentioned wind erosion, negative soil organic matter balance, soil borne diseases, and compaction as major problems and loss of biodiversity and salinization as minor problems (Table IV.5). Hence, the AEOs mentioned five problems in addition to compaction, but did not consider contamination.

Poland

In Poland, soil acidification is reported as a major problem (Set A). Problems in arable farming are related to water erosion, decrease in soil organic carbon, and to soil compaction on particularly the loamy soils (Table IV.4). AEOs (Set B) have mentioned wind erosion and negative soil organic matter balance as major problems and water erosion, contamination, loss of biodiversity, soil borne diseases and salinization as minor problems (Table IV.5). Hence, the AEOs mentioned five problems in addition to negative soil organic matter balance and water erosion, but did not mention soil acidification and compaction.

Summary

Summarizing, the main points about the soil degradation problems as reported for each of the CATCH-C countries as based on government and environmental agency studies (see Table IV. 2 upto and including Table IV.4) and the problems mentioned in the interviews by the agricultural extension officers (Table IV.5), are the following: (a) the reports for the CATCH-C countries (Appendix D) and the AEOs mentioned largely the same soil degradation problems, (b) the AEOs focused more on the field level and hence, mentioned more often problems as soil borne diseases, loss of biodiversity and wind erosion, (c) the country reports focused more on the wider (i.e. regional) scale and hence, mentioned more often the problem of contamination.

Table IV.5 Selected FTZs with their Soil degradation problems and Enhancing practices as based on interviews with agricultural extension officers for the selected FTZs in each of the CATCH-C countries. See Table II.6 for more information about the selected FTZs. The soil degradation problems are indicated as follows: A=Water erosion, B=Wind erosion, C=Contamination, D= Negative soil organic matter balance, E= Loss of biodiversity, F= Soil borne diseases, G= Compaction, H=Floods and land slides, I= Desertification, J= Salinization.

Country[1]	**AEZ ID**	**FTZ ID**	**Slope**	**Soil texture**	**Farm specia-liza-tion**	**Main problems,** Other problems	**Enhancing practices per problem**
AT	1	1A	gentle slopes	medium soils	arable	**A, B,** G	A-root crops without green manure crops; B- uncovered soil, root crops with slow growth, tillage, large slope length, G- increasing wheel loads
	2	2M	gentle slopes	medium soils	mixed	**A,** G, C, D, E	A- conventional tillage, frequent tillage, root crops, lack of soil coverage, G- increasing wheel loads, wrong timing for tillage, C- increased application of organic fertilizer and plant protective agents, D- reduced rotation elements, E- increasing wheel loads
	3	3C	strong to steep slopes	medium soils	dairy cattle	**A,D,E**,G, H,C	A-conventional tillage, D- monoculture (e.g. silage maize), E- increasing forest cover, G- high tire pressure, H- natural conditions, C- transit, industry (e.g. sulphur)
BE	4	4A	nearly level	medium fine soils	arable	**A**,G	A- Larger arable land parcels, grassland conversion into arable land, low organic matter input, hilly region, G- use of heavy machinery when harvesting in late fall or when applying manure in spring under wet conditions
	5	5C	level	coarse soils	dairy cattle	**B,G,D**,E, F	B- Intensive tillage leads to fine topsoil, G- Use of heavy machinery + often harvesting in late fall under wet conditions or applying manure in spring under wet conditions, D- Monoculture silage maize + cattle slurry is generally the only source of exogenous organic matter, E- Monoculture silage maize + cattle slurry is generally the only source of exogenous organic matter, F- No real enhancing practice
	6	6M	level	medium soils	mixed	**D,A**,F,G	D- Rotations with only horticultural crops, the application of large amounts of slurry, A- Intensive agriculture, row cropping, F- Rotations with only horticultural crops, intensive agriculture, G- Use of heavy machinery, incorrect plough set-up
DE	7	7A	level	coarse soils	arable+ mixed	**B**,A,D,E, G,F	B- high percentage of maize, potatoe and sugar beets in rotation, long period with uncovered soil, ploughing in fall, A- too much maize in rotation, D- remove of crop residues, monoculture, E- too big fields, big harvest machinery, maize monoculture, G- too heavy machinery, bad timing, F- too narrow rotations, too much potato in rotation, potato after maize, non- resistant varieties
	8	8A	level	coarse soils	arable+ mixed	**B**,A,D,E, G,C	B- uncovered soil during crop rotation, insufficient amount of soil organic matter, A- uncovered soil during crop rotation, insufficient amount of soil organic matter, D- narrow crop rotation with high amount of humus draining crops, rotation with maize, E- general problem of conventional agriculture,

							monoculture, G- less soil tillage, conservation tillage.
	9	9A	nearly level and gentle slopes	medium fine soils	arable+ mixed	**A**, G	A- too much tillage, ploughing at the wrong time, not putting enough lime, maize is replacing rapeseed and thus the soil is longer bare, G-mechanization, high axial load
ES	10	10A	level to modera te slopes	fine soils	arable	**A**,D,G, C,F,E	A- Conventional and excessive tillage, bare soil, D- Stubble burning (now forbidden), intensive tillage, C- careless fertiliser application, F- Monoculture, E- Inappropriate use of insecticides, fungicides, herbicides; disappearance of edges,
	11	11P	nearly level to modera te slopes	medium fine soils	Perma- nent crops	**A**,C,D,G, I,E,F, J	A- Intensive tillage and steep slopes, C- Herbicide application and light tillage, excessive application of fertilisers and herbicides, D- Excessive tillage, no tillage, bare soil, G- Using heavy machinery and deep ploughing,, no tillage and bare soil, I- Excessive use of herbicides, E- Incorporation of contaminated residues, Intensive monoculture, F- Excessive herbicide use, J- Irrigation with saline water
	12	12C	strong to steep slopes	medium soils	beef and mixed cattle + sheeps and goats	**A**,C,E,F, G	A- Excessive tillage, Over-grazing. Consumption of whole pasture, Excessive cattle density, C- Excessive cattle density, E- Eliminate the autochthonous vegetation, F- Soil born disease (Phytophthora cinnamomi), introduced from Portugal and. Causes holm oak die-off, G- High stocking rate for a long time
FR	13	13A	gentle slopes	fine soils	arable	**B**,A,E	B- conventional tillage, A- conventional tillage, E- conventional tillage
	14	14C	nearly level	medium fine soils	dairy cattle	**G**,H	
	15	15A	nearly level	medium soils	arable	**D,G,E**	D- selling of crop residues, monoculture, G- use of heavy machinery, E- monoculture
IT	16	16A	level	coarse to medium fine soils	arable	**A,D**,G	A- deep tillage, D- selling stalks, G-use of heavy machinery
	16	16C	level	coarse to medium fine soils	dairy cattle	**D,G**,E	D- change from FYM to slurry, G- Harvest operations, Slurry distribution operations (in narrow and sometimes unfavourable time window), E- excessive use of slurry
	17	17A	gentle and modera te slopes	medium and medium fine soils	arable	**A,D**,G,H	A- Tillage., Lack of money to properly manage the soil, Bare soil, D- rotation, G- on clay soils, H- due to lack of trees, may occur suddenly after heavy rainfall
NL	18	18A	level	medium and medium fine soils	arable	**G,D**,J,F	G- heavy machinery, larger farm sizes, root and tuber crops+ intensification, D- decreasing rotations with cereals, selling of straw, use of mainly mineral fertilisers, less possibilities for animal manure and compost applications because of regulation, J- too shallow drainage, natural infiltration of brackish water, F- Spread to this region from other regions through machinery and employees, too tight crop rotation
	19	19A	level	medium and medium fine soils	arable	**F,G,D**	F- narrowing rotation, frequent potato growing with non-resistant varieties, G- heavy machinery, heavy (harvest) machines in wet autumn, D- Selling of cereal straw, more root and tuber crops, little cereals and green manure in

							rotation
	20	20A	level	coarse soils	arable	**B,D,F**,E, G	B- conventional tillage (crop residues are incorporated in the soil), due to decreasing soil organic matter, too much soil cultivation, D- intensive rotations (mainly sugarbeet and potatoes), manure regulation allows less application of manure, too limited organic matter input (e.g. green manures, manure, crop residues or compost), F- Too intensive rotations wrong crop order in rotation,, limited chemical protection available, intensive rotations causing cyst nematodes, land exchange, E- too little subsidies, G- heavy machinery
	20	20C	level	coarse soils	dairy cattle	**D,G**,F,B	D- monoculture of maize, too little application of organic matter, caused by legislation, G- heavy macines, more extreme weather, F- monoculture of maize, lack of rotation, B- application of cattle slurry is forbidden, soil structure is too fine,
PL	21	21A	nearly level	medium fine soils	arable	**B,D**,A,E	B- Monoculture, soil without crop cover after the growing season, bare soil in winter, annual crops, D- Mono-culture, soil is without crop cover after growing season, selling of straw, mono-culture, A- irregular precipitation, E- monoculture
	22	22 M	nearly level	coarse soils	mixed	**B**,A,D,C	B- Monoculture, soil is without crop cover after growing season, culture is without cover crop, tillage, A- irregular precipitation, Monoculture, soil is without crop cover after growing season, D- Monoculture, improper crop rotation, C- Lack of organic matter and lime
	23	23C	level	coarse soils	dairy cattle	**B,D**,F,J, A,E	B- Tillage, bare soil, D- monoculture, F- monoculture, J- Excessive nitrogen fertilization, A- Heavy rain, flood, slope, E- monoculture

[1] AT= Austria, BE= Belgium, DE= Germany, ES= Spain, FR= France, IT= Italy, NL= Netherlands, PL= Poland

5 Discussion

An overview of the main soil degradation problems as reported for the eight CATCH-C countries, shows that water erosion, contamination, soil physical problems (mainly sub-soil compaction) and decrease in soil organic matter are problems in most countries, that salinization and desertification are mainly of importance in southern Europe (i.e. Spain, Italy), that low soil fertility is a problem in extensively managed areas in Spain, that floods and land slides do occur in the mountainous areas of France and Italy, and that soil acidification can be problematic in France and Poland and mainly with soils developed in acidic parent material.

The overview of the main soil degradation problems suggests that many of the problems are enhanced by current soil management. Examples are: sub-soil compaction due to the use of heavy machinery, water erosion by conventional tillage, decrease in soil organic matter due to the increasing cultivation of crops with lower amounts of crop residues, contamination due to excessive applications of fertilizers and pesticides, and wind erosion on sandy soils due to insufficient field coverage.

On the other hand, there are a number of ‘unmanageable factors’ that enhance the susceptibility of soils and aggravate the damage arising from un-adapted management. Examples of these factors are: climate (e.g. salinization and desertification which only occur in southern Europe), landscape (e.g. water erosion, floods and land slides which mainly are problematic in hilly and mountainous areas), parent material of the soils (e.g. soil acidification) and location (e.g. salinization in coastal plains).

Prevention of soil degradation problems which are not caused by current soil management, requires governmental actions at the regional and/or national scale, like improved irrigation or water management to prevent salinization, and forest protection, terracing and construction works to prevent water erosion, floods, land slides and desertification in mountainous and/or semi-arid areas.

The soil degradation problems that can be reduced by improved soil management are: wind and water erosion and the resulting loss of soil fertility and organic matter; sub-soil compaction and the resulting reduction in hydraulic permeabilit; decrease in soil organic matter and the resulting decrease in soil quality, structure and soil fertility; and contamination with nutrients and pesticides and the resulting pollution of ground and surface waters.

It is shown that the reports for the CATCH-C countries (Appendix D) and the information collected from the agricultural extension officers (AEOs) through the interviews per FTZ largely mention the same soil degradation problems. AEOs, however, focus more on the farmer’s direct interests and hence pay more attention to soil borne diseases, loss of biodiversity and wind erosion. The country reports focus more on the wider (i.e. regional) scale and environmental and social interests, and often pay more attention to broader issues such as contamination.

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V. Linking the main soil degradation problems to current management practices and possible remedies

1 Introduction

Information have been collected through interviews of agricultural extension officers (AEOs) and next compiled on current management practices for each of the selected farm type- agri-environmental zone combinations (FTZ) in the eight CATCH-C countries. Information on current field management has been collected about many topics (e.g. crop rotation, grassland, tillage, nutrients, water, and crop protection), as shown in the questionnaire in Appendix B. The presented information on current management practices in Section III covers the following topics: (a) use of green manure, (b) tillage practices, (c) application of organic fertilisers, and (d) incorporation of crop residues, expressed as area fraction for each of the FTZs, and for arable and for livestock farming separately.

The partners in the CATCH-C project have compiled information on the main soil degradation problems in their country and have produced country reports (Set A, Appendix D). This information about the main soil degradation problems in each of the eight CATCH-C countries has been compiled and briefly described in Section IV (see Tables IV.2 - IV.4).

We analyse here if the current soil degradation problems in each of the eight CATCH-C countries, as reported by the partners, can be explained from the current management practices and/or the FTZ characteristics. Note that this analysis is somewhat limited by the fact that only the four management practices, as mentioned above, are available for this analysis and not the information about crop protection and water application practices.

Finally, the AEOS have also been asked for their ideas about remedies against the current soil degradation problems (see Table IV.5). These remedies are summarized and discussed in the following for each of the soil degradation problems.

2 Linkages between soil degradation problems (Set A) and current management for the eight CATCH-C countries

Austria

Water erosion is an important problem because of the mainly hilly and mountainous areas in Austria. Soil physical problems (i.e. subsoil compaction) do particularly occur in arable farming. Main part of the crop residues are incorporated in both arable and livestock farming (Fig. III.7 and III.8), which may explain that decreases in soil organic carbon do not occur here. Only conventional tillage is performed in both arable and livestock farming (Fig. III.3 and III.4), which may partly (in addition to resp. topography and heavy machinery and wrong timing of farm operations) explain both the water erosion and the soil physical problems.

Belgium

Main soil degradation problems are related to the contamination of ground and surface waters with mainly nitrogen and phosphorus, water erosion in mainly the hilly areas, sub-soil compaction, and decreasing amounts of soil organic carbon in the topsoil. Animal manure (mainly pig and cattle slurry) is applied on most arable farms and on practically all livestock farms (Fig. III.5 and III.6) which explains the nitrogen and phosphorus leaching. This high slurry application can be explained from the high livestock density and thus high slurry production per hectare.

Only conventional tillage is applied in arable farming (Fig. III.3), which may partly explain both the water erosion and the soil physical problems. Non-inversion tillage is currently stimulated by the government, as its more wide-spread application would decrease these problems. The decreasing amounts of soil organic carbon in arable farming cannot be explained from the area fractions with green manures (Fig. III.1 --> 50% of total area) and also not from large applications of animal slurry (Fig. III.5), but partly from the limited incorporation of crop residues (Fig. III.7 --> 38% of total area) and possibly from changes in crop rotation towards mainly crops with low amounts of crop residues (e.g. tuber and root crops and maize, replacing small grain crops).

France

Soil degradation problems do occur in arable farming, such as water erosion, floods and landslides in particularly the hilly and mountainous areas, soil acidification in mainly soils derived from acidic parent material, decreasing amounts of soil organic carbon in the topsoil and soil physical problems. Contamination does occur on both arable and dairy cattle farming in France, with nitrogen and/or heavy metals. Animal manure is applied on practically all livestock farms (Fig. IIII.6) which explains the contamination with nitrogen, whereas for arable farming the area fraction with manure application is not available.

Only conventional tillage is applied in both arable and livestock farming (Fig. III.3 and III.4), which may partly explain both the water erosion and the soil physical problems. Problems with floods and land slides cannot be solved at the farm level. Soil acidification can easily be solved by applying sufficient amounts of lime, but that problem is strongly region-specific and that information is not collected in the management interviews. The decreasing amounts of soil organic carbon in arable farming cannot be explained, because no information on the area fractions with green manures, manure application, and incorporation of crop residues is collected. However, the main explanation for the decreasing amounts of soil organic carbon may be the following: changes in crop rotation towards mainly crops with low amounts of crop residues (e.g. tuber and root crops and maize, replacing small grain crops).

Germany

Wind erosion is a problem on the sandy soils, and water erosion and soil physical problems (i.e. soil compaction) in the hilly areas with loamy soils. On most farm types the amounts of soil organic carbon in the topsoil decrease over time and the lowest soil organic carbon contents are found on the sandy soils. Contamination with both nitrogen and heavy metals are a problem due to resp. excessive use of nitrogen in agriculture and both atmospheric deposition from industrial areas and application of sewage sludge. The problem with nitrogen eutrophication is most serious on the sandy soils in Northern Germany.

Animal slurry is applied on most arable farms with sandy soils in Northern Germany (Fig. IIII.5, see FTZ 7A) which explains the contamination here with nitrogen. However, on the other two FTZs (8A and 9A) in resp. Eastern and Central & Southern Germany the area fractions with manure application appear to be limited (<30%) which indicates that contamination could be less of a problem. Only conventional tillage is applied in arable and mixed farming (Fig. III.3), which may partly explain both the water erosion and the soil physical problems in the hilly areas with loamy soils.

The decreasing amounts of soil organic carbon in arable farming can be explained from the low area fractions with green manures (Fig. III.1 --> 10% of total area), from the applications of animal manure (Fig. III.5 --> low area fractions for FTZs 8A and 9A and high area fraction for FTZ 7a but with mainly animal slurry on sandy soils in Northern Germany), not from the incorporation of crop residues (Fig. III.7 --> 50 to 70% of total area) and possibly from changes in crop rotation towards mainly crops with low amounts of crop residues.

Italy

Main soil degradation problems are water erosion, floods and land slides with arable farming in the hilly and mountainous areas. On arable farms in general, both decreases in soil organic carbon in the topsoil and soil physical problems do occur. Salinity problems mainly occur in small lowland areas along the coast. Some contamination of the soils with excess amounts of nitrogen, phosphorus, pesticides and heavy metals is found.

Only conventional tillage is applied in both arable and livestock farming (Fig. III.3 and III.4), which may partly explain both the water erosion in hilly areas and the soil physical problems. Problems with floods and land slides and with salinity cannot be solved at the farm level. Animal manure is almost not applied on the arable farms (Fig. IIII.5), but is always applied on the livestock farms (Fig. III.6), where contamination with nitrogen and phosphorus is expected to be most serious.

The decreasing amounts of soil organic carbon in arable farming can be explained from the low area fractions with green manures (Fig. III.1 --> <10% of total area), the low applications of animal manure (Fig. III.5 --> <10%), partly from the moderate incorporation of crop residues (Fig. III.7 --> 40% of total area) and possibly from changes in crop rotation towards mainly crops with low amounts of crop residues.

Netherlands

Main soil degradation problem is the strong contamination with nitrogen, phosphorus, and pesticides and to a lesser extent with heavy metals. This can be explained from the present and particularly past high applications of both organic and inorganic fertilisers in Dutch agriculture, which are also shown in the high area fractions with manure applications on most arable and livestock farms (Fig. III.5 and III.6) . Another and minor problem is sub-soil compaction. Only conventional tillage (with heavy machinery) is applied in both arable and livestock farming (Fig. III.3 and III.4), which may partly explain these soil physical problems.

Poland

Soil acidification is a major problem and particularly on the soils derived from acidic parent material. Problems in arable farming are related to water erosion, decrease in soil organic carbon, and to soil compaction on particularly the loamy soils. Only conventional tillage is applied in arable farming (Fig. III.3), which may partly explain both the water erosion in the more hilly areas and the soil physical problems.

The decreasing amounts of soil organic carbon in arable farming can be explained from the low area fractions with green manures (Fig. III.1 --> 20% of total area), the low applications of animal manure (Fig. III.5 --> 20%), not from the considerable incorporation of crop residues (Fig. III.7 --> 65% of total area) and possibly from changes in crop rotation towards mainly crops with low amounts of crop residues. Soil acidification can easily be solved by applying sufficient amounts of lime, but that problem is strongly region-specific and that information has not been collected in the interviews.

Spain

Main soil degradation problem has to do with water erosion. This problem mainly occurs in the hilly and mountainous areas with a semi-arid climate with its limited vegetation cover and high rainfall intensity and is aggravated by the application of mainly conventional tillage (about 80% of the total area, see Fig. III.3 and III.4). On the arable farms decrease in the amounts of soil organic carbon in the topsoil, soil compaction and a low soil fertility are often a problem. In southern Spain with both arable and permanent cropping, salinization and desertification do occur.

The decreasing amounts of soil organic carbon in arable farming which may result in low soil fertility, soil physical problems and desertification, can be explained from the low area fractions with green manures (Fig. III.1 --> 10% of total area), possibly from the low applications of animal manure (however, no data collected for Fig. III.5), from the limited incorporation of crop residues (Fig. III.7 --> 25% of total area) and possibly from changes in crop rotation towards mainly crops with low amounts of crop residues. Salinity problems cannot be solved at the farm level.

3 Main soil degradation problems and enhancing practices as based on the inventories (Set B)

The current management practices that are mainly responsible for the different soil degradation problems, can be derived from the information given by the agricultural extension officers in their interviews for each of the FTZs (Table IV.5). These enhancing practices are summarized in the following for each of the soil degradation problems:

- **Water erosion**: lack of soil coverage, conventional tillage, root crops, too steep slopes, low organic matter input, row crops, and for grasslands, overgrazing and too high cattle density
- **Wind erosion**: uncovered soil, root crops, intensive tillage leading to fine topsoil, ploughing in fall, insufficient amount of soil organic matter, incorporation of crop residues in soil
- **Contamination**: excessive application of fertilisers and plant protective agents, excessive cattle density, high application of organic fertilisers, careless fertiliser application
- **Negative soil organic matter balance**: monoculture, replacing farm yard manure by slurry, rotation with only horticultural crops, removal of crop residues, selling stalks and straw, intensive tillage, culture of silage maize with slurry as only source of organic matter, decreasing rotations with cereals, too limited organic matter inputs in soil (e.g. green manure, manure, crop residues, compost)

- **Loss of biodiversity**: monoculture and particularly with only silage maize, conventional tillage, conventional agriculture, inappropriate use of biocides, incorporation of contaminated residues
- **Soil borne diseases**: monoculture, rotation with only horticultural crops, too intensive rotation, wrong crop order in rotation, limited chemical protection agents available, frequent potato growing in rotation, growing non-resistant potato varieties
- **Compaction**: high wheel loads, wrong timing for tillage, high tire pressure, use of heavy machinery, manure application and/or harvesting under wet conditions, bad timing of field operations, no tillage, high stocking rate for a long time period, cultivation of root and tuber crops
- **Floods and land slides**: lack of trees, heavy rainfall events, natural conditions (i.e. areas with steep slopes)
- **Desertification**: excessive use of herbicides
- **Salinization**: irrigation with saline water, too shallow drainage, natural infiltration of brackish water

4 Main soil degradation problems and possible remedies as based on the inventories (Set B)

The current management practices that are mainly responsible for the different soil degradation problems, have been derived from the information given by the agricultural extension officers (AEOs) in their interviews (see Appendix B) for each of the FTZs (Section IV.4). The AEOs have also been asked for their ideas about remedies against these soil degradation problems (Table V.1). These remedies are summarized in the following for each of the soil degradation problems:

- **Water erosion:** less tuber crops in rotation, direct drilling, green manure crops, reduction of wheel loads, reduced or minimum tillage, increased period with soil coverage, increase organic matter input (e.g. crop residues, manure) to increase soil organic matter content, apply erosion control practices (e.g. buffer strips, contour ploughing, smaller fields, terracing), under-seeding, catch and cover crops, mulching, temporary meadow.
- **Wind erosion:** direct drilling, green manure crops, increase organic matter input in soil, reduced tillage practices like non-inversion tillage that leaves crop residues at the surface, mulching, under-seeding, plant rows to be more narrow, reduce time between ploughing and seeding, plant maize rows crosswise to main wind direction, catch and cover crops, smaller field areas, anti-dusting agents.
- **Contamination:** mechanical weeding, adapted fertilizer application, field operations should be weather orientated and not date orientated, fertilizer applications according to crop needs, informing the farmers, raise awareness of plant protection agents, decrease cattle density, grow a correct rotation.
- **Negative soil organic matter balance:** change and make rotation less intensive (e.g. with cereals), grassland, grow catch, cover and legume crops, apply farm yard manure and/or compost, replace silage maize by grass or grain maize, return crop

residues (e.g. straw of cereals), reduced and minimum tillage, green manure, direct drilling, mulching.

- **Loss of biodiversity:** reduced tillage, return crop residues, rotation with cereals, apply manure and/or compost, strips of natural vegetation, harvest from inside to outside of field, hedges, keep edges with natural vegetation, biological farming, limited use of pesticides, biofumigation, reduced cattle density, reduce cropped fraction, non-inverse tillage techniques, locally adapted catch crops, green manure
- **Soil borne diseases:** sanitation measures, using wider crop rotations, include cereal crops in rotation, adequate (resistant) varieties, chemical agents, green manures, cover crops, farmer should check field regularly for diseases, temporarily rise of ground water level to kill nematodes, more extensive farming, risk inventories through soil sampling, better crop sequence in rotation, less disease problems with higher soil organic matter content and with liming, land exchange, fumigation
- **Compaction:** reduction of wheel loads, reduced tillage, use of green manure crops, optimize the timing of tillage and other field operations (i.e. at dry conditions), low pressure tires or dual tires, controlled traffic farming, rotate root crops with cereals, deep ploughing, reduce number of field passes, high flotation tires, reduce stocking density, improve drainage, add more organic matter to the soil.
- **Floods and land slides:** controlling of torrents and avalanche protection, plant trees on steep slopes.
- **Desertification:** cover crops.
- **Salinization:** apply leaching fraction with irrigation, try to use water of good quality, planting on ridges, deeper drainage or changeable drainage, more cereals, add more organic matter to soil.

Table V.1 Selected FTZs with their Soil degradation problems and possible remedies as based on interviews with agricultural extension officers in the selected FTZs in each of the CATCH-C countries. See Table II.6 for more information about the selected FTZs. The soil degradation problems are indicated as follows: A=Water erosion, B=Wind erosion, C=Contamination, D= Negative soil organic matter balance, E= Loss of biodiversity, F= Soil borne diseases, G= Compaction, H=Floods and land slides, I= Desertification, J= Salinization

Country[1]	**AEZ ID**	**FTZ ID**	**Slope**	**Soil texture**	**Farm specia-liza-tion**	**Main problems,** Other problems	**Remedies per problem**
AT	1	1A	gentle slopes	medium soils	arable	**A, B,** G	A- direct drilling, less tuber crops, green manure crops, B- direct drilling, green manure crops, G- reduction of wheel loads, reduced tillage, use of green manure crops
	2	2M	gentle slopes	medium soils	mixed	**A,** G, C, D, E	A- reduction of wheel load, , reduced tillage, increase period with soil coverage, G- reduction of wheel load, rough granulated seed bed, reduced tillage at dry conditions, appropriate management, C- mechanical weeding, adapted fertilization, D- adapted rotation, E- reduced wheel loads, reduced tillage
	3	3C	strong to steep slopes	medium soils	dairy cattle	**A,D,E,**G, H,C	A- reduced or minimum tillage, D- grassland/field forage, E- financial compensation for the cultivation of less favoured areas, G- low tire pressure, H-

							controlling of torrents and avalanche protection, C- control mechanisms (e.g. restriction of transit, …)
BE	4	4A	nearly level	medium fine soils	arable	**A**,G	A- Use of green manure crops, increase organic matter input and use reduced tillage to increase organic matter content at the surface, Increase soil organic C stock by manure application, apply erosion control practices, Non-inversion tillage, return of crop residues, G- use of low pressure tires or dual tires, avoid heavy loads when applying manure on the field, Use of tracks, Use of controlled traffic farming, Rotate root crops with cereals
	5	5C	level	coarse soils	dairy cattle	**B,G,D**,E, F	B- Increase organic matter input, less intensive tillage practice, G- Low pressure tires, D- Use of farmyard manure, cover crops. Replace a part of the silage maize by grass or grain maize (if possible), Return crop residues and apply farm yard manure and/or compost, rotation with cereals, E- Return crop residues and apply farm yard manure, and/or compost, rotation with cereals, F- Sanitation measures
	6	6M	level	medium soils	mixed	**D,A**,F,G	D- incorporation of straw of cereals, use of cover crops, Include cereals in the rotation, reduced tillage, compost and/or farm yard manure application, A- Reduced tillage, buffer strips, Contour ploughing, F- Using wider crop rotations, Include cereal crops in the rotation, G- Use low pressure tires
DE	7	7A	level	coarse soils	arable+ mixed	**B**,A,D,E, G,F	B- mulching, green manure, under-seeding, plant maize rows crosswise to main wind direction, direct seeding, plant rows more narrow, reduce time between ploughing and seeding, A- under-seeding, green manures, D- green manure, return of crop residues, rotation, E- strips of natural vegetation, chase away wildlife before harvest, use adequate harvest machinery, harvest from inside the field to the outside, G- deep ploughing, wide base tire, tire pressure regulation, appropriate timing (work on dry soil only), green manures, F- wide rotation, adequate varieties, chemical agents, choosing good varieties, green manure
	8	8A	level	coarse soils	arable+ mixed	**B**,A,D,E, G,C	B- catch/ cover crops, smaller field areas, under-sowing crops, A- catch/ cover crops, ploughing across the slope, smaller field areas, D- catch/ cover crops, legume crops, grassland, E- hedges, patches of natural vegetation, biological farming, G- deep ploughing, ploughing, C- field operations should be weather orientated and not date orientated
	9	9A	nearly level and gentle slopes	medium fine soils	arable+ mixed	**A**, G	A- appropriate timing for ploughing, contour ploughing, mulching, keeping the soil always green, cover crops , no-tillage, liming, mulching, G- deep ploughing in summer, reduce weight of machines, right timing for soil cultivation activities,
ES	10	10A	level to modera te slopes	fine soils	arable	**A**,D,G, C,F,E	A- Conservation Agriculture, Minimum tillage, direct drilling, mulching, D- Conservation Agriculture, Direct drilling. Returning residues, Vertical soil tillage and reduced tillage and incorporation of plant residues to the soil, C- Rational fertilisation, F- Crop rotation, E- Rational

							use of minimum quantities of pesticides necessary and keep the edges with natural vegetation
	11	11P	nearly level to moderate slopes	medium fine soils	Perma-nent crops	**A**,C,D,G, I,E,F,J	A- Cover crops, Terracing, C- Application of dose according to crop needs; awareness of plant protection products, Sustainable dose and organic products, Informing the farmers, D- Cover crops and amendments, G- located tillage and cover crops, Reduce number of field passes, high flotation wheels, tillage, I- cover crops, E- Control of residues, biofumigation and solarization, Increase the diversity and apply sustainable practices, F- Cover crops and tillage, J- Apply a leaching fraction with irrigation, Try to use water of good quality, Planting on ridges
	12	12C	strong to steep slopes	medium soils	beef and mixed cattle + sheeps and goats	**A**,C,E,F, G	A- stubble farming, Shallow tillage each 5-6 year, To leave a mulch of dry pasture at the beginning of autumn, Control erosion practices in gullies, C- alleviate cattle density, E- reduced cattle density and reduced cropped fraction, Keeping a minimum of area covered, F- Reforesting with resistant holm oaks, Cultivate only in appropriate areas, G- Reduce stocking density, Rest grazing system
FR	13	13A	gentle slopes	fine soils	arable	**B**,A,E	B- non inversion tillage techniques adapted to the local situation, A- non inversion tillage techniques adapted to the local situation, E- non inversion tillage techniques plus management of crop residues
	14	14C	nearly level	medium fine soils	dairy cattle	**G**,H	
	15	15A	nearly level	medium soils	arable	**D,G,E**	D- catch crops, G- lighter machinery, E- changes of rotations and introduction of locally adapted catch crops
IT	16	16A	level	coarse to medium fine soils	arable	**A,D**,G	A- reduced tillage, D- Return crop residues, Incorporate organic residues, G- ploughing
	16	16C	level	coarse to medium fine soils	dairy cattle	**D,G**,E	D- minimum tillage, return of crop residues, G- use of specific machinery, carry out operations involving heavy machinery at right moment,
	17	17A	gentle and moderate slopes	medium and medium fine soils	arable	**A,D**,G,H	A- improve the crop management, Temporary meadows, Soil preparation to get rid of excess water, D- Return crop residues, Incorporate organic residues, G- enter the field at right time, Soil preparation to get rid of excess water., Tillage at optimal soil water content, Return crop residues, Incorporate organic residues, H- Plant trees on steep slopes
NL	18	18A	level	medium and medium fine soils	arable	**G,D**,J,F	G- better drainage and more cereals, add more organic matter, D- return crop residues, use of green manures and compost, use farm yard manure and/or plant compost, To increase the quota for manure application, J- deeper drainage or changeable drainage, use only good fresh water, F- farmer can check his field regularly for diseases, change of crop (rotation), a higher water level can kill (potato cyst) nematodes, More extensive farming, resistant green manures
	19	19A	level	medium and medium fine soils	arable	**F,G,D**	F- rotation adaptation and risk inventarisation through soil sampling, farm strategy improvement, resistant varieties, extensify rotation, G- tillage only

							under good conditions, drainage and application of organic matter, D- application of compost and manure, chop straw, un-deepen tillage, green manures and extensify rotation
	20	20A	level	coarse soils	arable	**B,D,F**,E, G	B- non inversion tillage (crop residues stay at soil surface), allow cattle slurry application over sugar beets in spring, barley can be sown under main crop and killed later with pesticides, anti-dusting agents, D- green manures, compost or more extensive rotations, more organic matter inputs, F- More extensive rotations, less problem with diseases and better crop growth when there is more SOM and liming of soil, better crop sequence in rotation.
	20	20C	level	coarse soils	dairy cattle	**D,G**,F,B	D- rotation, earlier maize followed by green manure, better catch crops, compost, more use of own manure, better green manures, G- Lower tire pressure, better drainage, till dry, F- rotation, land exchange, earlier maize followed by green manure, More rotation and fumigation, rotation, B- leave green manure alive in spring, tillage resulting in coarse soil structure, keep green cover
PL	21	21A	nearly level	medium fine soils	arable	**B,D**,A,E	B- changes in crop rotation, ploughing of crop residues, Winter crops and green manures , D- changes in crop rotation, ploughing of crop residue, Correct rotation, A- reduced tillage, green manure, E- changes in crop rotation, ploughing of crop residues, Cultivation of different types of crop and catch crop, green manure
	22	22 M	nearly level	coarse soils	mixed	**B**,A,D,C	B- Improvement of crop rotation, ploughing of crop residues, Winter crop and green manures, A- Improvement of crop rotation, ploughing of crop residues, Correct rotation, reduced tillage, D- Improvement of crop rotation, ploughing of crop residues, Rotation with green manures, C- Correct rotation
	23	23C	level	coarse soils	dairy cattle	**B,D**,F,J, A,E	B- Winter crop and green manures, Reduced tillage, D- Correct rotation, Rotation with green manures, F- Correct rotation, J- rational nitrogen fertilization within a reasonable time, A- winter crop and green manures, E- changes in crop rotation, ploughing of crop residues

[1] AT= Austria, BE= Belgium, DE= Germany, ES= Spain, FR= France, IT= Italy, NL= Netherlands, PL= Poland

5 Discussion

The current soil degradation problems in each of the eight CATCH-C countries can be reasonably well explained from management practices in each of the countries, as given in Section III.3. For example, contamination does occur on most farms in Belgium, the Netherlands and Germany which can be explained by the animal slurry application on most arable farms and all livestock farms in these countries. Mainly conventional tillage is applied in all CATCH-C countries, and both on arable and livestock farms, which partly (in addition to resp. topography and heavy machinery and wrong timing of farm operations) explains the water erosion and soil compaction problems on most farms.

The current management practices that are mainly responsible for the different soil degradation problems, have been derived from the information given by the AEOs in their interviews for each of the FTZs (Table IV.5). These practices are summarized in Section V.3 and are the common practices in intensive and conventional farming with limited applications of organic matter and crop residues to the soil, monoculture, insufficient coverage of the soil, intensive tillage, use of heavy machinery with high wheel loads, high application levels of fertilisers and biocides, short rotations with intensive cultivation of tuber and root crops, high animal densities which often result in too high animal manure applications, and replacement of farm yard manure by slurry.

Ideas from the agricultural extension officers about possible remedies against each of the current soil degradation problems have been compiled and listed (Section V.4). The listed ideas give a good overview of improved or best management practices to limit the current soil degradation problems, such as: (a) Water and Wind erosion that can be limited by reduced tillage, increase of organic matter input into the soil, and better field coverage, (b) Contamination that can be limited by fertiliser applications that are more adapted to crop demands and weather conditions, by better informed use of biocides and improved plant protection, and by decreased animal density and thus manure production, and (c) Compaction that can be limited by reduction of wheel loads, use of low pressure tires, controlled traffic farming and reduced stocking densities.

Note that only qualitative relationships can be derived from this study: (a) between current management practices and soil degradation problems; and (b) between possible remedies (i.e. improved management practices) and the degree of reduction of these degradation problems. This is due to both the complex interactions between agri-environmental (i.e. soil, landscape and climate) conditions and the farm's characteristics with its specific current and historical management, and the approach for collecting information for the selected FTZs by way of interviewing agricultural extension officers. Within Work package 3 of the project, more quantitative information about Best management practices and soil quality will be derived.

VI. Policies related to soil degradation problems

1 Introduction

Methodologies to study interactions between EU policies and farm management have been extensively studied within the FP6 SEAMLESS project (Van Ittersum et al., 2008). Expertise built up during this project has been presented by Brouwer & Van Ittersum (2010). For example, Belhouchette et al (2011) analysed and presented the effects of the Nitrate directive on arable farming systems in the EU and their economic results and environmental impacts. Louhichi et al. (2010) simulated and analysed, also with a bio-economic model, the responses of EU arable and livestock farming systems to the CAP reform of 2003 with its market liberalization. These studies have shown how current policies and proposed changes may affect future farm management in different farming environments and farm types. In work package 5 of the CATCH-C project effects of current and possible future policies on farm management and related soil degradation problems will be explored.

2 Current and possible future EU policies

The CATCH-C project is focussed on deriving information about the effectiveness of Best Management Practices (BMPs) in reducing main soil degradation problems and about the compatibility of current and possible future EU soil policies with the introduction of the BMPs in different farming systems over the EU. In the current study we have compiled information about the main soil degradation problems in dependence of the current management practices. For estimating the possible reduction of the main soil degradation problems by introducing BMPs, results from the analyses of Long-term experiments on the effects of BMPs which work is currently done in Work package 3 of this project, will be combined with the FTZ typology and the information on current soil degradation problems as derived in the current study.

The review of the relevant soil-related policies at regional, national and EU level is currently done by Work package 5. For more information about the currently applied policy and technical measures in different EU countries related to soil management and soil degradation problems in EU agriculture, we refer to Section 4 and particularly Tables 4.6 and 4.8 in Louwagie et al. (2009).

Work Package 5 will analyse the compatibility of these soil policies with the most suitable BMPs for the selected FTZs in each of the eight CATCH-C countries. Relevant EU soil policies are, for example, the EU Soil strategy, the IPPC Directive(96/61/EC), Nitrates Directive(91/676/EEC); NEC Directive(2001/81/EC); Habitat Directive(92/43/EEC); Birds Directive(79/409/EEC), and the Framework Directives for Water (200/60/EC) and for the Use of Pesticides(COM(2006)373). These compatibility studies will indicate the possible interactions between current soil policies and the introduction of BMPs in farming systems in the different CATCH-C countries, the possible policy-related barriers against such BMP introduction, and the future soil policies required to support rapid introduction of BMPs in the CATCH-C countries and in the EU as a whole.

VII. Summary of conclusions and results

1 FTZ selection procedure

The derived agri-environmental zonation comprises the main variables (i.e. climate, soil texture, and terrain slope) that determine the biophysical characteristics per zone and the related degree of risk for soil degradation under current management practices. Via a procedure adopted from Kempen et al. (2011) we allocated the main farm types to each of the agri-environmental zones in the eight participant countries.

Hence, this zonation is suitable as a basis to do inventories of current management practices and soil degradation problems for major FTZs per country. It can also enable trade-off analyses between the benefits of reduced soil degradation and the costs for improved management. However, note that the more homogeneous landscapes are in terms of soils and climates, the better results can be achieved with agri-environmental zonation.

We are confident, based on the overviews made of the main farm types in each of the agri-environmental zones in the eight participant countries and on the procedure for FTZ selection, that the three selected FTZs per country represent the main agri-environmental zones, main agricultural areas and the main farming systems in the eight CATCH-C countries. The selected FTZs provide the backbone to carry out inventories on farm management and soil degradation problems in these eight countries. The used farm typology is the same for the eight participant countries, which allows comparisons of compiled data (e.g. current management) between the eight countries; it is based on the classes from FADN, being the standard in European policy making.

While the major FTZs selected for further work cover only part of the total farm area per country (maps in Appendix A), we stress here that our numerical database specifies all other FTZ units across Europe, too, with the same level of detail. This information, however, cannot easily be represented in maps because of the small sizes of units, and the limited number of colours that the eye can distinguish on a map. Finally, note that some countries have made their own aggregations of AEZ classes. For example, three slope classes were merged in one particular FTZ in Spain. Such compromises were sometimes necessary to arrive at major FTZs representative for the country.

2 Current management practices

An overview of current management practices was compiled based on interviews with Agricultural Extension Officers (AEOs) in each of the participant countries. This was done for the major FTZs (see above) per country. Main conclusions from the compiled information on arable farming are : (a) green manures are applied on average on 20% of the total area, (b) conventional tillage is practised on average on 70% of the total area, non-inversion tillage on 30% of the total area, and minimum tillage is hardly applied, (c) animal slurry is applied on the main part (60 to 90%) of the total area in Belgium, Germany and the Netherlands and on a limited part of the total area (<20%) on FTZs in the other CATCH-C countries, and (d) crop residues are incorporated on average in half of the total area.

Main conclusions from the compiled information on livestock farming are: (a) green manures are applied on a small part (i.e. 0 to 20%) of the total area, (b) conventional tillage is practised on average on 85% of the total area, non-inversion tillage on 15% of the total area, and minimum tillage is practically not applied, (c) animal slurry is applied on the main part

(>80%) of the total area on FTZs in all CATCH-C countries except for Poland where slurry is applied on less than 20% of the total area, (d) on FTZs in Belgium and Netherlands mainly animal slurry is applied, on FTZs in Austria, France and Italy both animal slurry and farm yard manure are applied, and in Poland mainly farm yard manure is applied.

Differences between FTZs in the occurrence of certain management practices can be explained from differences in farm type and farming intensity and from the cropping system and its biophysical conditions (e.g. minimum tillage is only applied in Spain and probably mainly in the dry and erosion-sensitive areas in southern Spain). However, part of these differences cannot be explained. We may assume that there are regional and national differences in farm structure and land ownership, historic development of agricultural sectors, protection of the environment and landscape, and main recommendations by agricultural extension services. These regional and national differences may cause differences between FTZs in the applied management practices.

3 Main soil degradation problems

Two approaches have been applied within this study to attain an overview of the main soil degradation problems in the participant countries: CATCH-C colleagues have prepared reports on the main soil degradation problems in their countries, based on documented sources available at national level (Set A; see Appendix D for country reports); and Interviews were held with extension officers, focussing on the selected FTZ units per country (Set B).

The overview (Set A) of the main soil degradation problems for the eight CATCH-C countries gives a number of insights: Water erosion, soil contamination (covering both excessive amounts of nutrients, heavy metals and biocides), sub-soil compaction and decrease in soil organic matter are problems in most countries. Salinization and desertification are mainly of importance in southern Europe (i.e. Spain, Italy). Low soil fertility is a problem in extensively managed areas in Spain. Floods and land slides do occur in the mountainous areas of France and Italy. Soil acidification can be problematic in France and Poland and mainly with soils developed in acidic parent material.

The overview of the main soil degradation problems shows that these problems can be partly explained from current soil management (e.g. sub-soil compaction due to the use of heavy machinery; decrease in soil organic matter due to short crop rotations with more root crops), but often too from unmanageable factors like climate (e.g. salinization and desertification in southern Europe), landscape (e.g. floods and land slides in hilly and mountainous areas), parent material of the soils (e.g. soil acidification) and location (e.g. salinization in coastal plains). These latter problems require governmental actions at the regional and/or national scale, such as improved water management, forest protection, and construction works.

Soil degradation problems that can be reduced by improving soil management on farm, are mainly sub-soil compaction and the resulting reduction in hydraulic permeability of the soil, decrease in soil organic matter and the resulting decrease in soil quality, structure and soil fertility, contamination with nutrients and pesticides and the resulting pollution of ground and surface waters, and wind erosion and possibly water erosion at the field scale and the resulting loss of soil fertility and soil organic matter.

The information collected from the AEOs through the interviews per FTZ (Set B) is largely consistent with the country reports (Set A). Extension officers mention largely the same soil degradation problems, but focus more on the field level and hence, mention more often problems, such as soil borne diseases, loss of biodiversity and wind erosion, whereas the country reports focus more on the wider (i.e. regional) scale and hence, mention much more often contamination as a problem.

4 Linking the Main soil degradation problems to Current management practices and Possible remedies

Current soil degradation problems in each of the eight CATCH-C countries can reasonably well explained from management practices in each of the countries. For example, contamination does occur on most farms in Belgium, the Netherlands and Germany which can be explained from the animal slurry application on most farms in these countries. Mainly conventional tillage is applied in all CATCH-C countries, and both on arable and livestock farms, which partly (in addition to resp. topography and heavy machinery and wrong timing of farm operations) explains the water erosion and soil compaction problems on most farms.

Current management practices that are mainly responsible for the different soil degradation problems, have been derived from the information given by the AEOs in their interviews for each of the FTZs (Table IV.5). These practices appear to be the common practices in intensive and conventional farming with limited applications of organic matter and crop residues to the soil, monoculture, insufficient coverage of the soil, intensive tillage, use of heavy machinery with high wheel loads, high application levels of fertilisers and biocides, short rotations with intensive cultivation of tuber and root crops, high animal densities which often result in too high animal manure applications, and replacement of farm yard manure by slurry.

Ideas from the agricultural extension officers about possible remedies against each of the current soil degradation problems have been recorded, which gives a good overview of ways to improve soil management practices to limit the current soil degradation problems, such as for example: (a) Water and Wind erosion that can be limited by reduced tillage, increase of organic matter input into the soil, and better field coverage, (b) Contamination that can be limited by fertiliser applications that are more adapted to crop demands and weather conditions, by better informed use of biocides and improved plant protection, and by decreased animal density and thus manure production, and (c) Compaction that can be limited by reduction of wheel loads, use of low pressure tires, controlled traffic farming and reduced stocking densities.

Note that only qualitative relationships can be derived from the above: (a) between current management practices and soil degradation problems; and (b) between possible remedies (i.e. improved management practices) and the degree of reduction of these degradation problems. This is due to both the complex interactions between agri-environmental (i.e. soil, landscape and climate) conditions and the farm's characteristics with its specific current and historical management and input level and the approach for collecting information for the selected FTZs by way of interviewing the AEOs. More quantitative information about Best Management Practices and soil quality will be derived in WP3. Work package 4 is dedicated to assess the compatibility of Best management practices with the respective, different farming contexts found in the partner countries.

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IX. Glossary

Agri-environmental zone (AEZ) – the applied zonation is based on three variables, i.e. climate (environmental zone), soil texture and slope

Agricultural extension officers (AEOs) – local experts who have supplied information (via interviews) on the current management practices and the main soil degradation problems for the selected FTZs in their country

Animal manure – the term as used in this study, covers both farm yard manure and animal slurry

Best management practices (BMP) –practices best suited to maintain the soil quality, productivity and climate change mitigation

Categories of soil management – crop rotation, grassland management, tillage, nutrient management, crop protection, and water management

Contamination - the term as used in this study, covers both excessive amounts of nutrients, heavy metals and biocides in soils, ground and surface waters

Current management practices (CMP) – management practices applied in current farming systems

Farm Accountancy Data Network (FADN) – see http://ec.europa.eu/agriculture/fadn/index_en.htm

Farm type * agri-environmental zone combination (FTZ) – combination (intersection) of farm type and agri-environmental zone

Farm type – applied farm typology is based on information about farm specialization and land use over Europe, as derived from FADN

Long term experiments (LTE) – experiments over more than five years to derive the effects of BMPs on soil quality

Soil quality – the ability of a soil to sustain high productivity of resources (i.e. crop production per unit resources); soil quality consists of three characteristics (a) biological soil health and disease suppressiveness, (b) chemical soil fertility and (c) soil physical structure and integrity of the soil (by soil conservation)

See Appendix C for the Glossary of Management practices.

X. Appendices

Appendix A. Overview of selected FTZs in each country

Farm type-agri-environmental zone (FTZ) combinations have been selected for each of the eight CATCH-C countries. The applied approach for selecting these combinations is described in Section II.4. For each of the FTZs, inventories on both current management and main soil soil degradation problems have been carried out.

A1. Selected FTZs in Austria

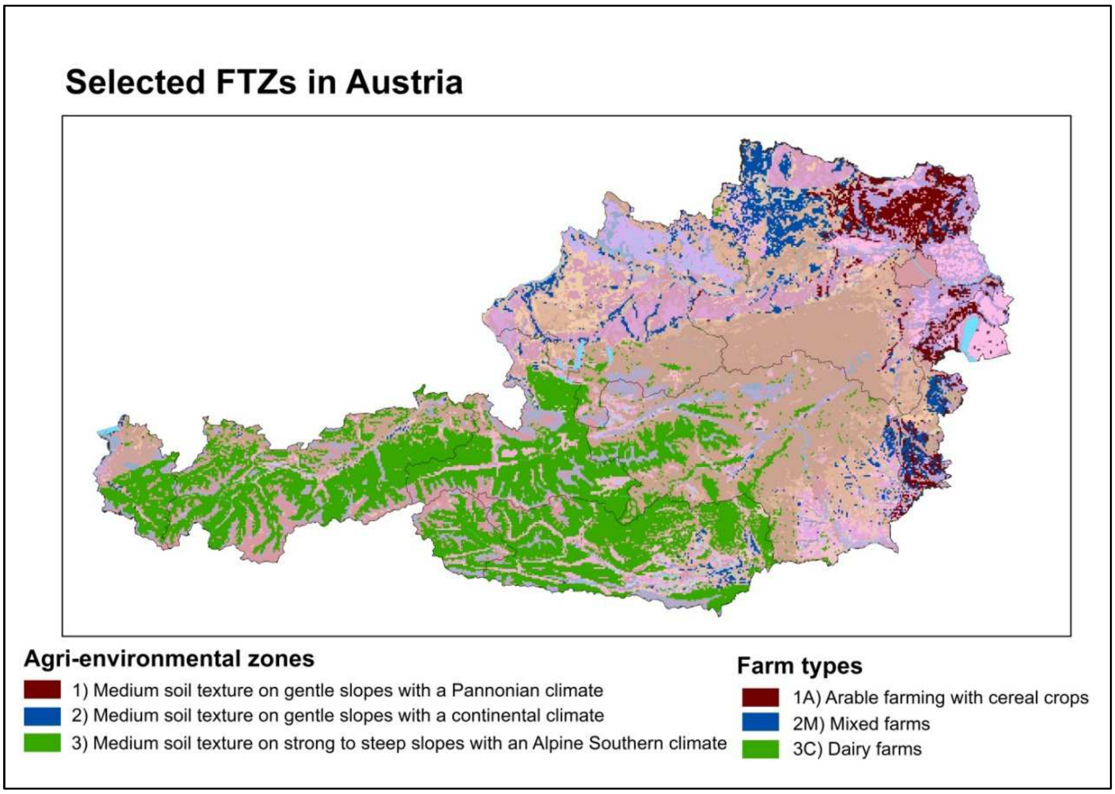

Figure1 Selected FTZs for Austria (see Table II.6 for more information about the selected FTZs)

A2. Selected FTZs in Belgium

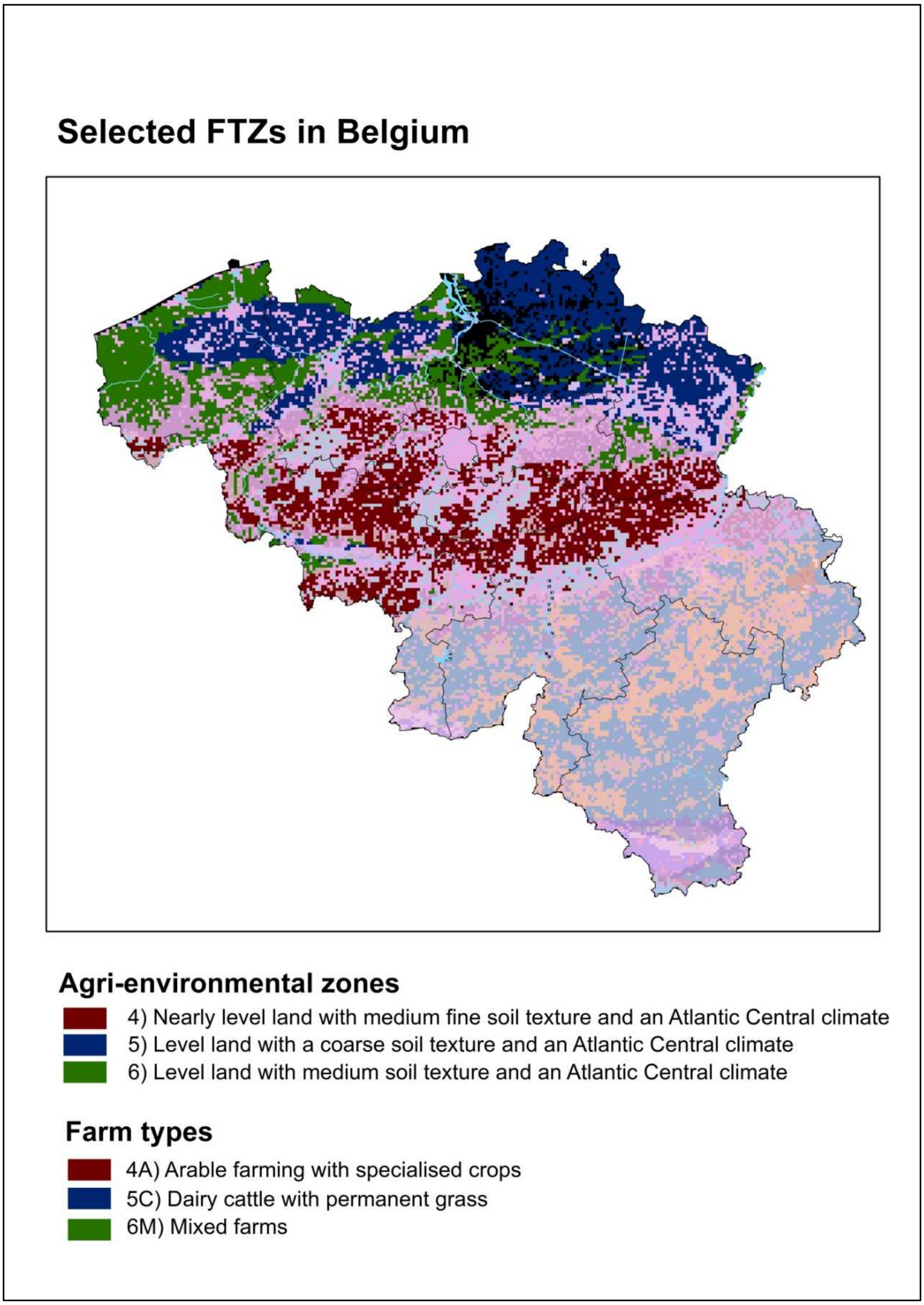

Figure 2 Selected FTZs for Belgium (see Table II.6 for more information about the selected FTZs)

A3. Selected FTZs in Germany

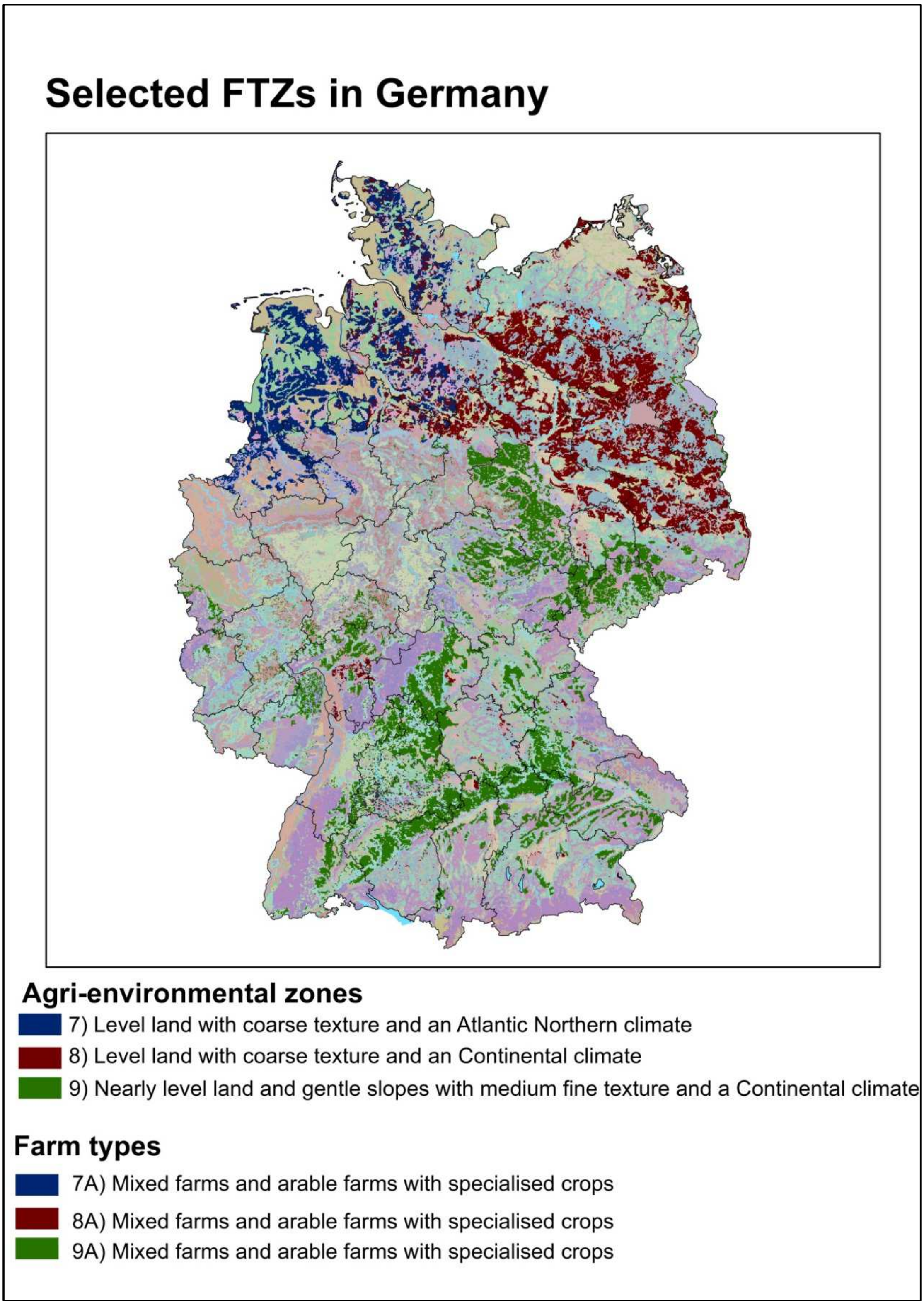

Figure 3 Selected FTZs for Germany (see Table II.6 for more information about the selected FTZs)

A4. Selected FTZs in Spain

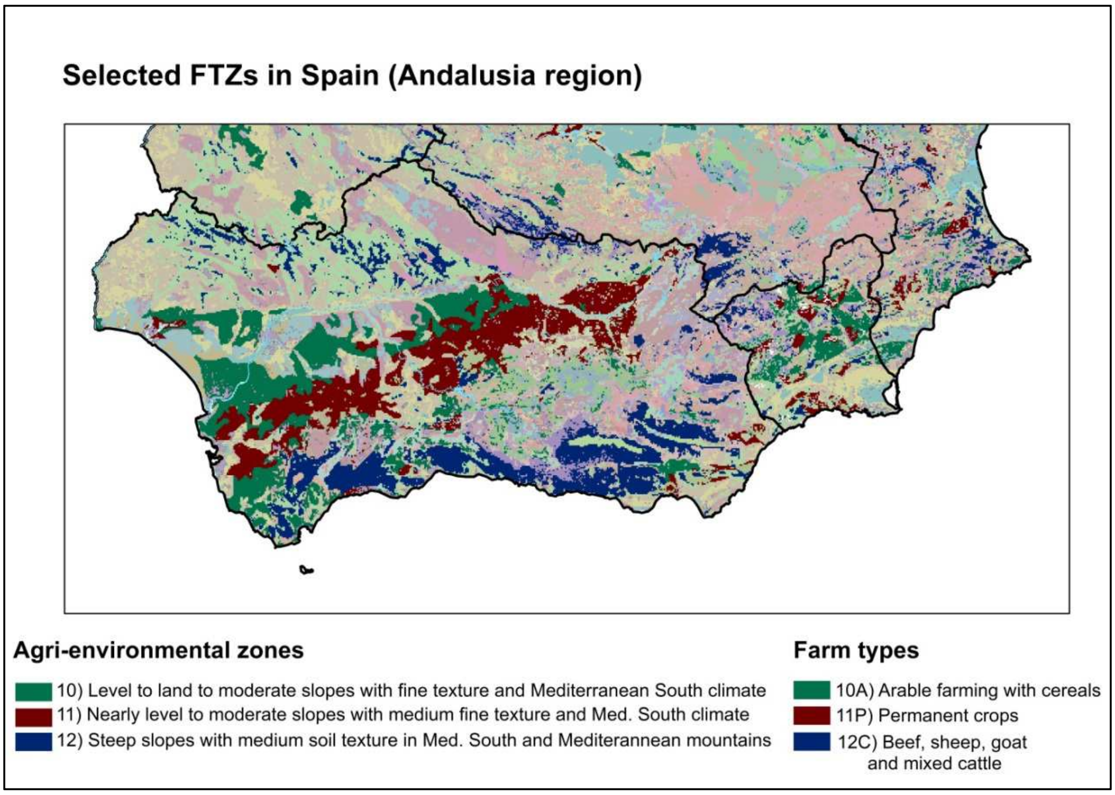

Figure 4 Selected FTZs for Spain (see Table II.6 for more information about the selected FTZs)

A5. Selected FTZs in France

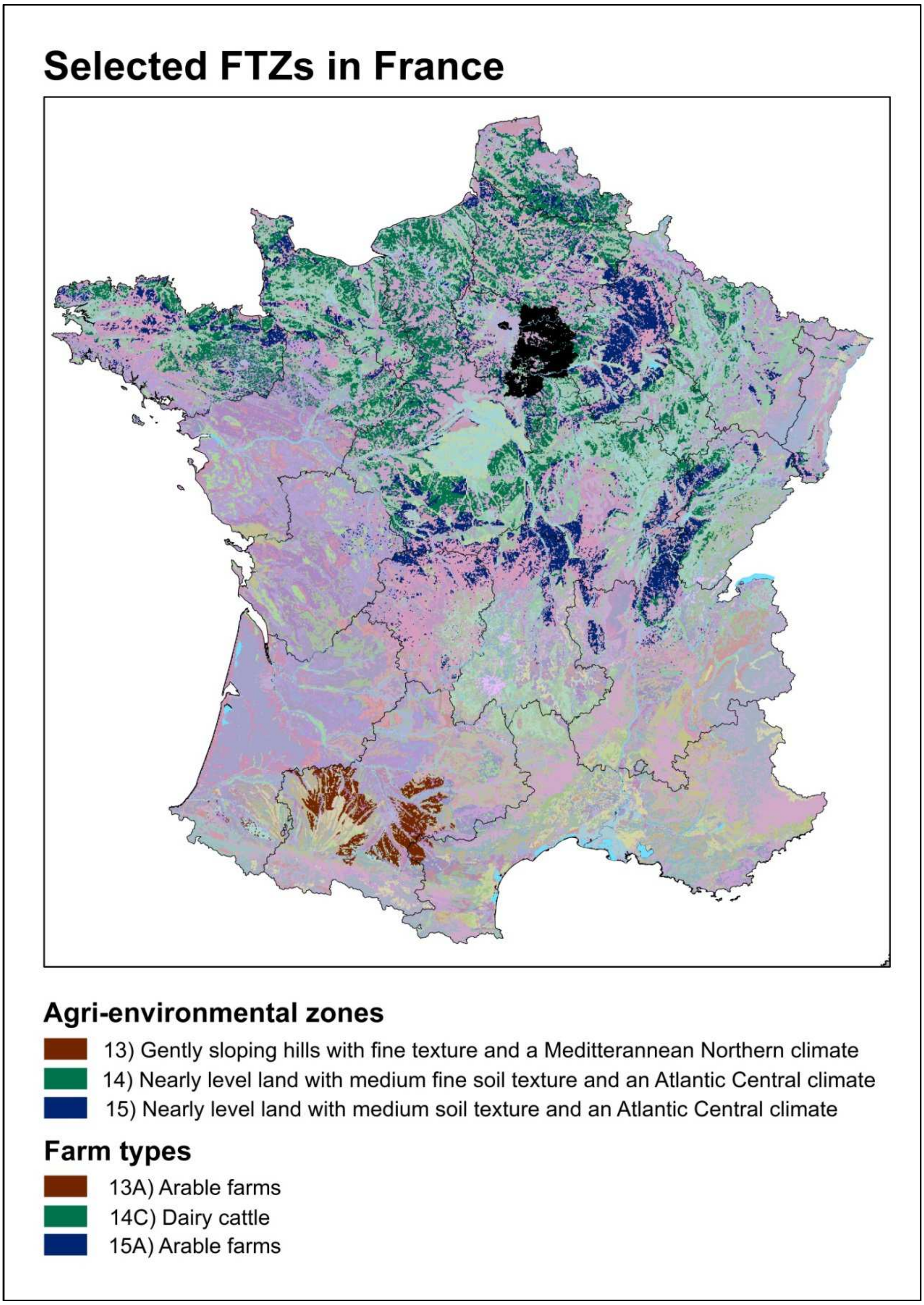

Figure 5 Selected FTZs for France (see Table II.6 for more information about the selected FTZs)

A6. Selected FTZs in Italy

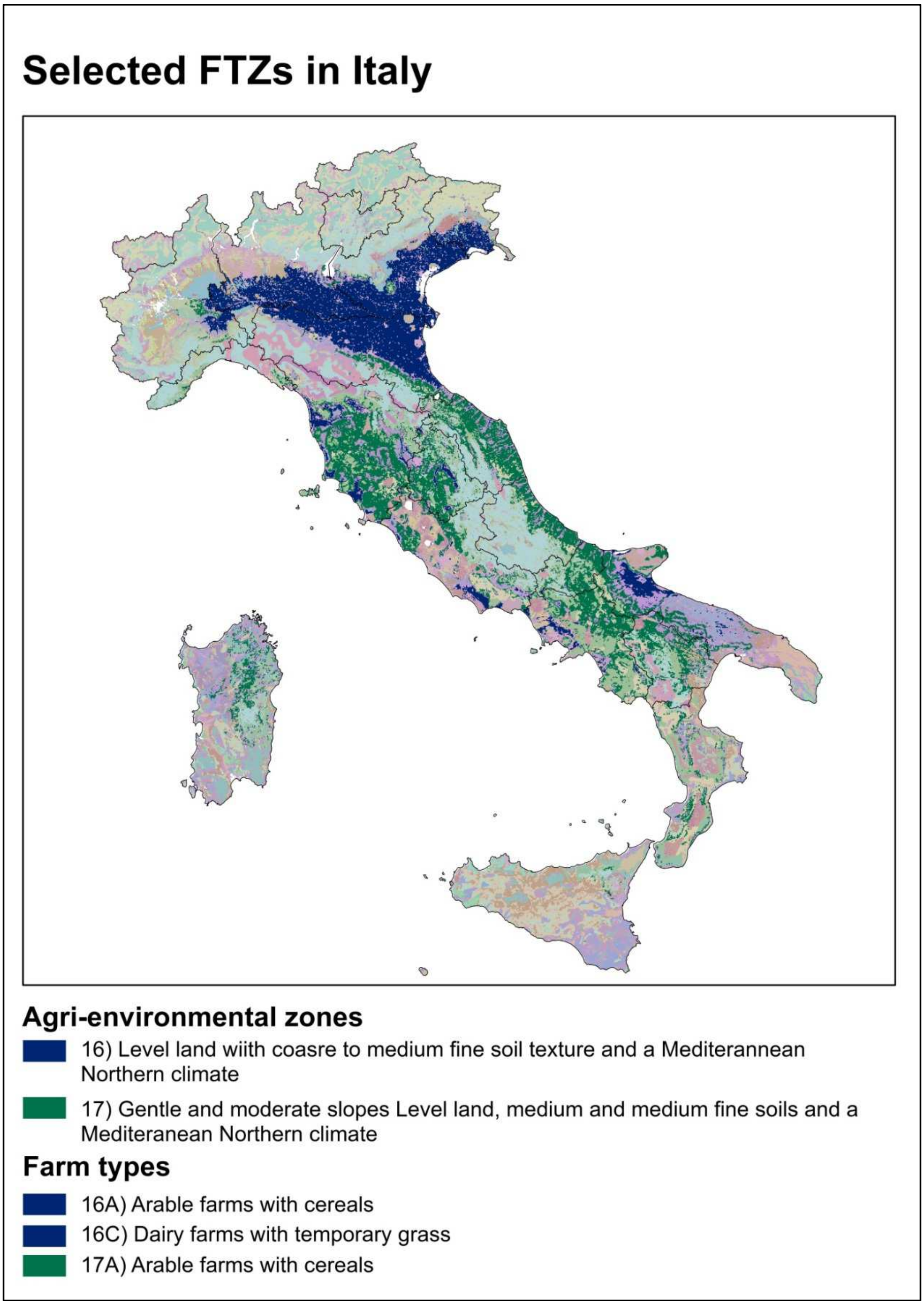

Figure 6 Selected FTZs for Italy (see Table II.6 for more information about the selected FTZs)

A7. Selected FTZs in The Netherlands

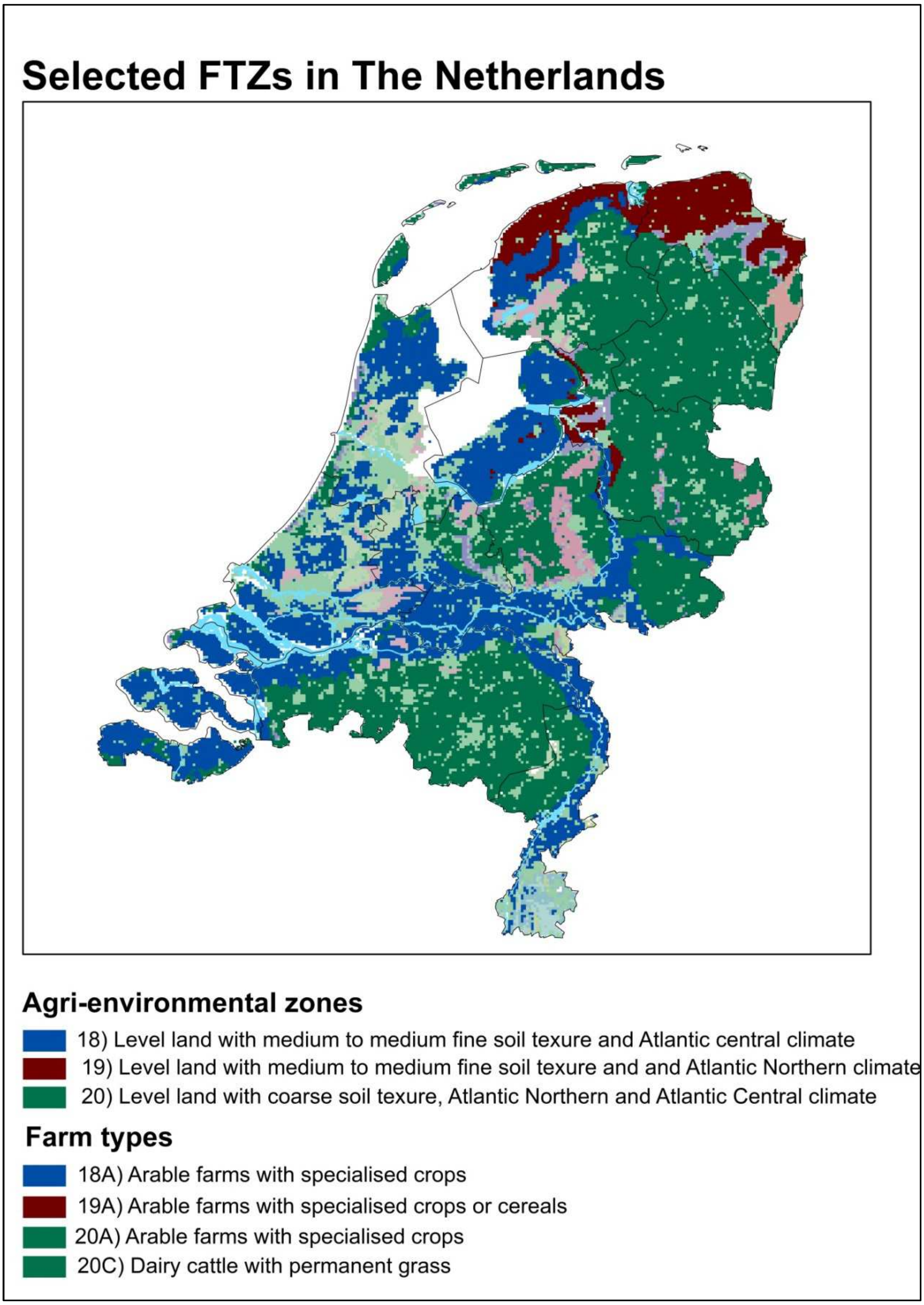

Figure 7 Selected FTZs for the Netherlands (see Table II.6 for more information about the selected FTZs)

A8. Selected FTZs in Poland

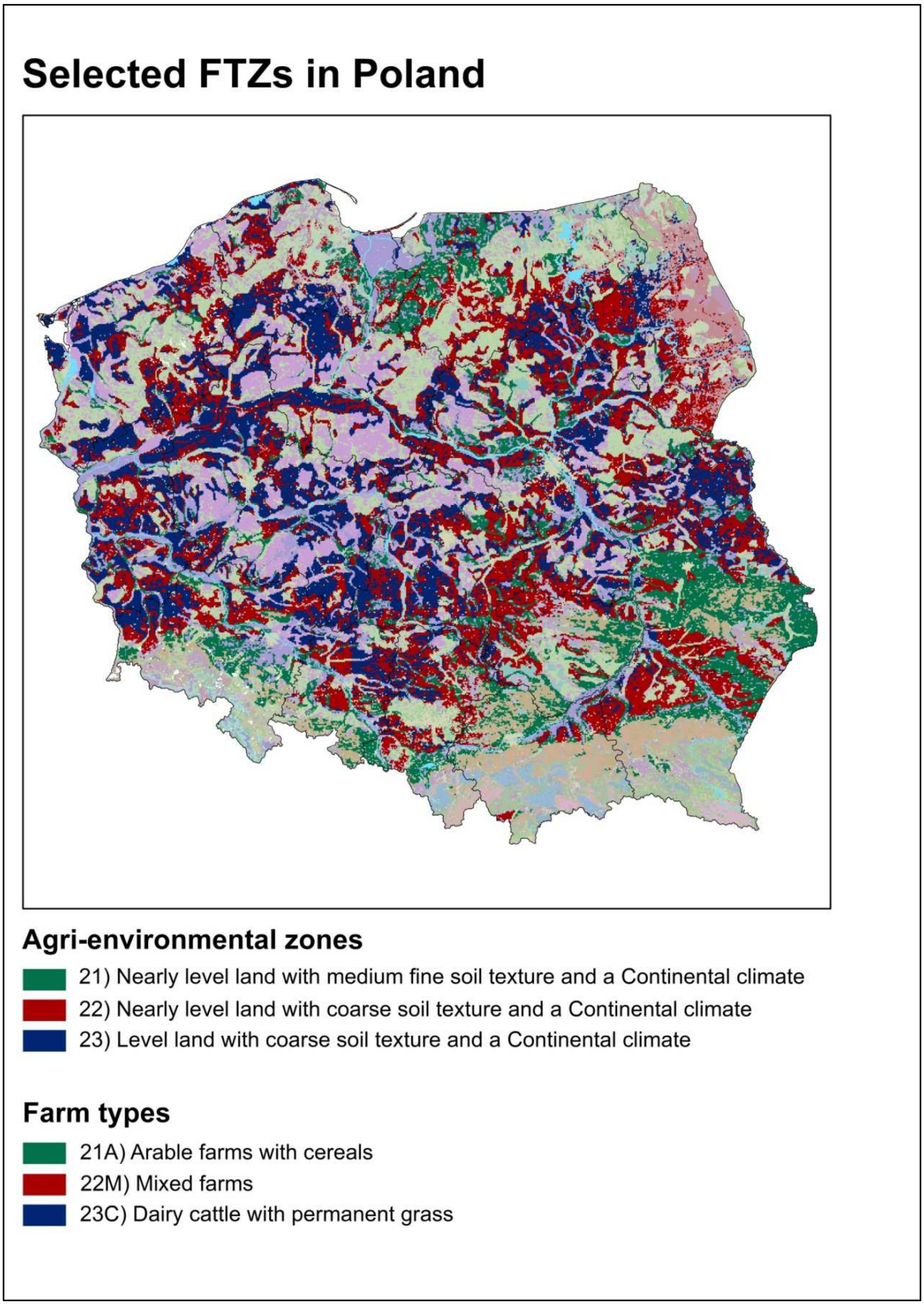

Figure 8 Selected FTZs for Poland (see Table II.6 for more information about the selected FTZs)

Appendix B. Questionnaire on current management practices

For each of the selected farm type - agri-environmental zone (FTZ) combinations in the eight CATCH-C countries, three agricultural advisors were interviewed to collect information about the current management practices and the related soil degradation problems. These interviews were performed using a standard questionnaire in English. This questionnaire is given in the following.

First page: Information for researcher

For each partner country in the Catch-C project, an investigation of current management practices will be made for your selection of major Farm types per agri-environmental zones (FTZ)s.

- The objective of this questionnaire: To create a baseline of current management practices for the major farm types in each country.
- For each FTZ, 3 interviews should be held with independent agricultural advisors in the respective region.
- The target of the questions is a FTZ; when in the questionnaire the term *these farms* is mentioned, this refers to the FTZ.
- For detailed descriptions of the used terms, see Appendix B for a glossary of management practices.
- Please follow this form and translate the questions to your own language when interviewing the agricultural advisor. Fill in the form yourself during the interview and enter this information in English into the excel file provided.
- Please note that you only have to hand in the excel files.
- When the percentages are asked, please note that the percentages of farm area (so number of ha/ total ha) is requested, not percentage of farms!

Questionnaire Current Management Practices CATCH-C

General information

FTZ: --

Country: --

Date: --

Name interviewer: --

Institute interviewer: --

Name interviewee: --

Organisation interviewee: --

Introduction

- Introduce yourself and the CATCH-C project. Explain the purpose of the survey.
- Explain your farm type and agri-environmental zone of interest. If appropriate, show the map with the AEZs. Remind the advisor during the interview of the farm specifications

1. Rotation (skip in case of animal farms)

1.1. What is your standard rotation recommendation for these farms? If more possible options, select more.

Monoculture/ rotation with cereals/ rotation with legume crops/ rotation with root or tuber crops/ rotation with fallow land/ rotation with grassland/ intercropping/ rotation with catch/ cover crops/ rotation with green manures

1.2. Why do you recommend this rotation?

1.3. Do farmers follow your rotation advice often? *Yes/no/ sometimes*

1.4. If not, why not? What is the main barrier?

1.5. What do you think are the percentages of farm land on which the following practices are used?

Practice	**Percentage of farm area (%)[4]**
Monoculture	
Rotation with cereals	
Rotation with legume crops	
Rotation with root or tuber crops	
Rotation with fallow land	
Rotation with grassland	
Intercropping	
Rotation with catch/ cover crops	

[4] As the categories are not exclusive, together these percentages can be more than 100%

Rotation with green manures	

2. Grassland management (this section not for arable farms)

2.1. What is your standard recommendation for grassland management for these farms? If more possible options, select more.

Permanent grazing/ rotational grazing/ zero grazing

2.2. Why do you recommend this practice?

2.3. Do farmers follow your advice on grassland management often? *Yes/no/ sometimes*

2.4. If not, why not? What is the main barrier?

2.5. What do you think are the percentages of farm land on which the following practices are used?

	Percentage of farm area (%)[5]
Permanent grazing	
Rotational grazing	
Zero grazing	
Total	**100**

[5] These percentages should add up to 100%

3. Tillage

3.1. What is your standard tillage recommendation for these farms? If more possible options, select more.

Conventional tillage/ No tillage/ Reduced tillage/ Minimum tillage/ direct drilling/ contour ploughing/ terrace farming/ controlled traffic farming/ deep ploughing

3.2. Why do you recommend this tillage practice?

3.3. Do farmers follow your tillage advice often? *Yes/no/ sometimes*

3.4. If not, why not? What is the main barrier?

3.5. What do you think are the percentages of farm land on which the following practices are used?

Practice	**Percentage of farm area (%)**	**Average depth of practice (cm)**[6]	**Spread of depth (cm)**
Conventional tillage			
No tillage			
Reduced tillage			
Minimum tillage			
Total	**100**		

[6] Under normal conditions

Practice	**Percentage of farm area (%)**[7]	**Average depth of practice (cm)**[8]	**Spread of depth (cm)**
Direct drilling		-	-
Contour ploughing		-	-
Terrace farming		-	-
Controlled traffic farming		-	-
Deep ploughing			

[7] As the categories are not exclusive, together these percentages can be more than 100%

[8] Under normal conditions

4. Nutrient management

4.1. What is your standard nutrient management recommendation for these farms? If more possible options, select more.

Mineral fertilisers /plant compost/ bio-waste/ sludge compost/ farm yard manure (FYM)/ cattle slurry/ poultry manure/ pig slurry/

4.2. Why do you recommend these fertilisers?

4.3. Do farmers follow your advice often? *Yes/no/ sometimes*

4.4. If not, why not? What is the main barrier?

4.5. What is your standard recommendation for crop residue management? If more possible options, select more.

Return of crop residues/ burning of crop residues/ feeding of crop residues/ selling of crop residues

4.6. Why do you give this recommendation?

4.7. Do farmers follow your advice often? *Yes/no*

4.8. If not, why not? What is the main barrier?

4.9. What do you think are the percentages of farm land on which the following practices are used?

Practice	Percentage of farm area (%)[9]
Mineral fertiliser application	
Plant compost application	
Bio-waste compost application	
Sludge compost application	
Farm yard manure (FYM) application	
Cattle slurry application	
Poultry manure application	
Pig slurry application	

Crop residues with no monetary value

Practice	Percentage of farm area (%)
Return of crop residues	
Burning of crop residues	
Total	**100**

Crop residues which have a possible alternative monetary value[10]

Practice	Percentage of farm area (%)
Return of crop residues	
Burning of crop residues	
Feeding of crop residues	
Selling of crop residues	
Total	**100**

[9] As the categories are not exclusive, together these percentages can be more than 100%

[10] For example: straw

5. Crop protection

5.1. What is your standard crop protection recommendation for these farms? If more possible options, select more.

Mechanical weeding/ Herbicide application/ push-pull strategies/ patches or stripes of natural vegetation/ pheromones application/ Insecticide application/ fungicide application/ nematicide application/ soil fumigation/ soil solarization

5.2. Why do you recommend these crop protection measures?

5.3. Do farmers follow your advice often? *Yes/no/ sometimes*

5.4. If not, why not? What is the main barrier?

5.5. What do you think are the percentages of farm land on which the following practices are used?

Practice	**Percentage of farm area (%)**[11]
Mechanical weeding	
Herbicide application	
Push-pull strategies	
Patches or stripes of natural vegetation	
Pheromones application	
Insecticide application	
Fungicide application	
Nematode application	
Soil fumigation	

[11] As the categories are not exclusive, together these percentages can be more than 100%

Soil solarization	
Biological pest control	

6. Water management

6.1. What is your standard water management recommendation for these farms? If more possible options, select more.

Surface irrigation/ drip irrigation/ sprinkler irrigation/ subsurface drainage

6.2. Why do recommend this practice?

6.3. Do farmers follow your advice on water management often?

Yes/no/ sometimes

6.4. If not, why not? What is the main barrier?

6.5. What do you think are the percentages of farm land on which the following practices are used?

Practice	**Percentage of farm area (%)**[12]
Surface irrigation	
Drip irrigation	
Sprinkler irrigation	
Subsurface drainage	

[12] As the categories are not exclusive, together these percentages can be more than 100%

7. Soil degradation problems

7.1. According to you, what are the main soil degradation problems with these farms in this region?

Wind erosion/ water erosion/ contamination/ negative soil organic matter balance/ loss of biodiversity/ compaction/ salinization/ desertification/ floods and landslides/ soil born diseases

7.2. Which practices do you recommend to combat this/ these degradation problems?

Main soil degradation problem	**Practice which is enhancing the problem**	**Practice which could help solve the problem**

7.3 What do you think are the percentages of farm land on which the following soil degradation problems occur?

Soil degradation problem	**Percentage of farm area**[13]
Wind erosion	
Water erosion	
Contamination	
Negative soil organic matter balance	
Loss of biodiversity	
Compaction	
Salinization	
Desertification	
Floods and landslides	
Soil born diseases	

[13] As the categories are not exclusive, together these percentages can be more than 100%

Inventory of Current Management Practices: Additional question

8.1 What are the 3 main crop rotations on farms in your region

Rotation 1:

Crop[14][15]	**% of farm area**
Total	100%

Rotation 2:

Crop	**% of farm area**
Total	100%

Rotation 3:

Crop	**% of farm area**
Total	100%

8.2 What is the relative importance of these rotations in this region?

Rotation	**% of land area in region**
Rotation 1	
Rotation 2	

[14] If a monoculture is important in this region, fill in the name of the crop in the left column and add 100% in the right column.

[15] If intercropping exists in this region, process the intercropping as one crop, so fill in the names of both two crops in one box at the left.

Rotation 3	

8.3. After which crops are green manures or catch/cover crops sometimes grown in this area? ....

8.4. On which **percentage of the area** are green manures or catch/cover crops actually grown each year?[16] ....

[16] **For example: If green manures are only grown in half of the cases after cereals and cereals constitute 30% of the area, the answer here should be 15%.**

Appendix C. Glossary of management practices

B1. Crop rotation

Practice	Description
Monoculture	The growing of a single arable crop species on a field year after year, for at least 9 to 10 years.
Rotation with cereals	The growing of different species of crops in a crop rotation with >50% coverage with cereals.
Rotation with legume crops	The growing of different species of crops in a crop rotation with >25% coverage with legume crops.
Rotation with tuber or root crops	The growing of different species of crops in a crop rotation with >25% coverage with tuber or root crops.
Rotation with fallow land	The growing of different species of crops in a crop rotation with >25% fallow.
Rotation with grassland	The growing of different species of crops in a crop rotation with >50% grassland.
Intercropping	The growing of two or more different arable crops simultaneously in different rows in the same field.
Rotation with cover/catch crops	The growing of different species of crops in a crop rotation with >25% coverage with cover/catch crops. **Cover/catch crops are harvested.** Double cropping (two different crops grown on the same area in one growing season) is here included.
Rotation with green manures	The growing of different species of crops in a crop rotation with >25% coverage with green manure crops. **Green manure crops are incorporated into the soil.**

B2. Grassland management

Practice	Description
Permanent grazing	Continuous feeding on standing vegetation by livestock.
Rotational grazing	Rotational feeding (i.e. changing the grazed parcels) on standing vegetation by livestock.
Zero grazing	No grazing but only mowing to harvest grass.

B3. Tillage

Conventional tillage	The conventional tillage consists of ploughing the soil, which causes turning, loosening, crumbling and aeration of the topsoil. This should result in a clean field surface.
No tillage	No tillage.
Reduced tillage	Tillage without inversion at a reduced depth (about 30% crop residues remaining on the field surface), with specific machines (often with grubber/cultivator) **more than once a year.**
Minimum tillage	Tillage without inversion at a reduced depth (about 30% crop residues remaining on the field surface), with specific machines, (often with a rotovator) **only once a year**.
Deep ploughing	The deep ploughing describes the use of the plough, where the soil is broken over a meter deep. It causes a turn, loosening, crumbling and aeration of the topsoil and subsoil. Furthermore, deep ploughing is used as a measure for agricultural land improvement or cultivation of peat.
Direct drilling	Direct drilling results in sowing without tillage. The residues of the plant material remain usually as mulch in the field.
Contour ploughing	Parallel ploughing to the contours of hill slopes.
Terrace farming	The term describes the use of graded terrace steps of sloped land, used to farm on hills and mountainous area.
Controlled traffic farming	Controlled traffic farming means using similar traffic lanes for different application within one year and the same traffic lanes between years , often applying a navigation system.

B4. Nutrient management

Mineral N application	Applications of nitrogen in inorganic fertilisers.
Mineral P application	Applications of phosphorus in inorganic fertilisers.
Mineral K application	Applications of potassium in inorganic fertilisers.
Plant compost application	Application of plant compost which results from biodecomposition of plant material in the presence of air.
Bio-waste compost application	Application of bio-waste which results from biodecomposition of organic material, such as animal wastes, plant residues, etc. in the presence of air.
Sludge compost application	Application of sludge which consists of suspended particles settling out of the water and sediment on the bottom in the presence of air including mechanical mixing and aerating. The term "compost" describes the additional mixinng of sludge with structural material, such as green waste, shredded, sawdust.
Farm yard manure (FYM) application	Application of manure from livestock which is a mixture of excrements (faeces and urine) of animals with a binding medium such as usually straw.

Cattle slurry application	Application of slurry from livestock which is mainly a mixture of faeces and urine.
Poultry manure application	Application of manure from livestock which is mainly a mixture of faeces and urine.
Pig slurry application	Application of slurry from livestock which is mainly a mixture of faeces and urine.
Return of crop residues	Crop residues (e.g. stubble and roots) that remain after harvesting and are ploughed in.
Burning of crop residues	Straws are left on the soil and set to fire after harvesting
Feeding of crop residues	Crop residues are fed to livestock present on farm.
Selling of crop residues	Crop residues are sold for different purposes to other farmers or processing industry (e.g. biogas).

B5. Crop protection

Mechanical weeding	The mechanical weeding uses technical tools to bury, cut or uproot the existing weeds. For this mechanical method, straight-row planting is essential.
Herbicide application	The application of herbicides to combat weeds and protecting crops.
Push-pull strategies	Push-pull technology is a method of biological pest control. Within cultures, crops are cultivated with repellent effects and outside the cultures crops are grown with attractive effects. This makes it possible to pull or to push the insects from the crops.
Patches or stripes of natural vegetation	Patches or stripes of natural vegetation are included in the field. They serve as a refuge for beneficial insects for biological pest control, for promotion of soil-field weeds, and to avoid erosion and prevent leaching of nutrients.
Pheromones application	The application of pheromones to influence plant growth.
Insecticide application	The application of insecticides to protect crops.
Fungicide application	The application of fungicides to protect crops.
Nematode application	The application of nematodes to protect crops.
Soil fumigation	After covering the soil the application of gaseous pesticides by specialized devices are used to control pests inside the soil.
Soil solarization	Covering the soil to trap solar energy and heat the soil to control pests.
Biological pest contol	Using biological control agents (natural enemies) to control pests

B6. Water management

Surface irrigation	Application of water to the field by surface irrigation.
Drip irrigation	Application of water under low pressure through a piped network in a pre-determined pattern, applied as a small discharge to each plant or adjacent to it and adjustable by irrigation nozzles.
Sprinkler irrigation	Application of water to the field by sprinkler irrigation.
Subsurface drainage	Artificial systems of furrows, ditches, pipes, etc. to improve drainage of excess water from the sub-soil.

Appendix D. Main soil degradation problems in participant countries

Overviews of the main soil degradation problems in the different participants countries within the CATCH-C project are given in the following. These reports for each of the countries are compiled by the CATCH-C participant(s) from that country. A short introduction and links to information about soil degradation problems in Europe as a whole are also given.

Soil degradation problems in Europe

Author: Joost Wolf

Wageningen University, Wageningen, The Netherlands

Different European reports with soil degradation information have been read to check if they also contain such information at the national level. This was practically not the case. This limits their usefulness for the CATCH-C project. However, this information may be used as background information on soil degradation problems in Europe. For these reports the summaries are given and the main maps and tables that are used as background information within the CATCH-C project.

Jones et al., 2012 – The State of Soil in Europe

From Summary:

This report provides a comprehensive overview of soil resources and degradation processes. The core of this report was prepared for the Assessment on Soil, which forms part of the 'The European Environment - state and outlook 2010 Report' (SOER) 20102, coordinated by the European Environment Agency (EEA). This Reference Report uses data from the European Soil Data Centre (ESDAC), managed on behalf of EU institutions by the JRC. For the report, see http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_2012_02_soil.pdf

This report contains maps for Europe of respectively,

a) Organic Carbon
b) N surplus
c) Soil erosion
d) Acidity deposition
e) Susceptibility to compaction
f) Irrigation
g) Sensitivity to desertification
h) Prone to landslides
i) Threats to soil biodiversity
j) Soil erodibility

Toth et al., 2008 – Threats to soil quality in Europe

From Introduction and Abstract:

The adoption of the EU Soil thematic strategy opens new perspectives towards a new definition of soil quality taking into account the various functions of soils: food and fiber production, buffering and filtering of contaminants, biodiversity pool, archive of cultural heritage, source of raw materials, substrate for housing and infrastructure, etc.

The re-definition of soil quality will also have a major impact on the environmental reporting process, both at national and International level. Soil Quality is a recognized indicator by the OECD countries and is included in the list of agri-environmental indicators relevant to EUROSTAT as well as to EEA. A more robust and innovative definition of soil quality for Europe will allow more efficient reporting about the status of the environment and will allow to design appropriate monitoring systems for detecting changes in soil quality over time.

The special session during EUROSOIL 2008 dedicated to the threats to soil quality in Europe has allowed for an indepth analysis of the status of research in this are and the identification of still existing research gaps for future action. The full coverage of the threats identified within the Soil Thematic Strategy will allow to further support the on-going process towards better soil protection in Europe.

This report is summarizing the results of recent research activities on the fields of soil degradation, soil quality and soil information systems performed in the Joint Research Center, in collaboration with partner institutions. An overview is given about the main soil threats (erosion, compaction, salinisation, landslides, decline of soil organic matter, biodiversity decline and contamination) and a soil quality concept with relevance to the Thematic Strategy for Soil Protection.

This report (see http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR23438.pdf) contains the following information about soil degradation at the European scale:

p. 27 etc. – Tables 5 and 7 Susceptibility to compaction per soil type; pedotransfer rule for compaction; European map of susceptibility to compaction

p. 39 – European map of Soil erosion risk (via PESERA model)

p. 52 – Erosion map for Alps region

p. 76 – European map of Saline and sodic soils

p. 93 – European map of Soil organic Carbon

Morvan et al., 2008 - Soil monitoring in Europe

From Abstract:

Official frameworks for soil monitoring exist in most member states of the European Union. However, the uniformity of methodologies and the scope of actual monitoring are variable between national systems. This review identifies the differences between existing systems, and describes options for harmonising soil monitoring in the Member States and some neighbouring countries of the European Union. The present geographical coverage is uneven between and within countries. In general, national and regional networks are much denser in northern and eastern regions than in southern Europe. The median coverage in the 50 km×50 km EMEP cells applied all over the European Union, is 300 km2 for one monitoring site. Achieving such minimum density for the European Union would require 4100 new sites, mainly located in southern countries (Italy, Spain, Greece), parts of Poland, Germany, the Baltic countries, Norway, Finland and France. Options are discussed for harmonisation of site density, considering various risk area and soil quality indicator requirements.

This article contains maps at the European scale (Figure 3) of the areas where the following degradation problems are of importance:

a) Soil erosion
b) Peat
c) High compaction risk

d) High cattle density
e) High pig density
f) High lead deposition
g) High cadmium deposition
h) High mercury deposition
i) High population density
j) Desertification risk

The used data sets for these degradation problems over Europe are given in their Section 2.2.

Louwagie et al. (SoCo project team), 2009 – Addressing soil degradation in EU agriculture

From Abstract and Introduction:

Agriculture occupies a substantial proportion of the European land, and consequently plays an important role in maintaining natural resources and cultural landscapes, a precondition for other human activities in rural areas. Unsustainable farming practices and land use, including mismanaged intensification as well as land abandonment, have an adverse impact on natural resources. Having recognised the environmental challenges of agricultural land use, the European Parliament requested the European Commission in 2007 to carry out a pilot project on "Sustainable Agriculture and Soil Conservation through simplified cultivation techniques" (SoCo). The project originated from a close cooperation between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC). It was implemented by the Institute for Prospective Technological Studies (IPTS) and the Institute for Environment and Sustainability (IES).

This report (see http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR23767.pdf) contains the findings of a stock-taking of the current situation within an EU wide perspective. It focuses on the nature, localisation and extent of soil degradation processes. It provides information on soil conservation practices in agriculture, their environmental effects as well as economic costs-benefits and where available, their uptake. Next, it provides a review of the regulatory environment and policy measures for soil protection, conservation and improvement in EU and national/regional implementation. Finally, it links the three preceding chapters to establish an EU-wide classification of farming techniques and policy measures addressing soil degradation processes. This is followed by the summary report of the stakeholder workshop on 22 May in Brussels and leads into an outlook on the further work of the SoCo project.

This report contains the following maps and tables about soil degradation problems at the European scale and about the effects of farming practices:

European map of actual Soil organic Carbon

European map of Susceptibility to compaction

European map of Saline and sodic soils

Table 3.1 Classification of soil preparation techniques

Table 3.3 Impacts of reduced and no tillage compared to conventional tillage

Table 4.1 List of national ministries and institutes contacted for EU wide survey of policies addressing soil degradation processes

Table 4.6 Summary of national measures within GAEC (Good agricultural and environmental condition)

Table 5.2 Effects of farming practices on physical/chemical/biological soil characteristics

Table 5.3 Effects of farming practices on soil degradation processes and related environmental issues

References

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Louwagie, G., Gay, S.H., Burrell, A. (Eds.) (SoCo project team), 2009. Addressing soil degradation in EU agriculture: relevant processes, practices and policies. JRC 50424, JRC-IPTS, Sevilla, Spain, pp. 208

Morvan, X., Saby, N.P.A., et al., 2008. Soil monitoring in Europe: A review of existing systems and requirements for harmonisation. Science of the Total Environment 391, 1-12.

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Soil degradation problems in Austria

Authors: P.Strauss, C. Krammer, E. Murer

Institute for Land and Water Management Research, Federal Agency for Water Management, Pollnbergstrasse 1, A-3252 Petzenkirchen, Austria

The main soil degradation problems in Austria are related to soil erosion and to subsoil compaction, which problems are described in two subsequent sections.

Soil Erosion

Soil movement and erosion control in alpine areas have been a major issue in all countries exhibiting high relief energies since longtime. However, this may be seen as a natural threat whereas focus of our report will be soil erosion as a threat due to human activities in agriculturally used areas.

Development since 1945

Soil erosion by water has been identified as a major threat of soil degradation since the early 1960's when increased problems of severe erosion events were reported for areas with viniculture (Mayrhofer, 1970). Soil erosion by wind was identified even earlier as a threat of soil degradation during the second half of 1949's (Blümel, 1945) as a consequence of wind erosion problems which occur mainly in the very Eastern parts of Austria. For a detailed delineation of risk areas please refer to Strauss and Klaghofer (2006). Activities were already set up in the 1950's to combat the problem. The measures taken were mainly construction of wind shelter belts in the risk areas. In contrast to the wind erosion threat, measures to combat soil erosion by water were not available at national scale until 1995. In 1995, the Austrian programme for an environmentally sustainable agriculture (ÖPUL) started together with Austria joining the European Union. Here, for the first time, activities to combat erosion at national scale were proposed.

Erosion risk classes for Austria

The spatial extent of soil erosion in Austria is presented in Figure 1.

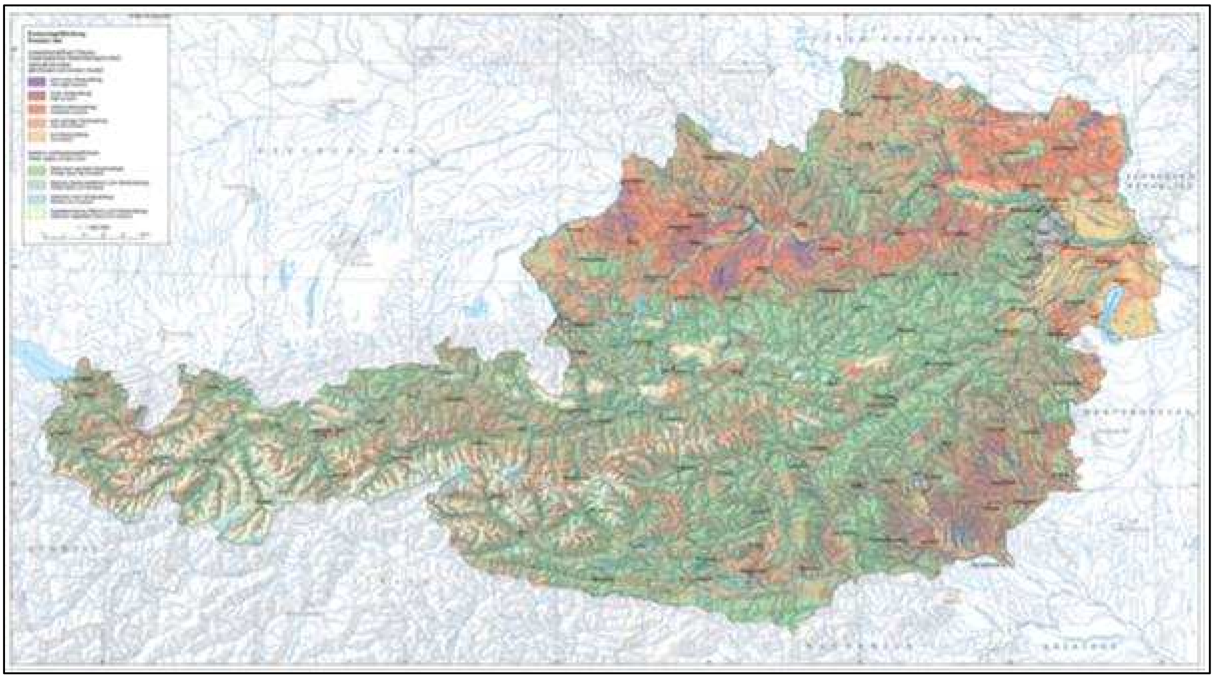

Figure 1 Spatial extent of soil erosion by water in Austria (Strauss, 2007)

Erosion rates were calculated using a modified version of USLE (for details refer to Strauss, 2007).

Figure 1 shows the spatial extent of soil erosion by water in Austria. Significant areas are:

1) Weinviertel region
2) Vineyard areas in Austria (Burgenland)
3) Alpine foreland
4) South-Eastern hilly region of Styria

Soil erosion occurs especially when certain conditions are fulfilled:

- A combination between geomorphological risk conditions (slope gradient and length) and intensive land use (tillage and crop practices).

- Although in alpine regions, the geomorphological risk is higher, we find a decrease of erosion risk in general, since - due to climatic reasons - within these regions the main crop is grass.

The OECD report *Environmental Performance of Agriculture at a Glance,* 2nd edition [see COM/TAD/CA/ENV/EPOC (2012)10, in press] contains information about the amount of soil erosion for the years 2004 and 2008 (Table 1).

Table 1 Arable land area of Austria affected by water erosion

OECD categories for water erosion levels	**2003-2004**	**2007-2008**
Total agricultural land (in 1000 ha) affected by:	..	..
Tolerable erosion <6.0 t/ha/y	586	593
Low erosion 6.0-10.9 t/ha/y	96	105
Moderate erosion 11.0-21.9 t/ha/y	53	62
High erosion 22.0-32.9 t/ha/y	14	17
Severe erosion >33.0 t/ha/y	12	17

Total reported land area affected by water erosion:	**761**	**795**

Between 2004 and 2008 the areas with higher erosion rates slightly increased. This is due to an increase in maize production, which in turn is the result of efforts to increase biofuel production as well as increased market prices for maize during recent years. This is a rather short term view of erosion risk changes. However, no time series of trends of soil erosion risk exist so far but would be needed in order to scale recent changes in soil erosion risk and identify long term farming and management effects on soil erosion.

Measures to mitigate soil erosion by water

ÖPUL contains a set of measures to combat soil erosion by water. Conceptually, they may be split into two groups, direct measures and indirect measures. Direct measures are those which are explicitly introduced as measures to combat erosion. Measures foreseen to be direct measures are “mulching and direct drill”, “erosion control in orchards” and “erosion control in vineyards”. For details please refer to (BMLFUW, 2007).

Table 2 Shares of arable land in selected erosion control measures (according to INVEKOS 2008) by province (in %) (BMLFUW, 2010)

	Federal provinces of Austria									
	BGLD	**KTN**	**NOe**	**OOe**	**SBG**	**STMK**	**TIROL**	**VBG**	**WIEN**	**Total**
Arable land in 1.000 ha	**160**	**63**	**690**	**295**	**6**	**139**	**9**	**3**	**5**	**1.369**
Direct Measures										
Greening during winter(19)	33,0	28,8	33,7	35,0	35,6	14,2	34,7	32,4	29,7	31,7
Mulching and direct drill(20)	8,6	2,1	12,8	13,4	0,4	1,6	0,0	0,8	11,5	10,6
Indirect Measures										
Biological farming (1)	17,5	12,1	10,7	8,2	35,8	5,8	10,6	4,9	12,7	10,6
Ecopoints NÖ (18)	-	-	5,1	-	-	-	-	-	-	2,6
Abandonment of yield increasing materials on arable land (3)	0,4	1,4	0,5	0,8	3,2	1,0	1,4	0,3	0,0	0,7
Abandonment of yield increasing materials on arable fodder land.(4)	0,4	8,2	0,9	4,9	17,8	5,7	28,7	8,4	0,2	2,8
Maintenance and development of natural protection areas (28)	2,6	1,5	1,4	0,0	3,6	0,7	0,5	0,0	0,0	1,2

As Table 2 shows, it can be seen that:

- Greening is very much in use.
- Mulching is still to be expanded. The mulching share of 10% of the total arable land however, is somewhat misleading because this option is used only for maize, beets and other row crops.
- In some provinces the mulching and direct drill measures are applied at lower percentages. This is due to the fact that climatic restrictions do not allow crops to be grown everywhere in Austria. The federal province of Tyrol for instance is a region with almost exclusively grassland as agriculturally used area.

Complementary to direct measures also indirect measures are contributing to an improved protection of soil against erosion. It is for example the measure “biological farming”, which shifts the crop rotation towards higher percentages of grass land and thus decreases erosion risk for these areas.

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Subsoil compaction on arable land in the alpine forelands of Austria

General presentation

The Project "Effectiveness of ÖPUL measures to avoid soil compaction" was conducted jointly by the Austrian Agency for Health and Food Safety (AGES) and the Federal Institute for Soil and Water Management (BAW) on behalf of the Ministry for Agriculture, Forestry, Environment and Water Management (BMLFUW). The project aim was the inventory of the compaction degree in compaction endangered arable sites with longtime ÖPUL participation, and the interpretation of the impact of these ÖPUL measures. As project area it was chosen the main production area "alpine forelands". Based on the data of the Austrian Soil Mapping, the compaction risk was calculated as the reciprocal of the subsoil precompression. The precompression represents a guideline for the mechanical strength of the subsoil.

Soil compaction is a form of physical soil degradation. On arable land with annual ploughing and cultivation with heavy wheel loads on wet soils, harmful subsoil compaction is most likely. In consequence, soil pore volumes decrease, especially the volume of the coarse pores. Compaction can reduce water infiltration capacity and increase erosion risk by accelerating runoff. Tillage and natural processes may release the topsoil. However, subsoil compaction remains as a serious problem. Loosening of the subsoil is very complex and expensive. A sustainable effect is all too often not guaranteed and of no long duration. In addition, loosening of subsoil is not suitable for every type of soil.

Method

Soil physical investigations were performed at 30 sites representative for the alpine foreland Austrian production area (Figure 1).The sites were selected with respect to:

- Long-standing participation in ÖPUL measures (greening, sowing or mulch) with compression-related management (for example corn and sugar beet) (ÖPUL);
- Compaction risk on the basis of precompression (EBOD);
- Main soil type (EBOD)

The soil structure (good, poor, critical) was assessed according to the threshold values of air capacity (≤5%) and saturated hydraulic conductivity (≤10cm*d-1) LEBERT und SCHÄFER (2005).

Samples were taken from the main soil types with different precompression stress on farms with frequent corn and sugar beet in the crop rotation. The precompression stress value was estimated according to the Austrian Soil Mapping and DIN V 19688 (2001) (Figure 2).

From the 30 sites there were taken samples with 9 cylinders for each soil horizon. The plough pan was detected with a penetrometer (cone Ǿ 15.95 mm, 60°). The cylinder samples (200 cm³) were taken at the position of the highest penetration resistance.

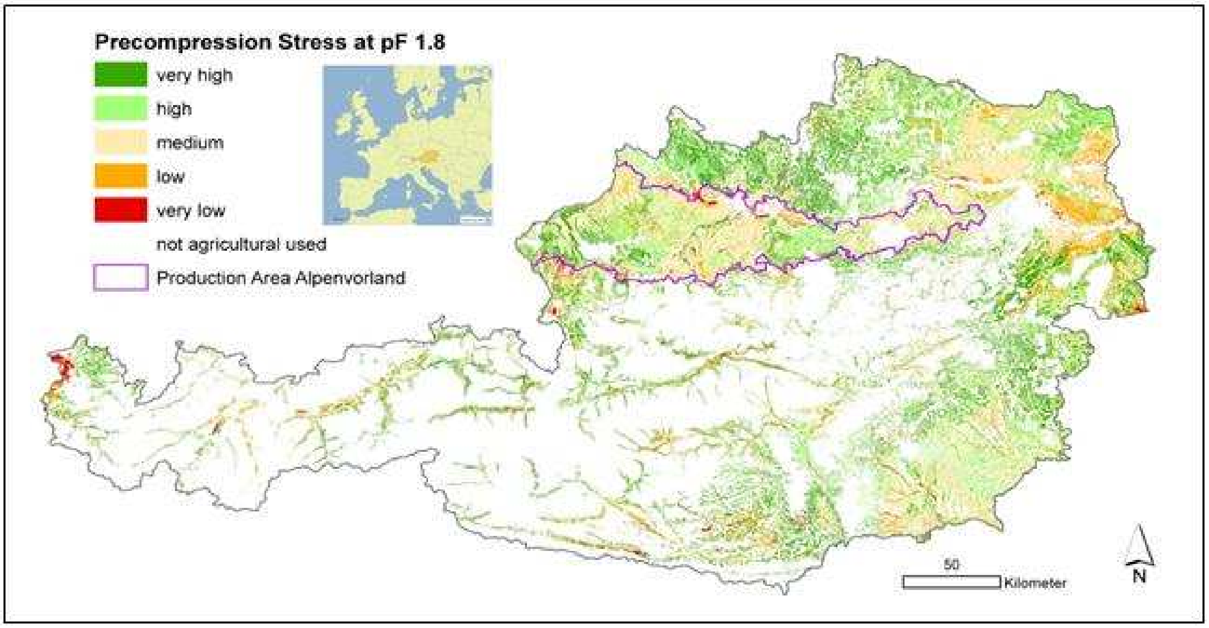

Figure 2. Pre-compression stress value at water content near field capacity (Basis BMLFUW / BFW / DIN V 19688; Analysis: BAW Petzenkirchen, E. Murer, 2011)

Results

Precompression

Slightly more than a half of the agricultural land in the project area has a "very high" to "high" precompression, about a third of the area has a mean precompression and about 10% of arable land has a small precompression. Only two and a half percent of agricultural soils have a very low precompression (Figure 2).

Structure state

The set of 30 sampling points represent a survey that is punctual, random and influenced by many factors. The soil types of the sampling sites have a similar frequency as the total agricultural land of the project area. (Table 3).

Table 3: Ratio of texture classes in the plough pan of the project and the sampling sites

Soil type after AD-HOC-AG BODEN (2005)	**Soil mapping (%)**	**Sampling sites (%)**
Ut4 (highly clayey silt)	25	23
Lu (silty clay)	16	20
Ut3 (medium clayey silt)	9	13
Tu3 (medium silty clay)	8	7
Total	58	63

To reach a better comparability of the results soil texture of the subsoil was grouped. This allowed individual farmers to draw conclusions of their cultivation practice on subsoil condition in comparison to their colleagues.

A wide range of saturated hydraulic conductivity was found (Figure 3). Harmful subsoil compaction was found in most of soil texture and soil types (Figures 4 and 5).

Statistical analysis showed a significant increase of penetration resistance and subsoil compaction on headland as compared to other parts of the investigated fields (Murer et al., 2012).

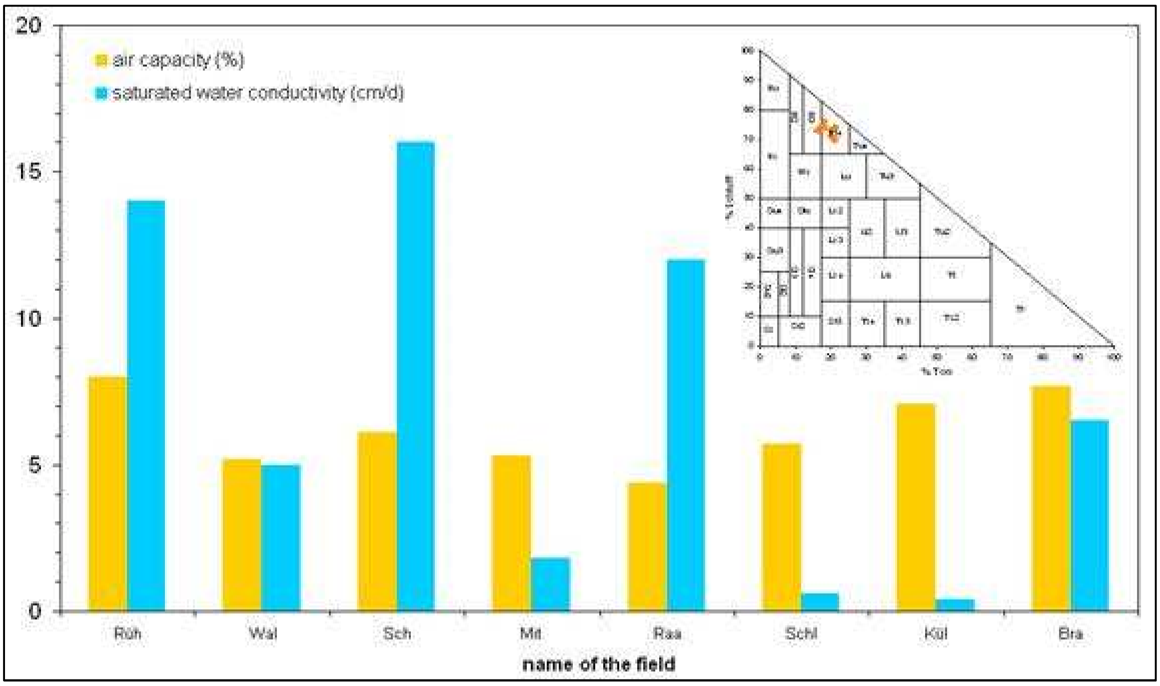

Figure 3: Measured soil physical properties for a group of similar soil texture (Murer, 2011)

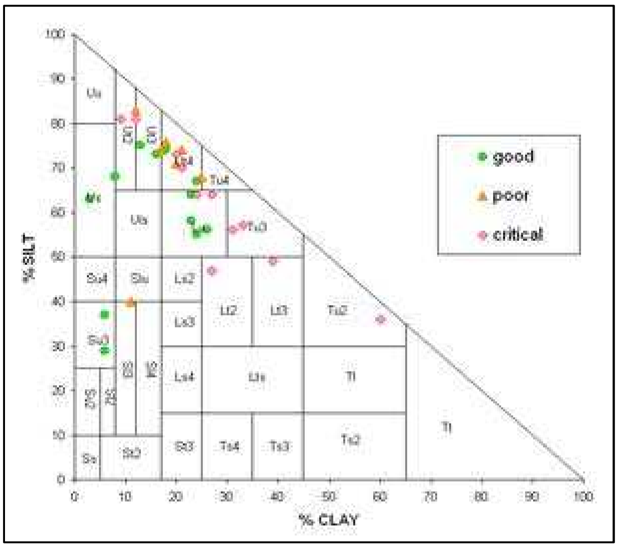

Figure 4 Soil texture classes of samples in the plough pan and their aggregate status (Murer, 2011)

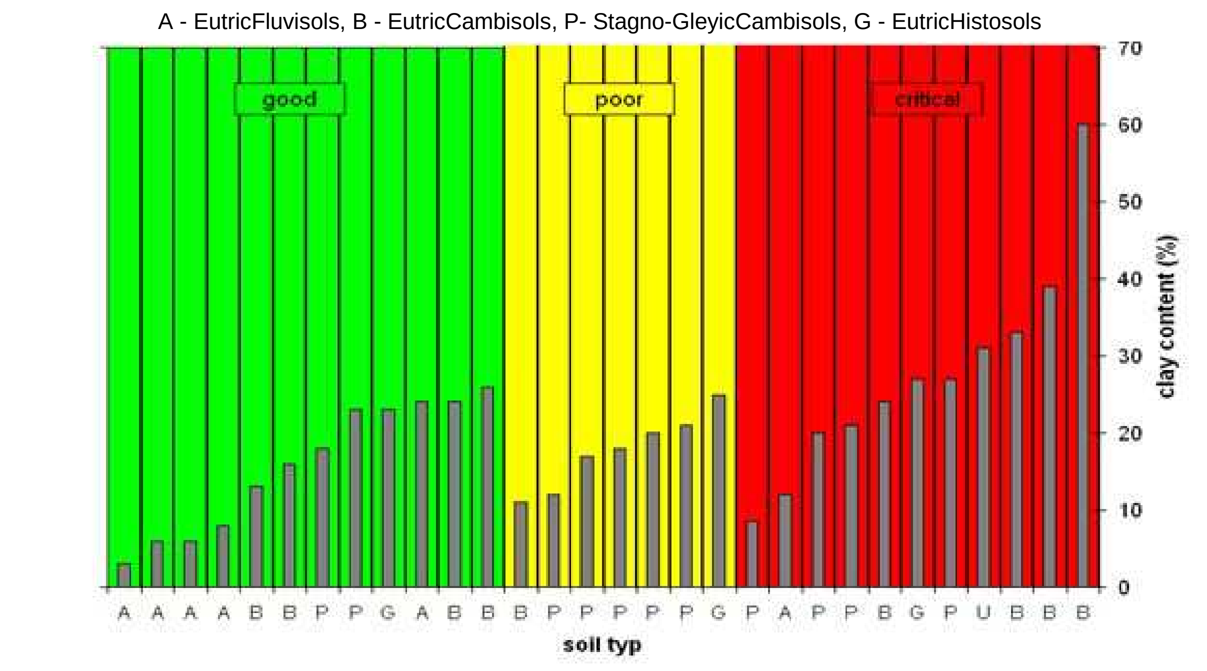

Figure 5 Soil types and subsoil structure classification of the test plots (Murer, 2011)

From all 30 samplings only 12 sites have a favorable structural state in the plow pan. Seven sites have a poor and 11 site have a critical structural state, this represents nearly 2/3 of the investigated sampling points.

In the class with favorable structural state all major soil types can be found, but especially the Eutric Fluvisoils.

In the class of poor structural state dominates Pseudogley. In the class of critical structural state are reflected all the main soil types and all soils with a clay content of about 30% in the plow pan.

Long-term soil physical findings of the Institute of Land and Water Management (IKT) in Petzenkirchen are summarized in a corresponding database. The locations of these findings are shown on the "EBOD" (www.bodenkarte.at). The analysis of 34 randomly selected sites from this data showed that about 20% of the sub-soils were classified as damaged compacted. The value obtained for the sampling sites' structural state cannot generally be transferred to the entire plot. Harmful soil compaction often affects the total area of a plot, but usually appears only in parts of it.

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Soil degradation problems in Belgium

Authors: Tommy D'Hose, Greet Ruysschaert

Institute for Agricultural and Fisheries Research (ILVO), Merelbeke, Belgium

Introduction

Soil protection policy in Belgium is regulated at the regional scale.
In Flanders, the Land and Soil Protection Service (LNE-ALBON) is responsible for the soil protection policy. The Soil Protection Service focuses its activities mainly on soil degradation by:

1. erosion
2. compaction
3. loss of organic matter

LNE-ALBON ordered several studies to map those soil degradation problems in Flanders and to come up with prevention and remediation measures. The main findings of those studies will be included in this report.

Next to the soil degradation problems mentioned above, also the eutrophication of groundwater and surface water with nitrogen and phosphate is an important issue in Flanders. Agriculture is a big contributor to this problem, resulting from excessive fertilization.

4. nitrate and phosphate in soil, groundwater and surface water

At Flemish level, the Flemish Environment Agency (VMM) aims at a good general status of the surface water and ground water in Flanders which is also the objective of the European Water Framework Directive. Therefore, the VMM measures and controls the quantity and the quality of surface water, groundwater and sediments and reports about the results by means of the Flanders State of the Environment Report (MIRA). MIRA describes, analyses and evaluates the state of the Flemish environment, discusses the environmental policy pursued and looks ahead at the future environment. In this document we will rely on the MIRA report for the evaluation of the groundwater and surface water quality.

Further, within the EU Water Framework Directive the Nitrate Directive is one of the key instruments in the protection of waters against agricultural pressures. In Flanders, the Flemish Manure Decree is the implementation of the EU Nitrate Directive. The Flemish Manure Decree describes the amount of organic and mineral fertilizers that can be applied on agricultural land depending on manure type, crop category and land category. Further, the Flemish Manure Decree states that the NO_3^--N residue in the soil profile (0-90cm) must remain below 90 kg ha^{-1} during a fixed curfew (i.e., October 1st until November 15th). This limit of 90 kg NO_3^--N in soil should insure that nitrate levels in surface and groundwater stay below the limit set in the Nitrate Directive (50mg of NO_3^- per litre). In Flanders, the Flemish Land Agency (VLM) is responsible for monitoring a correct implementation of the manure legislation. The results of the monitored soils are published every year in the progress report of the Manure bank, which is a part of VLM. In this document, we will rely on the 2012 progress report.

In Wallonia, the '*Cellule Etat de l'Environnement Wallon' (*which is a part of the *Direction Générale de l'Agriculture, des Ressources Naturelles et de l'Environnement (DGARNE) of the* Public Service of Wallonia) is responsible for publishing reports about the state of the environment in Wallonia. The Environmental Outlook for Wallonia (EOW) provides an update on Wallonia's environmental situation, based on a collection of environmental, social, health and other indicators which sheds some light on the pressure put on the environment (air, water, soils, fauna, flora, natural habitats, etc.) and its impact. The results of the 2008 and 2010 edition of the EOW (EOW 2008, 2010) are derived from the publication of the *Rapport analytique sur l'état de l'environnement wallon 2006-2007* and the *Tableau de bord de l'environnement wallon 2010* (Cellule Etat de l'environnement wallon 2007, 2010), which provide a more comprehensive and detailed environmental analysis.

The main soil degradation problems that have been discussed in both reports are:
1. soil erosion by water
2. soil compaction
3. loss of organic matter
4. nitrate and phosphate in soil, groundwater and surface water

Although Flanders and Wallonia are two different regions in terms of soil types, land use and topography, the same soil degradation problems seem to occur. Therefore, this document will describe the four main soil degradation problems that were mentioned before after which the spatial distribution of each of the main soil degradation problems in both Flanders and Wallonia will be shown.
Further, the FTZs that were selected for Belgium will be indicated on the maps:
- Arable specialised crops in ENZ7_SL2_TXT3 (**FTZ1**)
- Dairy farming permanent grassland in ENZ7_SL1_TXT1 (**FTZ2**)
- Mixed farms (horticulture) in ENZ7_SL1_TXT2 (**FTZ3**)

The selected FTZs correspond with different agricultural regions and provinces in Belgium (Figure 1 and Figure 2, Table 1). However, in order to avoid confusion, we will mostly refer to the FTZs in this report.

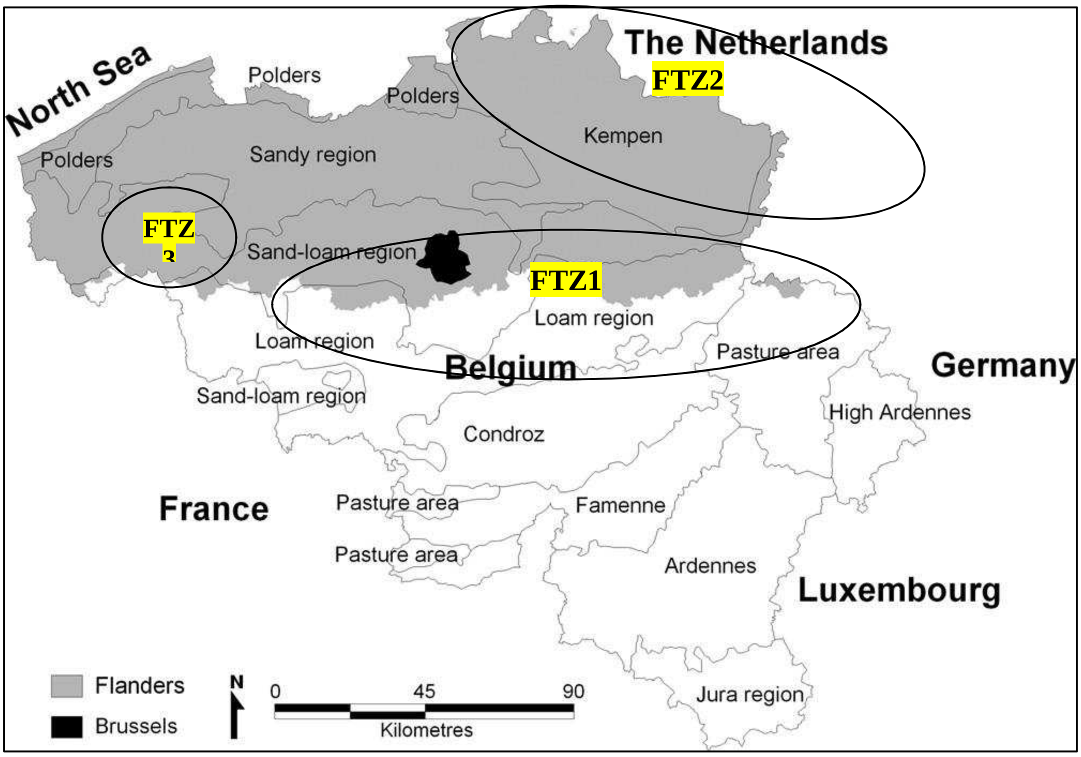


Figure 1 Agricultural regions in Belgium with indication of the FTZs used in Catch-C (Source: Ruysschaert et al. 2008)

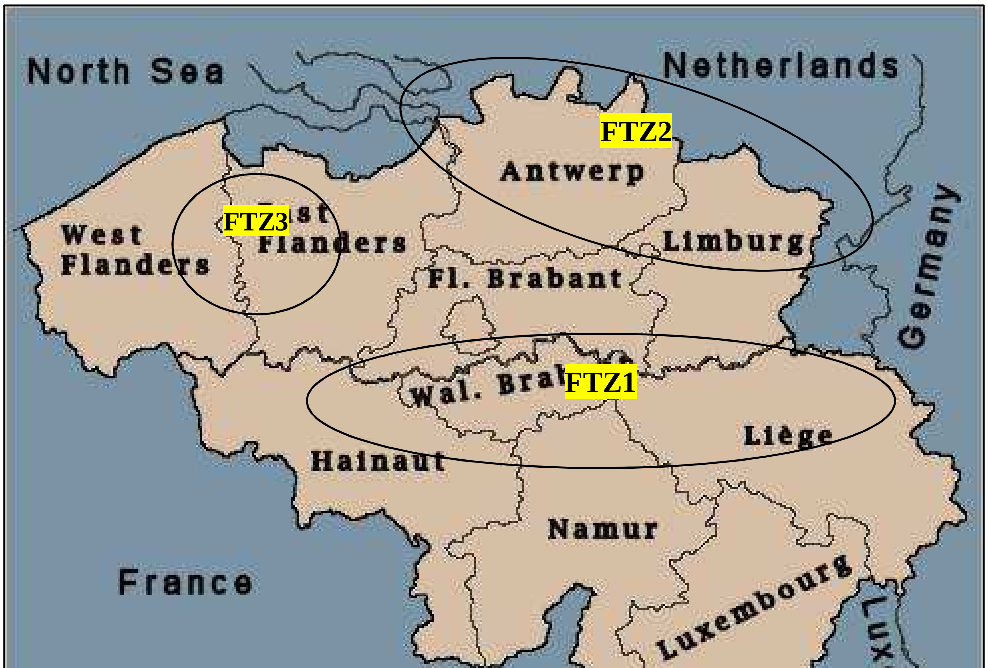


Figure 2 Provinces in Belgium with indication of the FTZs used in Catch-C

Table 1 Corresponding agricultural regions and provinces with the FTZs used in Catch-C

FTZ	Agricultural region(s)	Province(s)
1	Sand-loam loam	the southeast of East Flanders Brabant (Flemish and Walloon) the south of Limburg the north of Liège
2	Kempen	the north of Limburg the north of Antwerp
3	Sand-loam	the centre of West Flanders

Soil erosion

The process wherein soil particles are detached and transported by the various agents of erosion is known as soil erosion. The two main agents of soil erosion are water and wind but also certain tillage practices can result in the movement of soil particles when conducted on sloping agricultural land (Poesen and Govers, 1994). Soil erosion results in the loss of fertile topsoil and even the loss of important soil functions.

In Belgium, soil erosion mainly occurs in FTZ1, where silty to loamy soils, a hilly topography and a large share of cropland grown with crops susceptible to erosion (e.g. sugar beet, potato) are responsible for high soil loss rates on arable fields and muddy floods in build-up areas (Figure 3 and Figure 4).

In Flanders, water and tillage are regarded as the two most important agents causing soil erosion. The spatial variability of the mean potential soil erosion susceptibility (water erosion and erosion caused by tillage practices) for each plot of arable land in Flanders is given in Figure 3. The highest susceptibility has been noticed on the hilly fields in the loam region of FTZ1. The annual soil loss due to erosion in this FTZ1 has been estimated between 10 and more than 40 ton/ha (Mira, 2011a). Further, the share of water and tillage erosion in total soil erosion is regarded as nearly the same (Van Oost et al., 2009). In FTZ2 and FTZ3, the average annual soil loss due to water and tillage erosion is very low (< 0.5 ton/ha.year).

In Wallonia, only water erosion has been reported (EOW 2008, 2010). Potential soil losses due to water erosion are estimated at 2.9 ton/ha.year on average across the whole Walloon land area (EOW 2010). The highest quantities of eroded soil can be seen in FTZ1 (loamy and sandy-loamy regions) where the soils are particularly vulnerable to erosion (Figure 4, EOW 2008).

Overall, in Wallonia soil losses have increased by ± 75 % since 1971, although there have been significant changes from year to year, mainly linked to weather fluctuations (e.g. highly erosive rain in 2002). Over the 2001-2005 period, ca. 50 % of agricultural land was affected by soil losses higher than the threshold value of 5 t/ha.year, while this was less than 35 % of agricultural land in the 1986-1990 period (EOW 2008). This trend can largely be explained by the rise in the rainfall erosivity, as well as by the increasing proportion of agricultural land grown by row crops (maize, potato etc.), which do not provide much cover in spring when the rainfall is generally more erosive (EOW 2008, 2010).

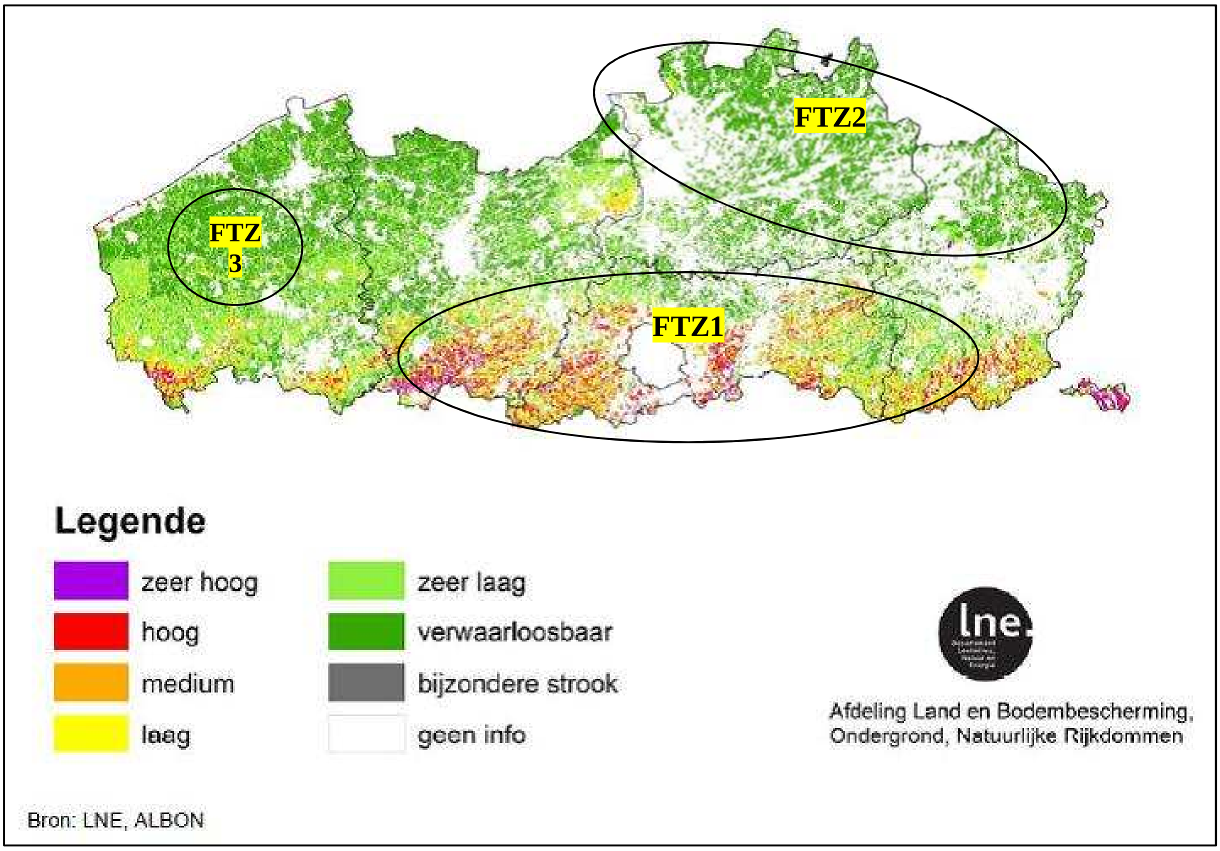


Figure 3 Spatial variability of the mean potential soil erosion susceptibility (water erosion and erosion caused by tillage practices) for each plot of arable land (Flanders, 2011) (Source: Mira 2011)
Legend: zeer hoog = very high, hoog = high, laag = low, zeer laag = very low, verwaarloosbaar = negligible, geen info = no info

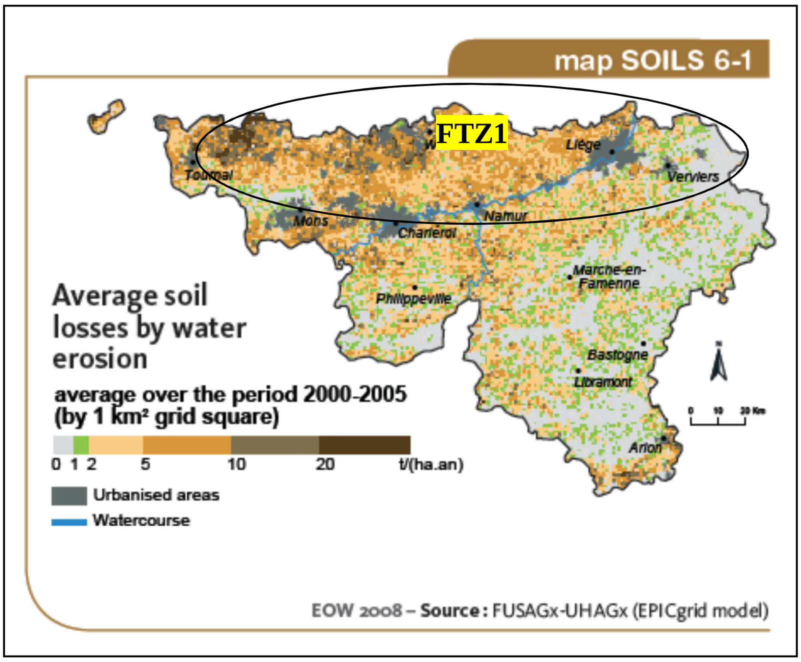


Figure 4 Average soil losses by water erosion in the Walloon region (Source: EOW 2008)

Next to water and tillage, the harvest of root and tuber crops, such as sugar beet and potato, also causes loss of soil from the field. For Belgium this was estimated by Ruysschaert et al. (2008). The estimates of yearly soil losses by root and tuber crop harvesting for the major agricultural regions in Flanders (Figure 1) are given in Table 2. According to Ruysschaert et al. (2008), on average 1.7 ton/ha.year of fertile topsoil is removed from Flemish arable land during the harvest of root and tuber crops. The highest values for soil loss due to crop harvesting (SLCH) were noticed in the loam region of FTZ1 (2.8 ton/ha.year) which could be attributed to the high share of total cropland grown with sugar beet. Soil losses by root and tuber crop haversting are less important in FTZ2 (the 'Kempen'). Clear figures for FTZ3 are not available.

Table 2 Absolute and relative importance of net sediment export from cropland due to soil loss due to crop harvesting (SLCHy) and water erosion processes (WE) per agricultural region within Flanders (Source: Ruysschaert et al., 2008).

Agricultural region	SLCHy[a] (Mg ha^{-1} $year^{-1}$)	WE[b] (Mg ha^{-1} $year^{-1}$)	Total (Mg ha^{-1} $year^{-1}$)	Relative share	
				SLCHy[a] (%)	WE[b] (%)
Loam region	2.8	4.1	6.9	40	60
Sand-loam region	2.2	3.6	5.9	38	62
Sandy region	1.1	0.5	1.6	68	32
Kempen	0.6	0.3	1.0	64	36
Dunes-polders	1.8	0.1	1.9	94	6
Flanders	1.7	2.0	3.7	46	54

[a] Based on 9-year average SLCHcrop values for 2002 (Fig. 3) and areal statistics (NIS, 'landbouwtelling', 2002).
[b] Sediment export by water erosion (WE) processes, modelled with WATEM/SEDEM using information on crop types grown per field parcel in 2002 and the average (1898–2002) rain erosivity factor (*R*-factor; Verstraeten et al., 2006) for Ukkel (based on Gobin et al., 2005).

Figure 5 indicates that the combination of open terrains and sandy soils in FTZ2 increases the potential for wind erosion to a soil loss, being estimated at 5-18 ton.ha^{-1}.yr^{-1} (Van Oost et al. 2000, Van Kerckhoven et al. 2009). However, Van Kerckhoven et al. (2009) estimated the average soil loss due to wind erosion in the whole of Flanders at 0.9 ton.ha^{-1}.yr^{-1}, what makes the effects of wind erosion rather limited. Also in Wallonia, few effects on wind erosion have been reported.

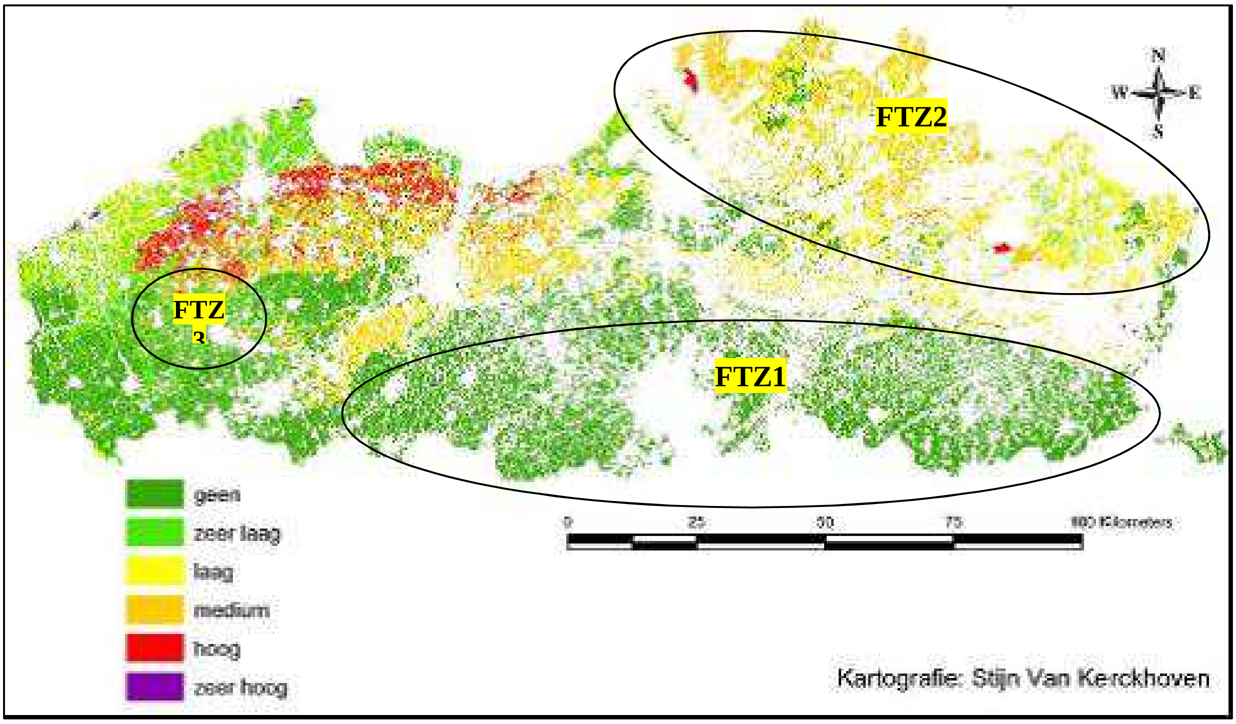


Figure 5 Spatial variability of the mean potential wind erosion susceptibility for each plot of arable land in Flanders (Source: Van Kerckhoven et al. 2009)
Legend: zeer hoog = very high (30-59 ton.ha^{-1}.y^{-1}), hoog = high (18-30 ton.ha^{-1}.y^{-1}), medium (10-18 ton.ha^{-1}.y^{-1}), laag = low (5-10 ton.ha^{-1}.y^{-1}), zeer laag = very low (2-5 ton.ha^{-1}.y^{-1}), geen = no potential wind erosion (0-2 ton.ha^{-1}.y^{-1})

Soil compaction

Soil compaction occurs when soil particles are pressed together, reducing total pore space (Van de Vreken et al. 2009). Distinguishing between topsoil and subsoil compaction is important. Topsoil compaction is likely to severely reduce plant productivity in the short term, whereas subsoil compaction is likely to reduce productivity for decades in the future.

Within the European Soil Thematic Strategy, compaction and especially subsoil compaction are considered as major threats for soil quality since they can result in the loss of important soil functions (European Soil Portal, 2013; Van de Vreken et al. 2009):

- increased bulk density and penetration resistance
- reduced nutrient uptake, infiltration and water holding capacity
- reduced root growth and soil biological activity

Soil susceptibility to compaction is the probability that soil becomes compacted when exposed to compaction risk (European Soil Portal, 2013). Soil susceptibility to compaction can be divided, into natural and man induced susceptibility. The reasons for natural soil susceptibility to compaction are resulting from the soil properties and the typical climate of the evaluated area. A high clay fraction and soil moisture content and a low soil bulk density and organic matter content will result in a higher susceptibility to soil compaction.

Reasons for man induced susceptibility are intensive cultivation practices, narrow crop rotations and the use of heavy machinery (especially in spring and fall when the carrying capacity of the soil is generally low due to a higher soil moisture content). Research has shown that machinery induced soil compaction can affect the soil to a depth of 0.6 m by which the greatest effects are expected in the top soil (0-10 cm) (Mira, 2011a; Van de Vreken et al. 2009).

In an exploratory study conducted by Van de Vreken et al. (2009) the susceptibility for compaction of arable land in Flanders was mapped. The susceptibility of soil to compaction is inversely related to its structural strength which can be expressed in terms of precompression stress (PCS). Soil compaction will occur when the pressure at a given depth exceeds the PCS. In order to construct maps of subsoil susceptibility the soil map of Flanders was upgraded by attributing a‘typical' PCS-value to the legend units. These PCS-values were estimated by means of pedotransfer functions (PTFs), valid either at pF 1.8 or pF 2.5 and at a depth of 41 cm. The results are shown in Figure 6. At pF 2.5, the sandy soils in FTZ2 are less susceptible to compaction compared to the loamy and sandy loam soils in FTZ1 and FTZ3, respectively. As expected, Figure 6B confirmed a higher susceptibility of soil to compaction when soil moisture content is higher. In wetter conditions the sandy soils in FTZ2 seem equally susceptible to compaction as the soils in FTZ1 and FTZ3.

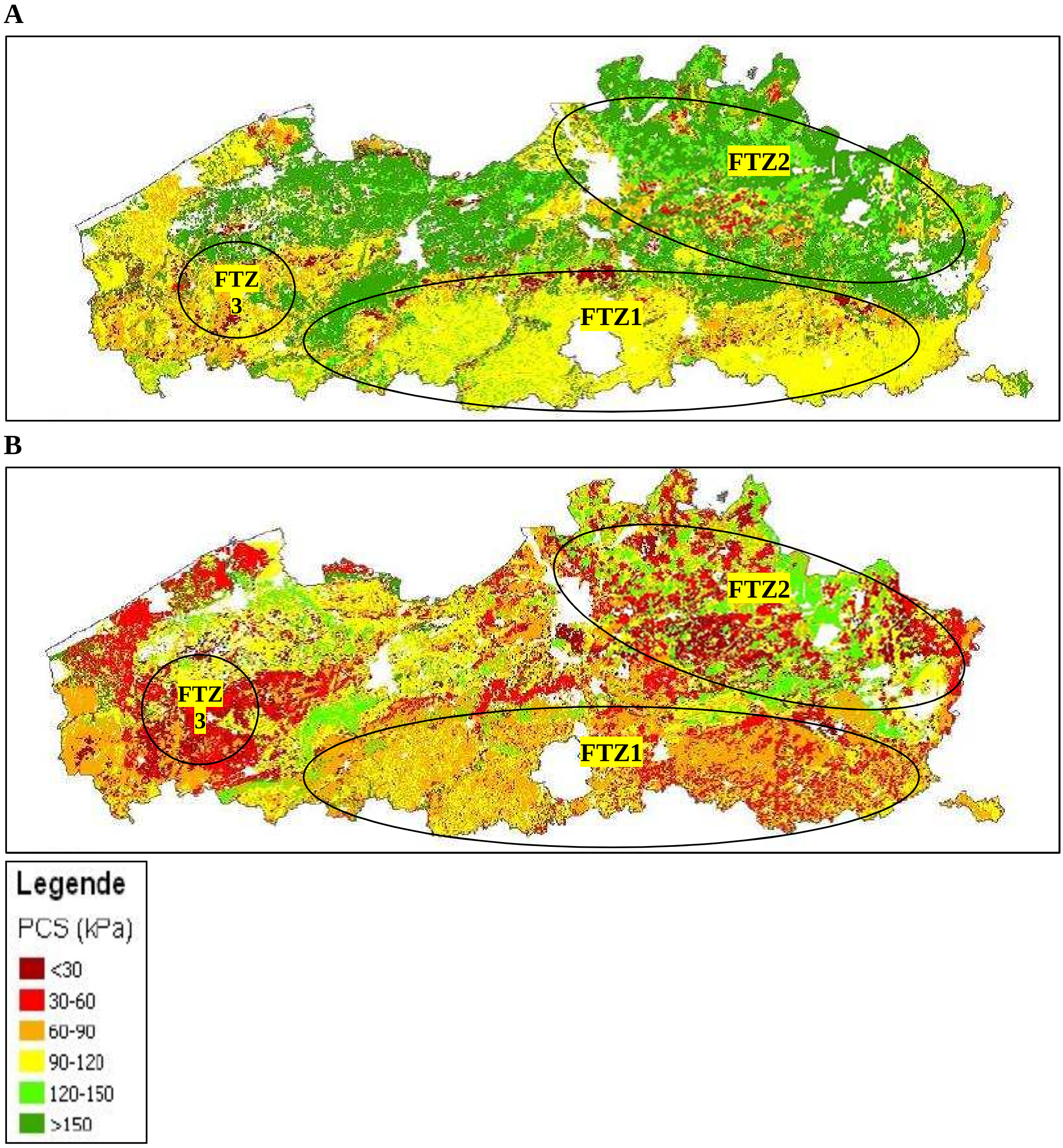


Figure 6 Soil susceptibility to compaction in Flanders, expressed as precompression stress (PCS) at a depth of 41 cm valid at pF 2.5 (A, dryer soil) or pF 1.8 (B, wetter soil) (Source: Van de Vreken et al. 2009)

In the Walloon region, the susceptibility of agricultural land for compaction was mapped by Rosière et al. (2009). The PCS-values for Wallonia were also estimated by pedotransfer functions (PTFs), valid either at pF 1.8 or pF 2.5 and at a depth of 41 cm. The results for pF 2.5 indicate that the soils in the northeast of Wallonia (a part of FTZ1) are highly susceptible to soil compaction (Figure 7). The results for pF 1.8 were not reported.

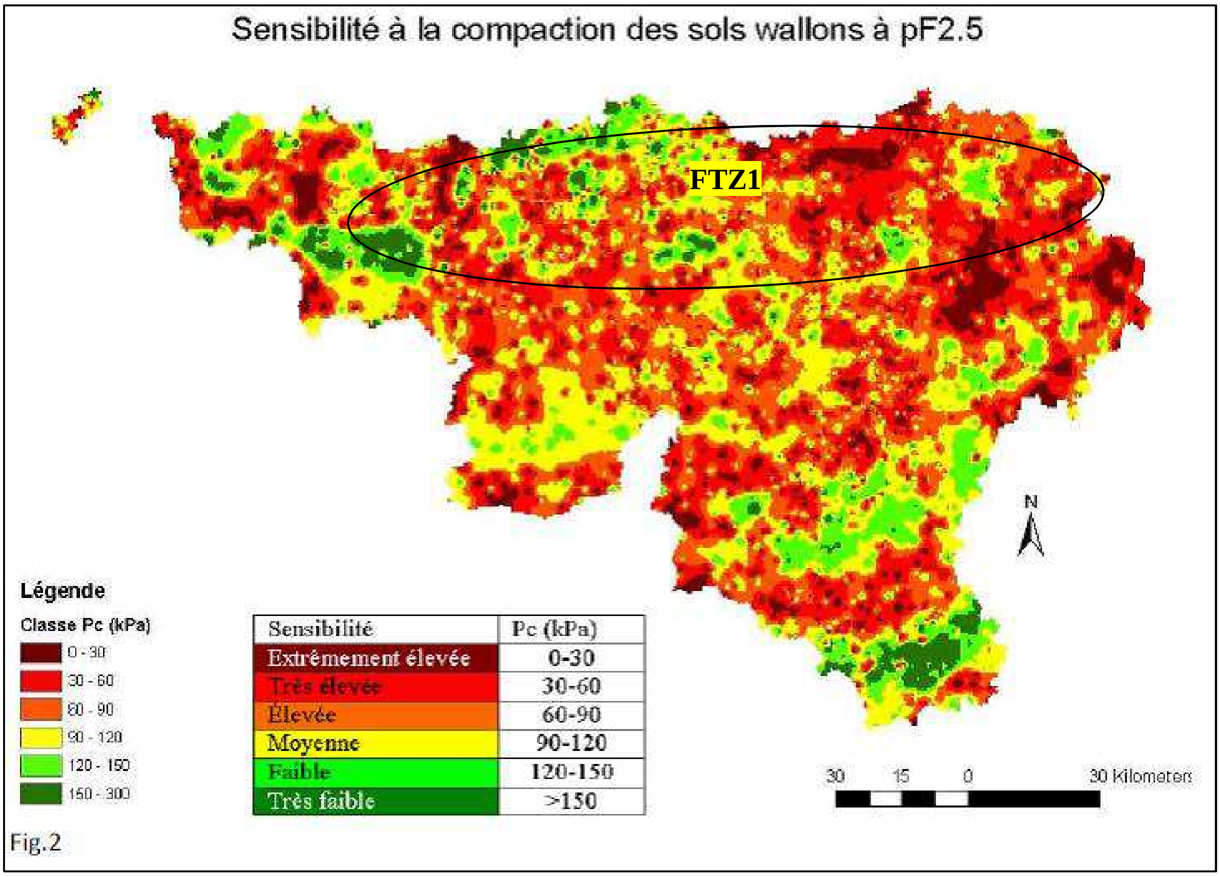


Figure 7 Soil susceptibility to compaction in Wallonia at a depth of 41 cm valid at pF 2.5 (Source: Rosière et al. 2009)
Legend: sensibilité = susceptibility, extrèmement élevée = extremely high, très élevée = very high, élevée = high, moyenne = medium, faible = low, tres faible = very low

The prevention of soil compaction is linked to the evaluation of soil susceptibility to compaction. It is important to know which soil is susceptible to compaction in order to be able to apply proper soil use and cultivation for preventing real compaction. Further, while topsoil compaction can be largely removed by tillage, subsoil compaction is much more persistent and difficult to remove. Therefore, subsoil compaction should be prevented instead of being remediated (Van de Vreken et al. 2009). Even on highly susceptible soils, relatively high wheel loads are possible by using large tyres with low inflation pressures or well-designed tracks. Also the use of permanent traffic lanes and improved steering systems (GPS) and adapted ploughs which allow the tractor to drive with all wheels on the untilled land can limit compaction (European Soil Portal, 2013). Other agricultural management practices to prevent or remediate soil compaction include the use of organic manures, cover crops and wider crop rotations (different sowing and harvest dates, permanent crops, deep rooted crops, etc) (Mira, 2011a).

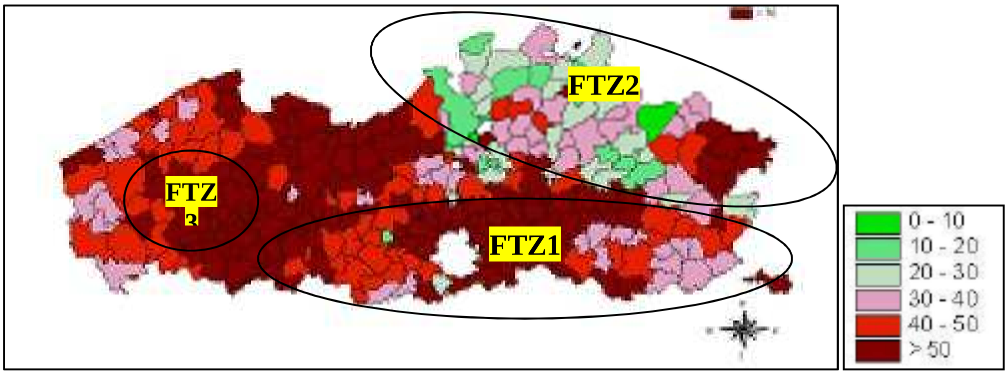
Soil organic matter

Soil organic matter plays a key role in soil fertility, soil biodiversity and several ecosystem services. It is a source of several nutrients and induces a good soil structure. This makes the soil more permeable to water and air and drastically decreases the risk of soil erosion and soil compaction. Thus, soil organic matter management is a key factor for fertile soils and a sound environment (Mira, 2011a). Due to intensive agriculture without sufficient addition of organic material, many soils in Flanders and Europe have critically low organic carbon stocks.

In Flanders, soil organic carbon (SOC) contents in arable (to a depth of 23cm) and grassland plots (to a depth of 6 cm) are closely monitored by the Soil Service of Belgium (SSB). Depending on the soil type, the SSB has set the optimal carbon content for arable land and grassland separately. According to the SSB, the optimal carbon content for arable and grassland ranges from 1.2 to 2.8 and from 2.6 to 5.5, respectively (Maes et al., 2012). Within these boundaries, farmers should be able to reach an economically optimal level of production.

Every three years, the results are grouped for each municipality after which the percentage of arable and grassland plots with a carbon content below the optimal zone is calculated. The results of the period 2004-2007 are presented in Figure 8 (Boon et al. 2009).

A.



B.

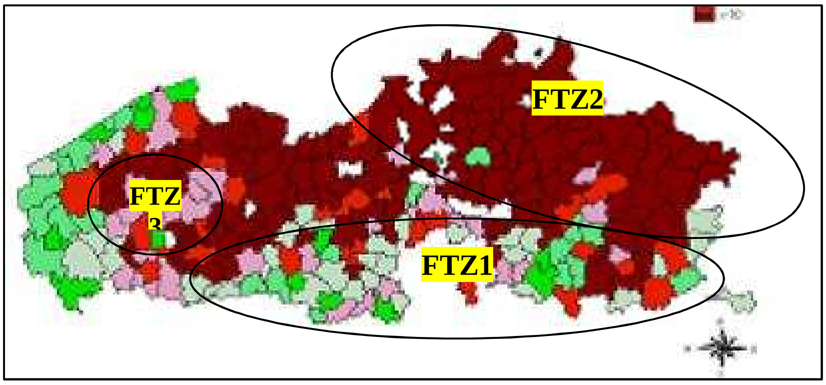
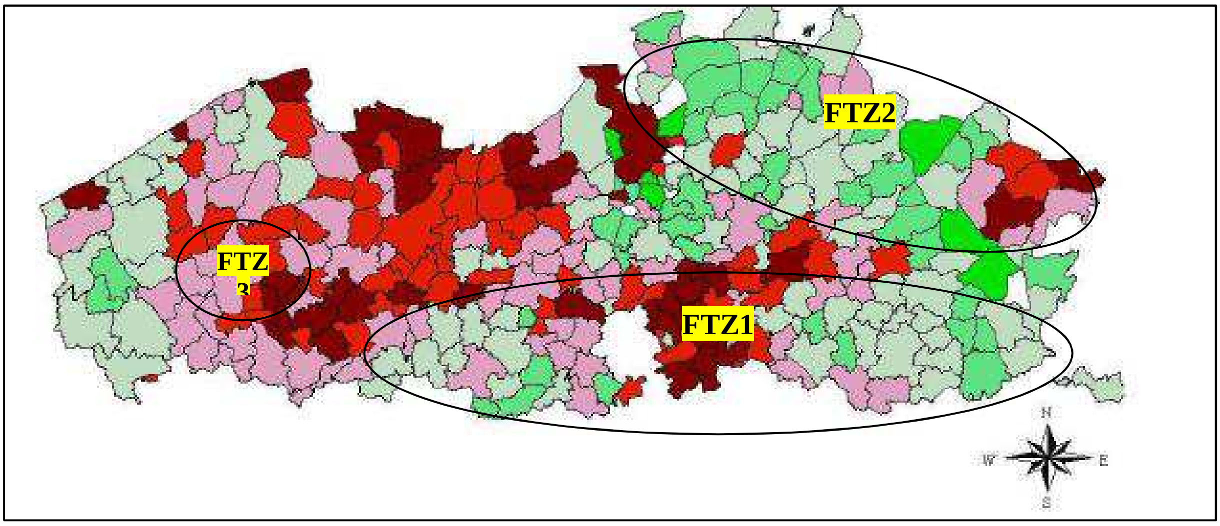


Figure 8 Relative amount (%) of arable (A) and grassland plots (B) with a soil organic carbon content below the optimal zone within each municipality of Flanders (2004-2007) (Source: Boon et al. 2009)

From 1982 till 2007 the soil organic carbon content of agricultural soils in Flanders decreased. In 2007, in many municipalities of FTZ1 and FTZ3 and in the municipalities in the eastern part of FTZ2, more than 50% of the arable pots showed a soil organic carbon content below the optimal zone. In the remaining municipalities of FTZ2, only 10-40% of the arable plots were classified below the optimal zone (Figure 8A). The results of the grassland plots are quite different from the arable plots. Figure 8B shows that in almost every municipality of FTZ2, more than 50% of the grassland plots were classified below the optimal zone. In most of the municipalities of FTZ1 and FTZ3, the amount of grassland plots with a soil organic carbon content below the optimal zone was only 10-40%. Restricted application of organic manures, an increased ploughing depth and the conversion of grassland to arable land were potential explanations for this ongoing decreasing trend (Mira 2011a).

From 2008 on, an increase in soil organic carbon has been noticed both for arable as for grassland soils (Figure 9). Compared to Figure 8, less arable and grassland plots are classified below the optimal zone.

A.



B.

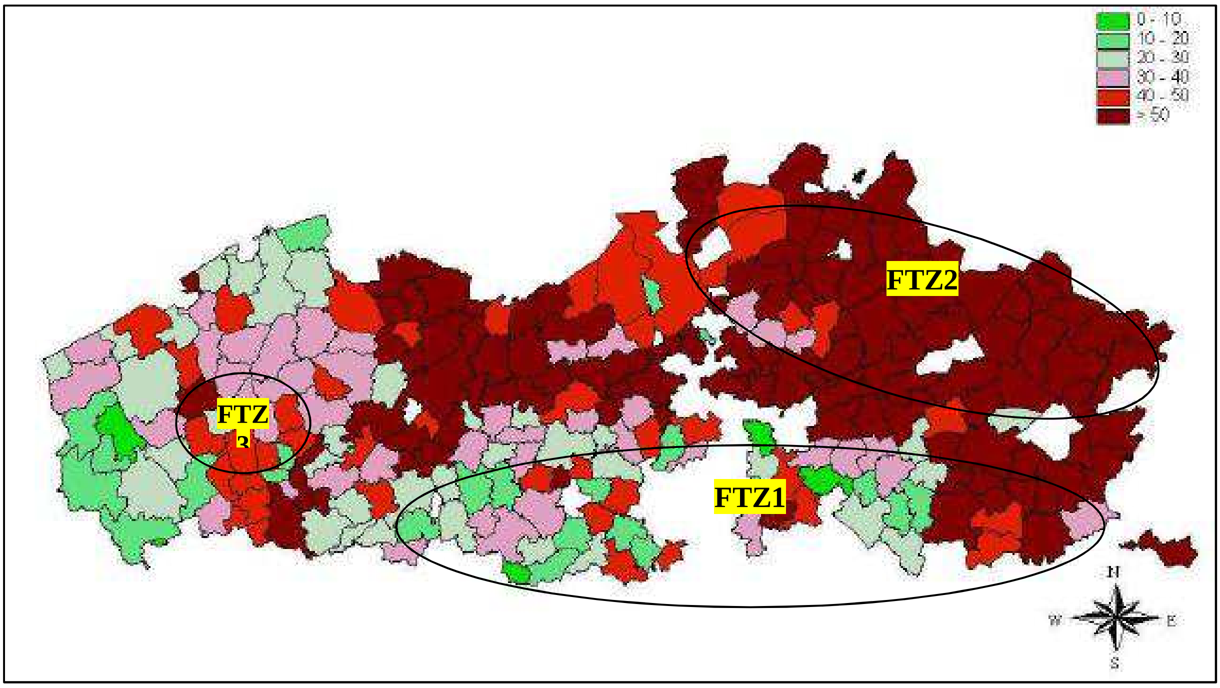


Figure 9 Relative amount (%) of arable (A) and grassland plots (B) with a soil organic carbon content below the optimal zone within each municipality of Flanders (2008-2010) (Source: Maes et al. 2012)

In FTZ2 there are less arable field plots with a SOC content below the optimal zone compared to arable soils in FTZ1 and FTZ3, while for grassland there are more field plots in FTZ2 with a SOC content below the optimal zone compared to FTZ1 and FTZ3 (Figure 9).

However, it is common knowledge that a change in SOC content is a slow process. Therefore, future samplings will have to sort out whether the decreasing trend in Flemish soils actually has been reversed.

In Wallonia, soils with an organic matter (OM) content below the critical 2 % OM threshold level represent about half of the cultivated land surface in Wallonia (EOW 2010). These soils are mainly situated in the loamy region (FTZ1, Figure 10), which is the arable crop region where the risk of soil erosion by water is high (Figure 4). In addition, since 1960 these soils have sometimes suffered from high OM losses. This trend is mainly attributed to reduced cereal crop areas, increased ploughing depth and the replacement of livestock manures by mineral fertilizers (EOW 2010).

The application of additional organic material like compost or organic manure (within the limitations of the manure decree) and the use of cover crops are just a few examples of potential solutions to the problem of low organic carbon contents in Belgian agricultural soils (Mira 2011a).

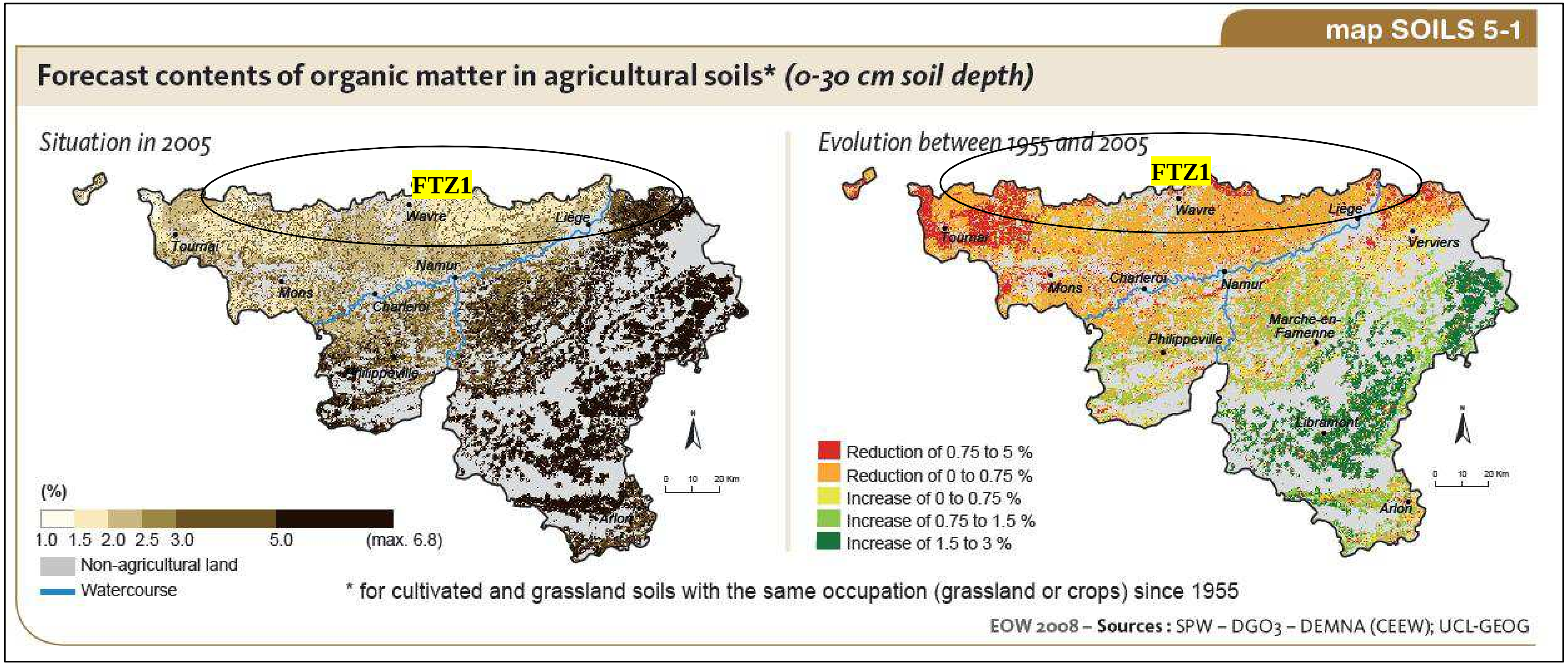


Figure 10 Soil organic matter in Walloon agricultural soils (0-30 cm soil depth). Left: situation in 2005, right: evolution between 1955 and 2005 (Source: EOW 2008)

Nitrate and phosphate in soil, groundwater and surface water

The presence of nitrogen and phosphorous in soils, at levels exceeding vegetation's uptake capacity, can present risks to the environment, especially in surface and groundwater. These surpluses can contribute to the eutrophication of watercourses, a loss of biodiversity as well as nitrate pollution of drinking water (EOW 2008).

As stated in the introduction of this document, in Flanders, an upper limit of 90 kg NO_3^--N in the soil profile (0-90cm) in autumn (October 1- November 15), i.e. called nitrate residue level, should insure that nitrate levels in surface and groundwater stay below the limit set in the Nitrate Directive (50mg of NO_3^- per litre). The 2012 progress report of the Manure bank, which is part of VLM, reveals a weighted mean nitrate residue level of 73 kg NO_3^--N kg/ha in the monitored soils in Flanders in 2011 (Figure 11, VLM 2012). In the period 2004-2007, a slight decrease in the nitrate residue level has been observed. Since 2007, the nitrate residue remained more or less constant.

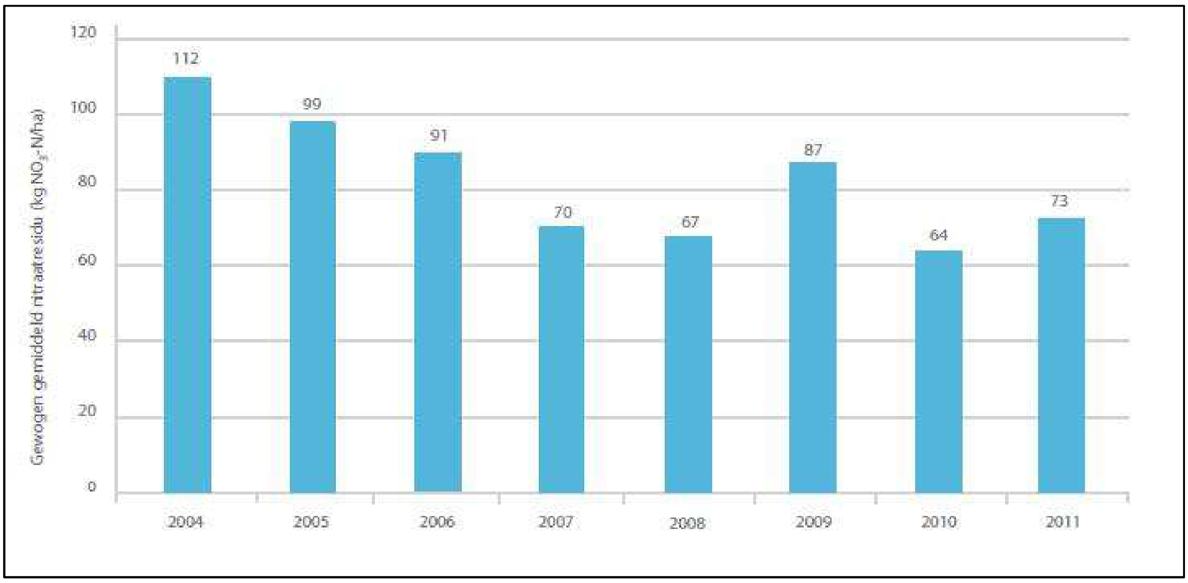


Figure 11 Weighted mean nitrate residue level (kg NO_3^--N/ha) in the soils (0-90 cm) monitored by the Manure bank (2004-2011) in Flanders (Source: VLM 2012)

In Wallonia, the nitrogen (N) enrichment of soils is estimated indirectly, by estimating the transfer of N to water bodies (EOW 2008). The flows are evaluated using the EPIC grid model which uses different parameters (climate, soil use and type, agricultural practices etc.). The model indicates that nitrate concentrations in the leaching water beneath rooting depth (> 1.5m) are higher than 50 mg/l (the norm for drinking water) for a large part of the loamy region of FTZ1 (Figure 12).

N leaching from agricultural soils is the main reason for groundwater degradation. Figure 13 reveals that at many groundwater monitoring sites, the limit of 50mg of NO_3^- per litre is exceeded in the north and the east of FTZ2, in FTZ1 and in FTZ3. According to Mira (2011b), the highest exceedings have been observed in FTZ3. In FTZ1 and FTZ2, soils show a high susceptibility for nitrate leaching while in FTZ3, the high nitrate concentrations are especially the result of high nitrogen inputs (Mira 2011b).

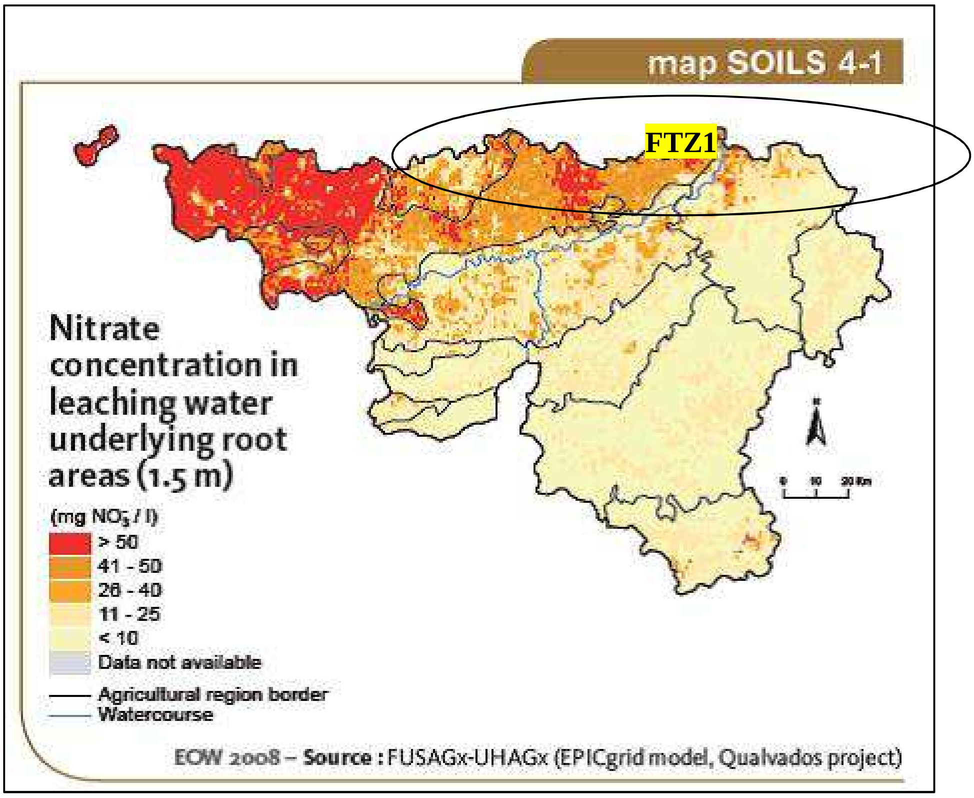
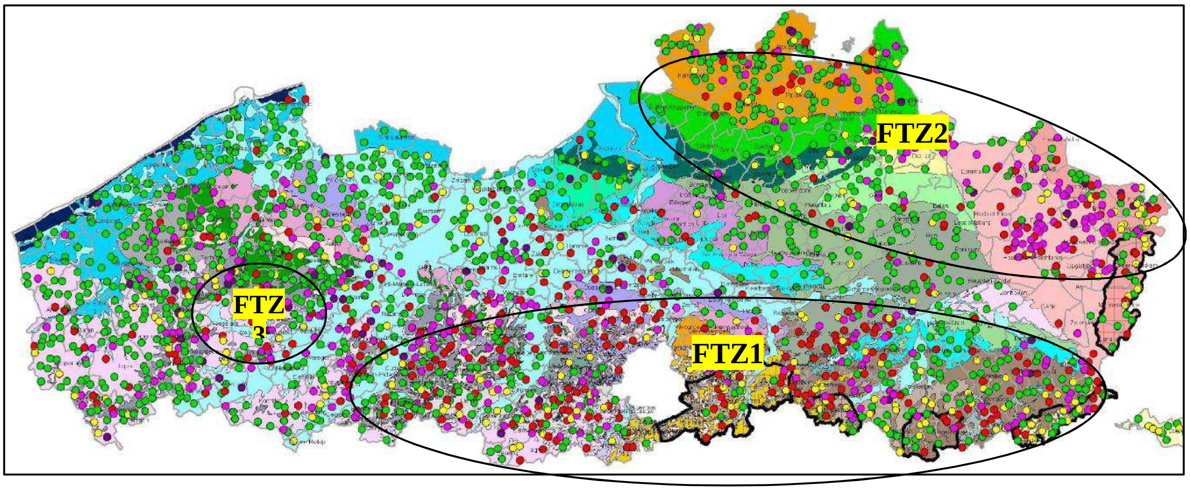


Figure 12 Nitrate concentration in leaching water beneath rooting depth (>1.5m) in Wallonia (Source: EOW 2008)



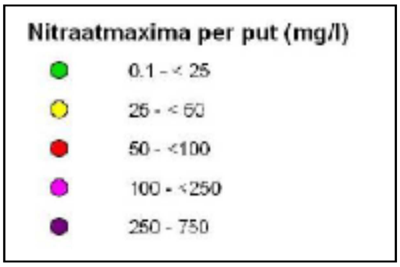


Figure 13 Maximum nitrate concentrations (mg/l) at each measuring site of the Flemish phreatic groundwater monitoring network (spring 2010) (Source: VLM 2010).

In Wallonia, the highest levels of contamination (> 40 mg $NO3^-/l$) are observed in FTZ1 (the groundwater bodies of the Cretaceous of the Herve area [1] and the Brusselian sands [3] (Figure 14). These are areas where the density of population and/or agricultural activity is particularly high (EOW 2008).

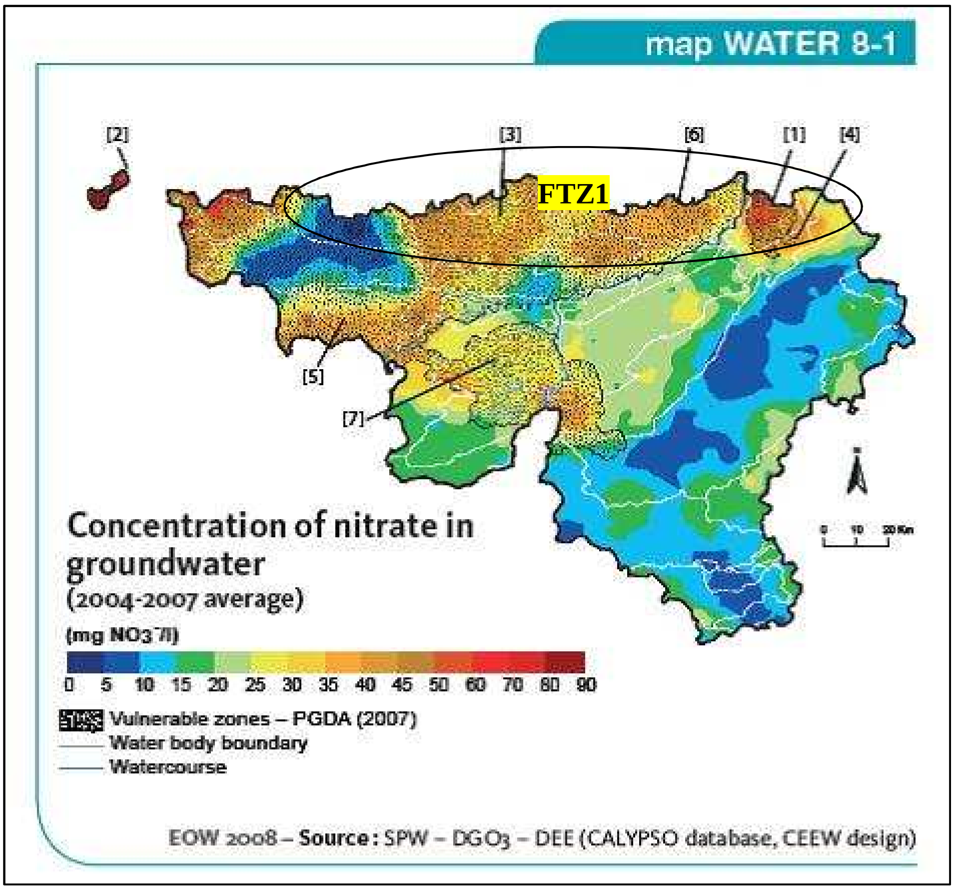


Figure 14 Nitrate concentration in groundwater in Wallonia (2004-2007 average) (Source: EOW 2008)

Groundwater contamination throughout Wallonia has slightly increased in recent years: the proportion of monitoring points with average nitrate concentrations higher than 40 mg/l rose from 15.1 % (2000-2003period) to 17.8 % (2004-2007period). Locally, the situation can be worrying, especially in certain vulnerable zones where nitrate concentrations rose on average by 0.1 to 0.6 mg/l a year between 1992 and 2007.

This trend is not necessarily linked to the current development of agricultural practices, which goes towards a reduction in nitrogen fertilization. The degree of contamination of the groundwater bodies depends on other factors such as rainfall, transfer time to aquifers (which can exceed 15 years) or the quantity of nitrogen still present in the soils (EOW 2008).

Within the scope of the Flemish manure decree, the VMM also monitors the quality of Flemish surface waters. The VMM uses a surface water monitoring network that comprises 800 measuring points that are located near typical agricultural regions (MAP monitoring network). The results of the 2011-2012 winter are shown in Figure 15. According to this Figure, the limit of 50 mg nitrate per litre is exceeded in het north and east of FTZ2 while in FTZ3 nearly all measuring points exceed the limit. Only a few exceedings of the limit have been observed in FTZ1.

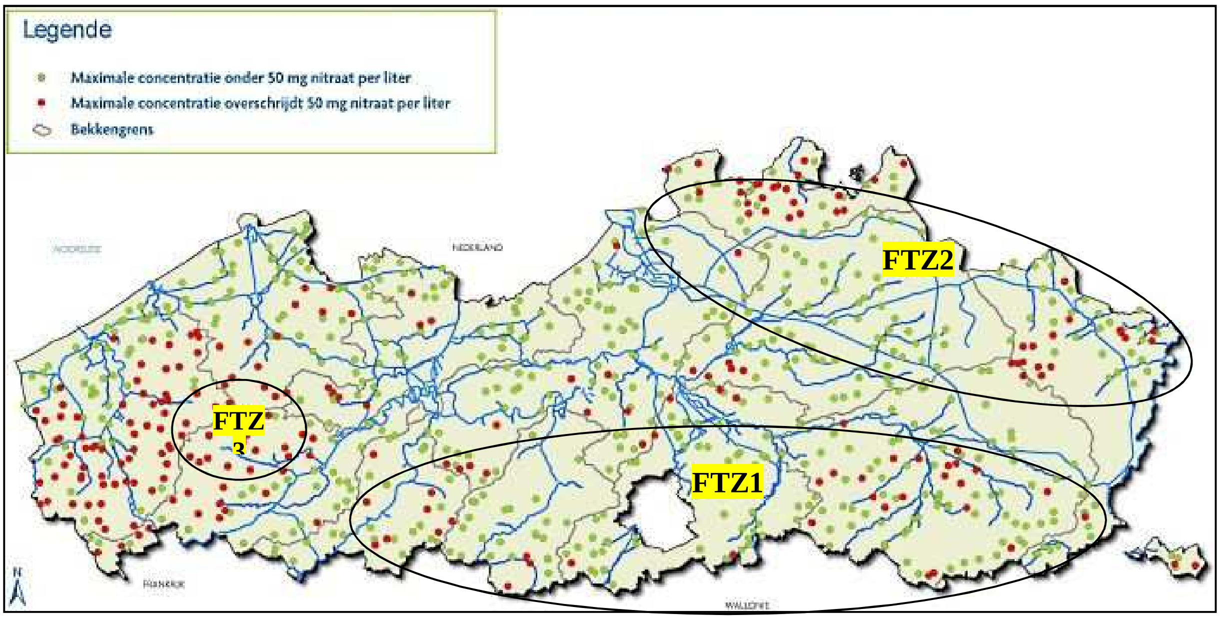


Figure 15 Maxiumum nitrate concentrations in the MAP surface water monitoring network in het winter of 2011-2012 in Flanders (Source: VLM 2012). Legend: red dots: maximal concentration exceeds 50 mg nitrate per litre; green dots: maximal concentration below 50 mg nitrate per litre

In Wallonia, nitrate concentrations in surface waters have not been reported.

Apart from nitrogen, also the presence of phosphorous in soils, can pose risks for eutrophication of surface and groundwater. The Flemish manure decree limits the amount of phosphorus than can be applied on agricultural soils. Plant-available phosphorus (ammonium lactate extract) is determined on a considerable amount of arable and grassland plots all over Flanders by the Soil Service of Belgium (SSB). Depending on the soil type, the SSB has defined the optimal content of plant-available phosphorus for arable land and grassland separately. In the 2008-2010 period, 77% of the sampled arable plots and 50% of the grassland plots showed a phosphorus content above the optimal zone (Maes et al. 2012). This is a slight decrease compared to the2004-2007 period (Boon et al. 2009).

Another important problem in Belgian agricultural soils is phosphate saturation. Certain areas which have been excessively fertilized in the past or where soils have a low phosphate binding capacity are P saturated and consequently highly susceptible to P leaching (Mira 2011b).

According to the EU, a soil is considered P saturated if the phosphate saturation degree (PSD) is > 35%. A study conducted by Van Meirvenne et al. (2008) indicated that a considerable part of the agricultural area in Flanders is P saturated. Figure 16 shows that P-saturation in the soils of FTZ2 and FTZ3 is high. The soils in FTZ1 are less susceptible to P leaching compared to FTZ2 and FTZ3.

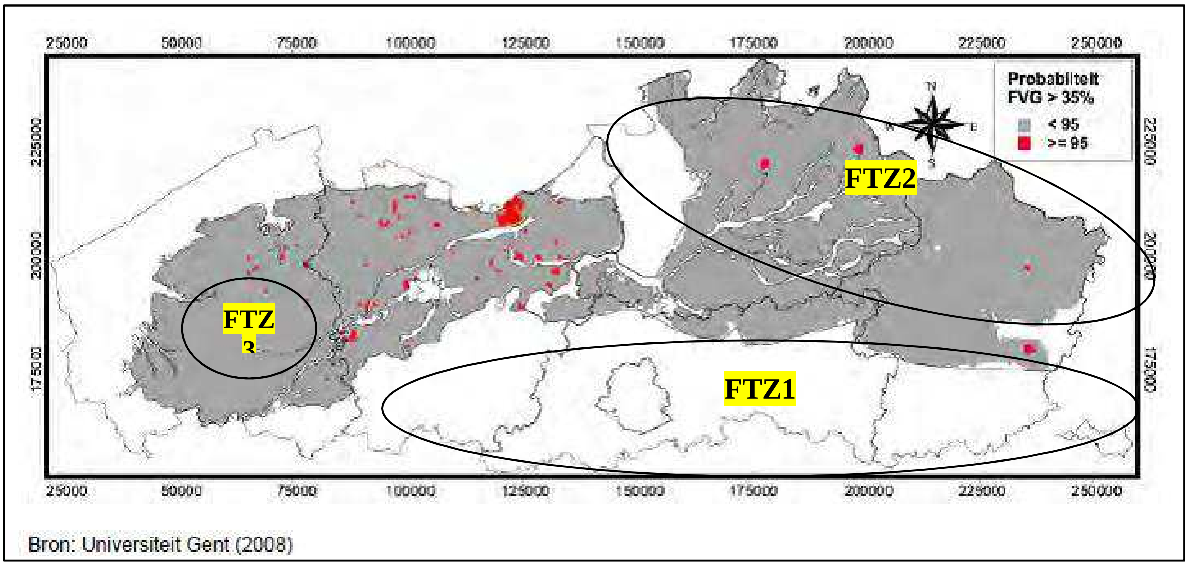


Figure 16 P-saturated areas in Flanders (red areas) where the 35% phosphate saturation degree limit is exceeded with 95% certainty (Source: Mira 2011b)

A study conducted by Meunier et al. (2010) determined the P saturation level of Walloon agricultural soils. The results are presented in Figure 17 and show that P saturation varies between 30 and 60 % north of the Sambre-and-Meuse rivers (FTZ1).

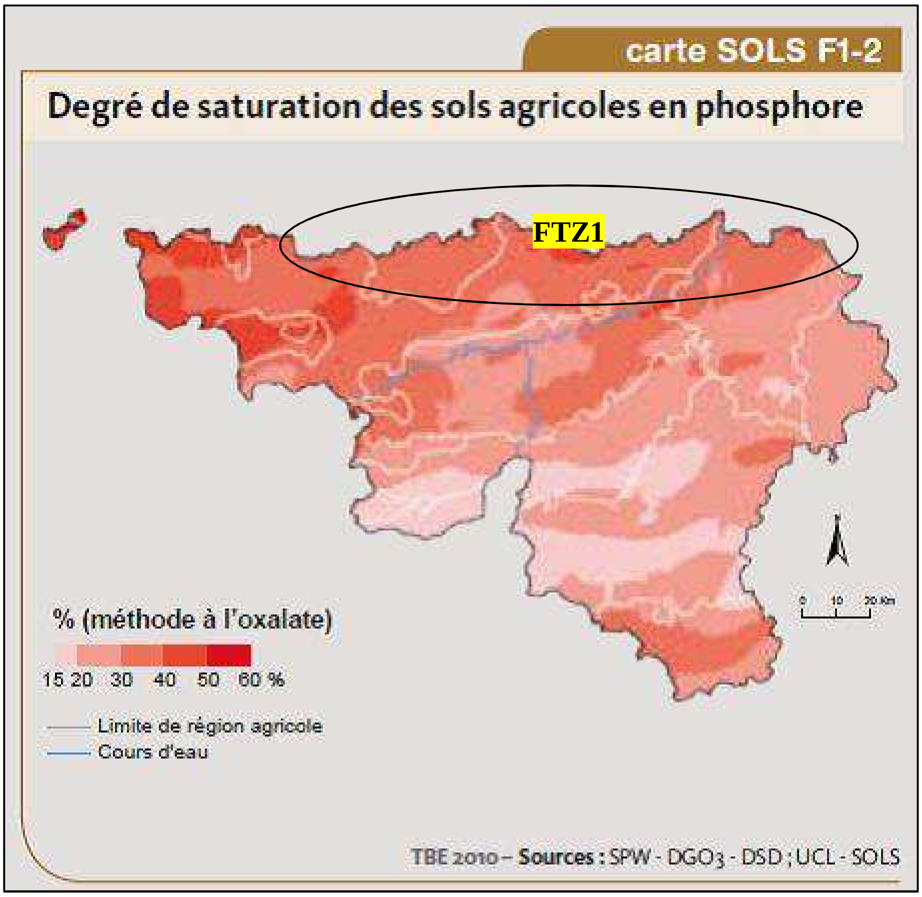


Figure 17 P-saturation degree in Walloon agricultural soils (Sambre-and-Meuse rivers indicated in blue) (Source: Cellule Etat de l'environnement wallon 2010)

While nitrate leaching is a major threat for groundwater quality, excessive discharges of phosphorous in fresh surface water may lead to eutrophication. This generally causes increased algae growth and less oxygen in the water, accompanied by an increased risk of mortality for some aquatic organisms (EOW 2008). Therefore, the amount of orthophosphate (o-P, water soluble phosphate) in Flemish surface waters is also monitored by the VMM in the MAP monitoring network. The results of the 2011-2012 winter are presented in Figure 18. Comparing the measured o-P concentrations with the limit set by the EU Water Framework Directive (0.1 mg o-P/l), shows that especially in FTZ3 many exceedings have been recorded.

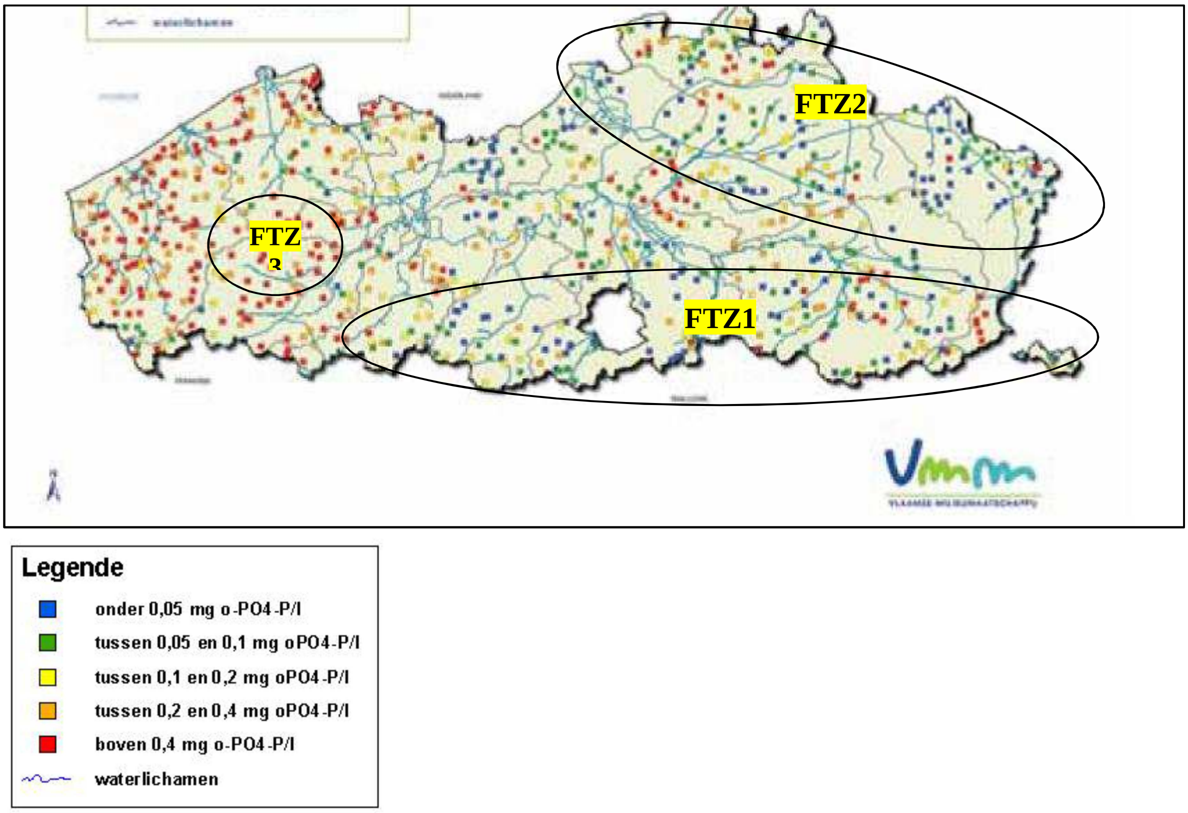


Figure 18 Average orthophosphate concentration in surface water in the MAP monitoring network in the winter of 2011-2012 in Flanders (Source: VLM 2012). Legend: onder = below; tussen = between; boven = above; waterlichamen = watercourses

Figure 19 shows that in Wallonia the watercourses with the highest concentrations of phosphates are situated in the north, in the Escaut river district where there is an important concentration of urbanized, industrial and agricultural areas (FTZ1).

Figures 10-18 indicate that there is still a long way to go in order to reach the objectives of the EU Water Framework Directive. What is more, the negative influence of agriculture on water quality remains very clear (e.g. high nitrate and/or phosphate concentrations in the regions with intensive dairy/pig farming (FTZ3 and FTZ2) or horticulture (FTZ3).

Therefore, farmers are still encouraged to optimize their fertilization, to grow cover crops as much as possible, to install buffer strips alongside waterways and to participate in ‘water quality groups’ to exchange knowledge and practical experience (Mira 2011b).

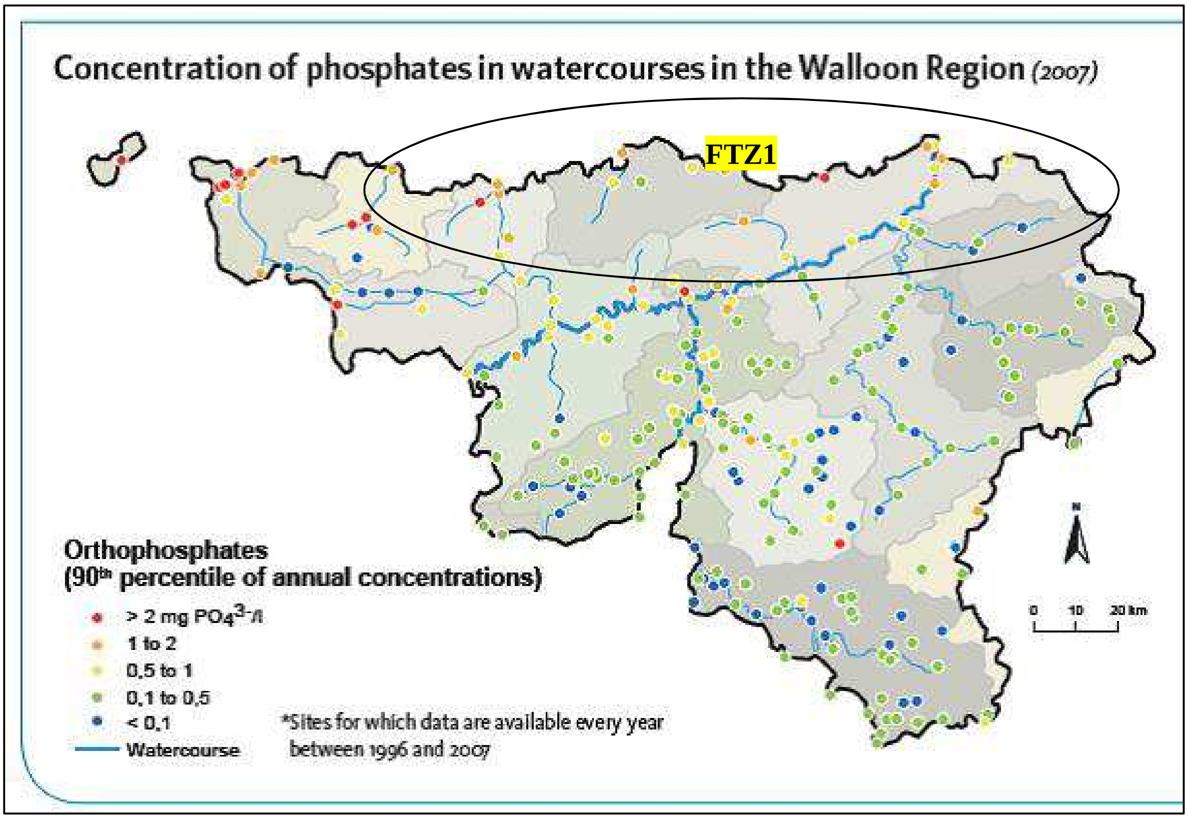


Figure 19 Concentration of phosphates in watercourses in the Walloon Region (2007) (Source: EOW 2008)

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Soil degradation problems in France

Authors: N. Guiffant, E. Perret and N. Turpin

AgroParisTech, INRA, IRSTEA & VetAgro Sup, France

In Europe, more than 16% of the total land area is affected by degradation processes (ESBN, 2005). The degradation processes affect a larger share of soil in France, where at least 18% of the soils are at medium to very large erosion risk (GIS Sol, 2009). The issues are numerous and can be cumulative. Some are considered in national or regional policies.

Information from soil threats and soil quality are collected by the GIS sol consortium (http://www.gissol.fr/index.php). They are of two kinds, a collection of statistics from soil sampling, organised in yearly databases (average composition are available at LAU1 level); the quality of the statistics strongly depends on the samples that farmers collect and send to labs for analysis (Figure 1). More homogeneous information is provided by models, which are better scaled that sampling information, but somehow still suffer from some imprecisions too.

The main soil degradation problems in France as discussed in the following, are: soil sealing, erosion, loss of soil organic matter, soil compaction, loss of biodiversity, contamination and acidification.

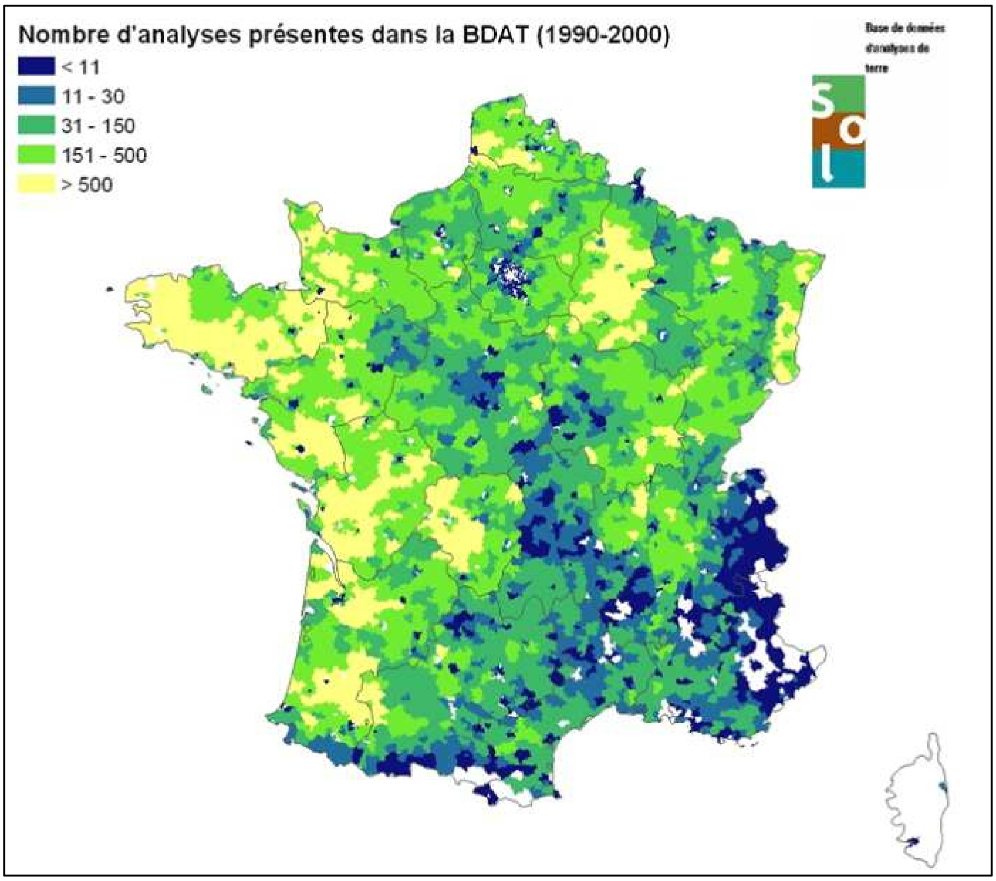


Figure 1 Soil sampling database from GIS sol – number of analysis in the database

Soil sealing

In France, the total agricultural area covers 30 million hectares (53 % of the total area). Between 2000 and 2006, 0,2 % of this agricultural areas have been converted to urban infrastructures, especially in periurban areas, and close to main communication roads and railways (Figure 2).

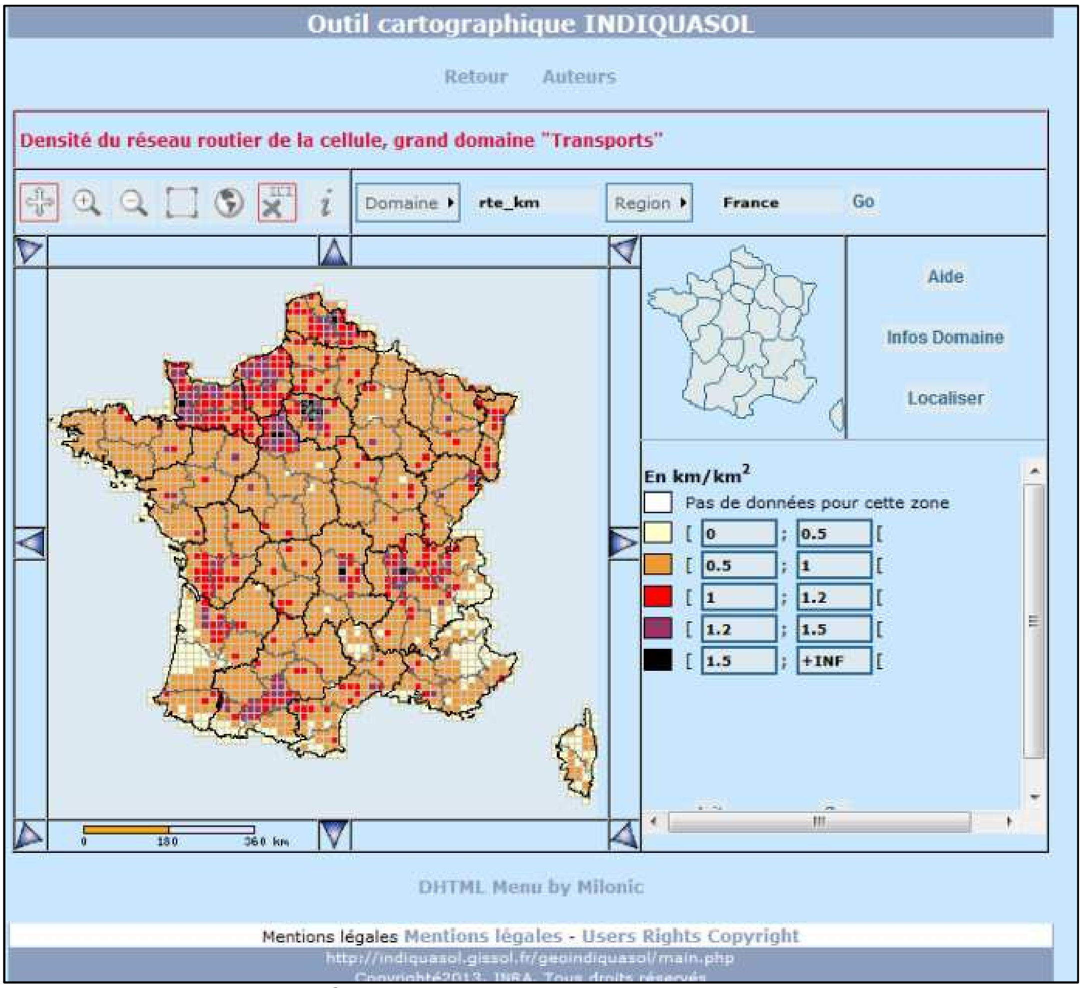


Figure 2 Road density (km/km^2)

Erosion

At field level, damages from water erosion include destruction of crops, loss of thin elements from the surface layers (the processes are important for water contamination by phosphorus for example, or for losses of fertility). Extreme events may lead to landslide and accumulation of mud on roads, urban settlements, and private ownerships. Only the latter are part of the French regulation.

Landslide is well monitored in France, in application of the decree 2005-117 applying regulation 2003-699; according to this regulation, the prefects have to map landslide risk on each department (Figure 3), and take appropriate measures to avoid damages to infrastructures and populations..

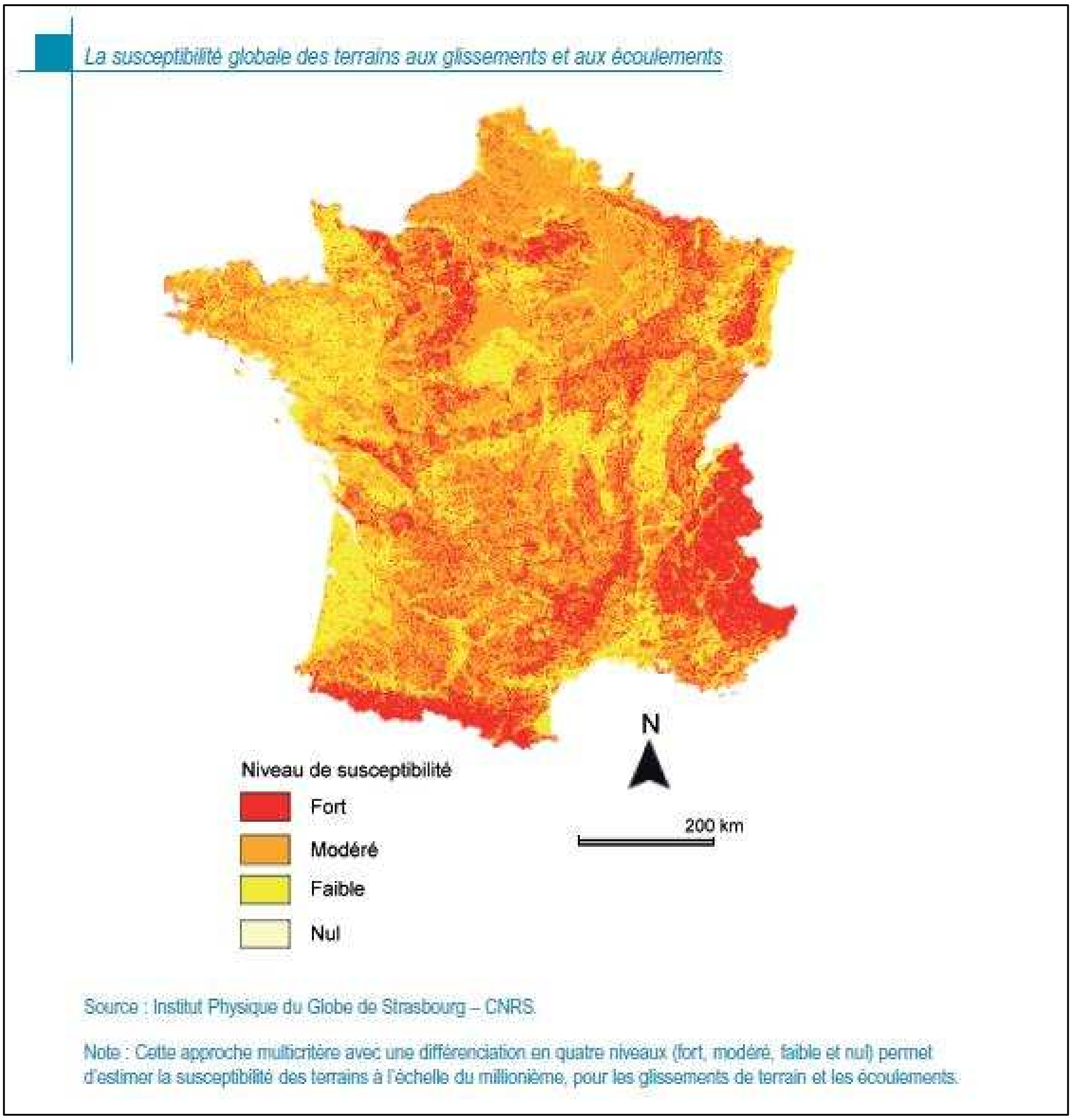
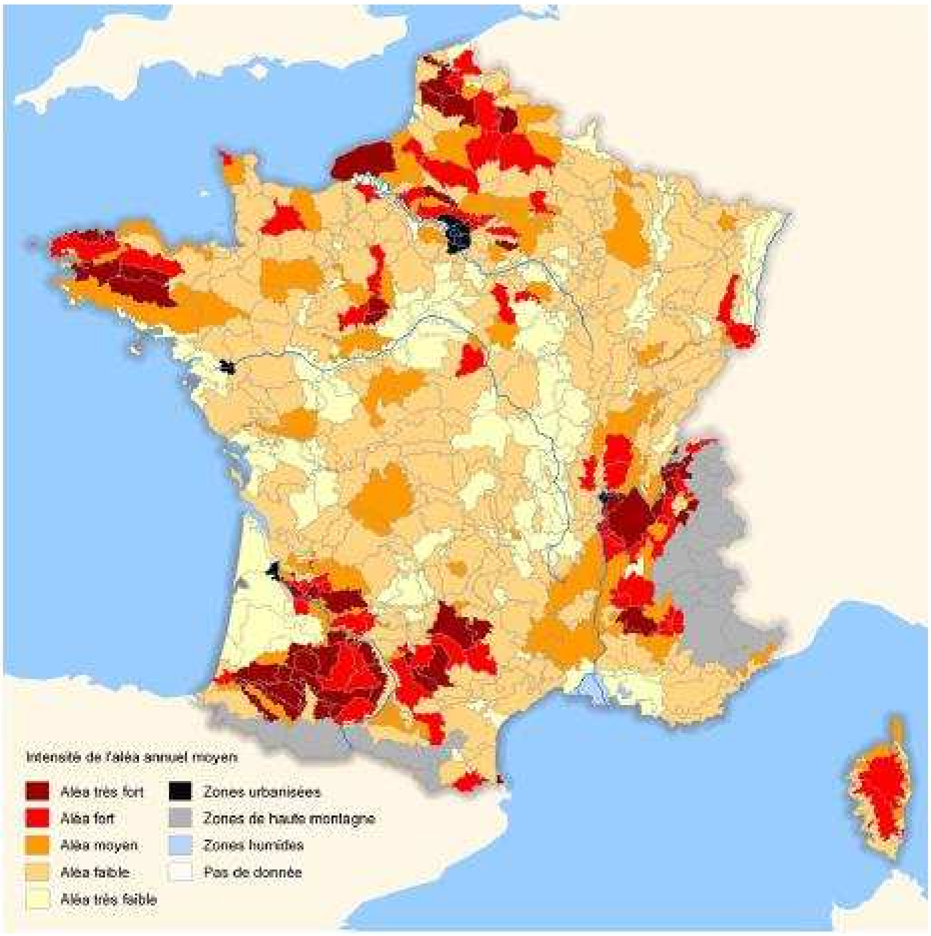


Figure 3 Landslide risk in France

Erosion is considered as a risk (hazard * probability of occurrence). Maps of erosion risk per agricultural zones are public (Figure 4). They have been designed by INRA, using a model named Mesales.

Aléa d'érosion des sols*



* **Note** : Aléa érosif des sols par petite région agricole, déterminé à l'aide du modèle Mesales, qui combine plusieurs caractéristiques du sol (sensibilité à la battance et à l'érodibilité), du terrain (type d'occupation du sol, pente) et climatiques (intensité et hauteur des précipitations).
Source : Gis Sol – Inra – SOeS, 2010.

Figure 4 Erosion risk, information used by the French Ministry of Environment

Loss of organic matter

This issue is related to long term carbon storage in soils, and highly linked to the dynamics of organization and mineralization of carbon in soils, despite most authors still consider soil carbon content because it is the most currently available indicator (Figure 5). Sampling for soil organic matter content is very heterogeneous across France.

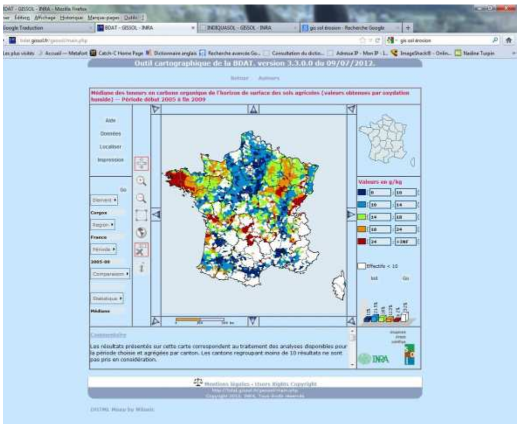


Figure 5 Organic C content of top soil (median on samples)

Models suggest a slightly different pattern (Figure 6). In France, the lower stocks are in Languedoc-Roussillon, a vineyard area south of France; they are also low in Beauce and Nord regions, devoted intensive arable farming. Medium stocks are observed under forested soils or breeding regions like Bretagne, Normandy, east or Massif Central. High stocks are encountered in specific areas like under altitude pastures, former marshlands, or volcanic soils in Massif Central.

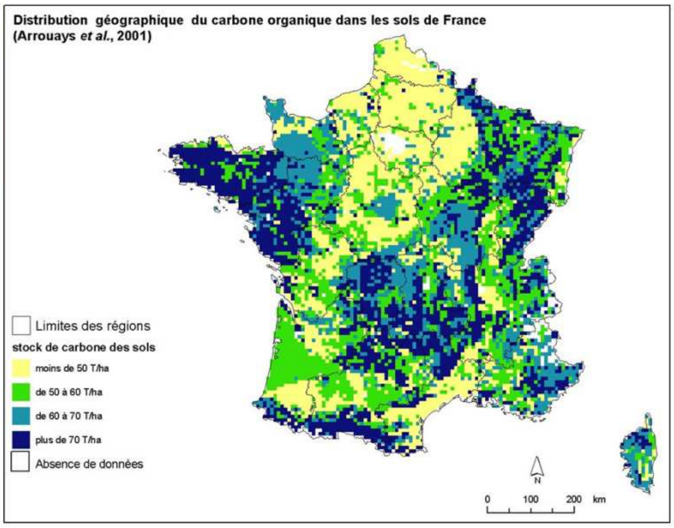


Figure 6 Soil organic C content, as a result of a model (Arrouays, et al., 2001)

More important, as previously quoted, is the dynamics of organic matter in soil. In France, there is a general trend towards a decrease of organic matter in soils, due to ploughing of old pastures, clearing of forests, intensification of farming practices. It is worthwhile noting that, because carbon accumulation under grasslands is far slower than its decrease after pastures are ploughed, when old pastures are ploughed and replaced elsewhere by long term grassland, the overall balance of carbon storage is negative. Interesting too is that in intensively farmed areas, the overall trend to organic matter decrease seems to stabilise and, in some places, to slightly reverse towards an increase.

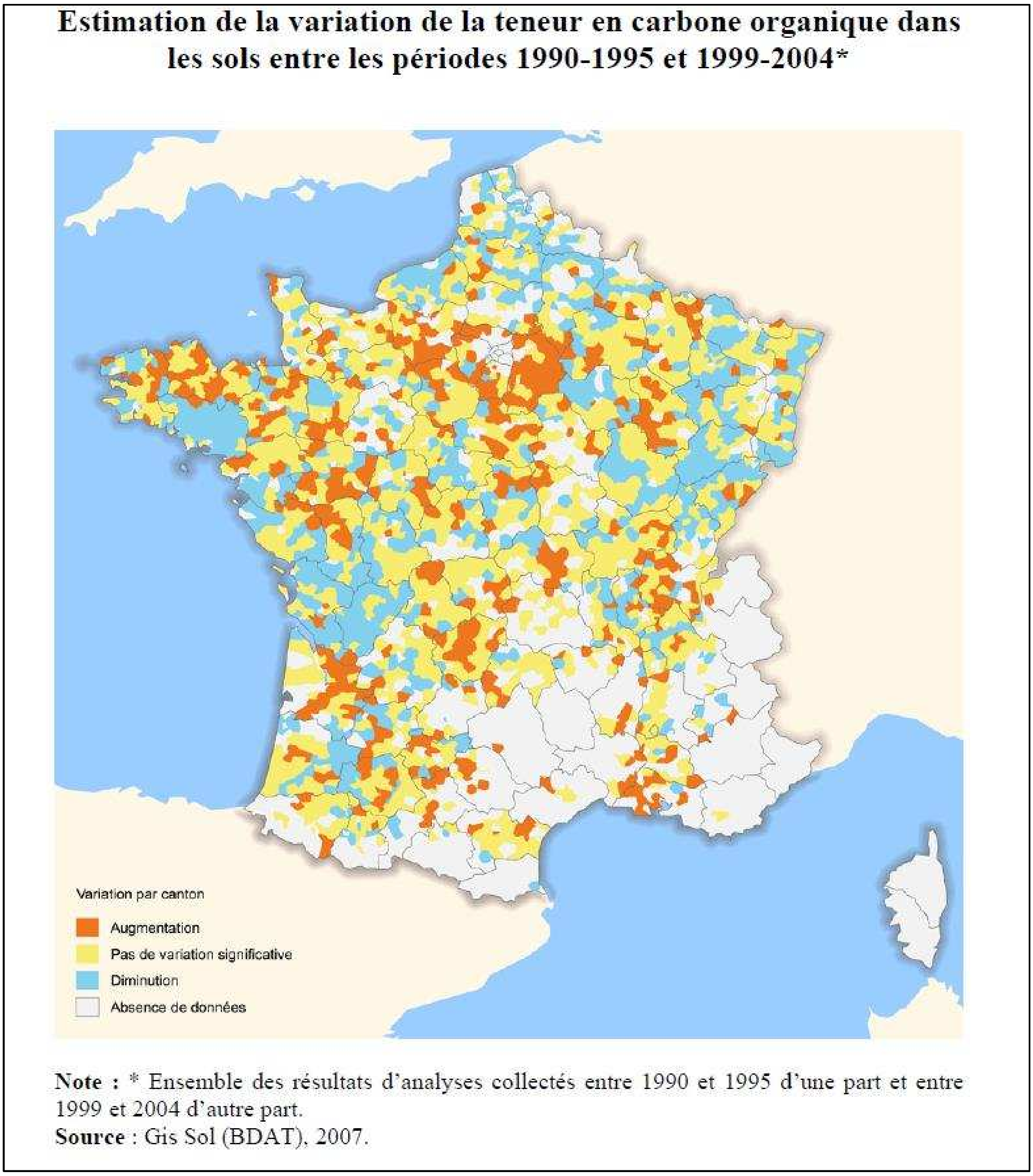


Figure 7 Evolution of soil organic C content from 1990-1995 to 1999-2004 (data from the French Ministry of environment)

Soil compaction

Compaction of the top or deeper layers result from overuse of heavy machinery during cropping operations, or over density of animals, especially during wet periods, on grasslands. The resulting loss of macro and microporosity impedes the capacity of the soil to conduct air and water; higher bulk densities are an obstacle to correct roots development and result in decreasing water content). Water management (irrigation) can correct water content issues, but won't do anything for water and air movements in pores. Subsoil compaction can limit root growth, decrease yields and can increase local issues due to waterlogging.

However, compaction risk is not yet monitored in France.

Loss of biodiversity

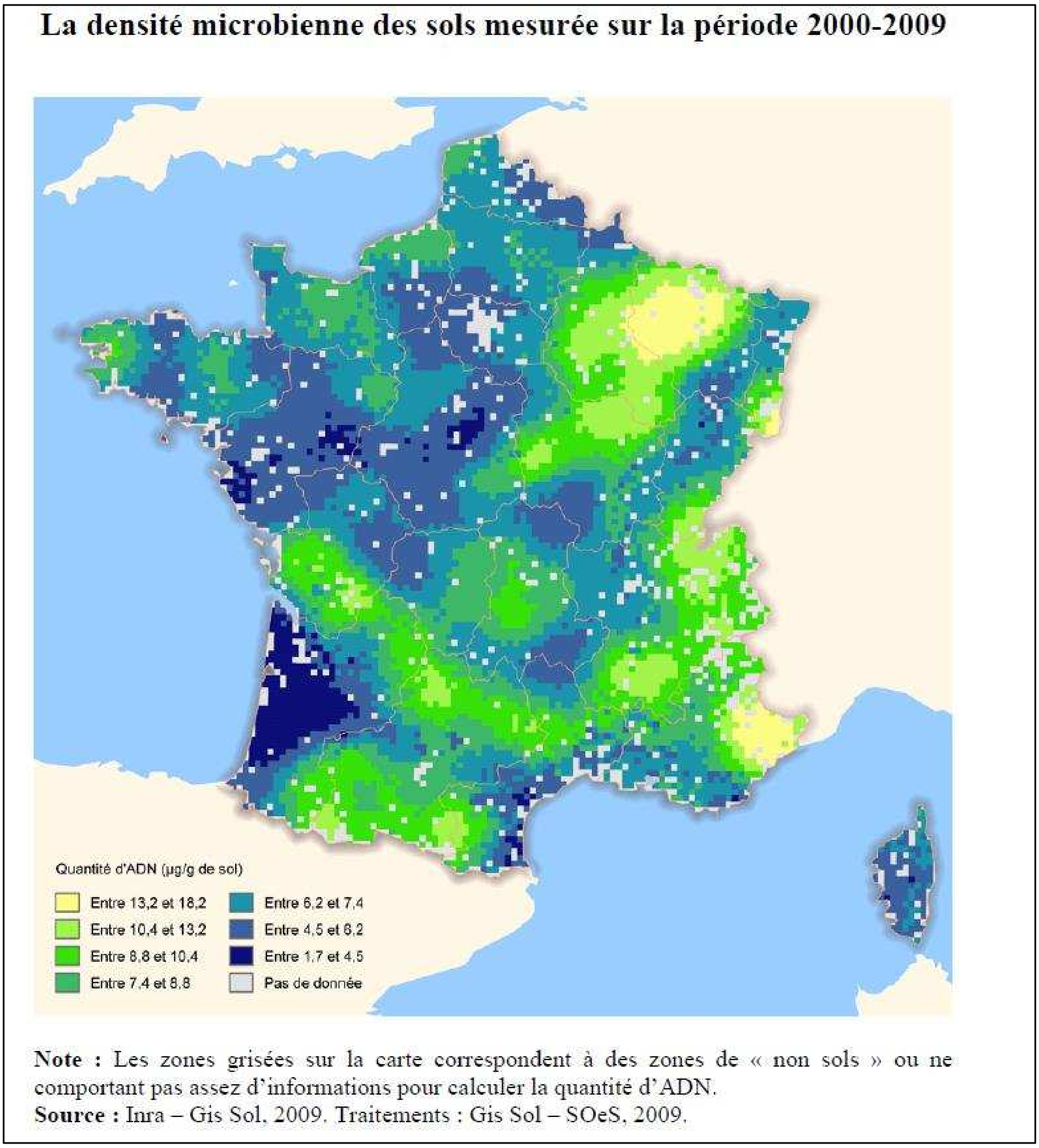


Figure 8 Estimation of soil biodiversity, data from the French Ministry of Environment

Despite an increasing literature stressing the importance of soil biodiversity and the functions it fulfils, there is still very little practical knowledge on how, and what, to monitor at higher levels than fields. The relationships between species are complex and still poorly understood. Some authors suggest DNA measurements (Dequiedt *et al.*, 2010), and it is the indicator used in France (Figure 8).

Contamination

From an agronomic point of view, there is a risk of lack in several soils in France. Most quoted are bore, copper, manganese and zinc. But there are also contaminations of soils by heavy metals, manly coming from the parent material on volcanic areas, or from overuse of sludge from wastewater treatment plants.

Contamination, along with settlement proximity, is one major reason for unavailability to soil for sludge spreading (Figure 9).

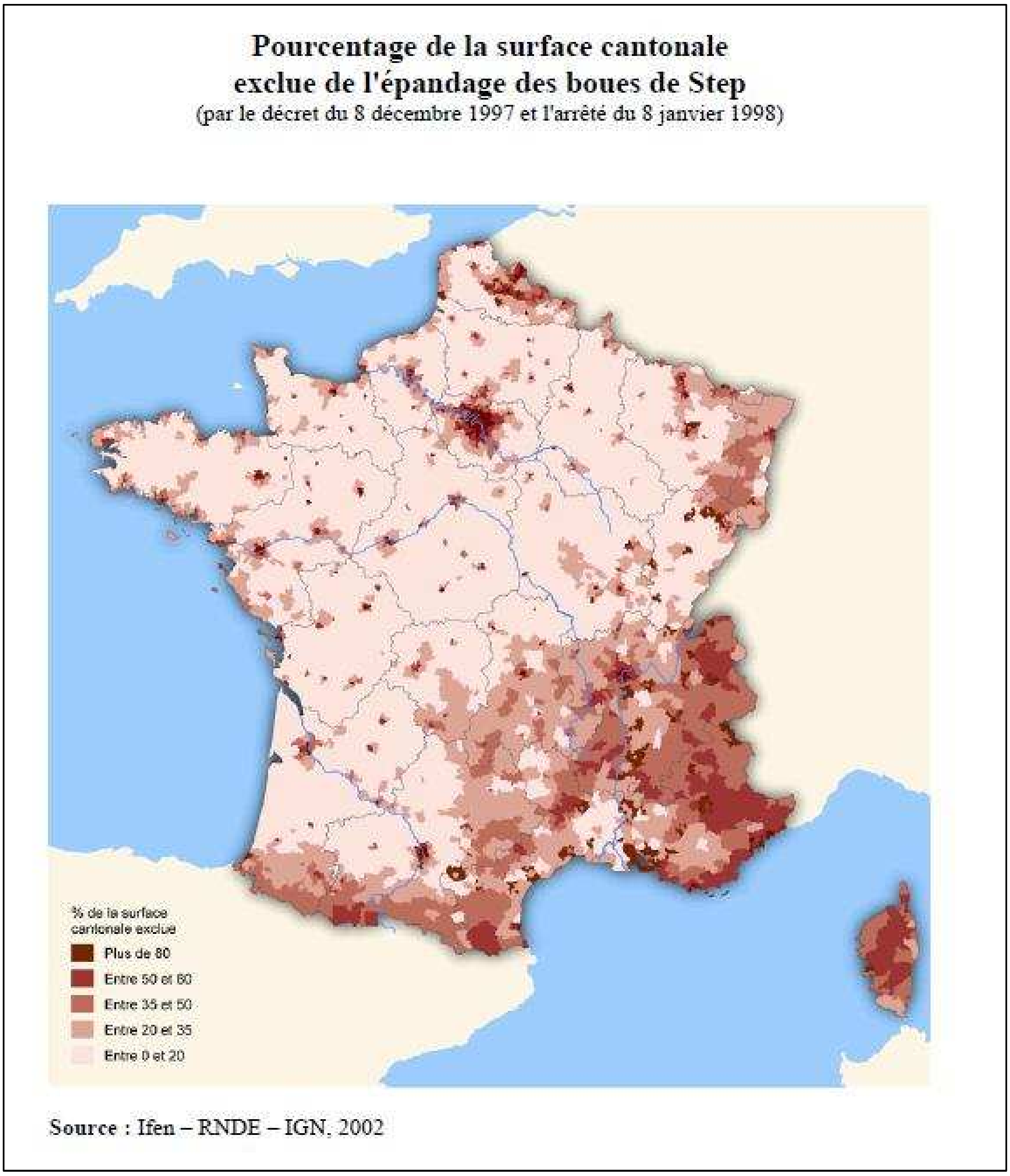


Figure 9 Percent of LAU1 area unavailable for sludge spreading (data from the French Ministry of Environment)

Acidification

In France, acid soils correspond to filtering materials leading to cation leaching, and that don't have alterable minerals able to resupply. This is mostly the case of sands in the Landes region, and of soils developing on sandstones in the Vosges, along with some granitic areas.

Moderate acid soils are found on old materials like in the Massif Armoricain or the Massif Central.

Neutral soils are to be found on the arable plains, where the neutral “natural” pH is maintained by regular liming operations.

Saturated soils are found on calcareous parent materials, and in salted areas (Camargue, Poitevin marsh), the pH are very high.

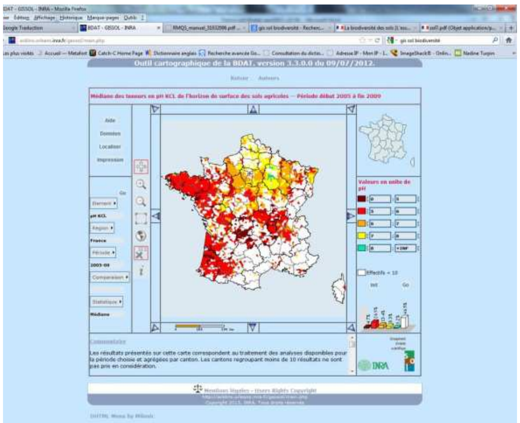


Figure 10   Median of pH from samples in France

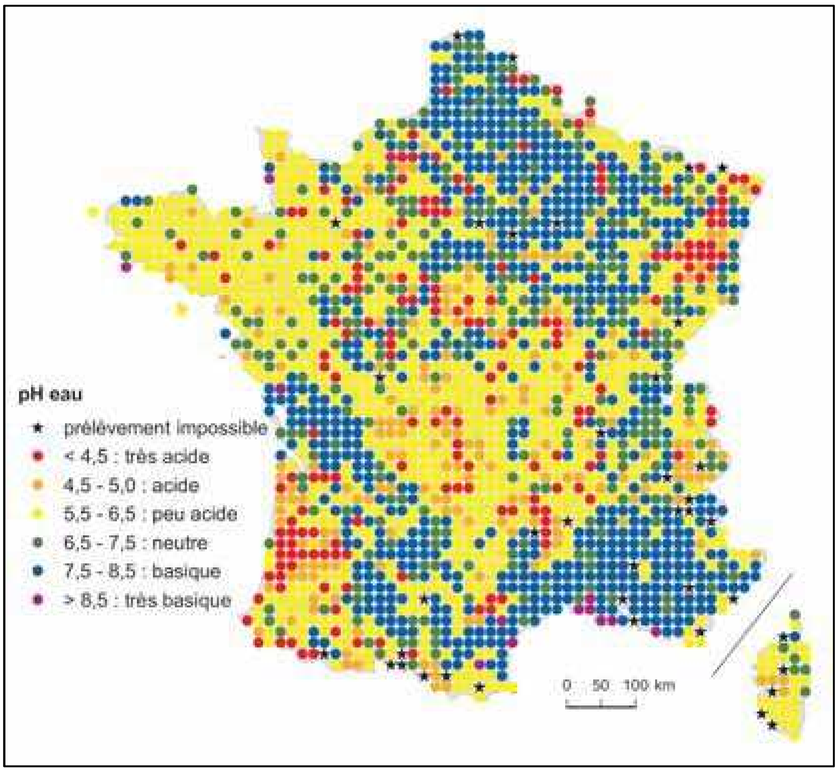


Figure 11   Prediction of native soil pH (source Gis Sol, RMQS, 2011)

There is no spatially harmonized database of soil samples (although the initiative from GIS Sol is very useful) and the various aggregation levels at which data are made available (LAU1, agricultural zones, pixels of various sizes) render cross analysis a bit tricky.

Other threats

There are many other threats on soils, most of them are monitored.

Radioactivity

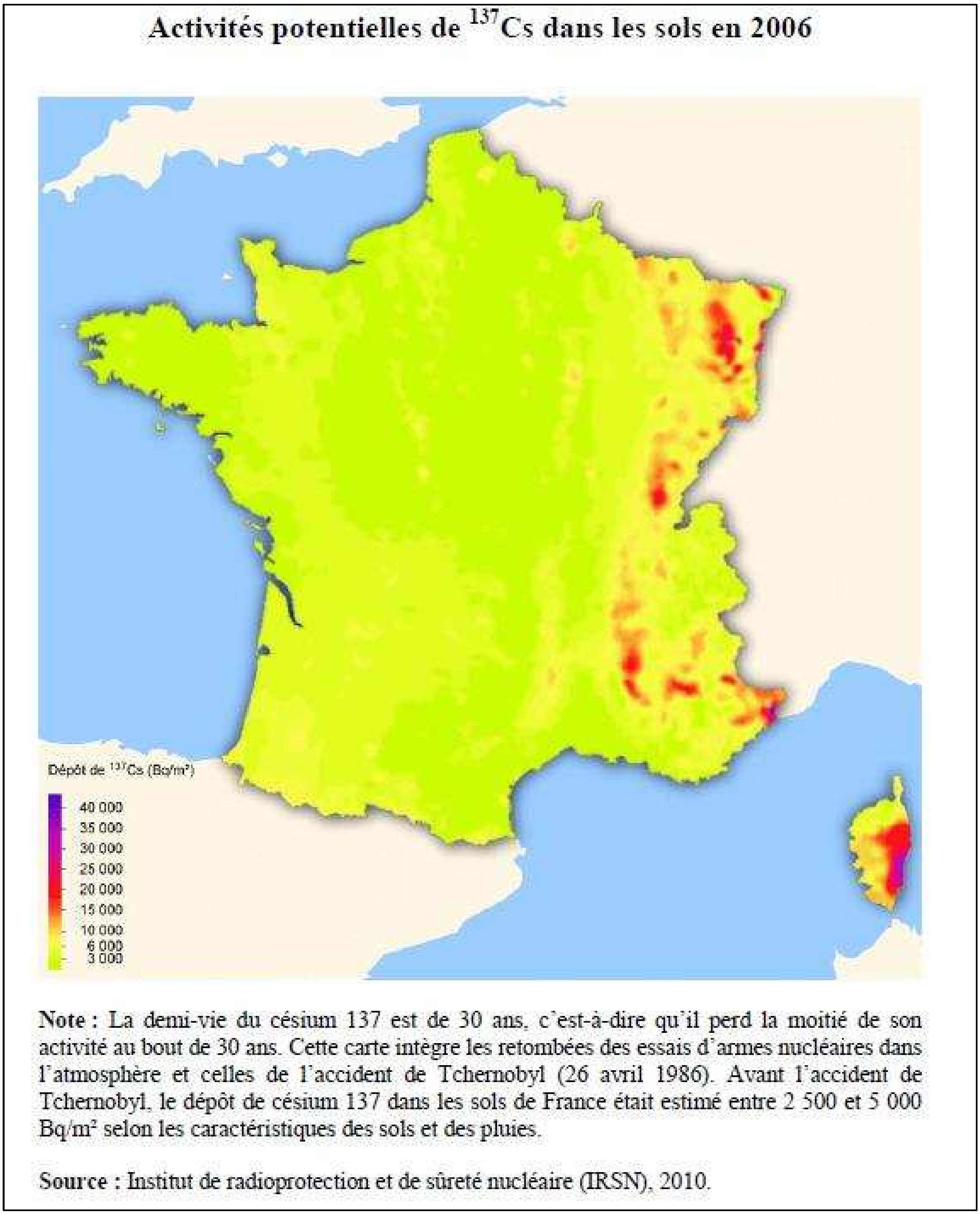


Figure 12 Concentration of Cesium in French soils (data from the French Ministry of Environment)

Polluted sites

Soils are subject to many pollutants, resulting from industrial point pollution. They are inventoried in a public database (http://basol.environnement.gouv.fr/home.htm).

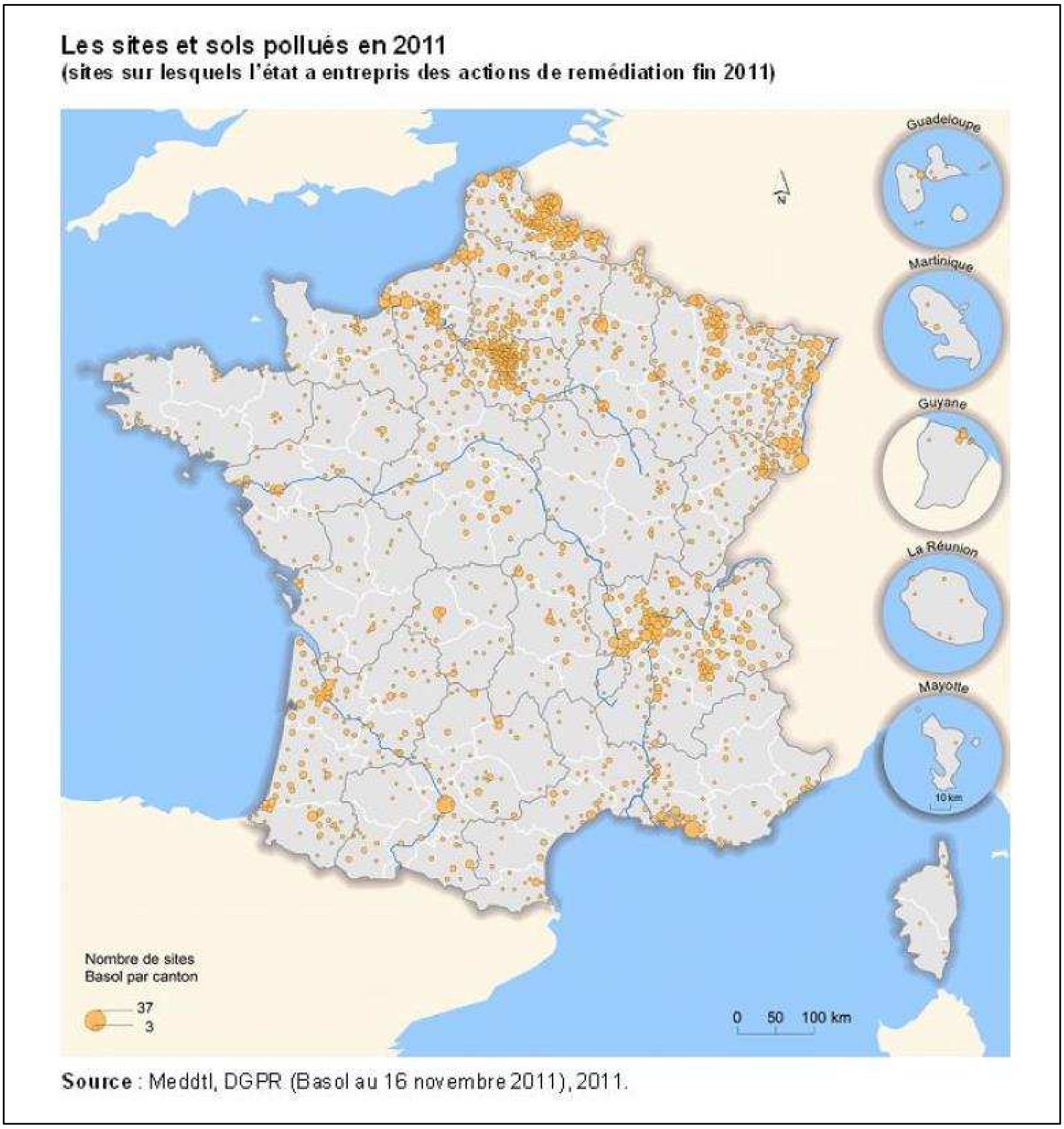


Figure 13 : number of polluted sites per LAU1 where remediation is ongoing in 2011 (data from Ministry of Environment)

N_2O emissions

N_2O emissions are estimated in France by models. Uncertainties are still important both on data measurements and on the models, so they are not used n public decision making yet.

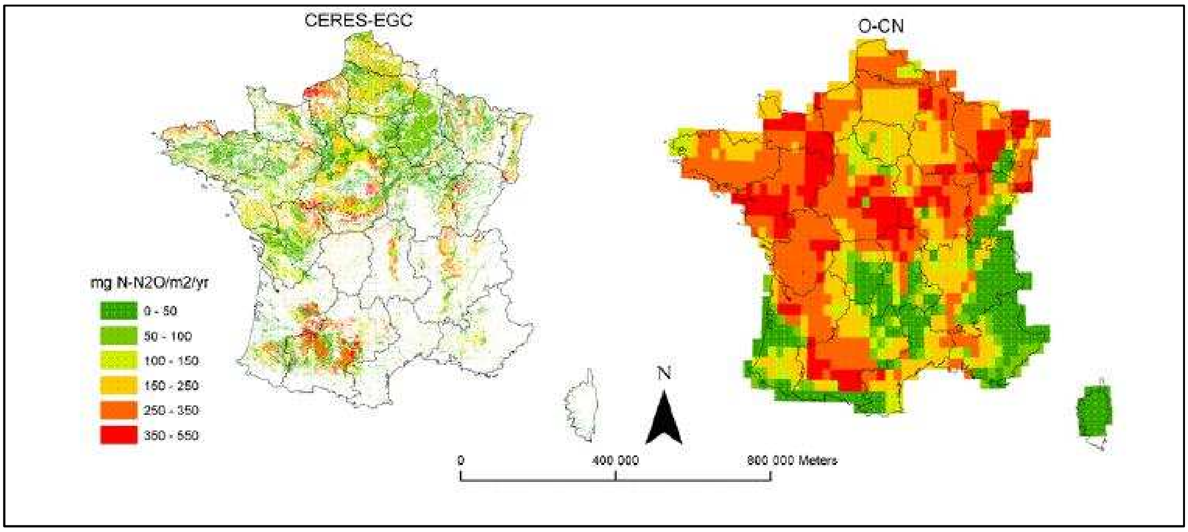


Figure 14 Spatial distribution of N_2O emissions over France for 2007 as simulated by two models (CERES-EGC left and O-CN right) – maps from Gabrielle et al. (2012).

European perspective

The Eurosoil database from JRC provides very useful information on soil threats at EU level. For some indicators, there are discrepancies with nationally used information.

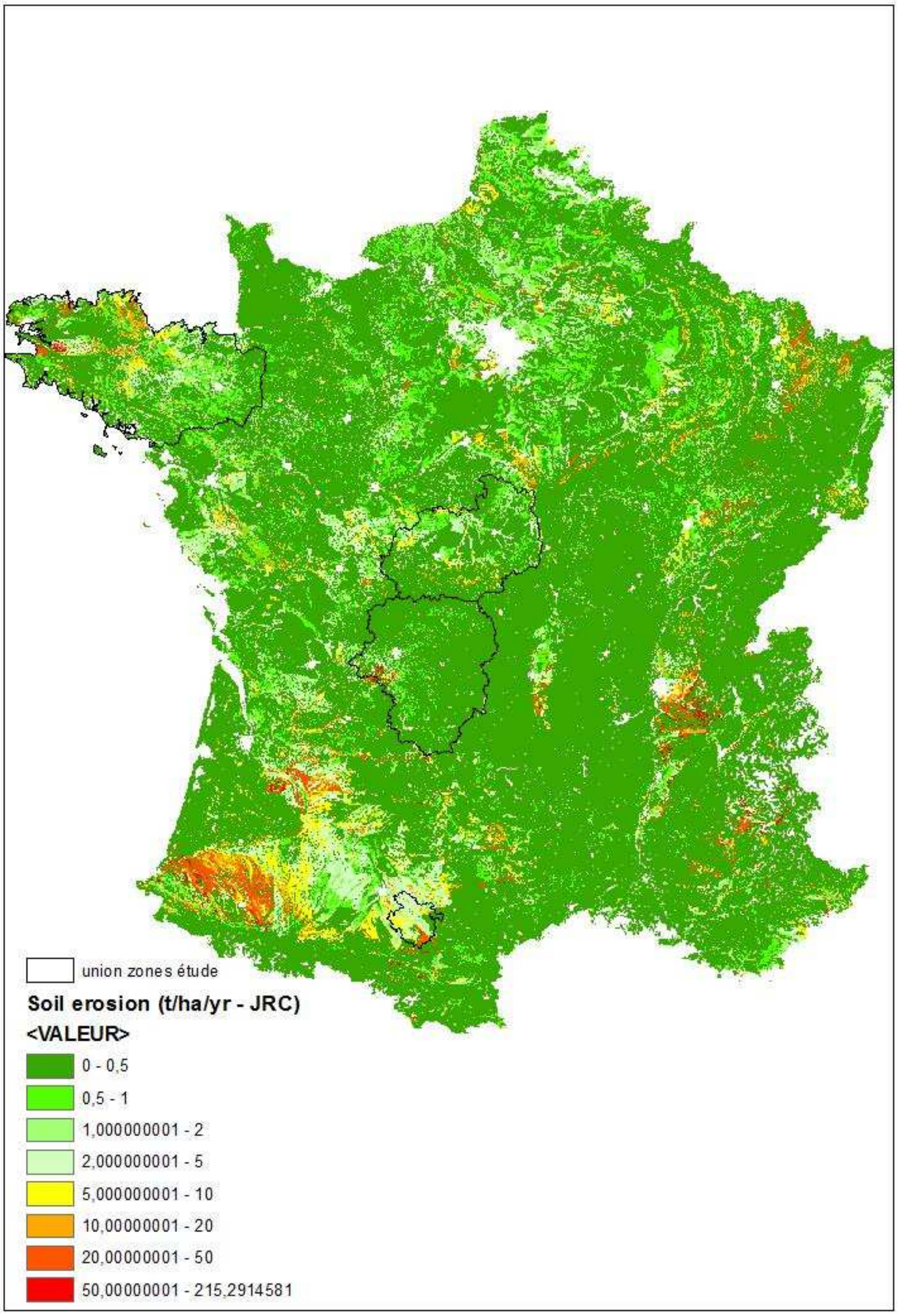


Figure 15   Pan European Soil Erosion Estimates (values for France)

At EU level, erosion is assessed with the same model as in France (Mesales). As such, the information from the Pan European Soil Erosion Estimates is consistent with the one used by French policy makers. But a comparison of Figures 4 and 15 highlights that the aggregation level at which information is displayed can lead to very different patterns of erosion risks.

The European Landslide Susceptibility Map (ELSUS1000) shows levels of spatial probability of generic landslide occurrence at continental scale. Its pattern is similar to the one used in France for mountains, but depicts variability in the north west of France (considered as medium to high in France and low to very low at EU level), and on a zone located south of the Bassin Parisien (same discrepancy).

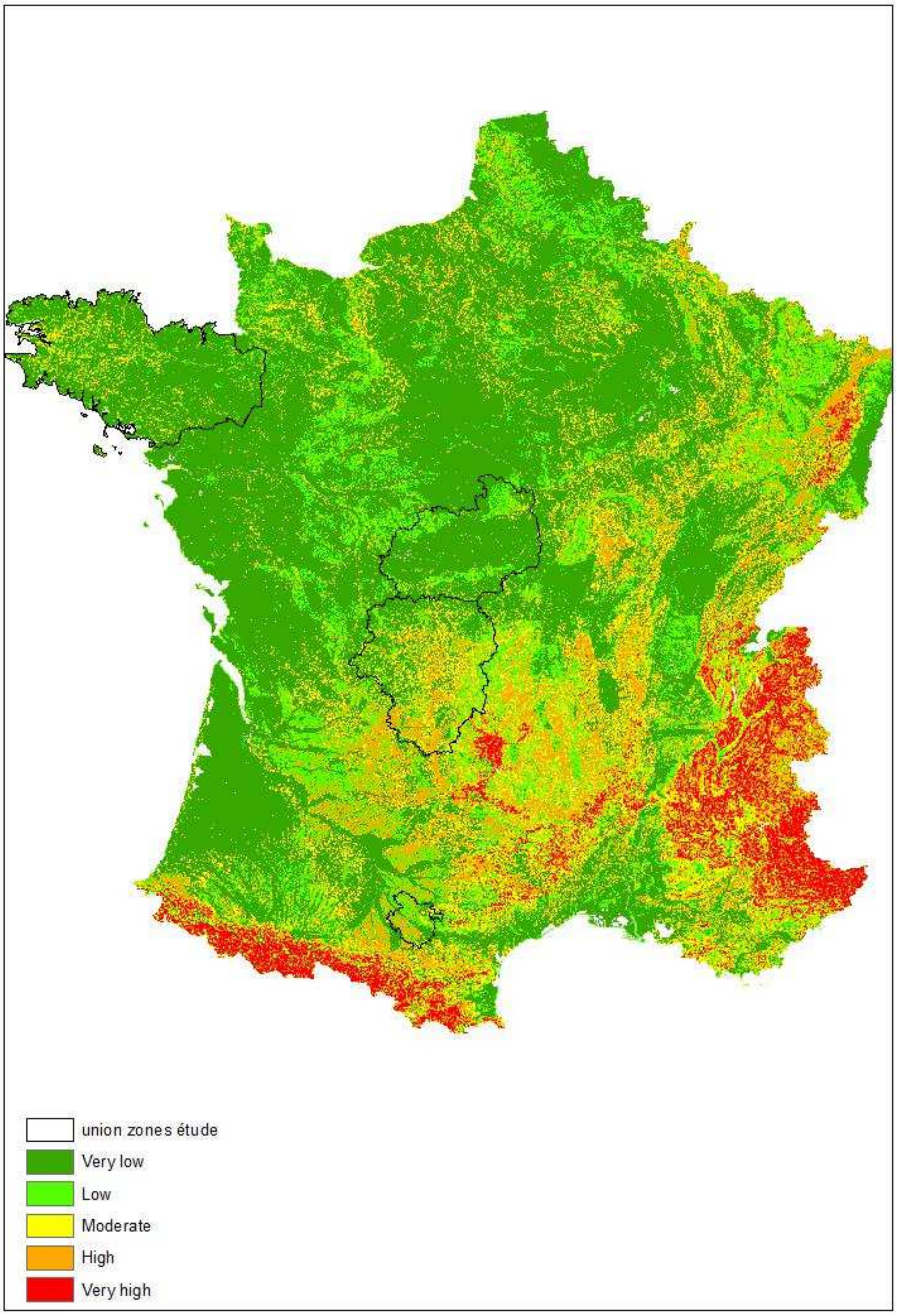


Figure 16 Classified European landslide susceptibility map (Günter et al., 2013)

Similarly as pointed out for France, there is a lack of quality data on soil organic matter content at the EU level. So far, the most homogeneous and comprehensive data on the organic carbon/matter content of European soils remain those that can be extracted and/or derived from the European Soil Database in combination with associated databases on land cover, climate and topography.

The French pattern of organic carbon content of soil is very different from the one used in France, mostly in breeding areas (Bretagne, Normandy, and east of the country), where measurements are way much higher than those assessed by the EU model.

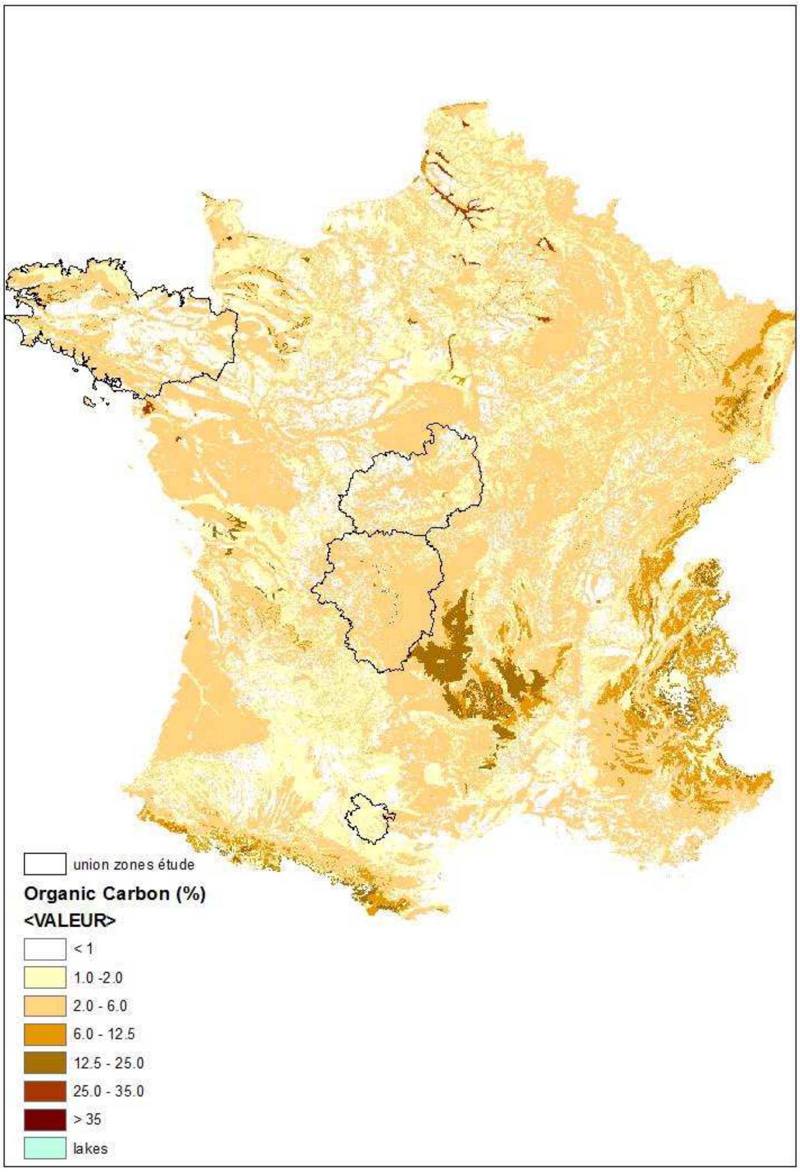


Figure 17 Organic carbon content (OCTOP) in the topsoil layer (0-30 cm), calculated for 1 km x 1 km grid. OCTOP was calculated from the European Soil Database by combining refined pedo-transfer rules with spatial thematic data layers of land cover and temperature, as 1 km raster layers Based on the work of Jones et al. (2003)

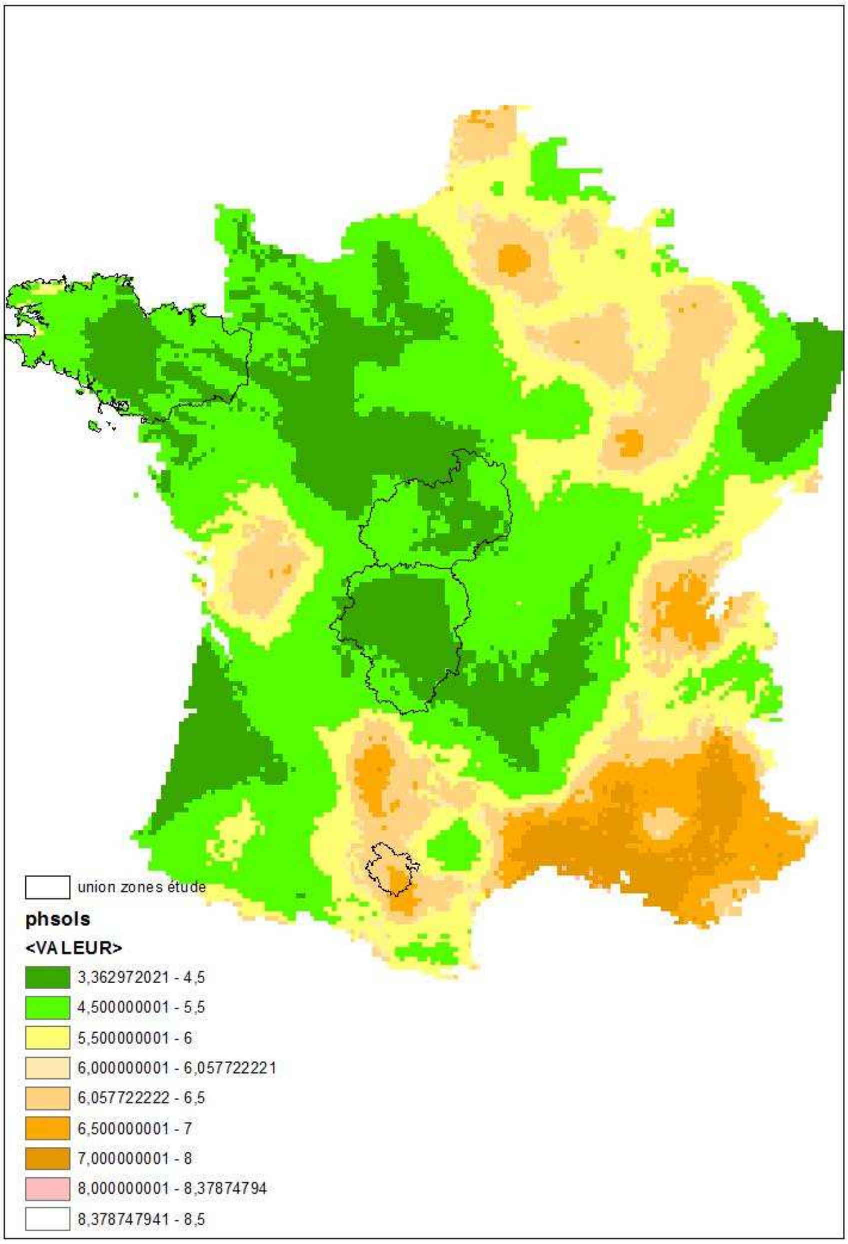


Figure 18 Soil pH of top layer (JRC)

The JRC created a quantitative map of estimated soil pH values across Europe from a compilation of 12,333 soil pH measurements from 11 different sources, and using a geo-statistical framework based on Regression-Kriging (Figure 18). Both patterns look very similar from the EU and the French one.

Soil compaction is assessed by scoring information provided by from the European Soil Database (SGDB) (http://eusoils.jrc.ec.europa.eu/library/themes/compaction/susceptibility.html). No comparison is possible with French assessments (which do not exist yet).

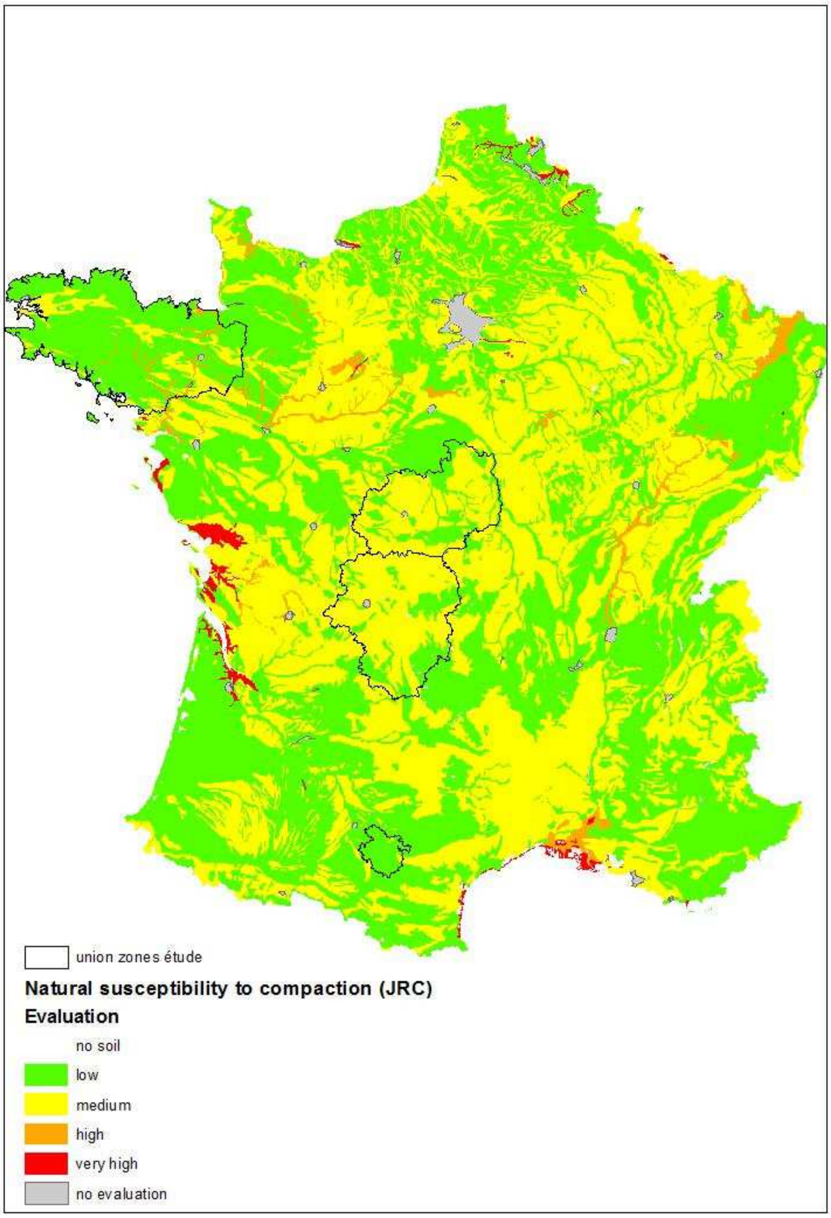


Figure 19 Soil compaction (JRC)

Synthesis: cross-cutting issues

In order to cross analyse the various threats for soils in France, and despite some discrepancies with the national datasets, we used the JRC information, because it is provided roughly at the same scale for each indicator. Raster maps from JRC have been vectorized, then piled up in order to build up a database in which each soil unit is attached to indicators of soil erosion risk, pH, landslide susceptibility, organic carbon content and sensitivity to compaction. Continuous variables have been cut in classes that correspond to the classes used by JRC. A multifactorial analysis on this database highlights that there is a continuum of threats combinations rather than specific groups of soils (Figure 20).

First axis separates soils with extreme pH from medium one, considers on the left side soils with low sensitivity to compaction, low carbon content and high erosion risk (Figure 21). On the right hand side, are soils sensitive to compaction, with high carbon content and low erosion risk. There is no direct relationship between carbon content and pH. The second axis adds information on landslide (at the bottom are high landslide sensitivity).

The four study areas are well scattered on this factorial plan (Figure 22).

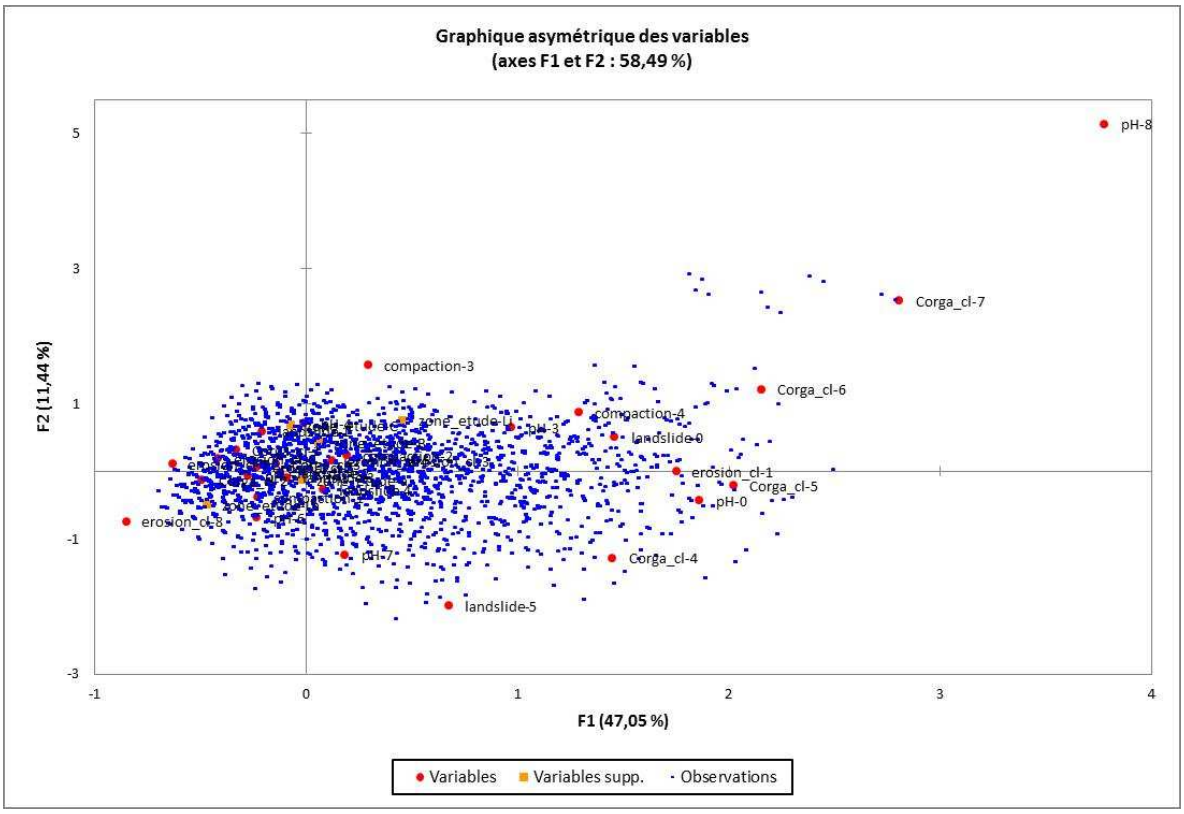


Figure 20   Multifactorial analysis on soil threats in France from JRC databases, soils in blue

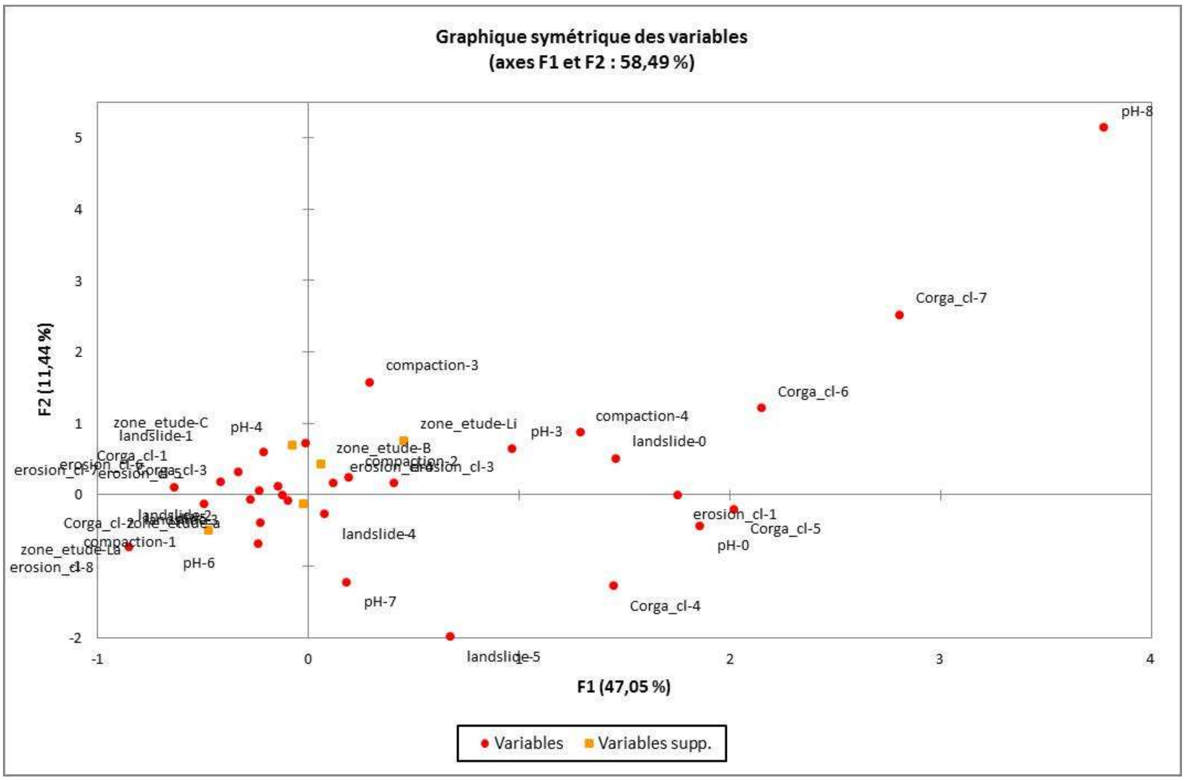


Figure 21 Multifactorial analysis on soil threats in France from JRC databases, variables

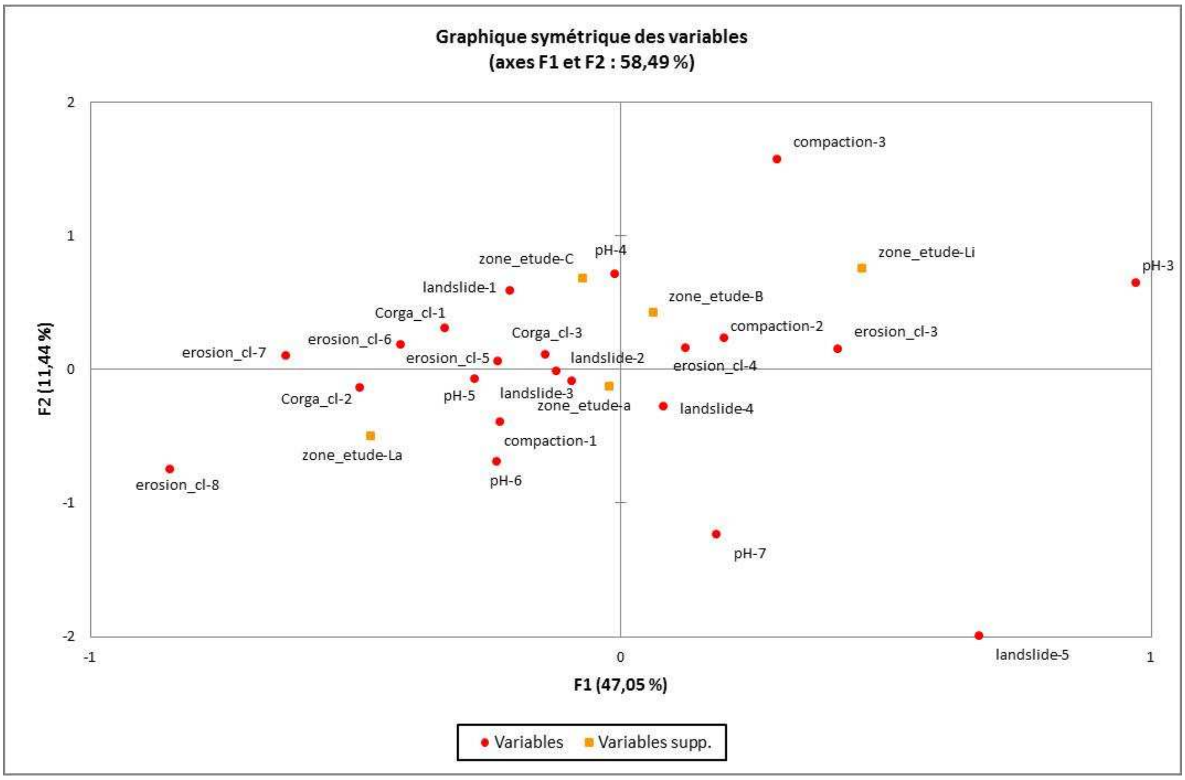


Figure 22 : multifactorial analysis on soil threats in France from JRC databases, extract of Figure 21

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Soil degradation problems in Germany

Authors: Janine Krüger, Jörg Rühlmann

Leibniz-Institute of Vegetable and Ornamental Crops, Grossbeeren, Germany

Introduction

The EU Thematic Strategy for Soil Protection (2006) defines the following soil degradation threats: erosion, loss of organic matter, compaction, flood, salinization, landslide, contamination, sealing.

Studies on soil degradation problems were initiated by the Federal Soil Protection Act (established 1998) and the German Federal Soil Protection Act and Ordinance Federal (established 1999). Both laws correspond with the EU Soil Strategy. The Second Soil Protection Report of the German Federal Government (2009) from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) presents instruments to describe and to monitor the soil status in Germany. Included is also a summary of the status of the identified soil threats that is used as starting point. Detailed reports and publications e.g. from the Federal Environment Agency (UBA), Federal Institute for Geosciences and Natural Resources (BGR) and further institutes will be used herein to complete available facts on soil degradation of Germany.

List of soil degradation problems in Germany

The following soil relevant issues are identified and considered in the Second Soil Protection Report of the German Federal Government to describe and to monitor the soil status:

- soil erosion induced by water
- soil organic matter
- soil compaction
- soil contamination
- soil covering / sealing

The authors added:

- soil erosion induced by wind and
- soil biodiversity

as the federal environmental agency currently focuses on these relevant topics.

Soil degradation threats

Soil erosion

Soil erosion induced by water

Publications on soil erosion mainly concentrate on the sector water. The estimation of the averaged potential erosion risk in Germany amounts to 27.2 tons per ha and year for agricultural areas (BMU, 2009). To estimate the risk of soil erosion the General Soil Erosion Equation (a modified version of the Universal Soil Loss Equation (USLE) approach) is used. This approach considers six different factors: R as rain and surface runoff, K as erodibility, S as slope gradient, L as slope length, C as cover and tillage, P as erosion protection. C and P are not relevant for the calculation of the soil status. L is not considered for each estimation version. The calculation for whole Germany was performed on 50 x 50 m grid cell resolution. The risk of soil erosion from arable soils according to tillage management is estimated at 4.2 tons per ha and year for conventional tillage and 2.1 tons per ha and year for minimum tillage (Erhard et al., 2005). A study of Erhard et al. (2003) used CORINE land use data with a spatial resolution of 1000 x 1000 m. The coarse data resulted in average of only 7.2 tons per ha and year for Germany. This shows exemplary how input data influence the output results.

The detailed report of Wurbs and Steininger (2011) about soil erosion and climate change classifies Germany in four natural landscapes for a first overview. The result of the potential erosion risk under consideration of the three factors R, K and S is illustrated in Figure 1a. The northwest and northeast German Lowland show low potential for soil erosion in consequence of low slopes and low erodibility. With increase of S and erodibility of soils (mainly loess sites) rises the risk of soil erosion in the low mountain range and their forelands. At higher elevations of the low mountain range and the area of the Alps higher R factors intensively increase the erosion risk potential.

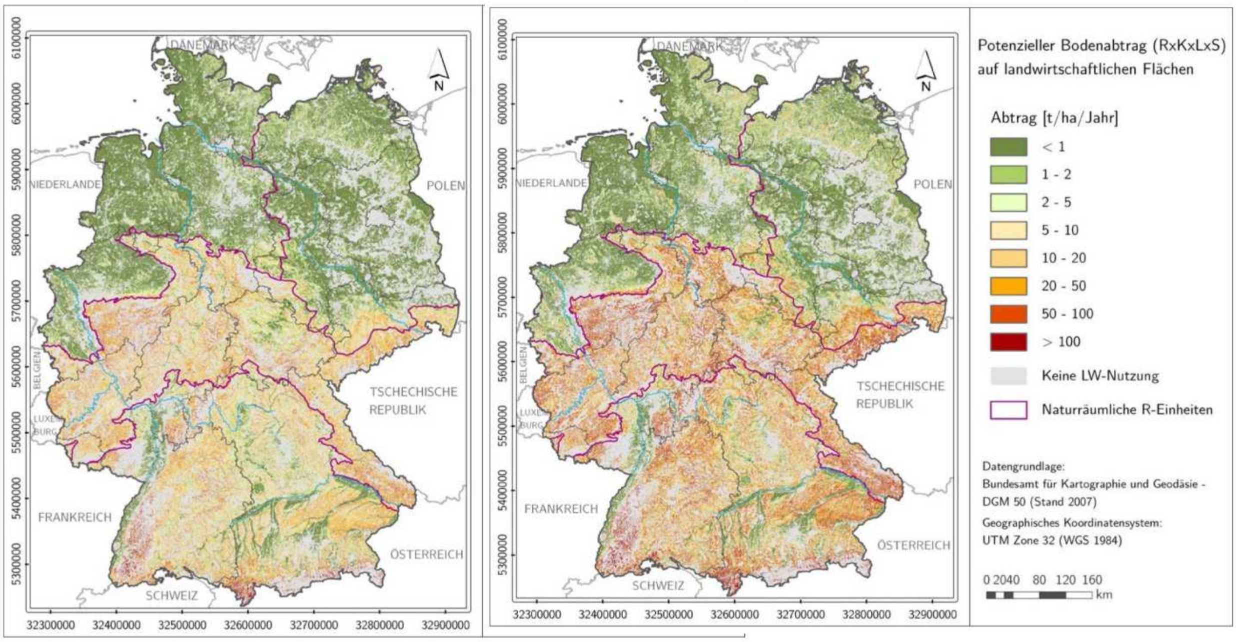


Figure 1 Potential risk of soil erosion (in tons per ha and year) under consideration of factors (a -> left) R x K x S and (b --> right) R x K x L x S (Wurbs and Steininger, 2011)

The added consideration of the factor L (slope length) should emphasise a higher risk for regions with large slope length in comparison to the version R x K x S (Figure 1b). However, a significant shift of general hot spots areas could not be determined ((Wurbs and Steininger, 2011).

The second version of potential risk of soil erosion in Germany additionally considered the percentage of arable land. For that the statistical parameters of soil erosion amount (

Table 1) demonstrate both lowlands (NW & NE) to show a similar erosion behaviour (shown in Figure 2a and b). That means 50 % shows averaged soil erosion between 0.3 and 1.8 tons per ha and year (NW) and 0.4 and 1.6 tons per ha and year (NE). As expected for the low mountains and the Alps higher erosion amounts were determined. Under consideration of the factor L both German lowlands and the southern low mountains and Alps show a twofold increase for the calculated soil erosion. The western and eastern low mountains have an above 100 % increase of soil erosion (Figure 2b).

Table 1 Statistics of potential soil erosion (tons per ha and year) for classification of natural landscapes Germany (Wurbs and Steininger, 2011)

Classification of natural landscapes	**Version**	**Median**	**Mean**	**Mini-mum**	**Maxi-mum**	**Upper quantile**	**Lower quantile**
NW German lowland	RxKxS	0.6	1.5	0	15.1	1.8	0.3
NW German lowland	RxKxLxS	1.2	3.3	0	43.6	3.8	0.4
NE German lowland	RxKxS	0.7	1.8	0.1	20.8	1.6	0.4
NE German lowland	RxKxLxS	1.4	4.4	0.2	53.4	3.5	0.8
Western & eastern low mountains	RxKxS	21.9	26.6	3.1	94.3	33.5	15.7
Western & eastern low mountains	RxKxLxS	50.1	56.3	7.8	145.8	70.6	37.2
Southern low mountains & Alps	RxKxS	17.6	48.7	0,4	446.5	36.8	9.2
Southern low mountains & Alps	RxKxLxS	39.5	95.5	0.6	964.8	77.5	22.4

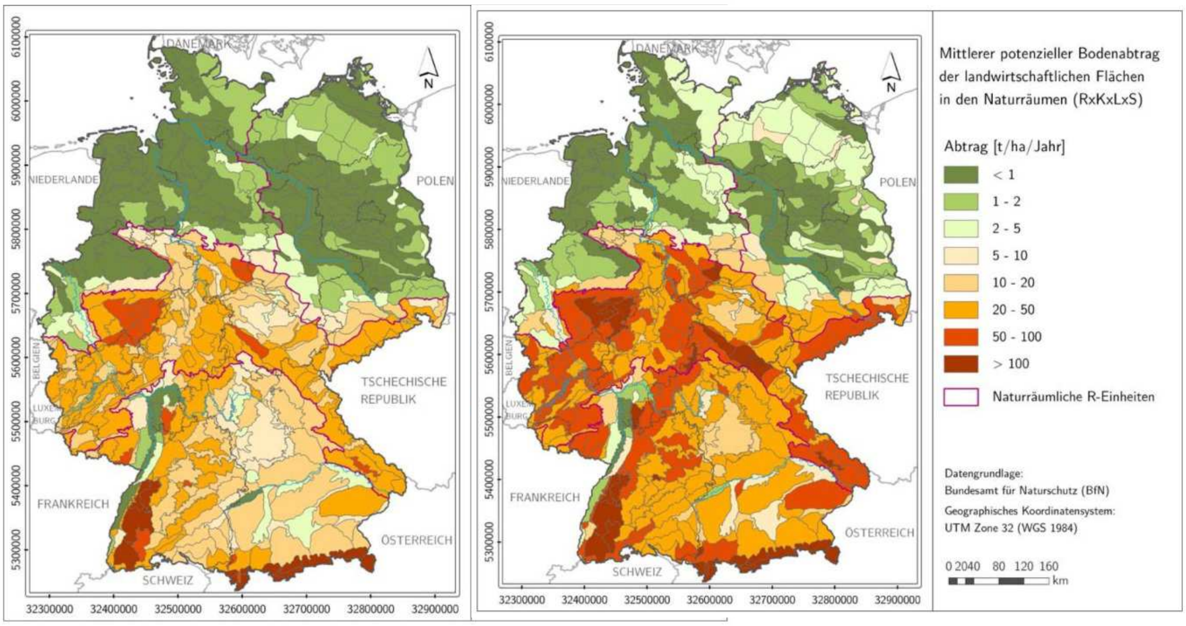


Figure 2 Averaged potential risk of soil erosion risk (in t per ha and year) for arable land under consideration of factors (a --> left) R x K x S and (b --> right) R x K x L x S (Wurbs and Steininger, 2011)

The online publication of the Federal Environmental Agency is based on Wurbs and Steininger (2011) that simplifies and categorizes soil erosion risk into five classes. Accordingly, 38 % of the arable areas in Germany have high and very high soil erosion risk potential (Figure 3). These high risks are concentrated at the middle and southern parts which are confirmed by Erhard et al. (2005).

49 % of the areas used for agriculture shows no or very low risk. 13 % is categorized as low and medium risk potential.

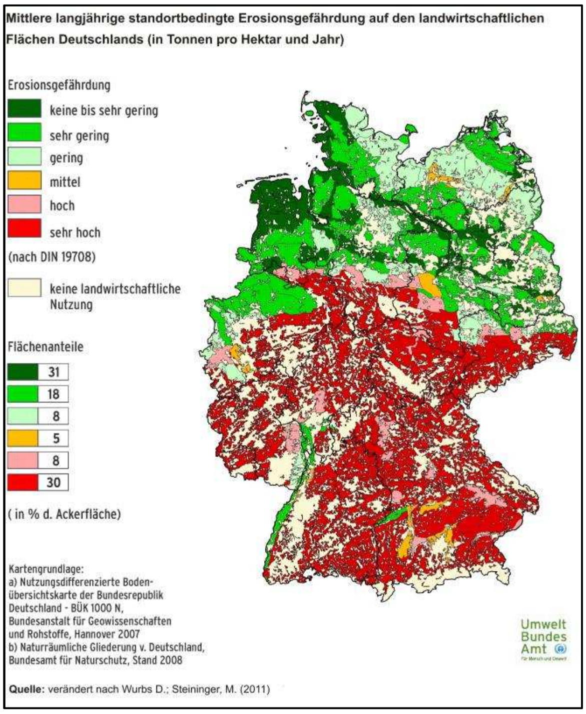


Figure 3 Potential soil erosion risk for arable land (dark green = no or very low, green = very low, light green = low, orange = moderate, rose = high, red = very high, white = no arable land (UBA, 20.04.2013)

Soil erosion induced by wind

The topic wind erosion is an identified soil threat in Germany. However, the amount of reports and research is not comparable to the soil water erosion. Funk et al. (2004) used the model WEPS (Wind Erosion Prediction System) to compare measured and simulated soil loss for 49 erosion events (field study) with good results.

With the help of the general soil map (scale = 1 : 1,000,000) which includes a land use differentiation, various regions of northern Germany could be identified to exhibit a potential risk for wind erosion (Figure 4, brown and yellow soil areas).

Light soils (silt and fine sand) are often prone to wind erosion (brown and yellow soil areas). Wind erosion is furthermore intensified agricultural land use particularly in spring with uncovered soil surface and no wind protection. Additionally, crop rotations with maize and potatoes (late growing crops) promote a late covering of soil. A further influence factor results from the past in the north-eastern part of Germany. Political decisions at the time consolidated arable areas to large units and eliminated natural patches and hedges. This increased contact surfaces and in parallel the wind risk potential. Periods of dryness force the mentioned situation additionally. Soil transport through wind needs a wind speed of 6 to 8 m per second in combination with a dry soil on the one hand. On the other hand it also requires flat or very low slopes in an open landscape.

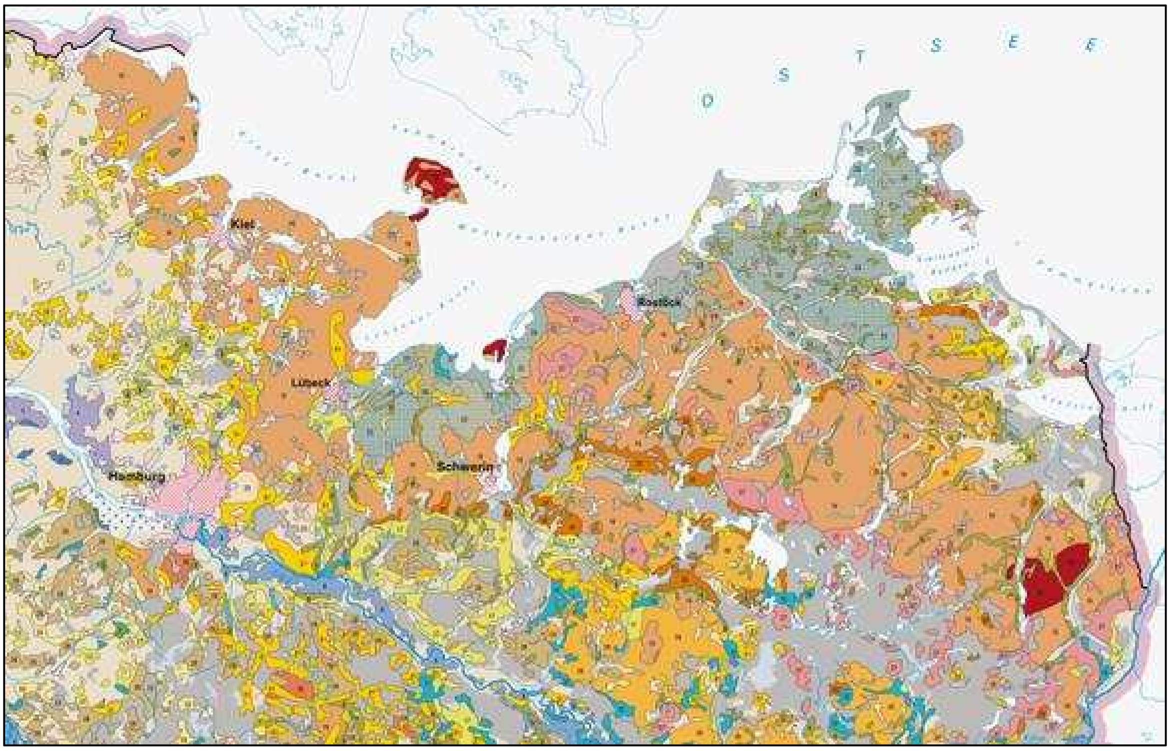


Figure 4: Soil map (section of north-east Germany) (BGR, 20.04.2013)

A study of the federal state Brandenburg demonstrates the potential wind erosion risk of arable areas in the north eastern part of Germany (Richter and Gentzen, 2011). In introduces wind erosion risk classes derived by a combination of substrate and hydromorphology types (Table 2). The classification of the agricultural soils of Brandenburg indicates a high percentage of the area with high and very high wind erosion risk (41 %). The risk areas are located in the sand areas of the river Oder, in the very light sand sites of southern Brandenburg as well as in the northwest lowlands (Figure 5).

Table 2: Matrix to determine potential wind erosion risk derived from surveying and mapping (LUGV, 20.04.2013)

Substrate type	Hydromophology type		
	Predominant percolate water	Predominant water stagnation or ground water	Predominant ground water or extreme water stagnation
Predominant sand, loam sand, sand loess	High and very high risk	Moderate risk	No risk
Deep loam, peat above sand	Medium risk	Moderate risk	No risk
Loam, loam sand, alluvial loam	Low risk	Low risk	No risk
Grassland	No risk	No risk	No risk

Figure 5 shows also large areas of Brandenburg (33 %) with medium risk. The characteristics sandy substrate, percolating water and fast drying result in areas with high risk. However, shallow ground water can influence sites and cause continuous moist conditions that in turn have no wind erosion potential.

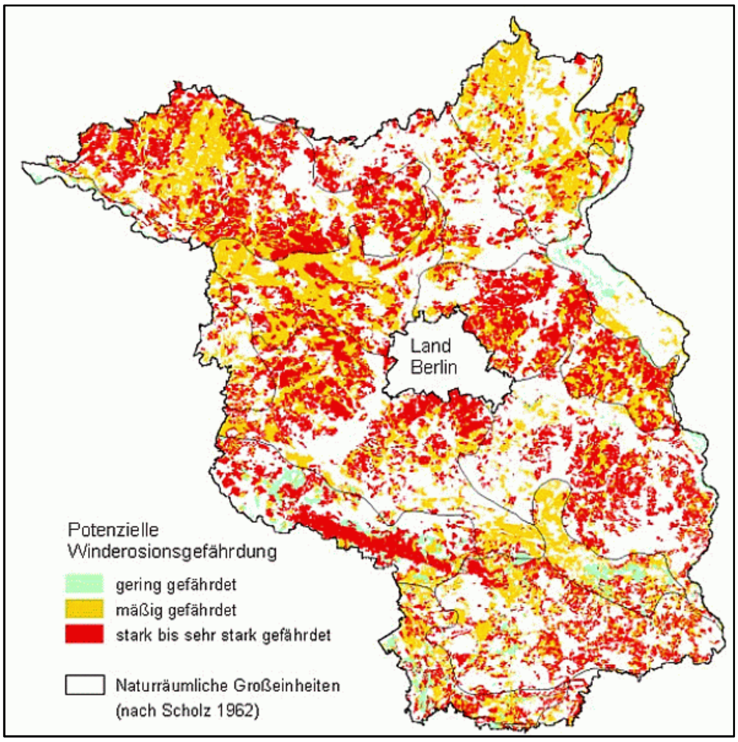


Figure 5 Potential wind erosion risk of the federal state of Brandenburg (light blue = low risk, yellow = medium risk, red = high to very high risk) (Richter and Gentzen, 2011)

Soil organic matter

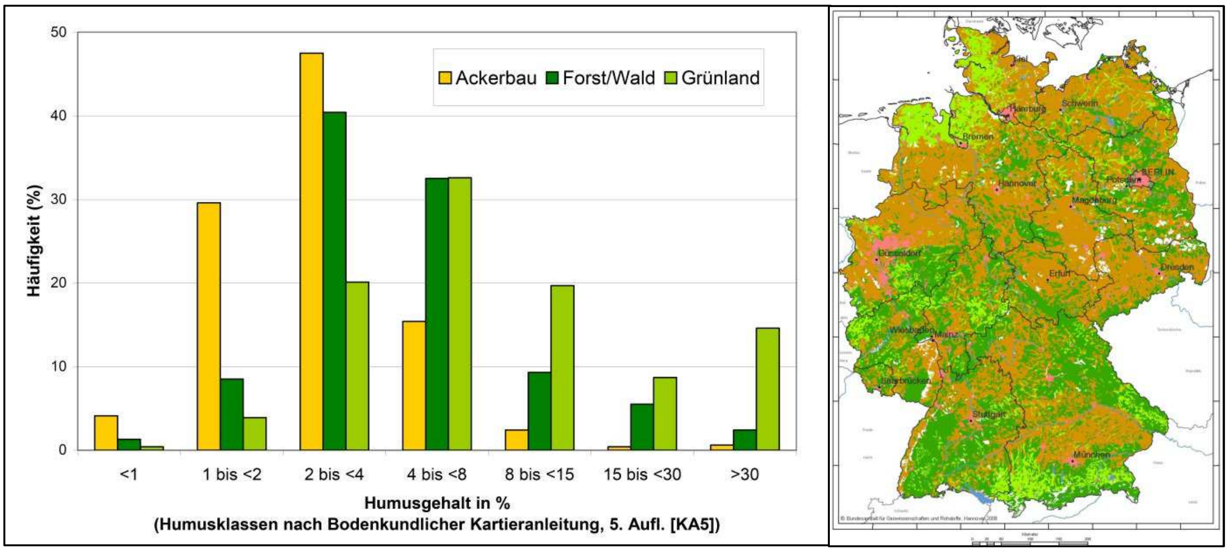


Figure 6 Classification of humus content for arable land (yellow), forestry (dark green), grassland (green) of Germany (map – arable land = brown, light green = grassland, dark green = forestry, white = others) (Düwel et al., 2007)

The distribution of the soil organic matter (SOM) was differentiated by land use, climate and substrate (Table 3). The land use differentiation shows the general influence on SOM. Figure illustrates the relative frequencies of SOM contents for the three main land uses – agriculture, grassland and forest.

Table 3: averaged C-org content (M. %) of arable land in Germany (Wessolek et al., 2008)

Sand			Silt			Loam			Clay		
C_{org}	sd	n	C_{org}	sd	n	C_{org}	sd	n	C_{org}	sd	N
1.2	0.9	178	1.5	0.7	172	1.3	0.8	127	2.6	1.8	46

An increase of SOM content has the following order: agriculture < forest < grassland. Under agricultural use the SOM content is predominantly classified with h2 and h3. The areas with forest are characterized with h3 and h4. Grassland use consists of h4 and h5. Extreme values confirm the mentioned trend. The humus class h1 is mostly represented by arable use, the class h7 by grassland (Table 4).

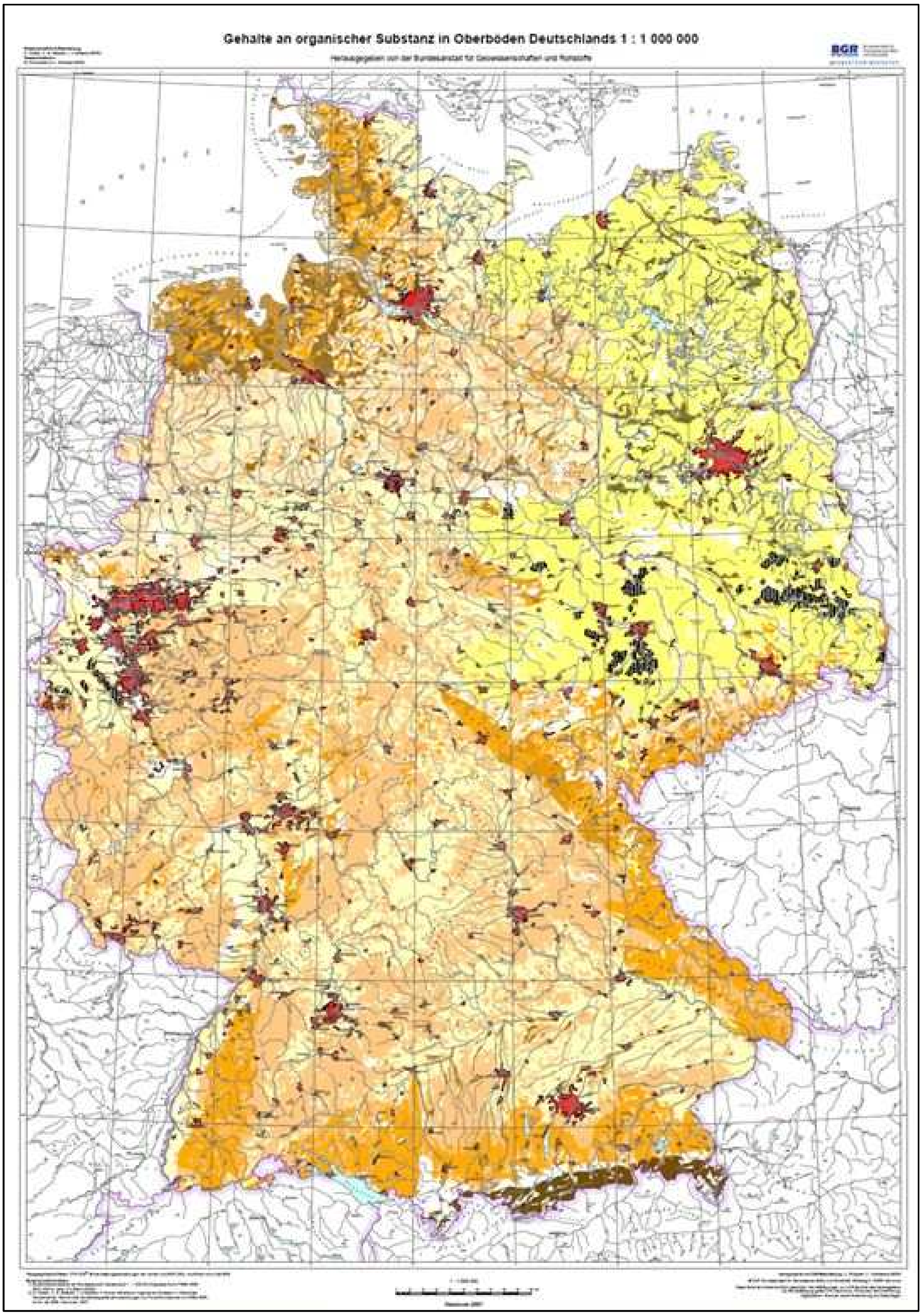
Table 4: Humus classes and the conversion to soil organic carbon by the factor of 1.724
(Düwel et al., 2007)

Class	Humus content (M. %)	Description	Soil organic carbon (M. %)
h0	0	no humous	0
h1	< 1	very weak humous	< 0.58
h2	1 - < 2	weak humous	0.58 - < 1.16
h3	2 - < 4	medium humous	1.16 - < 2.32
h4	4 - < 8	high humous	2.32 - < 4.64
h5	8 - < 15	very high humous	4.64 - < 8.70
h6	15 - < 30	extreme humous	8.70 - < 17.40
h7	> 30	organic	> 17.40

The map of the organic matter content of Germany (Figure 7) shows that the units with very weak humous topsoil can be mainly found in the region of the sub-continental temperate climate (north-eastern Germany). These soils consist of sands to sandy layers above tills and from marls. These units are invariably used as arable land.

Very high humous and extreme humous top soil horizons (class h5 / h6) are situated in soils of tidal sediments, floodplain sediments and peats. Occasionally these units also occur at sandy soils with grassland and in soils developed from carbonate in the climate region of the Alps. The class h7 is only located in peat soils as expected.

The study on SOM in the top soils of Germany was conducted by Düwel et al. (2007). Under consideration of land use, climate and soil substrate 22.000 sites were used to map SOM for approximately 82 % area of Germany. The main aim of this study was to use statistics of areas, to quantify “typical” contents and to characterize the variability of SOM contents. The detailed result about soil organic matter will be used for ecological and economical tasks.



1 - < 2 % (h2) 2 - < 3 % (h3) 3 - < 4 % (h3) 4 – 6 % (h4) 6 - < 8% (h4)
8 - < 11 % (h5) 11 -< 15 % (h5) 15 - < 30 % (h6) > 30 % (h7) not specified

Figure 7: Soil organic matter contents of top soils (as medians) in Germany

The study of Düwel et al. (2007) gives a first overview about SOM content in soils of Germany. However, Prechtel et al. (2009) pointed out a lack of data concerning SOM. Therefore a baseline of C stocks as a reliable reference to determine changes in the future could not be realized. The existing map with the scale of 1 : 1,000,000 is the only nationwide map which includes and aggregates data over large areas. The national inventory report (2006) stated that this map scale results in a potential error of 70 % for C stocks.

The German Soil Protection Law pronounces the maintenance of the soil organic matter indirectly in the different passages. Sites classified with “typical humus contents” are explicitly mentioned to be maintained. The soil assessment of the supply status with organic matter will be done by a suitable balance method as no reliable values for the SOM in soils are derived or defined (Hüttl et al., 2008).

Soil compaction

The report of Lebert (2010) about “Development of a test concept to assess the real vulnerability to compaction of agricultural soils” analysed soil physical data of 1300 agricultural soils in Germany to evaluate the status of soil compaction. The first step focussed on the mechanical susceptibility to compaction by pre-compression stress. Table 5 presents classes of mechanical susceptibility and the percental share of arable land in Germany.

Table 5 Mechanical susceptibility to soil compaction (Lebert, 2010)

Mechanical susceptibility	Percentage of arable land with different soil water content			
	100 % field capacity	80 % field capacity	70 % field capacity	60 % field capacity
Very low	0	42	42	94
Low	22	0	52	2
Moderate	20	52	2	0
High	52	2	0	0
Very high	2	0	0	0

The second step analysed the soil structural quality. In the perspective of soil compaction the classification considers the following properties: air capacity, saturated conductivity and bulk density (Table 6). The result is mapped in Figure 8a.

Table 6: Classification of structural soil quality under the view of soil compaction (Lebert, 2010)

Bulk density (g cm^{-3})	Air capacity (Vol.%)	saturated conductivity (cm/d)	Structural quality
≥1,8	< 5	< 10	Very unfavourable
1,7 - < 1,8	5 - < 7	10 - < 40	Unfavourable
1,6 - < 1,7	7 - < 13	40 - < 100	Moderate
1,4 - < 1,6	13 - < 26	100 - < 300	Favourable
< 1,4	≥ 26	≥ 300	Very favourable

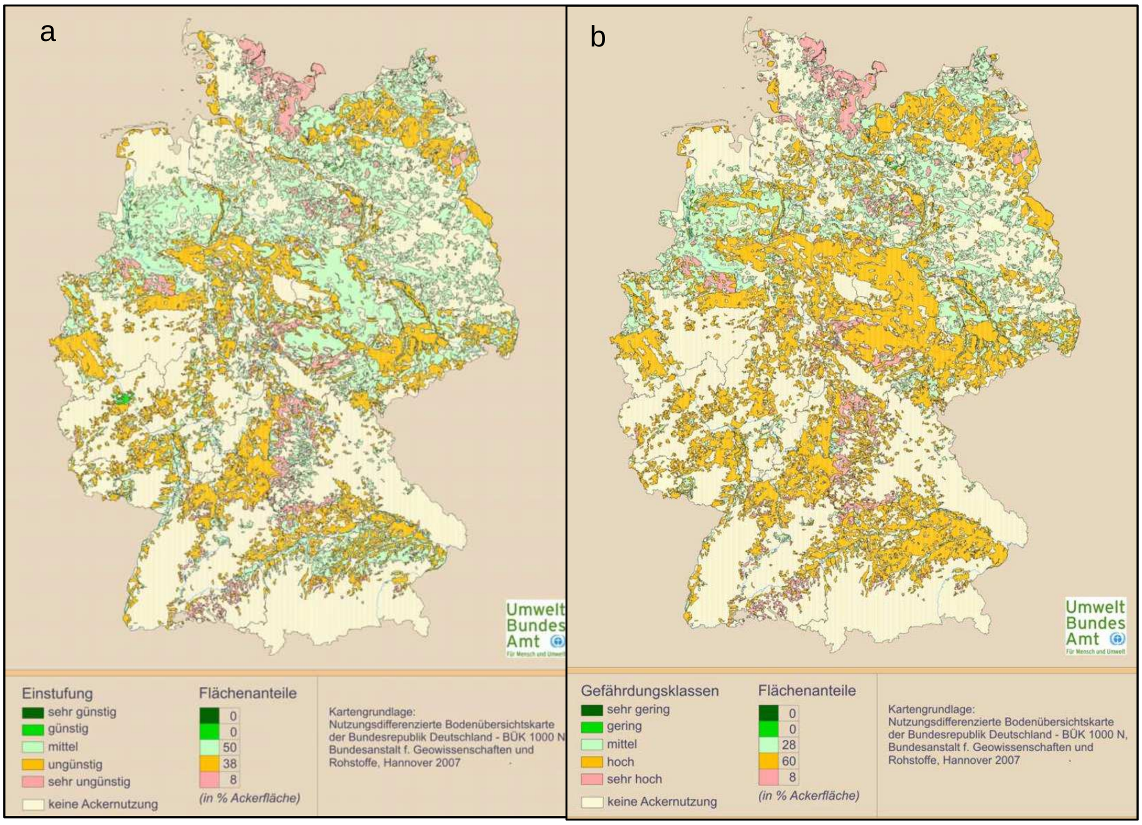


Figure 8 (a --> left) Soil structural properties of sub soils (dark green = very favourable, green = favourable, light blue = moderate, orange = unfavourable, rose = very unfavourable, white = no arable land); and (b --> right) risk of soil compaction with 100 % field capacity (dark green = very low, green = low, light blue = moderate, orange = high, rose = very high, white = no arable land) (Lebert, 2010)

The third step combines both results of the previous steps to assess soil compaction. Figure 8b shows the threats of soil function in sub soils through compaction and under the condition of 100 % field capacity. Approximately, 8 % of the sub soils of arable land in Germany possess a very high risk. Affected are tills of the young moraine landscape (Vistula) in the north, tills of the lower moraine (Saale), tills (Würm) in the south, parts of marshes and soils from marls and argillaceous rocks. The largest area (60 %) is characterized by soils with high risk (orange in the map). Sandy loams of the young moraine landscape, parts of the marshes, clayey, loamy and silty river deposits and the entire loess landscape, except sandy loess, loamy and clayey soils characterize this class. Moderate risk (class 3) is present in many parts of the sandy lower moraine landscape, sandy terrace deposits, the sandy loess areas and areas of loess with constituent material. The low and very low risk classes do not exist for these conditions.

Figure 8b reveals that a high to very high threat of soil functions occurs through compaction on a considerably large area (68 % of all arable land). The underlying soil water content of 100 % field capacity is very high for the use of agricultural machinery. The combination of very high moisture conditions and unfavorable as well as moderate structural soil properties results in a high threat on soil functions.

In the following figures, the considerations for soil compaction are extended to lower soil water contents. With dryer soil condition, at 80 % field capacity, a very high soil compaction risk is no longer present (Figure 9a). Soils with a high risk are reduced to 32 %. Affected are still tills of young moraine landscape, marshes, loamy and clayey alluvial deposits and loess soil with a clayey silt or silty clay texture with and without characteristics of Chernozem. Loess soils with silt loam texture and loess with constituent material are now classified as moderate risk as well as the sandy loams of the young moraine landscapes. Sandy soils of the lower moraine landscape, sandy terraces and alluvial deposits possess low risk. At a soil water content of 80 % field capacity, low, moderate and high risk areas consist of one third of the arable land in Germany. With decreasing field capacity (Figure 9b) the risk of soil compaction decreases also. The high risk amounts to 8 % only.

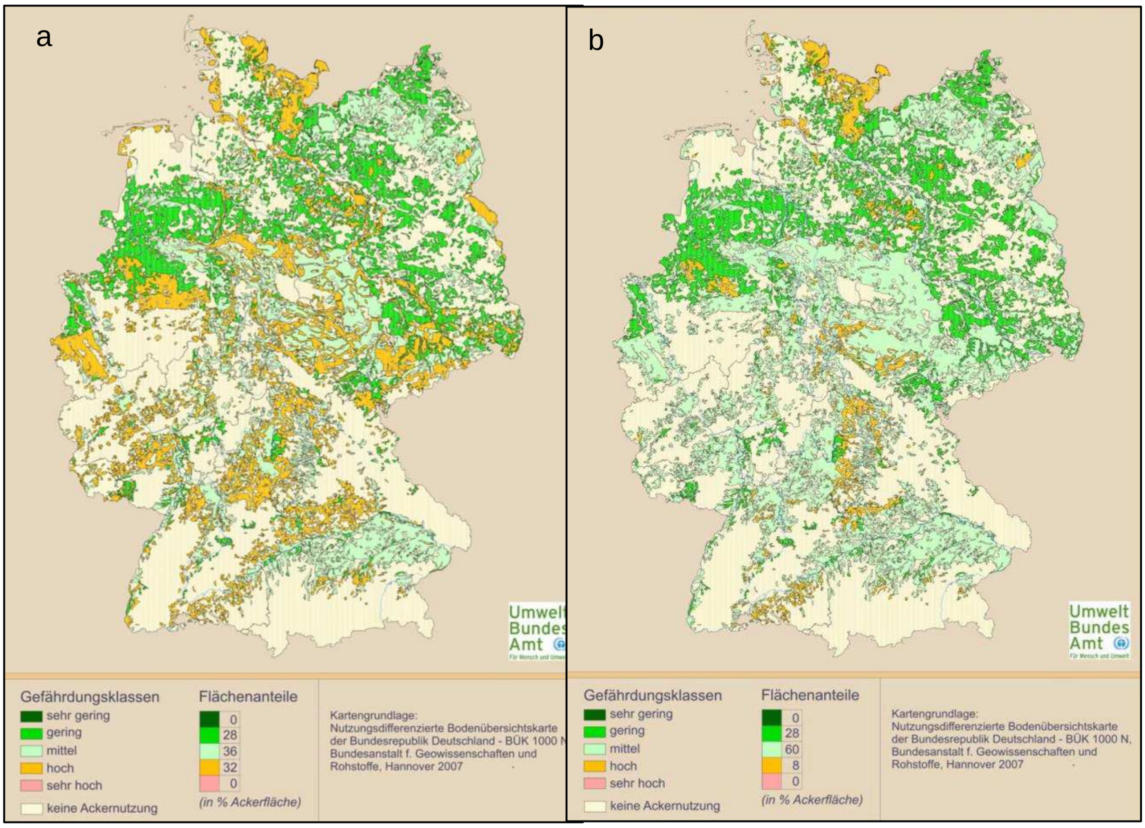


Figure 9: Threat of soil function in sub soils by compaction with (a --> left) 80 % field capacity, and (b --> right) 70 % field capacity (dark green = very low, green = low, light blue = moderate, orange = high, rose = very high, white = no arable land) (Lebert, 2010)

The soil compaction report is far beyond a classical potential risk study. The combined consideration of soil mechanical susceptibility, structural properties and soil water content provides a soil-physical-based approach on compaction of German soils. The assessment of soil compaction outlines large areas with high compaction risk, that in turn, is a clear indication for an extended need for action.

Soil contamination

From the past

Since the mid-1980s, Germany has made great efforts in the remediation of contaminated sites. However, the federal states of Germany still possess more than 300,000 possibly contaminated sites. Up to now, 25 % of the possibly contaminated sites have a finalized risk assessment. For approximately 10 % of the sites remediation actions are initiated or already finished (Frauenstein, 2010). Detailed numbers are summarized in Table 7.

Table 7 Statistics about contaminated sites in Germany (ALA, 2012)

Federal states	Possibly contaminated sites	Contaminated sites	Remediation finished	Risk assess-ment finished	Contaminated sites in remediation	Monitoring
Baden-Württemb.	13820	2275	2780	15902	616	431
Bavaria	16450	1085	1823	5651	992	93
Berlin	5493	982	210	n. a.	75	85
Brandenburg	19763	1465	4189	4409	137	256
Bremen	3532	398	653	1023	37	186
Hamburg	1717	557	438	3223	153	149
Hesse	1035	460	960	2141	264	69
Mecklenburg-W. P.	5802	1010	1197	1847	363	575
Lower Saxony	88921	3492	2023	4608	407	596
North Rhine-Westph.	81825	n. a.	6213	21292	553	n. a.
Rhineland-Palatinate	11651	324	152	6943	172	71
Saarland	1977	456	156	379	35	64
Saxony	19672	592	2991	6745	408	675
Saxony-Anhalt	16428	193	1739	3780	75	55
Schleswig-Holstein	13689	330	968	2570	75	73
Thuringia	12078	790	845	4992	280	75
Sum	313853	14409	27337	85505	4642	3453

Heavy metals and nutrients

According to Federal Soil Protection and Contamination Ordinance (BBodSchV, 1999, Appendix 2) an essential basis to derive and to update values for prevention, evaluation and application is the knowledge about representative but natural occurring background concentrations of contaminants in soils (LABO, 2003).

The study of the Federal Environmental Agency (Duijnisveld et al., 2008) has evaluated available data sets depending on the parent material of soil formation, soil horizons, main land use and settlement structures to derive nationwide and country-specific background concentrations of organic and inorganic matter (As, Cd, Hg, Pb, etc.) for topsoil, subsoil and underground. Figure 10 shows the background concentration of Pb in top and sub soil as an example.

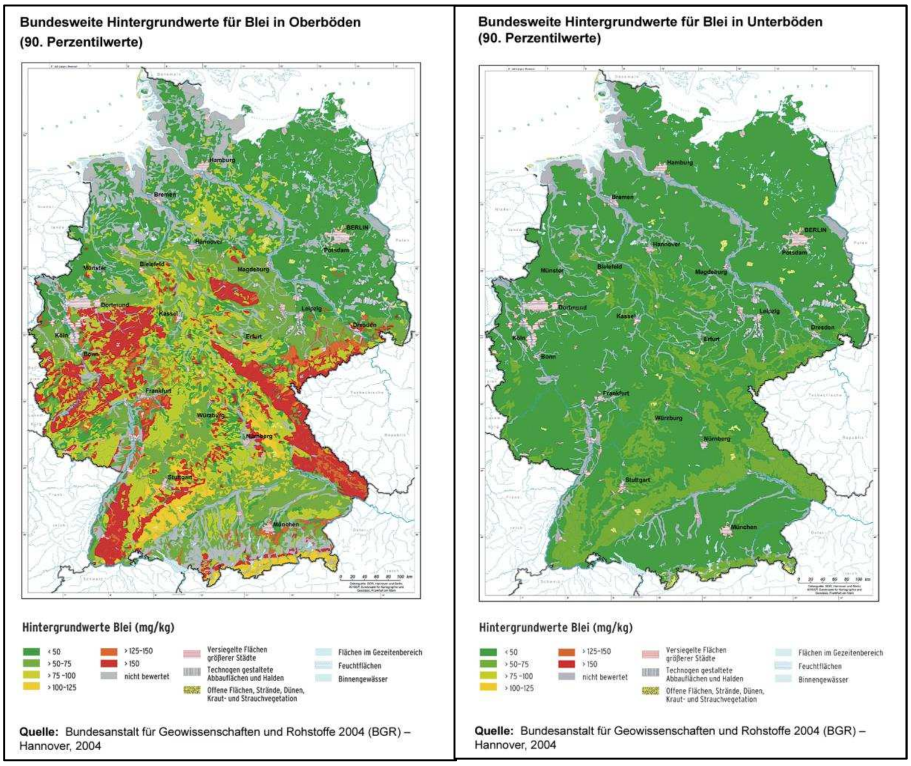


Figure10: Background concentration of Pb in top soil and sub soil (UBA, 20.04.2013)

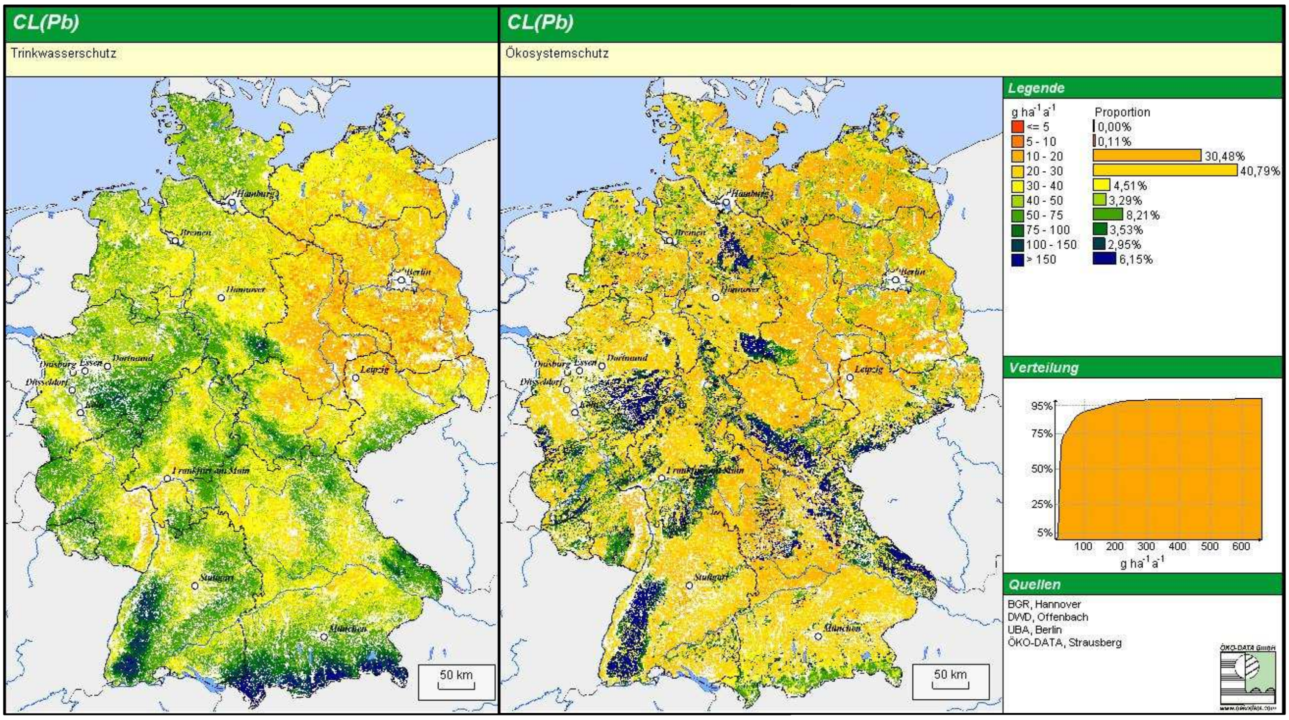


Figure 11: Critical load of Pb (a) drinking water protection, (b) eco system protection (Gauger et al., 2008)

The critical load (CL) represents the effect of pollutants on the environment. The critical load of a metal is defined as the highest total input rate in grams per hectare per year that is still below a limit-rate which will have no harmful effects on human health and ecosystems. The critical load concept demonstrates the sensitivity against metal inputs (e.g. Pb) (Figure 11). Based on the total area of Germany, the CL (Pb) values are mostly between 10 to 30 g ha^{-1} a^{-1} (ecological effects) and between 20 to 75 g ha^{-1} a^{-1} (protection of drinking water). For both receptors, less than 2 percent of the values are less than 10 g ha^{-1} a^{-1} (Gauger et al., 2008).

The risk of effects can only be evaluated by comparing of critical loads with actual inputs. The deposition input of Pb in 2004 is illustrated in Figure 12. Peak deposition can be detected in the urban industrial areas in western Germany (Ruhr area, Saarland, Bremen, Hamburg, Berlin). Lower Pb values were measured in the southern part of Germany (except the Black Forest). From 1995 to 2004 annual average Pb total deposition estimates are decreased by an average of 4.3 %.

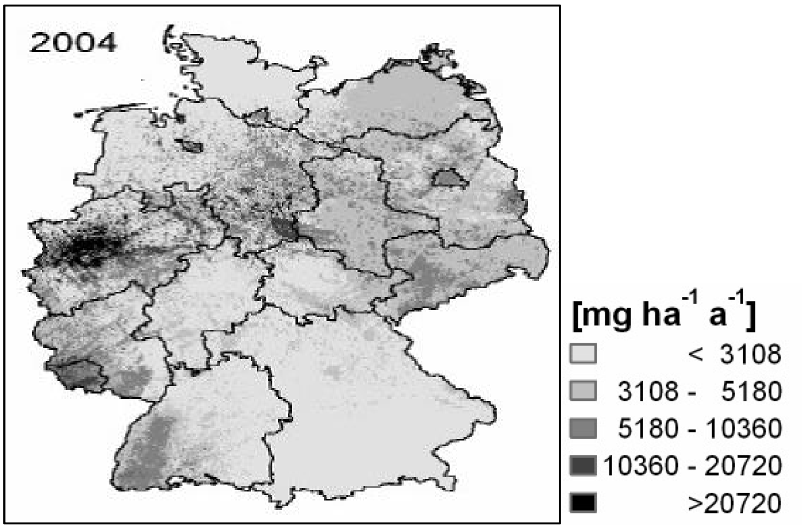


Figure 12: Deposition input of Pb (Gauger et al., 2007)

The range of possible inputs from fertilization amounts to Pb: 1.8 to 316 g ha^{-1} a^{-1}; Cd: 0.4 to 4.1 g ha^{-1} a^{-1}; Hg: 0.01 to 1.2 g ha^{-1} a^{-1}. For mineral and organic fertilization the Pb input is less than 10 g ha^{-1} a^{-1}. The critical load (Pb) of arable land is characterized at 16.7 g ha^{-1} a^{-1} (ecological effects) and 18.6 g ha^{-1} a^{-1} (protection of drinking water). With application of mineral and organic fertilization the CL (Pb) will not be exceeded. For compost and sewage sludge the Pb entries are above 40 g ha^{-1} a^{-1} Therefore, the average CL (Pb) will be exceeded for arable land (both in terms of ecosystem and drinking water protection) (Gauger et al., 2008).

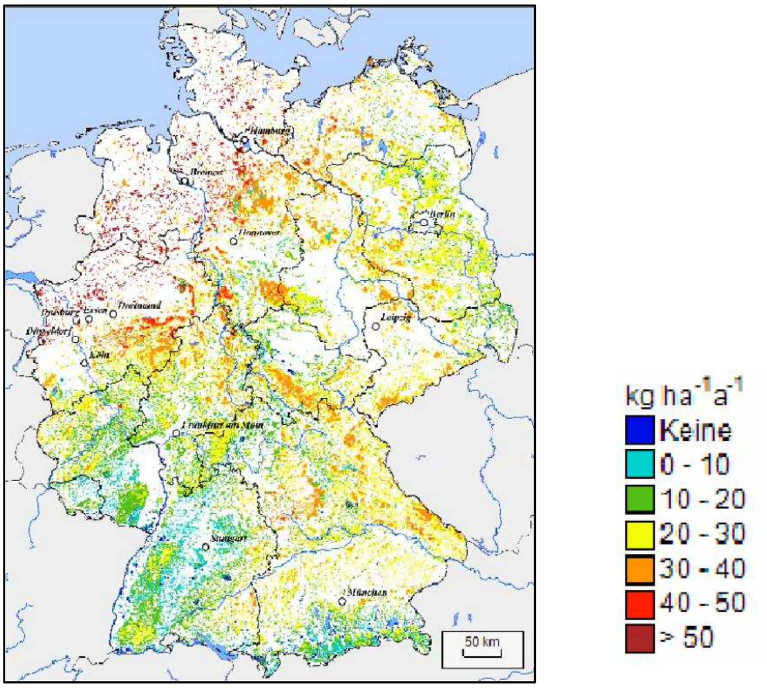


Figure 13: Spatial distribution of exceedance of critical loads for nitrogen eutrophication (2004) in Germany (Gauger et al., 2008)

As shown in Figure 13 an exceedance of the critical load for nitrogen is given in Germany. Critical loads for eutrophication exceeded about 95 % of the area of sensitive ecosystems. From 1990 to 2010 a small declining trend could be detected. During the last years the N input could not be significantly further decreased. If this trend maintains the N input will be one of the main threats for biodiversity in Germany (Figure 14) (BMU, 2009).

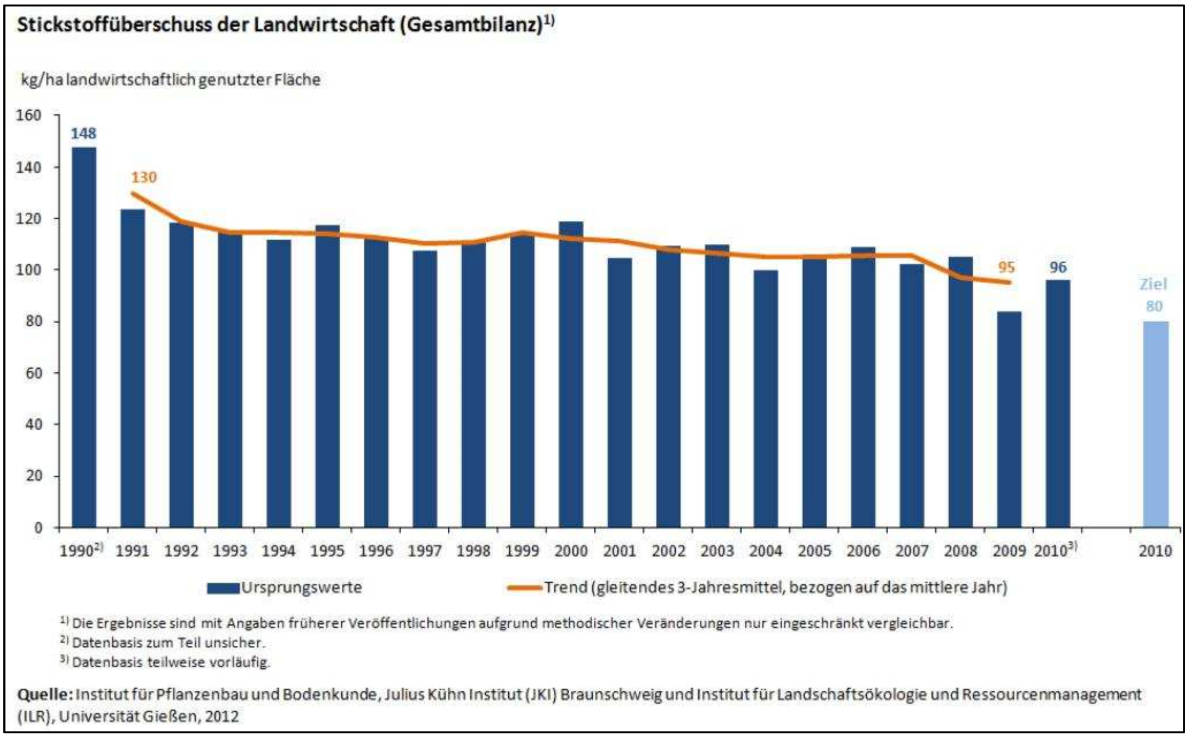


Figure 14: Nitrogen surplus of agriculture in Germany (UBA, 20.04.2013)

Soil biodiversity

The soil biodiversity and its assessment are focussed on the soil protection law in Germany. The report about “Determination and analysis of the soil quality in the context of the implementation and further development of the National Strategy on Biodiversity” (Römbke et al., 2012) describes that an improved monitoring of soil biodiversity will be extended on the existing permanent soil monitoring sites (BDF) (Figure 15).

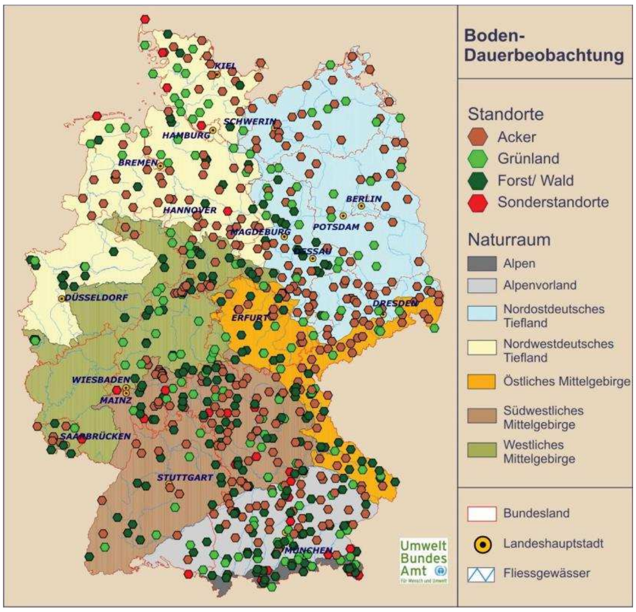


Figure 15: Permanent soil monitoring sites of Germany (points: brown = arable land, green = grassland, dark green = forestry, red = specific sites, areas: grey = Alps, light grey = foothills of the Alps, light blue = north-east lowland, beige = north-west lowland, orange = eastern low mountains, brown = south-western low mountains, green = western low mountains (Römbke et al., 2012)

The intensification of the monitoring will be used to define suitable biological indicators and to assess soil quality on the one hand. On the other hand reference values will be established to evaluate if the soil fulfils the habitat function. The monitoring of soil biodiversity is not centrally organized in Germany (Table 8).

Table 8 Investigation of soil biological parameters on permanent soil monitoring sites in Germany (2008) and percentage of the total numbers of sites per federal state (Glante, 2008; Römbke et al., 2012)

Federal states	Microbial biomass	basal respiration	metabolic quotient	Lumbricida	Small annelida (Enchy-traeidae)	Collembola	Nematoda	Enzyme activity
BB	30 (83%)	30 (83%)	30 (83%)	30 (83%)				
BW	156 (98%)	156 (98%)	156 (98%)	156 (98%)				
BY	133 (100%)	133 (100%)	133 (100%)	133 (100%)		133 (100%)	133 (100%)	133 (100%)
HH	3 (100%)			3 (100%)	3 (100%)			
HS								
MV	1 (n.a.)	1 (n.a.)		17 (n.a.)	17 (n.a.)	17 (n.a.)	17 (n.a.)	
NI	90 (100%)	90 (100%)	90 (100%)					
NRW	20 (100%)	20 (100%)		20 (100%)	20 (100%)			
RP	2 (13%)				2 (13%)	2 (13%)	2 (13%)	
SH	38 (100%)	38 (100%)			38 (100%)			
SL								
SN	5 (9%)	5 (9%)	5 (9%)					
ST	69 (99%)	69 (99%)	69 (99%)	69 (99%)				40 (5/%)
TH	32 (100%)	32 (100%)	32 (100%)	32 (100%)	14 (44%)	14 (44%)	14 (44%)	14 (44%)

In several federal states of Germany such as Baden-Württemberg, Brandenburg, Bavaria, Hamburg, Lower Saxony, North Rhine-Westphalia, Schleswig-Holstein and Thuringia a substantial amount of BDF data is available. However, in other states no or only a few investigations were conducted. Turbé et al. (2010) criticised the decentralised monitoring and the often practiced case-by-case basis. As Gardi et al. (2009) postulated the biodiversity monitoring with different approaches in the Germany federal states results in gaps and sampling differences.

Therefore, the mentioned report of the Federal Environmental Agency included the BDF and literature data about four soil biological groups (collembola, oribatida, lumbricida, enchytraeidae). The bio-geographical distribution of selected species of these four groups and their occurrence were assessed depending on the most important location factors (land use, pH, texture, organic content). Based on statistical analysis, reference values were proposed that are differentiated by habitat type or land use (Table 9).

Table 9: Reference and abundance values of oribatida for different biotope types as an example (Römbke et al., 2012)

Reference value	**deciduous forest**	**coniferous forest**	**grassland**	**arable land**
Sites	40	8	21	4
Abundance				
Mean	31000	46000	5800	750
Lower level	3500	14500	2300	400
Upper level	113000	125000	10000	1200
Number of species				
Mean	53	52	20	7
Lower level	25	43	8	4
Upper level	92	67	34	10

The biodiversity of three groups (except collembola as this species is not representative for Germany), is fully recognized in the analysed data. Therefore, the use of oribatida, lumbricida and enchytraeidae for soil biological site classification and assessment is recommended by the report due to the high diversity and high ecological relevance.

Despite of the recommendation the report summarized the following deficits: (i) the geographical distribution of study sites is very heterogeneous (Figure 16), (ii) the permanent monitoring sites do not provide data about collembola and oribatida at this time, (iii) microorganism’s data are not suitable for the evaluation of biodiversity.

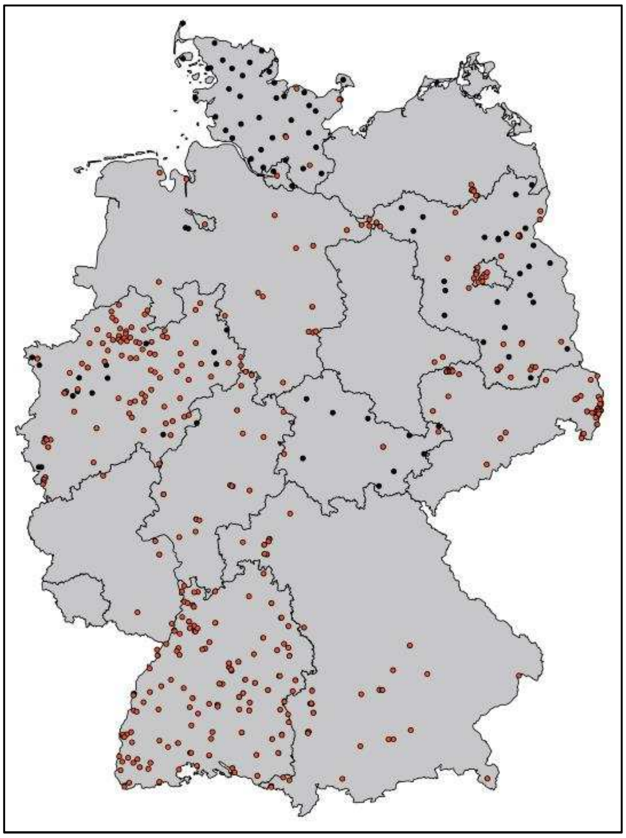


Figure 16: Sites with soil biodiversity data (Römbke et al., 2012)

To establish a sustainable monitoring of soil biodiversity in Germany, the survey of a representative data base for reference value should be pursued. The permanent soil monitoring sites represent a suitable base grid. 344 sites are located in arable use areas, 146 in grassland 247 in the forest, the rest is situated in special habitats.

The report also summarized the following recommendations about the monitoring of soil biodiversity in Germany in terms of a further development: (i) embrace more agricultural sites as they are currently underrepresented, (ii) realization of a cross-national approach of monitoring.

The BDF program is an excellent basis. With the mentioned extensions a comprehensive biological monitoring for sustainable suitability of soils could be realized in Germany.

With the help of the already existing point data about earthworms and raster data of climate, soil and land use a map about the appearance and biodiversity of earthworms for Germany was estimated (Figure 17). South and southwest of Germany is dominated by all forms of earthworms. The central part of Germany is characterised by anecic and endogeic lumbricida. Depending on the soil types the northern part of Germany only encompasses endogeic species.

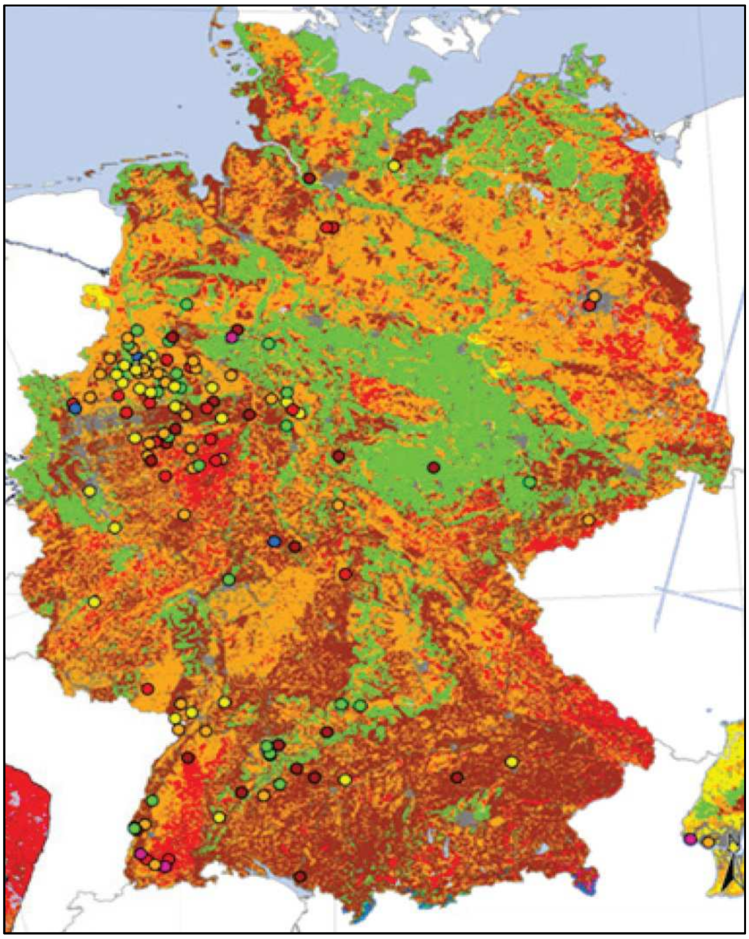


Figure 17: Appearance of earthworms in Germany based on locations (points) and site properties (climate, soil and land use), (blue = aneci, yellow = endogeic, red = epigeic, green = anecic + endogeic, pink = anecic + epigeic, orange = endogeic + epigeic, brown = all forms, grey = urban areas) (Römbke et al., 2012)

Soil covering / sealing

The soil covering in Germany consists of 53 % agricultural area, 29.8 % forest, 12.8 % urban area, 2.3 % water bodies and 2.1 % of other areas in 2004. From 1992 to 2007 urban areas increased to 16.1 % (1.1 % per year) due to urbanizational development. This corresponds to an average increase of 118 hectares per day during this period (settlement area = 95 ha per day, traffic = 23 ha per day). In general, the growth of urban areas results in a decrease of areas with agricultural use in Germany (BMU, 2009).

The adhoc-Working Group on Soil (LABO) estimates (data origin from the year 2006) a national average of sealed areas of about 46 % for settlement and traffic. In absolute terms, sealed urban areas amount to around 21,000 km² of the total area of 46,548 km². This represents about 6 % of the federal territory. But also unsealed settlement and traffic areas are often compacted by intensive use, contaminated with pollutants or denatured to other way.

According to the latest data (end of 2007) from the Federal Statistical Office, the settlement and traffic area contains 13.1 % (46,789 km²) of the soil area of Germany (357,104 km²).

A continuous increase of urban area in the last years caused a range of negative environmental and economic effects. E.g. important habitats for flora and fauna as well as agriculture and forestry were reduced, which are important for food production as well as resources and energy supply. Moreover, the associated fragmentation of the landscape may lead to a decrease of species and habitat diversity.

Therefore, the reduction of land use for settlement and transport is one of the seven priority goals in the National Sustainable Development Strategy of the Federal Government (established in 2002). The objective of the federal government of Germany is to reduce the average claiming of 120 ha per day over the last 12 years to 30 ha per day in 2020 (Figure 18). The on-going report of the German Government 2012 shows a further decrease. For 2007 to 2010 the daily average claiming amounts to 87 ha (Bundesregierung, 2012).

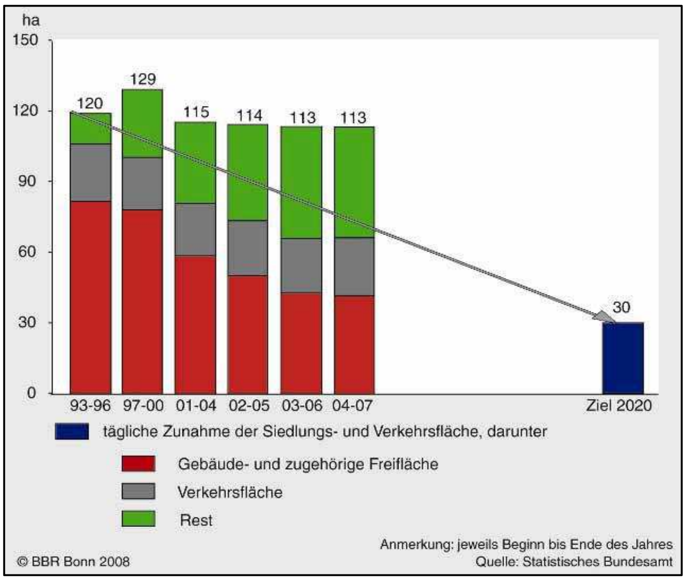


Figure 18: Daily claiming of urban areas (red = settlement, grey = traffic, green = other, blue = aim of 2020) (BMU, 2009)

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Soil degradation problems in Italy

Authors: Luca Bechini[1], Chiara Costamagna[2], Carlo Grignani[2], Laura Zavattaro[2]

[1] University of Milano, [2] University of Torino

Introduction

To carry out the review of soil degradation problems in Europe and Italy we have collected and analysed published European-level and national-level information, starting from the following tentative list of potentially important issues:

- erosion;
- decrease of soil organic matter content;
- reduced drainage;
- concentration of heavy metals;
- landslides;
- salinisation;
- soil acidification.

The information available about these issues is discussed in this document. For some of them we do not recommend the inclusion in CATCH-C as relevant soil degradation problems in Italy.

For some of the other issues (those that are important) we have attempted at linking the degradation problems at the ENZ (agri-environmental zones, for which we have used the version sent by Renske in May). It is important to note, however, that the link with ENZ was made on the basis of our knowledge, in a rather qualitative way. A more rigorous link between the soil degradation problems and the ENZ (or FTZ) could be more clearly established using a GIS to link the two maps (degradation problem and ENZ or FTZ). There is one problem to do that, though: we do not how many of the maps that we have found so far are available in a format that can be processed with a GIS.

Besides the review of information at the European and Italian scale, we have also made some inquiries at the regional (NUTS2) level, for which we report some examples. The region does not appear, however, as a reasonable scale for further surveys in CATCH-C. The problem in Italy is that most of soil surveys have been carried out at the regional level, and it is difficult to find aggregated information at the national level.

After we will have received a first feedback on this preliminary version, we may better detail (if needed) the link between soil degradation problems and crop management. Let us also remember that the definition of ENZ and FTZ might change in the near future.

European-wide sources of information

One source of maps for soil threats[17] is that maintained by the JRC within the European Soil Portal[18]. These maps are cited below in this document.

[17] http://eusoils.jrc.ec.europa.eu/library/themes/ThreatsMaps.html

We have also found an interesting review about soil monitoring in Europe and its harmonisation (Morvan et al., 2008).

Regarding the texture map that is shown on the European Soil Portal[19], we have verified and confirm that information on soil texture is not correct for northern Italy.

Erosion

Van der Knijff et al. (2000) have carried out a European-level estimate of the erosion risk, with details for Italy available in Van der Knijff et al. (1999). The study was carried out using the well known Wischmeier's equation and parametrising it locally. The cover management factor *C* was derived from remotely sensed NDVI values, separately for soil cover classes.

The map obtained in the study by Van der Knijff et al. (1999) is reported in Figure. The areas with the highest risk of erosion are found along the Alps and the Apennines. When this map is compared with the agri-environmental zones (Figure), it can be observed that the areas most affected by the risk of erosion are those with a typical Mediterranean climate, an intermediate soil texture (clay < 35%; sand < 35%) and a slope ("SL4") of 4-7 degrees (ENZ12_SL4_TXT2 in the eastern part of Apennines in the centre and south of Italy, and ENZ13_SL4_TXT2 in Sicilia). In these areas erosion is variable, with losses up to a maximum of 40 t ha^{-1} yr^{-1}. Most of areas having a risk of erosion have a slope higher than 4 degrees; these include areas with relatively low slopes (4-7°) and areas in the mountain (Alps, Apennines). In the mountains, erosion is somewhat limited by forest cover. The southern region of Piemonte has high soil losses (20-40 t ha^{-1} yr^{-1}); for this area a regional study reports losses up to 60 t ha^{-1} yr^{-1}. Lower erosion levels in the plains (0-1 t ha^{-1} yr^{-1}) are not without risks, due to the losses of N and P that may be associated to fine soil particles, and thus induce eutrophication.

[18] http://eusoils.jrc.ec.europa.eu/

[19] http://eusoils.jrc.ec.europa.eu/ESDB_Archive/sgdbe/TEXT-SRF-DOMa3.pdf

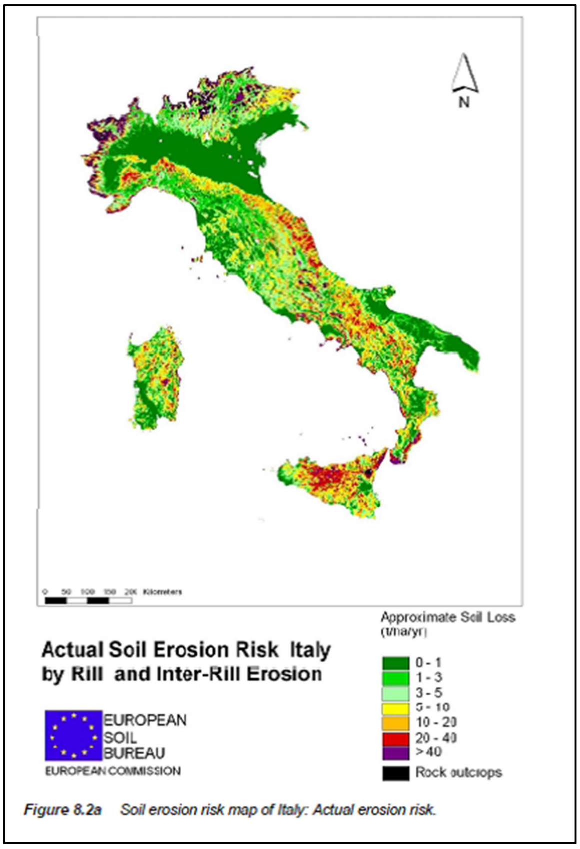

Figure 1. Actual soil erosion risk in Italy (from Van der Knijff et al., 1999).

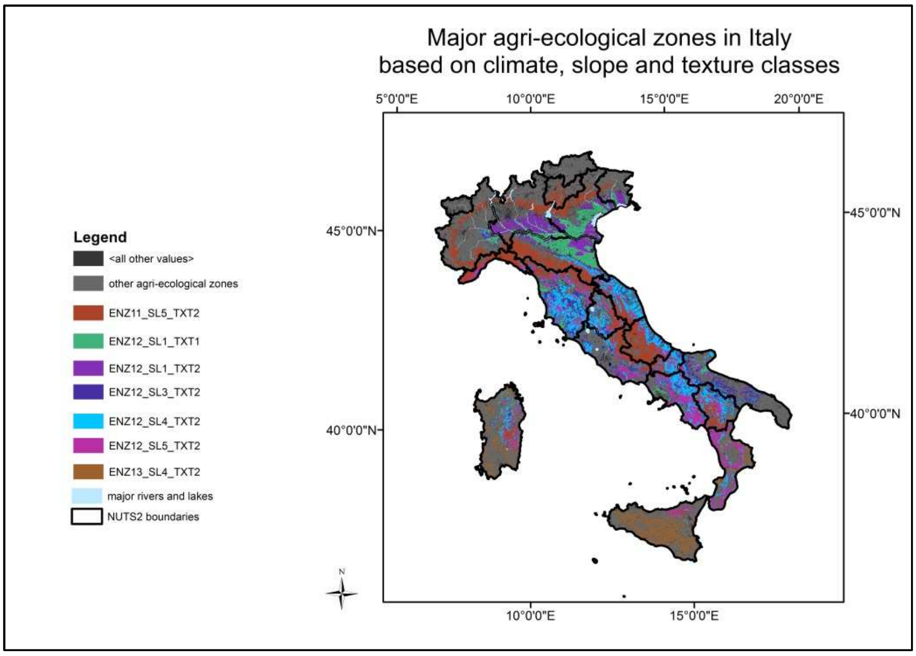

Figure 2. Major agri-environmental zones (ENZ) in Italy based on climate, slope and texture (CATCH-C project, version 22 May 2012).

Agri-environmental zones of Figure 2 are reported in Table 1and linked to the risk of erosion described in Figure. When the final version of the ENZs will be available, we can go back to this table and update it.

Table 1. Relationship between agri-environmental zones (ENZ) and estimated risk of erosion.

ENZ	Comment	Erosion risk ($t\ ha^{-1}\ yr^{-1}$)
ENZ11_SL5_TXT2	Alps and Apennines have variable risk of erosion, with more risk in the Centre and South of Italy	from 0-1 until > 40
ENZ12_SL1_TXT1 and ENZ12_SL1_TXT2	This area is concentrated in the Po valley; low risk of erosion due to low slope	0-1
ENZ12_SL3_TXT2	Spots of average risk, in the Centre (Toscana) and South (Puglia) of Italy	1-10
ENZ12_SL4_TXT2 (part)	The problem is located in the eastern Apennines and the Adriatic coast. It is also found in Basilicata (southern Italy)	10-40
ENZ12_SL4_TXT2 (part)	The problem is located in the western Apennines and the coast in Toscana	0-10
ENZ12_SL5_TXT2	The problem is spread in Southern Italy, in Calabria and small spots in the islands and in the Apennines of Liguria and Toscana	1-20-(40?)
ENZ13_SL4_TXT2	The problem is mainly found in Sicilia	5-40

Salinisation

A map of saline and sodic soils (Figure 3) is available at the European scale (European Soil Portal, 2012d). At the Italian level, Dazzi (2006) published a map of soil salinisation (Figure 4). He indicated that a larger portion of the national area (compared to the report of the European Soil Portal) is affected by salinisation, with large areas in Sicilia (about 10% of total area or 250,000 ha). Part of saline soils in Sicilia are gypsiferous. In the rest of Italy, saline soils are located in the coast in Toscana, Sardegna, Sicilia, Puglia and Emilia-Romagna. It should be underlined, however, that Dazzi (2006) did not indicate the methodology (source data, calculations procedures) used to realise the map. Differences with the map provided by the European Soil Portal may be due to the fact that Dazzi (2006) might have included areas with both primary and secondary salinisation[20].

[20] *Salinisation "is the accumulation of soluble salts of sodium, magnesium and calcium in soil to the extent that soil fertility is severely reduced" (European Soil Portal, 2012d). "A distinction can be made between primary and secondary salinisation processes.* ***Primary salinisation*** *involves salt accumulation through natural processes due to a high salt content of the parent material or in groundwater.* ***Secondary salinisation*** *is caused by human interventions such as inappropriate irrigation practices, e.g. with salt-rich irrigation water and/or insufficient drainage".*

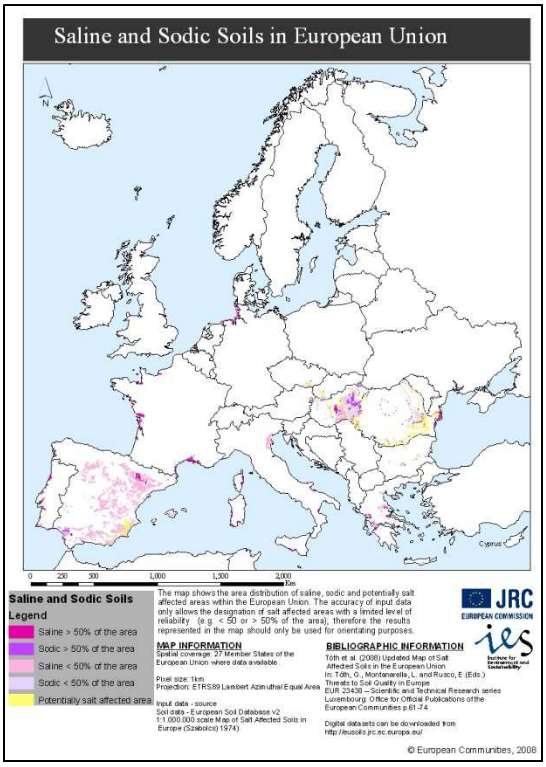

Figure 3. Map of saline and sodic soils in European Union (European Soil Portal).

Figure 4. Distribution of saline soils in Italy (Dazzi, 2006). In Sicily gypsiferous soils are included as well.

The problem of salinisation is concentrated in relatively small portions of Italy, and therefore we do not recommend further analysis in CATCH-C for our nation.

Decrease of soil organic matter content

For the whole Europe, a map of soil organic matter estimates in topsoil (Figure 5) was developed using data of the European Soil Database (Jones et al., 2003 and 2005) and is available on the JRC web site (European Soil Portal, 2012c).

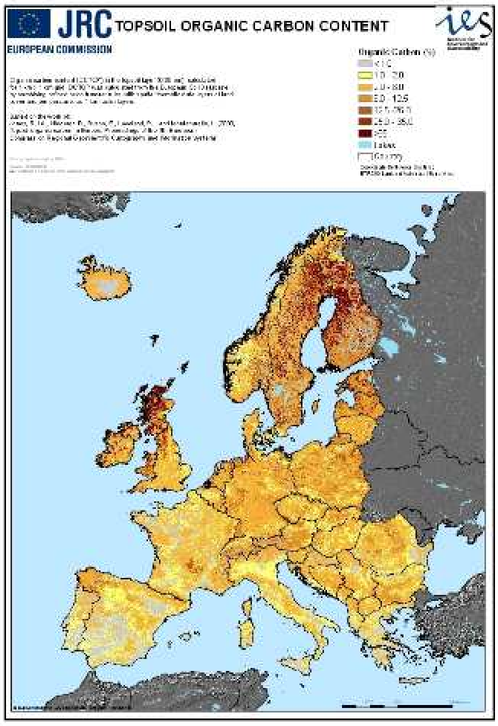

Figure 5. Map of topsoil organic carbon concentration (European Soil Portal).

These concentrations of soil organic carbon are neither compared with an ideal threshold nor are available for two or more moments in time. For this reason, it is not easy to use them to identify a soil degradation problem.

For Italy, Fantappiè et al. (2010) estimated soil organic carbon stock (CS) variations during the last three decades (from 1979 to 2008) and related them to land use changes. They used 20,702 georeferenced and dated observations (soil profiles and minipits) of soil organic carbon concentration and then spatialised point information using geographic attributes (decade, land use, SOTER morphological class, soil region, soil temperature regime, soil moisture regime, soil system lithology, soil temperature, soil aridity index, and elevation) to obtain estimates of soil carbon stocks with multiple linear regression.

Of interest for CATCH-C is the time trend of soil organic carbon concentration (Figure 6) estimated by Fantappiè et al. (2010) using multiple linear regression at three decades (1979–1988; 1989–1998; 1999–2008). Current estimates of soil organic carbon concentrations are significantly lower than those of about 30 years ago. As mentioned above, however, it is important to underline that these data were not measured, but estimated based on data measured at different dates and sites, and combined with a multiple regression approach (R^2 = 0.16, showing that the model only explains a small portion of data variability). The RMSE were of 73, 45 and 65 Mg C ha^{-1} for the three decades.

Three comments can be made regarding Figure 6: (i) the reduction of soil organic C concentration from 1979–1988 to 1989–1998 might have both environmental (climatic) and management reasons; (ii) the organic C concentration is lower in soils under arable crops than under meadows: this suggests that arable crops have the potential to accumulate more C than they actually have; (iii) soil organic C concentration is lower in some areas of Italy than in the rest of Europe. Figure 7 reports the map of estimated SC for the most recent decade, showing higher C stocks in the mountains where land use is mostly forest (areas with the highest slopes, indicated with SL4 and SL5 in the ENZs of Figure 2) and lower stocks in the plains.

For all these reasons, due to the importance of the problem and to the amount of data available, we recommend including the issue of soil organic carbon among those considered in CATCH-C.

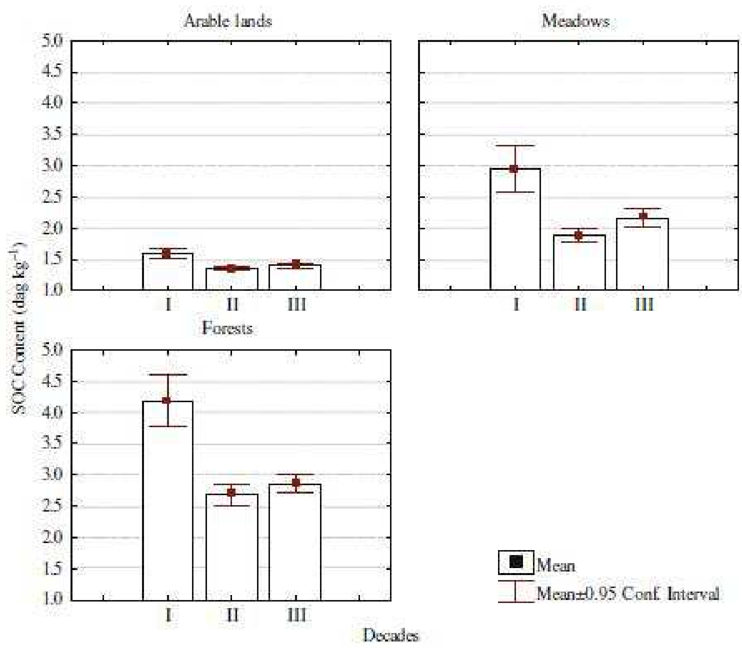

Fig. 34.7 Soil organic carbon content in the three decades considered and land uses. Differences between means are all statistically different ($P < 0.01$, or $P < 0.05$, between arable lands in decades II and III), except for the difference between forests in decades II and III

Figure 6. Soil organic carbon concentration in Italy in three decades for three land uses (Fantappiè et al., 2010).

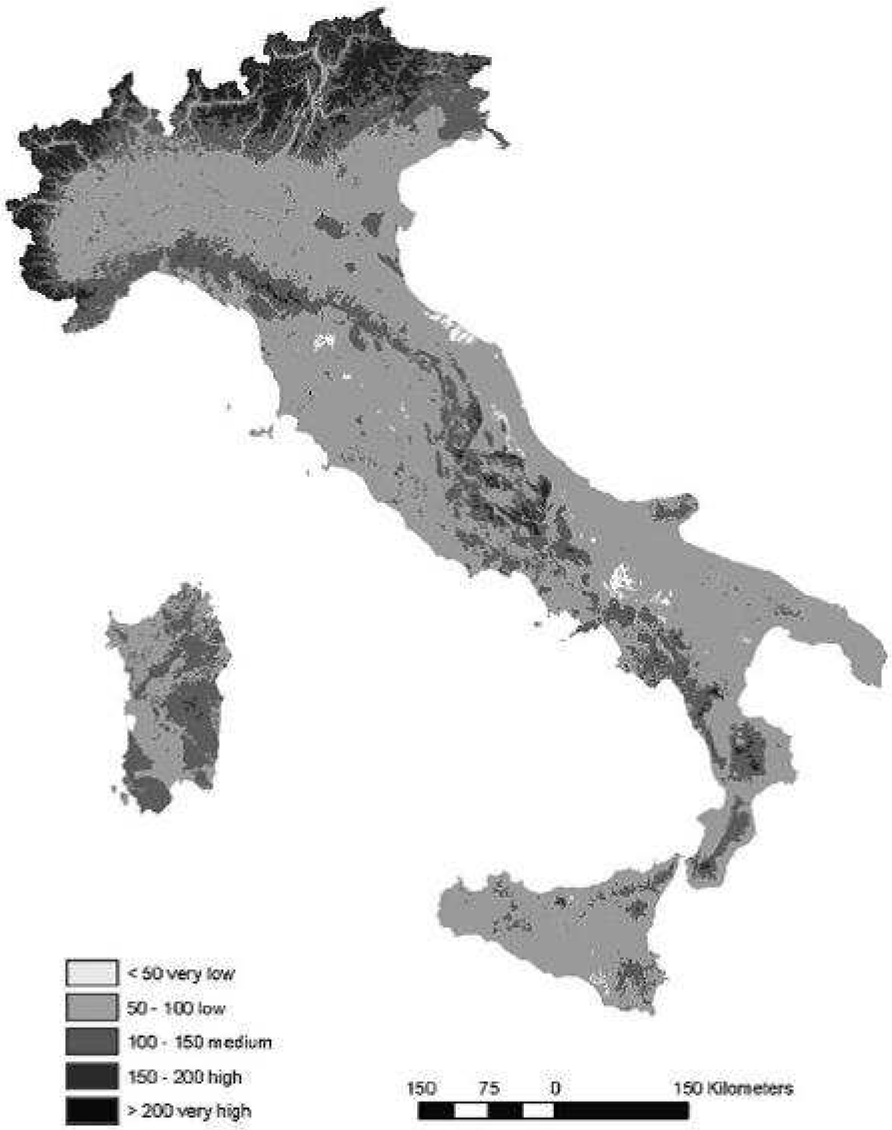

Fig. 34.10 Soil organic carbon stock of Italy in the years 1999–2008

Figure 7. Soil organic carbon stock of Italy (t C ha^{-1}) in the decade 1999-2008 (Fantappiè et al., 2010).

An example of regional-scale survey of soil organic matter is that available for Abruzzo (Marchetti et al., 2012). The Lombardia region (Brenna et al., 2010) has started a project, named SOILQUALIMON, which aims at periodically monitoring chemical, physical and biological soil properties. During the first campaign (2007–2009) these indicators were measured on samples taken at 44 sites: pH, organic C and N, carbonates, available phosphorus, heavy metal concentrations (Cd, Cu, Mn, Ni, Pb, Zn), C in microbial biomass, soil respiration, metabolic quotient, mineralisation coefficient, electrical conductivity, bulk density.

Another example of regional soil data is that of Piemonte. There are two web pages [21,22] reporting soil maps at the 1:250,000 and 1:50,000 scale. Of interest for CATCH-C are those of topsoil organic C stock, pH, carbonates, drainage and texture.

Soil acidification

The JRC created a quantitative map[23] (Figure 8) of estimated soil pH values across Europe by spatially interpolating 12,333 soil pH measurements from 11 different sources (European Soil Portal, 2012b).

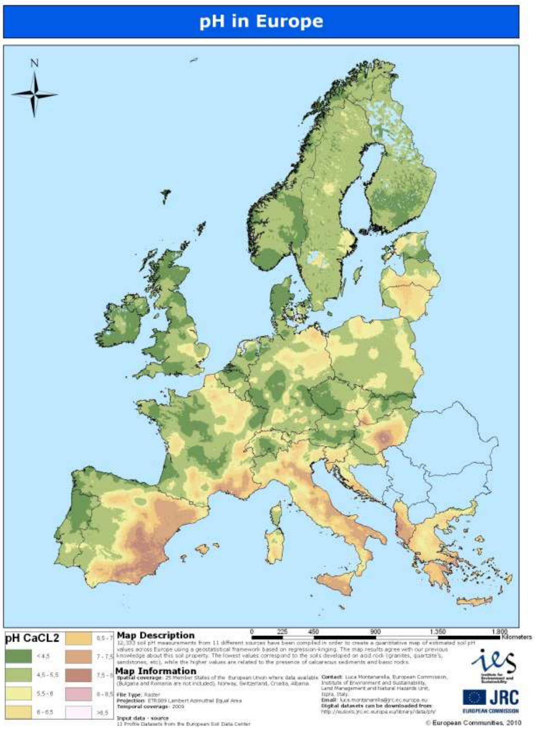

Figure 8.. Map of estimated soil pH in Europe (European Soil Portal).

The problem with this map is that it is available only for one moment in time. Comparisons are not possible with other moments, and therefore it is not possible to evaluate if acidification is on going. The box plot reported in Figure 9 shows that half of estimated pH values for agricultural soils lie between about 5.5 and 7.2.

[21] http://www.regione.piemonte.it/agri/area_tecnico_scientifica/suoli/suoli1_250/atlante_carto.htm

[22] http://www.regione.piemonte.it/agri/area_tecnico_scientifica/suoli/suoli1_50/atlante_carto.htm

[23] http://eusoils.jrc.ec.europa.eu/library/data/ph/Resources/ph2.jpg

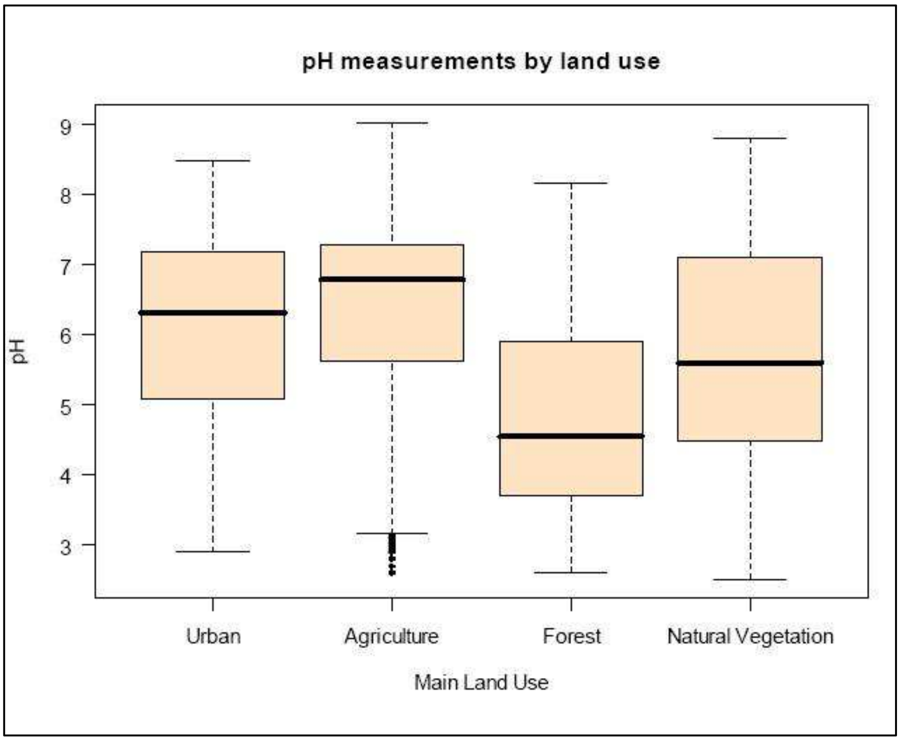

Figure 9. Boxplots of estimated pH ($CaCl_2$) for different major land use categories[24]

We did not find a study at the national level describing acidification problems of Italian soils. We do not expect acidification to be a major problem of soil degradation in Italy. Data comparing soil pH (measured or estimated) in different years are missing. We conclude that at the moment it is not recommended to include this issue among those considered in CATCH-C for Italy. We can probably try to gather some information from the analysis of literature about LTE, to understand how strong was acidification in Italian soils following different management options.

Landslides

The Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione Idrogeologica has developed since 1990 a database of historical information on landslides and floods in Italy, known as the National Research Council's AVI (Damaged Urban Areas) archive (Guzzetti, 2000; Guzzetti and Tonelli, 2004; IRPI, 2012). The database covers systematically the period 1917 to 2000, and non-systematically the periods 1900 to 1916 and 2001 to 2002 (Guzzetti and Tonelli, 2004). A web-based GIS system shows an estimate of geo-hydrological (i.e. landslide and flood) risk in Italy based on the available historical information (Figure; IRPI, 2012). The maximum susceptibility occurs in ENZ areas with high slope ("SL5"). There are also problems of landslides in Sicilia and along the western coast of Italy, where slope is lower (ENZ13_SL4_TXT2, ENZ_12_SL4_TXT2:Figure 2). The plains of the Po valley and of Puglia have the lowest susceptibility (0.0 - 0.2) and are characterised by low slopes.

It has to be discussed if this soil degradation problem is relevant within CATCH-C. On the one hand, as far as we know none of the LTEs in Italy with arable crops is dealing with this problem. On the other hand, management options used in agriculture can contribute to prevent landslides. Therefore we are rather uncertain if this issue should be included in CATCH-C.

[24] http://eusoils.jrc.ec.europa.eu/library/data/ph/

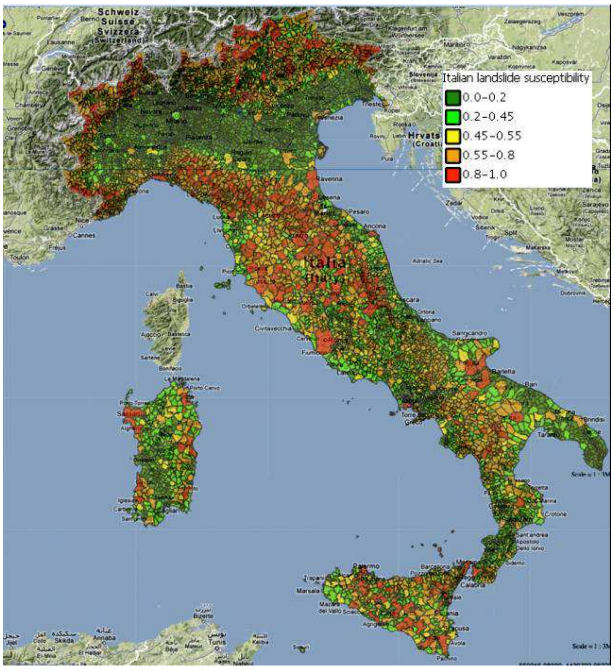

Figure 10. Italian landslide susceptibility (IRPI, 2012: http://webmap.irpi.cnr.it/).

Reduced drainage and compaction

On the European Soil Portal (2012a) a map[25] (Figure 11) is available that shows the natural susceptibility of agricultural soils to compaction if they are exposed to compaction. Therefore this map is more that of potential rather than actual compaction. "The evaluation of the soil's natural susceptibility is based on the creation of logical connections between relevant parameters (pedotransfer rules). The input parameters for these pedotransfer rules are taken from the attributes of the European soil database."

[25] http://eusoils.jrc.ec.europa.eu/library/themes/compaction/Resources/Compaction_300dpi.jpg

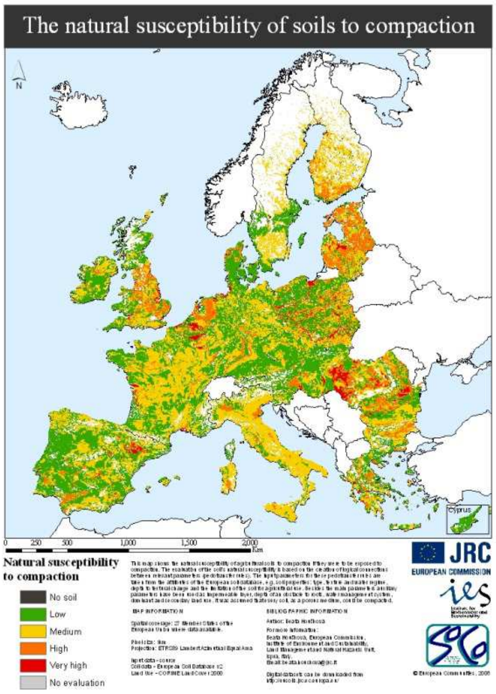

Figure 11. Natural susceptibility of soils to compaction (European Soil Portal).

Moreover, Jones et al. (2003) have elaborated a method to estimate vulnerability of subsoils for Europe, and have provided a provisional map (Figure 12).

Despite having few local data available for Italy, we think that soil compaction is a degradation problem that we should deal with in CATCH-C, due to its agronomic importance in our cropping systems.

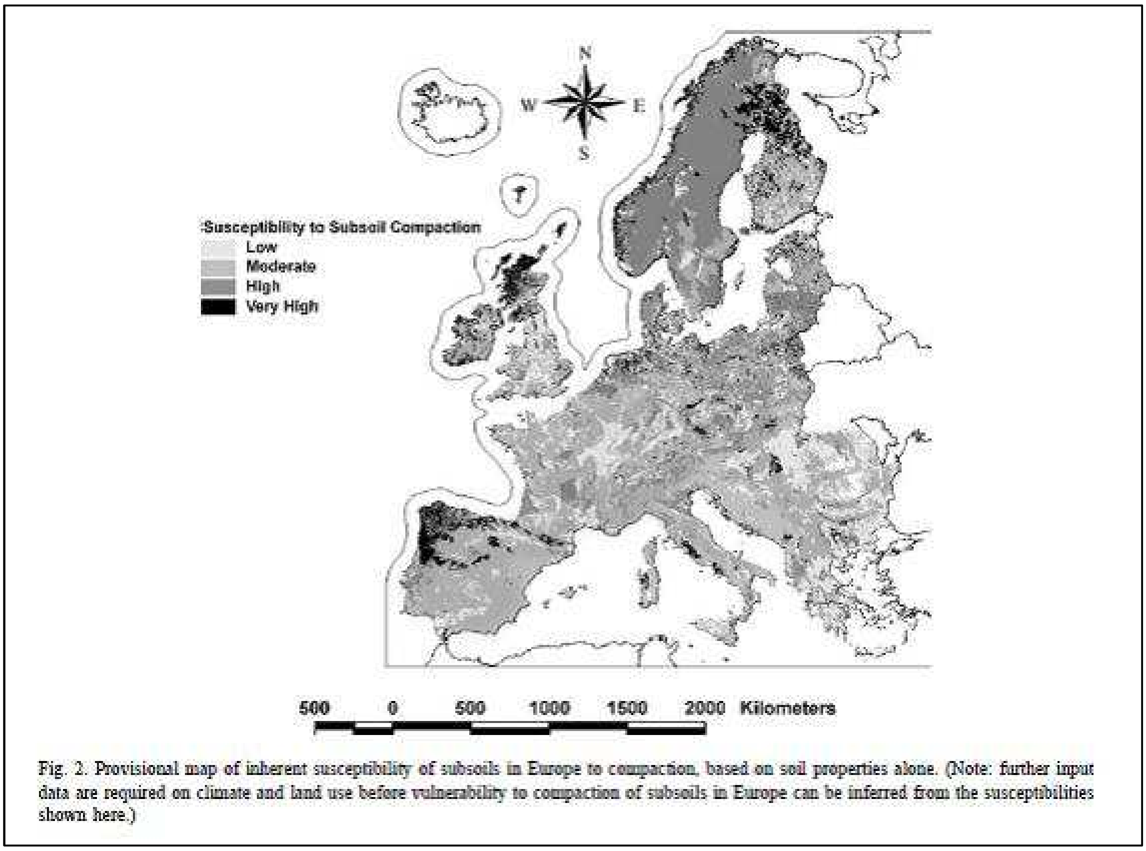

Figure 12. Provisional map of vulnerability of subsoil to compaction (Jones et al., 2003).

Concentration of heavy metals in the soil

The only report we have found with soil concentration of heavy metals is the work by Rodríguez Lado et al. (2008). They have carried out a geostatistical interpolation of 1588 georeferenced soil samples to model the distribution of eight critical heavy metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) in topsoil.

Morvan et al. (2008) cite the work that is carried out in the EMEP programme: "Deposition of heavy metals can cause soil contamination. The EMEP programme notably focuses on providing monitored and modelled data on concentrations, depositions and trans-boundary fluxes of heavy metals (Ilyin et al., 2006[26]) (...) in Europe. It relies on three main elements: the collection of emission data, the measurements of air and precipitation quality and the modelling of atmospheric transport and deposition of air pollution. (...) The EMEP programme provides data on annual averages of lead, cadmium and mercury concentrations in air and annual averages of lead, cadmium and mercury depositions."

In a work carried out for the Italian region of Lombardia (Sacchi et al., 2007) the concentration of cadmium, copper, nickel, lead, zinc and manganese was measured in about 1000 soil profiles that had been sampled previously during the preparation of pedological maps. The results have shown

26 http://www.msceast.org/reports/2_2011.pdf?00abd285a5050fb401a1aac822a594df=7904d337d073d2a5db08bd1083d61e3c

that: (i) in general (with the exception of soils cultivated with grape) heavy metals concentration in soils is largely below the thresholds commonly found in legislation; (ii) enrichment in heavy metals in agricultural soils can be observed near urban centres; (iii) the contribution of agriculture to heavy metal contamination exists, but it is limited to areas with grape cultivation and intensive livestock grazing; (iv) the contribution due to industrial activities and traffic appear much higher.

Water quality

Finally, we plan to review also the sources of information describing water quality to take into account the effects of inappropriate soil and crop management through measurable variables regarding water bodies. We believe that this survey is important, even if water quality itself is not a soil degradation problem.

We believe that data are available at the national level in Italy for nitrate, phosphorus and pesticide concentrations in the water.

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Soil degradation problems in the Netherlands

Authors: Annette Pronk, Hein ten Berge

Plant Research International, Wageningen The Netherlands

Introduction

In anticipation of the upcoming EU Thematic Strategy for Soil Protection in 2006, the Ministries of Agriculture, Nature and Food Quality (LNV) and Housing, Spatial Planning and the Environment (VROM) requested in 2004 a study on the soil status of the Netherlands related to the issues mentioned in the Strategy (Römkens and Oenema 2004). This study was then used to initiate quick scans on those issues that needed to be considered according to the EU Thematic Strategy for Soil Protection but which were not yet or insufficiently included in the Dutch soil policy (Bouma 2006, Hendriks 2011). In 2006 the Ministry requested a study to identify which topics were relevant for the Dutch situation (Wesselink, et al. 2006).

This document will first present the results of the quick scans, then summarize the publications on the identified threats according to the Government of the Netherlands (Bodem en ondergrond 2012) followed by a summary of the issues of the EU Soil Strategy not considered a threat at the moment according to the Government of the Netherlands.

Basic publications

The report "Quick scan soils in the Netherlands: overview of the soil status with reference to the forthcoming EU Soil Strategy" by Romkens and Oenema (2004) is one of the first documents that provides an overview of the soil status addressing the topics of the upcoming EU Soil Strategy:

(1) soil organic matter, (2) soil pollution (metals , nutrients, atmospheric N and S deposition and pesticides), (3) soil erosion, (4) soil compaction, (5) soil biodiversity, (6) soil salinization and (7) soil covering (sealing).

For the **decrease of organic matter** (1), they stated that "most soils in the Netherlands have a fair to large amount of organic matter, because soils are fertile, and receive organic matter via crop residues and animal manure. The large import of animal feed for the large number of pigs, poultry and in part callte in the Netherlands also contributes to the input of organic matter to soil. Yet, soils on average are loosing organic matter, as a consequense of drainage of peat soils, intensive cultivation and uneven distribution of crop residues and animal manure. Especially peat soils are loosing organic matter through the oxidation of peat."

For **soil pollution** (2) they stated that "Inputs of nutrients and heavy metals to agriculture (2 million ha) exceed the output via harvested biomass, leaching and natural decomposition. As a result soils have become enriched, especially with phosphorus and heavy metals. It has been estimated that 2 million ha of land has heavy metals contents in soil that impair soil funcitons. An estimated 1.3 million ha are phosphate saturated soils where P leaching loss exceeds or will exceed ecological tolerable limits." The protocol to estimate phosphate saturation of sandy soils (Van der Zee, et al. 1990, 1990) has been approved where for clay soils this was at the time still under consideration.

For **soil erosion** (3) the stated that "soil erosion through overland flow and wind is locally of concern in the hilly löss area in the south and in the reclaimed peat lands in the Veenkoloniën, respectively".

For **soil compaction** (4) they stated that "soil compaction is often a result of the heavy machinery when soil is wet".

For **soil biodiversity** (5) they stated that “soils hold a huge biodiversity of soil life, but only few species are known yet. There is evidence that land use, soil cultivation and soil pollution has altered soil biodiversity. Such changes may have consequenses for current and future soil functions”.

For **soil salinization** (6) they stated “a continuing soil subsidence in combination with the steady sea level rise will contribute to increasing salinization of soils and surface waters and will force the Netherlands to take drastic structural measures in the current century”.

Wesselink et al. (2006) compared the Dutch Policy for soil quality with the upcoming EU Soil strategy and answered three questions of which the first one was: What are the soil problems in the Netherlands?
They stated that: “The Dutch soils are characterized as “man made soil”. The intensive land use in the Netherlands, especially in the past, has not always been sustainable. Persistent problems in the Netherlands are local soil contamination from the past, the diffuse contamination with heavy metals and nutrients, and the oxidation of peat soils due to drainage. Due to the upcoming climate change, salinization may become a problem of a considerable magnitude. Appendix 1 shows in detail the identified problems, the changes over time, actions taken by the government and how it relates to the EU Soil Strategy. Appendix 1 also indicates that some themes from the EU Soil Strategy are not evaluated in the Netherlands and/or estimated to be of minor importance.

At this moment the Government’s official point of view is that 1. contamination, 2. loss of organic matter (humus) and 3. the construction of roads and buildings that seal the soil from the outside air, are the three most important threats of the soil (Bodem en ondergrond 2012). Soil compaction, salinization and erosion are considerable threats to agricultural soils.

Publications on identified soil threats (Bodem en ondergrond 2012)

Soil contamination

From the past

Van Wezel et al. (2007) indicated that about 400,000 locations are heavily polluted (Figure 1) of which about 11,000 locations are a yet a threat to humans, the so called emergency locations. From the 400,000 locations approximately 40% is situated on agricultural land (Figure 2).

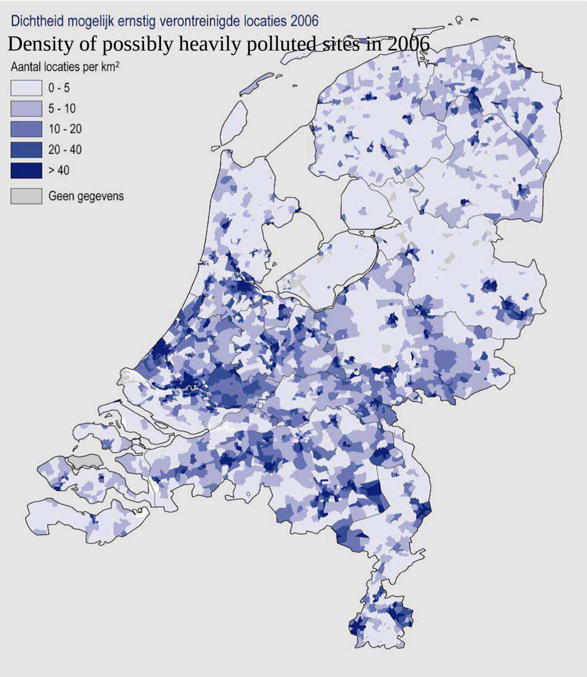

Figure 1: Distribution of the 400,000 locations suspected of severe pollution.

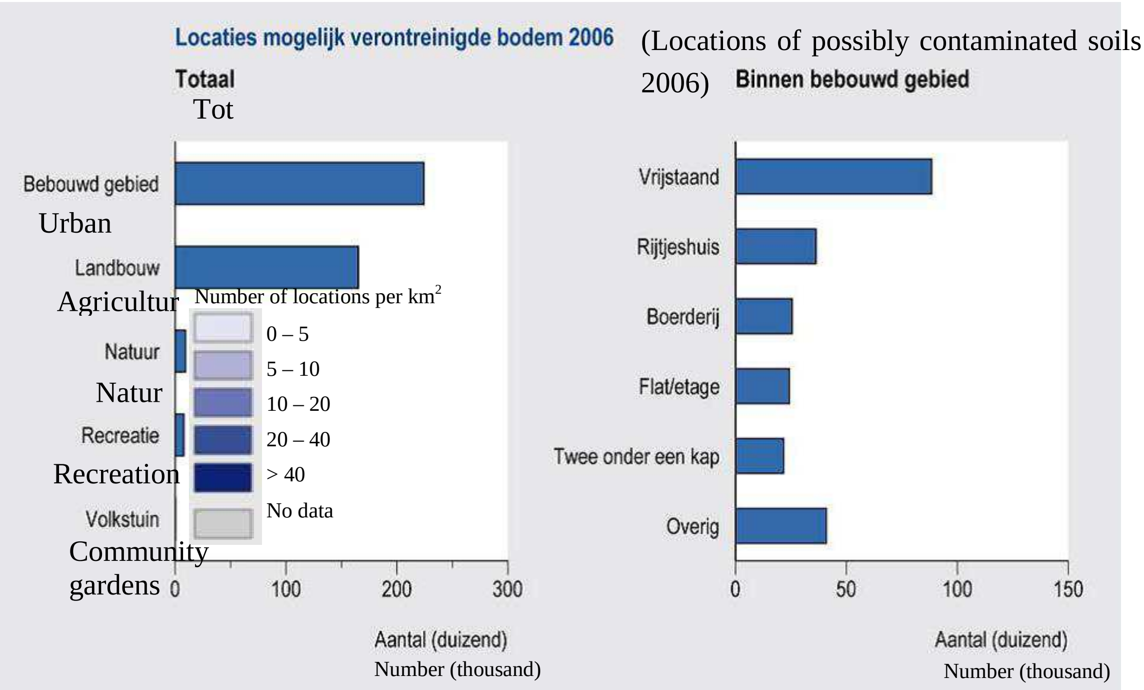

Figure 2: Overview of possible contaminated sites in relationship to land use and kind of house (Van Wezel, et al. 2007).

Diffuse contamination by heavy metals, pesticides and nutrients

- Heavy metals: up to 2005, the diffuse contamination by heavy metals is mainly caused by agricultural land use (www.emissieregistratie.nl), in particular by the use of fertilizers (synthetic and organic fertilizers). In 2005 the accumulation of heavy metals had slowed down compared to 1990 but eventually high concentrations above standard levels may occur.

- Pesticides: The objectives for 2010 for the environment and safe handling by workers (Ministerie van Landbouw Natuur en Voedselkwaliteit 2004) have not been achieved although crop protection has become more sustainable (Van Eerdt, et al. 2012). Van Eerdt et al (2012) conclude: " As a result of successful regulation, the use of plant protection products by farmers and growers has placed a considerably smaller burden on the environment, over the 1998-2010 period. Two-thirds of the environmental benefits were found to be due to the implementation of emission reduction measures. However, surface waters still contain too many residues from plant protection products. This adversely affects aquatic organisms as well as drinking water. Moreover, growers to date still pay insufficient attention to risks related to plant protection products and their safe handling."

- Nutrients: Excess application of fertilizers and manure increased nutrients in the soils from 1960 to 2000 with 60-100 kg P_2O_5/ha causing about 55% of the agricultural land to be saturated (Figure 3 left) with phosphate (Schoumans 2004). This is slightly lower than estimated by Romkens et al. (2004) due to a slightly different definition of phosphate saturation on clay soils. N-applications have induced N leaching to the surface and shallow groundwater (Fraters 2000) and are still forming a threat (Boumans and Fraters 2011). Most problems (Figure 3 right) are found at this moment at the sandy soils in the south of the Netherlands (Schoumans, et al. 2012).

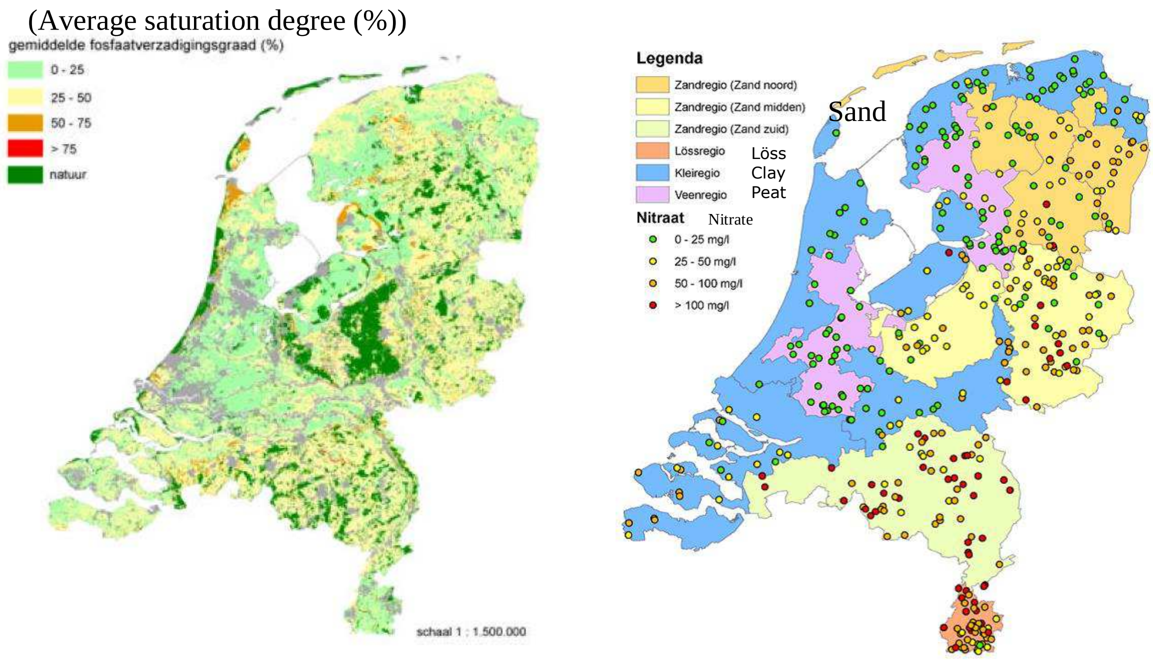

Figure 3: Left: phosphate saturated soils in the Netherlands as measured in the period 1992-1998. For agricultural land, four classes have been distinguished that take into account a criterion for the degree of phosphate saturation for specific types of soil (Schoumans 2004). Right: nitrate concentrations measured in the shallow ground water between 2007 and 2010 on farms of the LMM (nationwide monitoring network on the effects of the manure policy (Hooijboer and De Klijne 2012))

Loss of organic matter

The government considers loss of organic matter a threat to soils (Bodem en ondergrond 2012). Through the loss of organic matter and humus, soils will loose fertility, biodiversity, water holding capacity, increase climate change through an increased production of CO_2 released from humus breakdown and loose structure which causes erosion and local flooding problems. The effects of the loss of organic matter depend on soil types.

The oxidation of peat soils due to drainage

The major concern is that organic matter of peat soils is declining due to drainage (Kuikman, et al. 2005). The losses were estimated to be 2.2 ton organic matter per year (Smit and Kuikman 2005). However, the percentage of organic matter in these soils is not declining; it is the carbon stock that is deceasing. The area involved is approximately 290,000 ha (Kuikman, et al. 2005).

Soil organic matter in mineral soils

The threat may be a decrease of soil organic matter content of mineral soils. On average, there is no decrease of organic matter contents of most soils in the Netherland (Chardon, et al. 2009, Hanegraaf, et al. 2009, Reijneveld, et al. 2009) although the organic matter stock declines on peat soils. In addition, some areas have suffered from declining soil organic matter contents as they are no longer classified as peat soils (Pleijter 2004). For example, from 1980 to 2003 approximately 46% of the peat soils in the vicinity of Schonenbeek are no longer classified as peat soils due to decreased soil organic matter contents (Figure 4) (De Vries 2006). Also, some studies indicate that on sandy soils in Drenthe with potato, bulbs and grass slight decline on organic matter content could be found (Hanegraaf, et al. 2009) and that on dune sand in Noord Holland and Zuid Holland with ornamental crops like bulbs, perennial flowers and ornamentals, organic matter content declines to below 1% (Pronk 2007, Pronk, et al. 2012). However, for other regions, such as sandy soils in Noord Limburg and West Brabant, organic matter content can be sustained with relative simple measures (Pronk and Korevaar 2008).

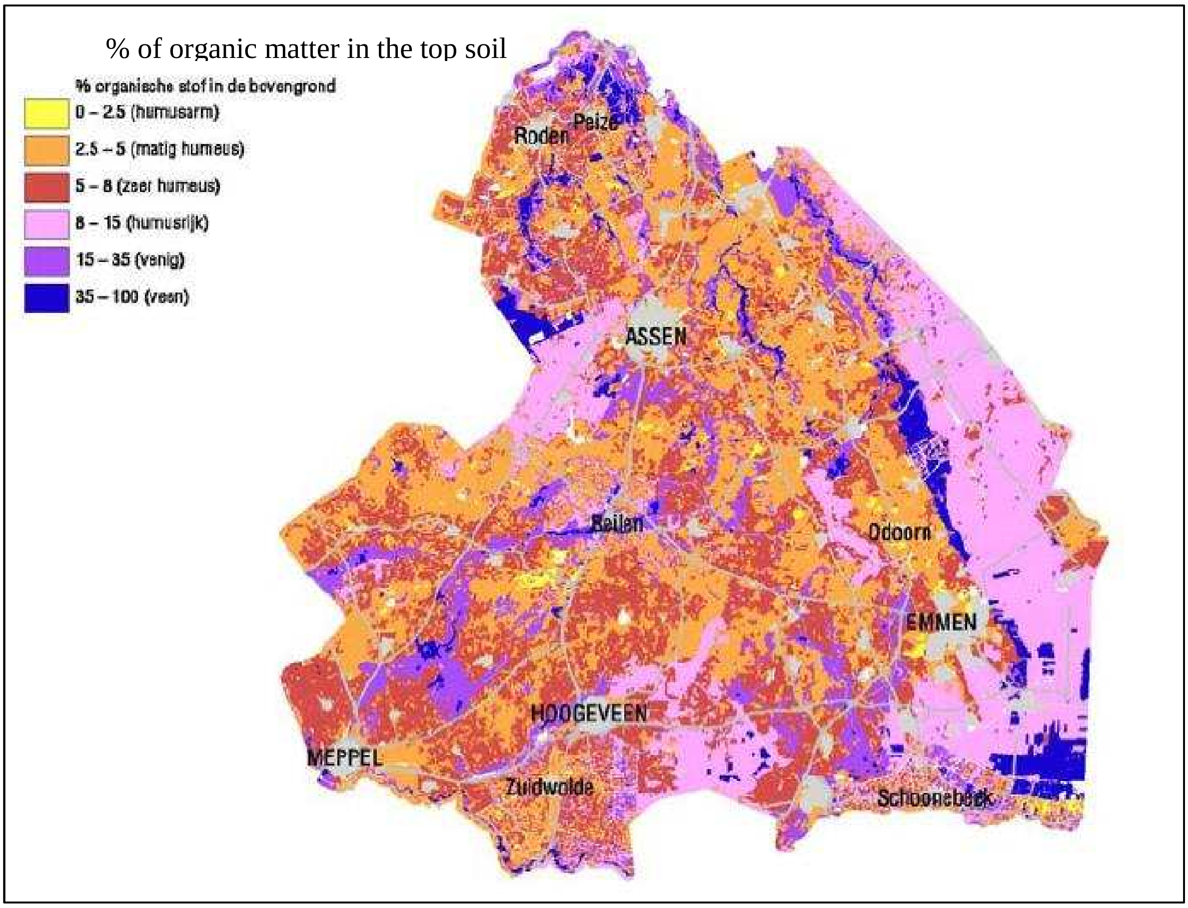

Figure 4: Organic matter content in the top soil of Drenthe (De Vries and Brouwer 2006)

The "National Soil Quality Monitoring Network"

The National Soil Quality Monitoring Network is a long term monitoring program with approximately 200 sampling locations, mostly on agricultural land with discernible agricultural farm types (10 classes) (De Jong and Van der Hoek 2009). The network was initiated in 1993 and two rounds of evaluation have been carried out, one in 1997 and one in 2003. The primary goal of the network is to monitor changes in soil quality in the rural area related to diffuse emissions. The second goal is the description of the current soil quality and if possible the explanation of the current soil quality.

Soil covering

The Quick Scan on soil covering/sealing (Bouma 2006) revealed that a policy exclusively on soil sealing was not in place at the moment (2006) or in preparation but that the issue was addressed from adjacent policies like the prevention of trouble by flooding or special planning. In these adjacent policies measures are in place that prevent or regulate soil sealing. The Technical Committee Soil Protection (TCB) was asked by the Ministry of VWA in 2008 to investigate the effects of soil sealing and to prepare an advice on the effects of soil sealing (TCB 2009). The TCB displayed the benefits and burdens of soil sealing. The study also showed that methods to evaluate "soil sealing" are not standardized and that national data on soil covering in the sense of soil sealing are not available. However, based on recent studies on green areas related to postal zones, the TCB estimates that soil sealing is in general approximately 20% for rural areas and approximately 80% for urban areas (TCB 2009). Most soils are covered due to urbanization. It is therefore that the TCB has carried out a study which proposed to set limits on soil covering in newly developed urban areas (TCB 2010). In addition, a decision support tool was developed for rural areas to mitigate effects of soil sealing on ecosystems services and to provide boundary conditions for the mitigation measures (Huijsmans, et al. 2011).

Publications on additional soil threats

Soil erosion

The threat on soil erosion may be due to water and/or wind erosion. Soil erosion due to water erosion occurs in the hilly part of the Netherlands in the south. Estimates of the loss of soils into water basins for the Etzenrade catchment in Zuid-Limburg was approximately 14 tons per ha per year on average, 418 tons/ha over a period of 30 years (De Roo 1991). In addition, eroded soil from the top of the hills is deposited onto the lower areas, in the valleys. The maximum erosion rate associated with this process were to be up to 155 tons per ha per year and the deposition rate at the lower areas of the valley was approximately 145 tons per ha per year (De Roo 1991). This corresponds to a maximum loss of the top soil of approximately 0.8 to 1 cm per ha per year from the top of the sloped fields. For arable fields an erosion of 24 tons per ha per year is estimated (Geelen and Swets 2006) and Reubens et al (2010) suggest losses of 10 to over 20 tons per ha per year although no reference is given for these latter values. Soil erosion due to water erosion is also identified to contribute to the emission of nutrients to the surface waters (Koopmans, et al. 2012). Soil erosion due to wind occurs in the Reclaimed Peat District (Veenkoloniën, North East) (Riksen 2006), on dune sands (West and coastal area) and to a lesser extent on the sandy soils in West Brabant and Zuid-Limburg or on arable farms situated in open and wide landscapes (Hessel, et al. 2011). Soil erosion due to wind is characterized as a local problem confined to arable land. The Agricultural Union for arable crops (Hoofd Productschap Akkerbouw, HPA), governed by public law with regulatory powers (www.productschapakkerbouw.nl), forced farmers and growers to cover the land to prevent wind erosion (green manures, straw, manure, etc.) (HPA 2003). However, this obligation has been lifted in 2003 as these measures have become general practices by growers and farmers involved (HPA 2003).

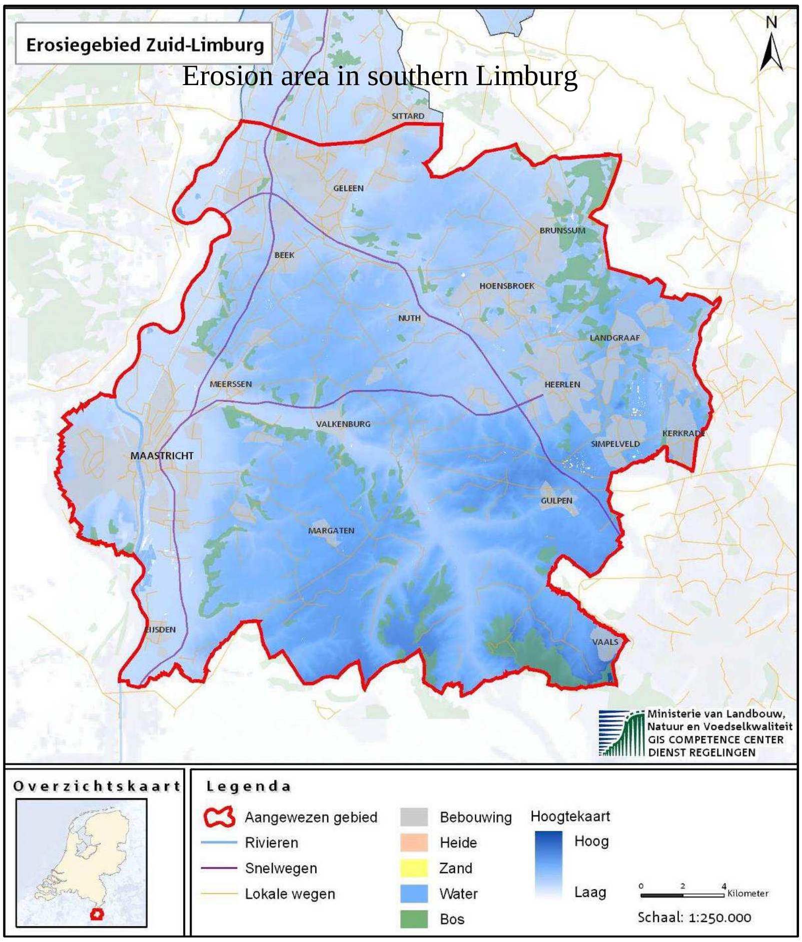

Figure 5: Overview of the area in southern Limburg where mandatory actions apply to prevent erosion (PA 2008)

The regions southern Limburg (runoff) and the Veenkoloniën (wind) are suggested to become priority areas for soil erosion (Hessel, et al. 2011). PA and PT (Productschap voor de Tuinbouw/Agricultural Union for vegetable growers, also governed by public law with regulatory powers (www.tuinbouw.nl)) have anticipated on soil erosion problems in Zuid-Limburg (Figure 5) and developed legal obligatory measures to mitigate effects (Productschap Akkerbouw and Productschap Tuinbouw 2011, PT 2009). From 2013 a new regulation comes in place that bans arable production on slopes >18% and introduces mandatory non-inversion soil management practices in combination with green manures. In addition, specific problems will face additional measures such as grass strips as buffers and/or collection ponds for runoff waters (Anonymous 2009, Productschap Akkerbouw and Productschap Tuinbouw 2011).

Soil compaction

This threat may be the loss of soils by irreversible compaction. Compaction of soils can happen in the top soil or subsoil. Top soils are frequently loosened and therefore less likely to become irreversibly compacted as compared to subsoils (Van den Akker and De Groot 2008). At locations in fields where heavy machinery is turning, subsoils were even more compacted. An inventory on

the compaction of subsoils showed that compaction is likely to occure on sandy soils and loamy soils (Boels, et al. 1982). The total area at risk for subsoil compaction is estimated at 340,000 ha.
More recently, a risk assesment was done to estimate the susceptibility of subsoil compaction with three methods (Hack-ten Broeke, et al. 2009). The conclusion was that large parts of the country were susceptible to subsoil compaction based on different methods to estimate subsoil compaction (Figure 6), but that hardly any measurements are available to support that conclusion. More detailed maps with the risk of subsoil compaction in the different rural areas of the Netherlands have recently been completed (Van den Akker et al., 2013).

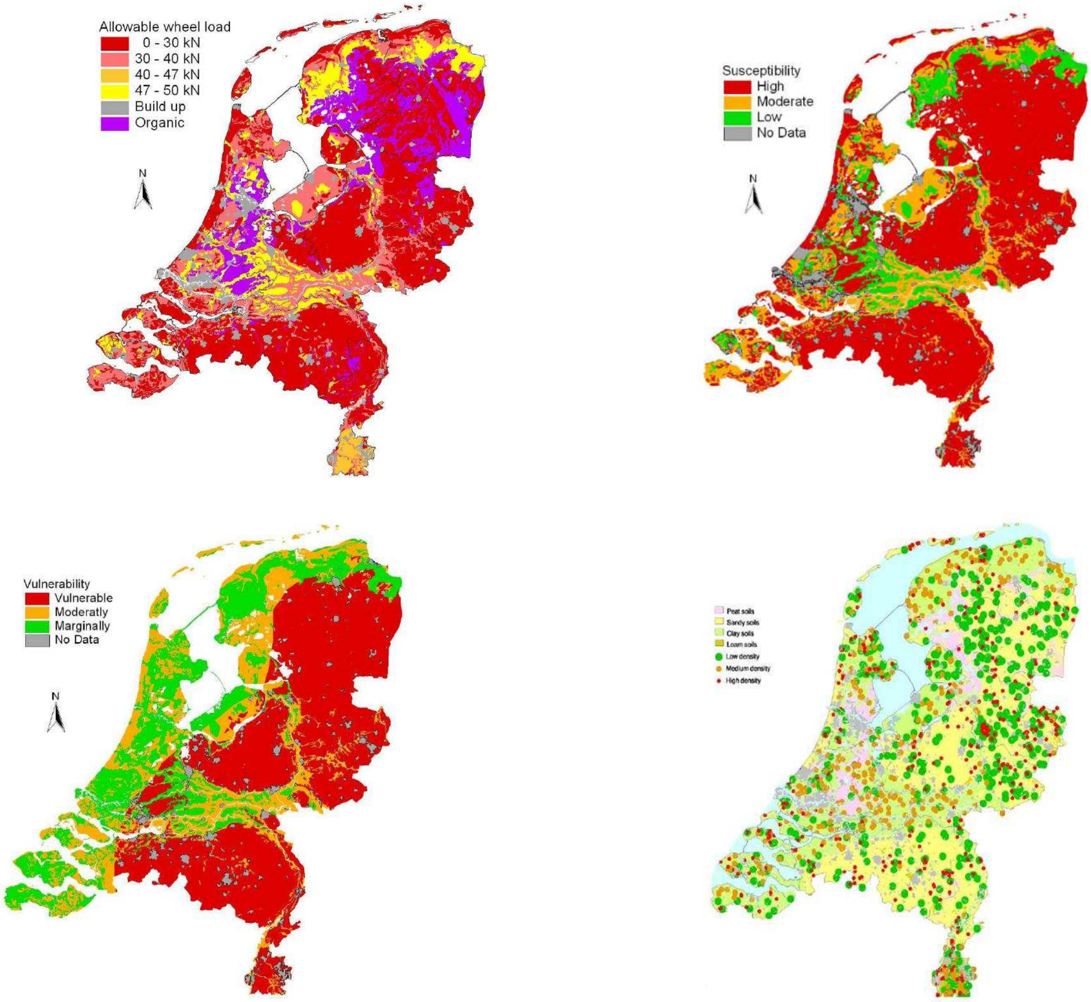

Figure 6: Susceptibility of subsoil compaction based on texture and packing density ratings related to the Dutch soil classification using the method of SIDDAS (top left), Spoor et al. (2003) (top right), Jones et al. (2003) (bottom left) or measured bulk densities (bottom right (Hack-ten Broeke, et al. 2009)).

A historical overview of soil compaction is given by Vermeulen and Van den Akker (2010). Based on the development of machinery, they estimated the changed pressure in the top soil and the subsoil. The results show that compaction due to machinery has changed from 1980 compared to 2010 (Figure 7).

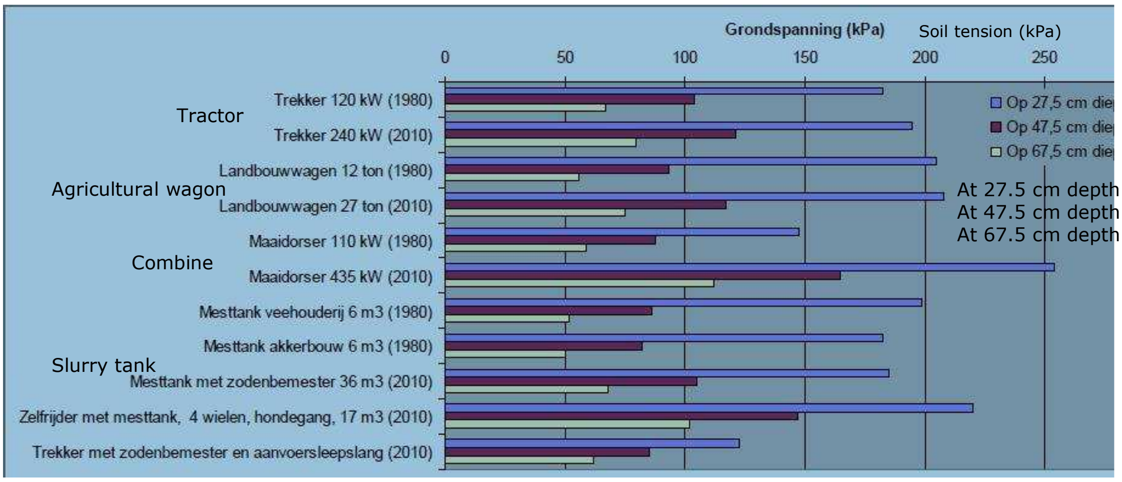

Figure 7: Estimated changes in soil compaction due to changed machinery (Vermeulen and Van den Akker 2010).

From Figure 7 it can be concluded that compaction in the subsoil only slightly increased between 1980 and 2010 for machinery in the field with high loads per axes compaction has considerable increased. These results are based on technical speficications of the available machinery. However, it is unknown what the actual fleet of machinery on agricultural farms is, what tire tension is used and to what extent the machines are used on the fields.

Soil biodiversity

Biodiversity in general has been under consideration for some time due to the action plan Biodiversity 2008 – 2011 (Anonymous 2012) in order to comply with the EU regulation. Soil biodiversity is part of this action plan and several projects have been carried out to investigate soil biodiversity. Initiatives focus on biological soil quality, how to measure and evaluate biological soil quality and how biological soil quality can be used to its advantages in agricultural production systems (Rutgers and Dirven-van Breemen 2012). Although closely related, biological soil quality differs from biodiversity. Biological soil quality includes both biodiversity (number of species) as well as biomass (of micro organisms) whereas biodiversity not necessarily includes biomass. With respect to biodiversity related to agricultural land use, only indirect relationships have been found: biodiversity declines when soil organic matter decreases or when soil compaction increases and decreased biodiversity is expected to reduce the so called "ecosystems services" (Rutgers, et al. 2009). Levels of organic matter and compaction are closely related to soil type and the intensity of the agricultural systems. On clay soils higher organic matter contents coincide with higher levels of biodiversity, irrespectively of agricultural system (husbandry of arable) whereas on sandy soils no clear relationship was found.
Biodiversity is at the moment not considered a threat as such, but the issue is taken care of through the threat 'loss of organic matter', mentioned in paragraph 3.3.

Soil salinization

Expected threats of salinization of soils are related to the salinization of surface water bodies and the groundwater resources. There are basically two levels of the threats identified (Brouwer and Huitema 2007): 1) at a local scale and 2) at a national scale.

The local scale

The salinization of surface water bodies is related to increased temperatures and drier conditions during the summer (Klopstra, et al. 2005). In those periods there is a shortage of fresh water in the water bodies in addition with low water tables of the rivers and subsequently low supply of fresh water. As sea levels are expected to rise the inlets to supply the fresh water bodies will be increasingly infused by sea water and the water bodies become salter. That salt will eventually salinize the soils. However, at the moment this threat is small and not considered an immediate threat or priority. It is put on the agenda for 2015 in the National Water Plan combined with the effects of climate change in the Netherlands (2010).

The national scale

The expected rise of the sea level will likely induce salinization of fresh groundwater bodies through 1. salinized surface waters and 2. Infusion of sea water through the dunes into the fresh water bodies (Van der Hoek 2012) and thus threatening the fresh water reservoirs for drinking water. In addition, sea water infusion may eventually also lead to salinization of agricultural soils.

Where salinization is considered a threat of the future, drought and flooding are problems that have the attention of politicians right now. Approximately 60% of the countries area is susceptible to flooding and that includes the most economic active part of the country, the west coast (www.rijksoverheid.nl/onderwerpen/deltaprogramma/aanleiding-deltaprogramma). Concerns were transformed into actions and the national Deltaprogram was initiated. The program aims at a save and attractive country to live, work and invest in. To make this possible an integrated strategy is chosen between safety and fresh water supply, and dikes and ground water table control.

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Appendix 1: Identified soil degradation in the Netherlands (Wesselink, et al. 2006).

Problems	Trend	Policy in the Nederland	EU Soil Strategy	Best management practices
Local historical chemical contamination: many locations in the Netherlands are contaminated due to various actions in the past. It is estimated that 55,000 locations have heavily polluted soils (Van Wezel, et al. 2007).	**The Dutch sanitation target is known and the progression is evaluated. During 2000-2004 5,188 polluted sites were cleaned (De Vogel, et al. 2005)**	The Dutch policy is registered has in the law on Soil Contamination end the applications in the Order of Council and regulations. The aim is to finish the sanitation process in 2030. The current speed of progress seems sufficient.	Strategy, aim and draw up a remediation program	Not relevant
Decline of organic matter: The Netherlands has 300,000 ha of land with a high percentage of organic matter, >10% (peaty soils). These soils are susceptible to oxidation followed by a decreased of the percentage of organic matter which leads to lower soil levels and increased CO_2-emisions	In most regions of the Netherlands the percentage of organic matter stabilized since the 70th, although hard evidence is lacking. On peaty soils the amount of organic matter is decreasing due to lower ground water levels. The fall of the soil level in the western peaty grassland area is on average 1 cm per year.	No specific policies exist on the conservation of organic matter in soils. On peaty grassland, falling soil levels by peat oxidation is a known problem for which long term solutions are being developed in several policy documents in different governmental departments. A crucial instrument is the decisions on the water table levels, issued by the Dutch water boards for a period of approximately 10 years for specific regions.	Identify risk area's, draw up action plans and execute these actions plans.	No removal of crop residues Use of green manures Increase water table on peaty soils Include crops that have more crop residues (silage corn to corn for corns only)
Wind erosion: area's sensitive to wind erosion are located in the east of Northern Brabant and the peaty soils in Groningen and Drenthe. Wind erosion is a small scale phenomenon in the Netherlands: it exists only on peaty areas during dry spring times or dry falls for a few of days per year.	Unknown. Small scale phenomenon	Since 2003 a regulation on wind erosion has been withdrawn (HPA 2003). The measures like soil cover with green manures, straw, crop residues or manure are common practices these days on wind erosion sensitive soils of bulb growers and in the peaty area's.	As above	Use green manures/cover crops, straw, or cellulose
Water erosion: water erosion is an issue on the hilly part in the south of the Netherlands. Estimated of de Roo (1991) based on long term measurements suggest an erosion of approximately 0.8 to 1 cm per year.	Unknown. Water erosion is not monitored.	In Limburg regulations on erosion prevention are effective (HPA 2003, PT 2004). Farms have to comply with these regulations in order to apply for income support within the CAP (Common Agricultural Policy) regulations (cross compliance).	As above	Use of Cover crops No arable crops on slopes < 2%
Soil compaction: Fine textured soils and medium textured soils are susceptible to compaction. Up till now, quantitative information on soil compaction problems and slacking is lacking.	Unknown. Soil compaction is not monitored.	There are no policies related to soil compaction. Soil compaction receives attention in agricultural practices as machinery increased in weight. The compaction due to increased weight of agricultural machines is for example compensated through lowered tire tension.	As above	Use of reduced tire tension of machinery
Salinization: irrigation does not contribute to salinization in the Netherlands. However, in the western part of the Netherlands salty seepage contributes to salinization. At the moment fresh water bodies can stand the salty seepage and only incidental and local salty seepage reaches the upper soils. Yield losses and subsequent loss of income related to salty seepage are yet limited (Klopstra, et al. 2005).	Salty seepage may increase in the future due to a rising sea water table, soil level decrease, the extraction of fresh water for irrigation and in periods with reduced precipitation.	The Dutch water boards, responsible for the local water quality as well as the quantity, have developed detailed procedures to maintain salt levels in the water bodies as low as possible.	As above	In the future: use salt tolerant crops
Soil sealing: by building houses, offices, business's and roads, soils are	In the Netherlands, soil sealing increases as the urban	There are no or only limited policies that explicitly are	Take suitable actions to	Not relevant

sealed. About 14% of the surface in the Netherland is covered (or semi-covered) by building (Centraal Bureau voor de Statistiek 2003). Within the EU only Belgium has a more land covered by buildings.	area increases.	targeting the reduction of soil sealing. In the Dutch policy for special planning and for water, several guidelines contribute to the awareness of and economical use of soils and subsoil's. These policies indirectly limit the effects of soil sealing.	limit soil sealing or to limit the effects of soil sealing.	
Diffuse contaminations: Heavy metals: there is a net increase of heavy metals on agricultural soils due to the use of fertilizers. This does not result in the loss of agricultural soils yet, or to problems related to food quality. Exemptions are the delta area's of the main rivers and area's with large scale historical diffuse contaminations (Kempen and the western peaty grassland area's, approximately 8% of the countries agricultural land). Agriculture is the largest source of (registered) emissions of heavy metals to the soil (Emission registration 2005). Crop protection: crop protection residues above the residue standard are found in 1.7-3.5% in the food produced in the Netherlands, averaged to daily intake. In the surface waters, one or more crop protection residues above the value of the Maximum Allowable Risk level (MTR-value) were found in 2003-2004 at approximately 50% of the sampling locations (MNP, 2006a).	The loading of agricultural soils with heavy metals is in 2003 reduced with 40% for zinc, 50% for copper and 80% for cadmium compared to 1990 (Emission registration, 2005). But heavy metal contents are still increasing. The time frame to which this can lead to exceeding standards is relatively long. The contamination of the soil system by crop protection emissions is reduced with 78% between 1998 and 2005 (Van Eerdt, et al. 2006)	The supply of zinc and copper is regulated since 2001 through limits on heavy metal contents in animal feed. The supply of cadmium decreased as phosphate fertilizer use decreased (following the Dutch fertilizer application regulations, including manure) and though the use of P-fertilizers low in cadmium. In addition, the EU water Framework Directive may lead to a further reduction of diffuse contaminations in soils through future standards of priority substances in water. The policy on crop protection products includes regulations on admission of use, reduction of emissions and norms of residues on or in crops and the support of integrated crop protection strategies.	Prevention of the loading of substances which hamper soil functions or which may potentially form a risks to humans or to the environment.	Not relevant
Over supply of nutrients: Through an over supply with fertilizers and manure, nutrient levels in the soil increased between 1960 and 2000 with an average of 60-100 kg P_2O_5 per ha agricultural land. The result is that approximately 55% of the agricultural soils are P-saturated (Schoumans, 2004).	The supplements of nitrogen and phosphorus on agricultural land are expected to be reduced with 50% and 70% respectively, compared to 1990 (Rijksinstituut voor Volksgezondheid en Milieuhygiene 2006). As a consequence, phosphorus accumulation reduces.	The Dutch implementation of the EU Nitrate Frame work includes a maximum nitrogen application with manure of 170 kg/ha (250 kg/ha for dairy farms within the derogation), and a standard for the total application of nitrogen which is crop specific. These standards aim to meet the nitrate standard of 50 mg NO_3-N/L in the groundwater. The EU and the Netherlands agreed on a balanced P-fertilization in 2015 (Tweede Kamer 2005). In addition, the EU water Framework Directive may lead to a further reduction of nitrogen and phosphorus accumulation in soils.	Prevention of the loading of substances which hamper soil functions or which may potentially form a risks to humans or to the environment.	Measures are mentioned in Best management practices of Fertilization of arable crops (De Haan and Dekker 2005): - determine the N and P demand - select relevant manure products - use a catch crop or green manure - leave straw on the field - alternate deep rooting crops with shallow rooting crops - maintain or improve soil structure - optimize irrigation - shallow ploughing or non turning soil management - use split applications for N - incorporate mineral soil levels into the application of N - use crop analysis to adjust N-applications to crops need - Use small not fertilized plots to determine crops need - use liquid fertilizers - use row application of N and P - use methods of application low in emissions - calibrate fertilizer application machinery to apply the right amount

Soil degradation problems in Poland

Authors: Grzegorz Siebielec, Artur Lopatka, Ewa Czyż, Alina Syp

Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy, Poland

This paper is a contribution to CATCH-C project – the task aimed at defining soil degradation processes within agri-environemntal zones of Europe. The data is based on large monitoring programs coordinated by IUNG. The paper is structured according to threats to soil quality as defined by EU Soil Thematic Strategy. The precise quantification of degradation processes within given agri-environmental zones would require linking IUNG spatial information with borders of the zones.

Organic matter content

Soil organic matter (SOM) content spatial variability in Poland is strongly driven by natural factors such as texture, slope or water regime. Higher located light texture soils are beyond impact of groundwater, and therefore are generally characterized by lower SOM content. The range of SOM in arable soils of Poland is wide (0.5-10%), however the average content is 2.2%. Organic soils are usually used for grasslands or are not utilized in agriculture.

The presented data is based on more than 45000 soil samples evenly distributed throughout the country, analyzed in 90s, but regularly updated with new information. The map of spatial distribution of SOM is produced based on this data and geocoding process utilizing SOM point data and soil map (1:25000) content (texture, soil suitability units) (Figure 1).

Share of soils with extremely low SOM content (<1%) is 6% whereas share of other content group is the following: 50%, 33% and 11% for 1-2%, 2-3.5% and >3.5% contents, respectively. Totally SOM content in 89% of soils is below the level of 3.5% (approx. 2% C) treated in Europe as low content. This is, however, consequence of specificity of Polish soils – often characterized by light texture and low water retention determining unfavorable conditions of OM accumulation processes. The highest share of soils with SOM>3.5% has been observed in Dolnoslaskie, Pomorskie and Slaskie NUTS2 regions.

In some regions the area of land utilized only for crop production increased with limited animal production and manure return to soil. This causes, along with simplification of crop rotation, negative balance of OM at farm level. We produced the map of OM balance based on data on crop structure and manure fertilization (Figure 2). Positive values (more OM provided of left in soil than lost with yield) are located in the areas of intensive animal production or substantial grassland contribution.

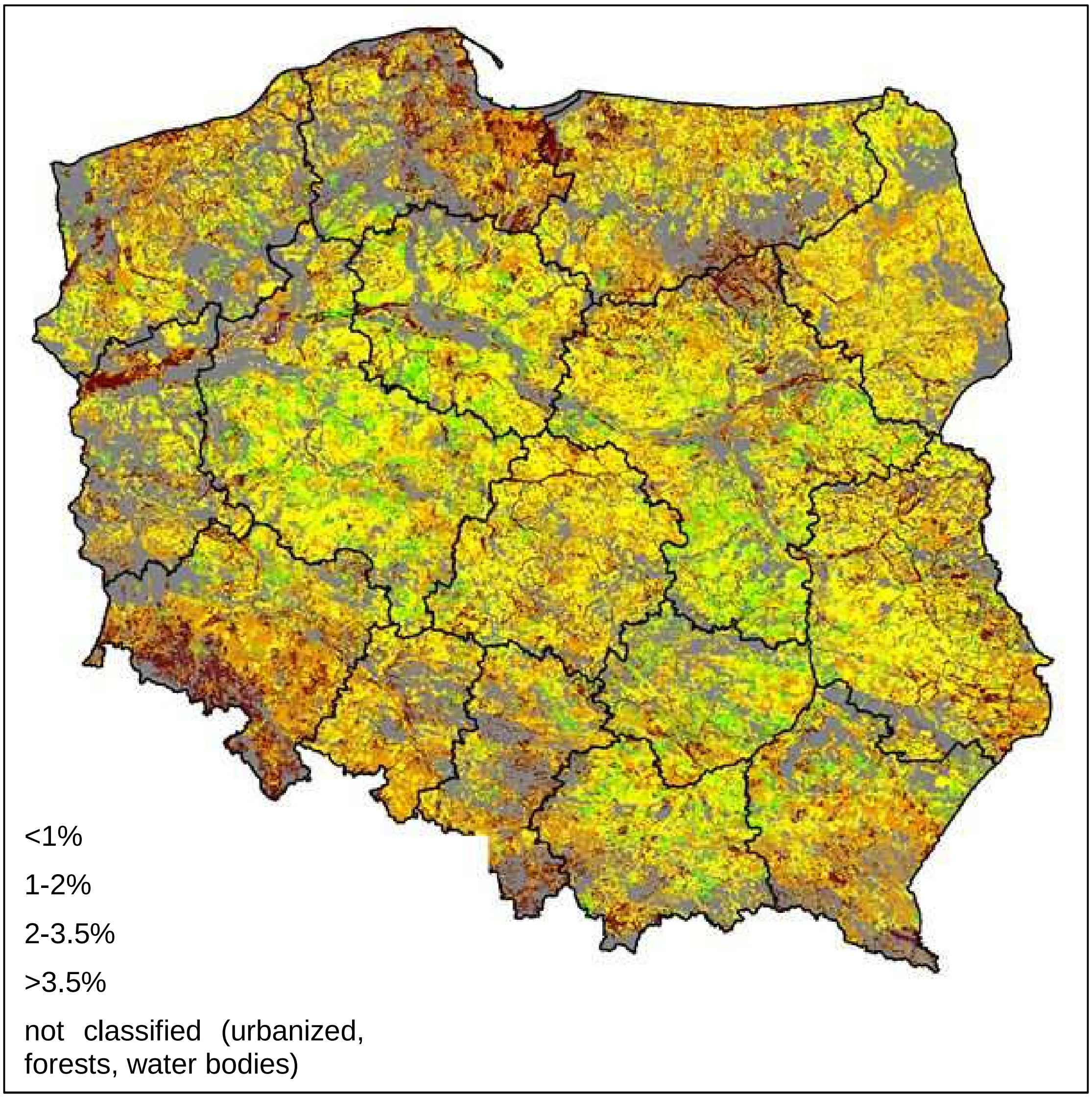

Figure 1. Map of SOM content in Poland

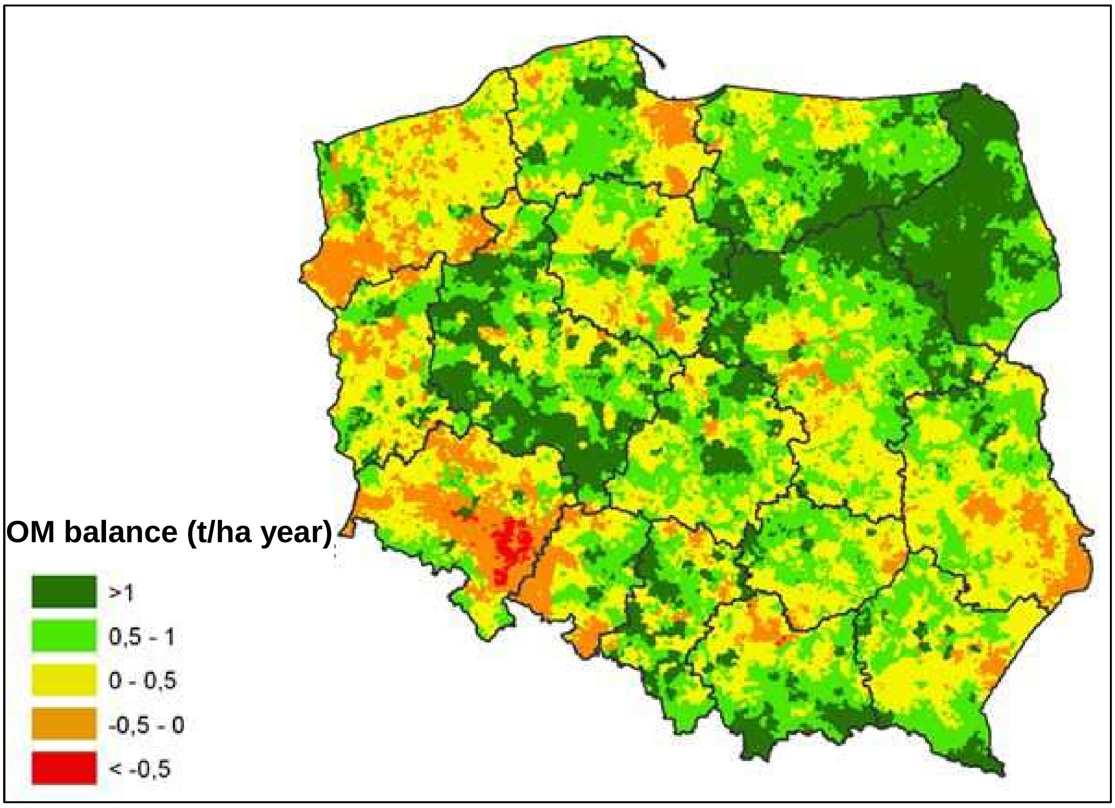

Figure 2. OM balance at farm level based on OM input/output statistics

Erosion

Water erosion data presented here was calculated using USLE model that that consists with such components as rainfall erodibility, soil susceptibility, slope and plant cover. According to the modeling results 96.7% of land in Poland is characterized by low erosion. The highest share of soils under high erosion risk is present in Malopolskie and Podkarpackie regions (7.4 and 5.1% of area, respectively) in the southern Poland (Figure 3).

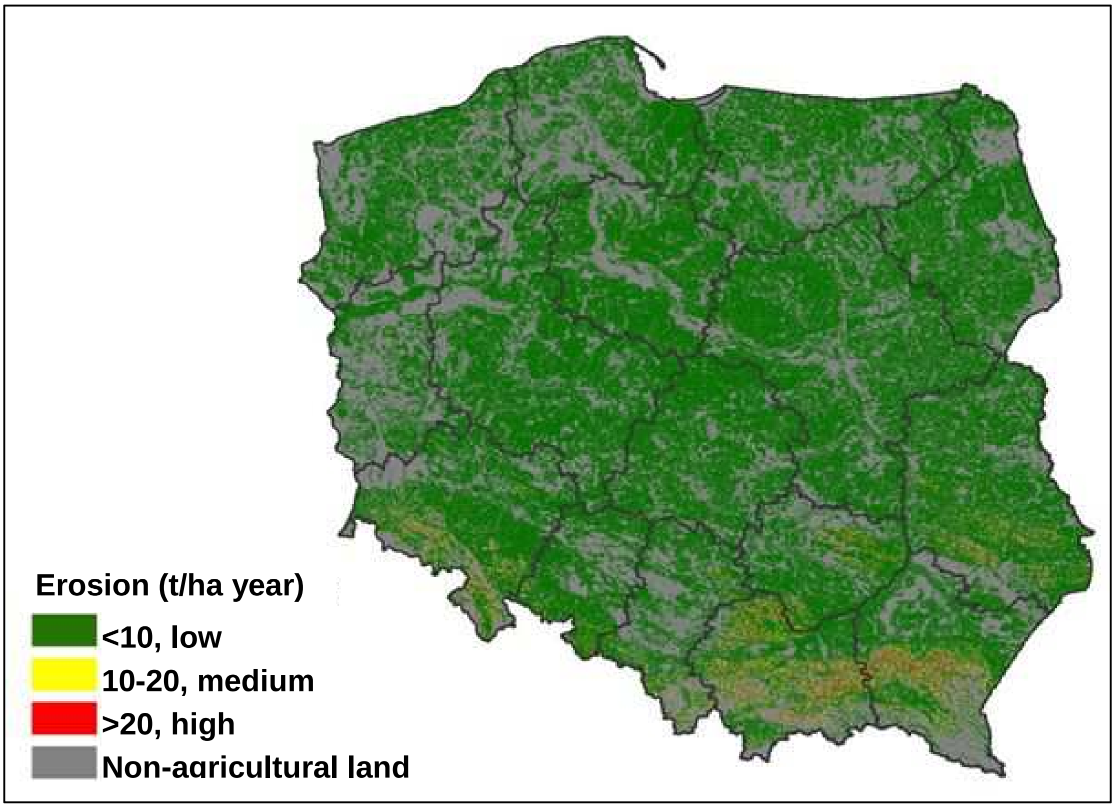

Figure 3. Soil water erosion within agricultural lands calculated by USLE model

Compaction

The map of soil susceptibility to compaction was produced based on simplified Alcor regression model utilizing SOM and texture information (Figure 4). The spatial input data originates from 1:100000 soil map with polygons linked to SOM and texture information representing 45000 soil profiles.

Polish soils exhibit high spatial variability of susceptibility to compaction which is related to mosaic of soil texture groups in most of regions. The highest share of soils sensitive to compaction stress has been measured in Dolnoslaskie and Malopolskie NUTS-2 regions.

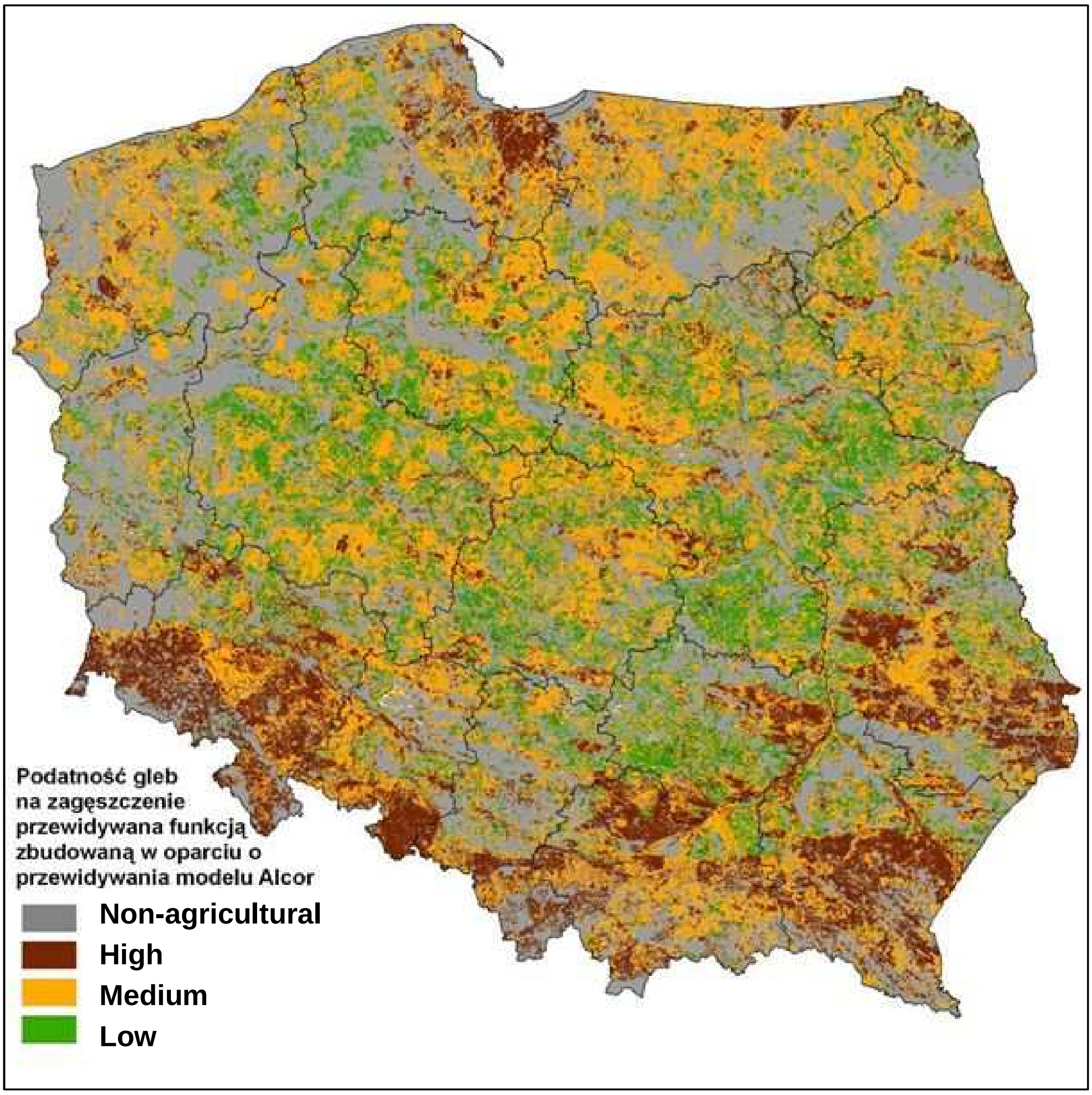

Figure 4. Map of soil susceptibility to compaction based on simplified Alcor model

Acidification

Acidification has not been listed by EU commission among major threats, however soil acidity is a major factor affecting crop production in Poland. Over 50% of agricultural soils is classified as acidic (pH in KCl <5.5). This fact is mainly related to the type of soil parent rock material (sedimentary rocks with light texture) and leaching of alkaline cations down in the soil profile as a result of downward water movement.

Spatial distribution of acidic soils is driven by soil texture (light soils with low buffering system) and abundance of soils developed from acidic igneous rocks in southern parts of the country.

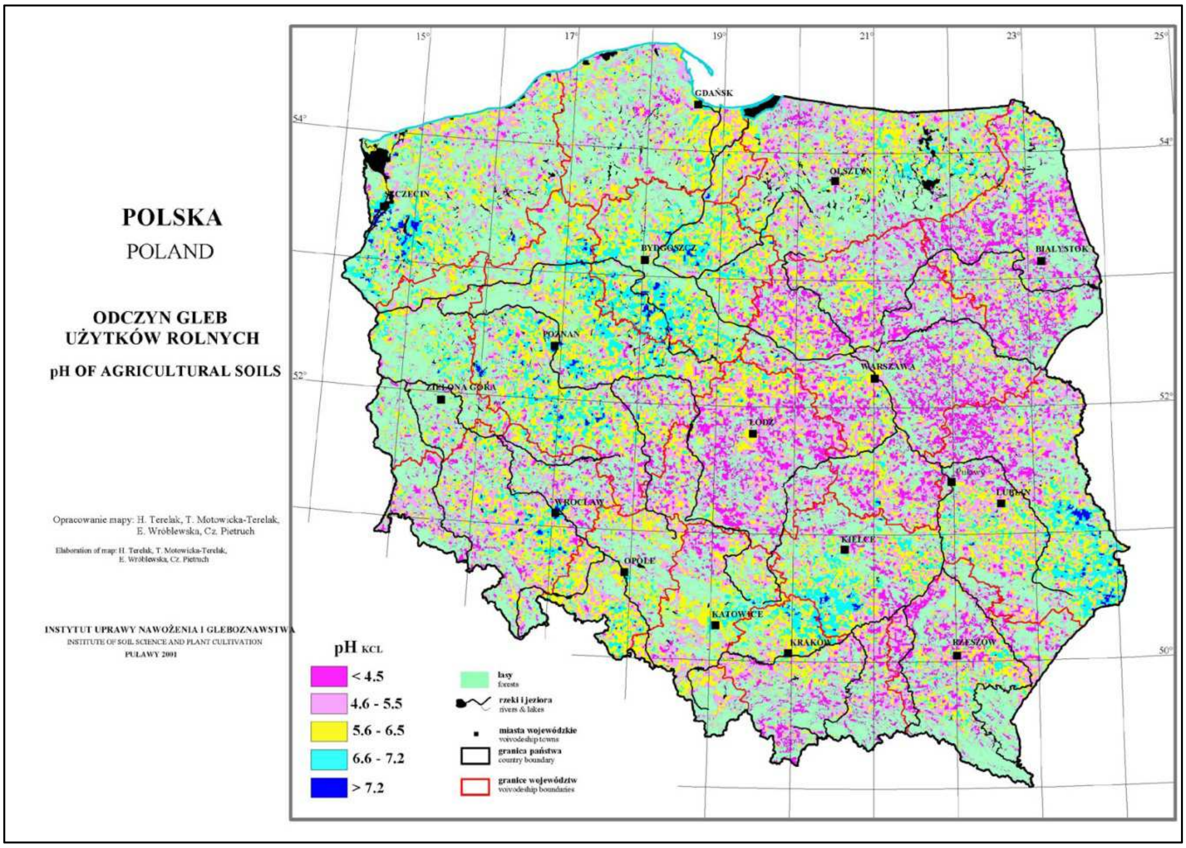

Figure 5. Soil pH map

Contamination with trace elements

The information on soil contamination with trace metals presented here originate from large national monitoring program performed in 1992-1997. The program covered above 45000 samples evenly distributed throughout agricultural lands of the country. The program was coordinated by IUNG. According to the project results over 99% of agricultural soils can be treated as uncontaminated referring to the existing national regulations (e.g. thresholds value for Pb: 100 mg/kg) . The only sites with exceeded thresholds values for Pb, Cd and Zn are located in Silesia region as an affect of smelting and mining long term activities and in some cases high metal content in soil parent rock material.

The spatial variability of cadmium is shown in Figure 6 as classes of the metal content specified by guideline values (Kabata-Pendias et al., 1993). These values are not implemented to regulations but provide certain risk assessment approach since take soil properties (pH, clay) into account. The highest Cd and Pb contents in soil are measured in Silesia region in Southern Poland, which is historically and currently most industrial part of Poland. Approximately 5-10% soils in the Silesia region are contaminated which in certain locations is a limitation due to risk of food contamination and common in this area land abandonment.

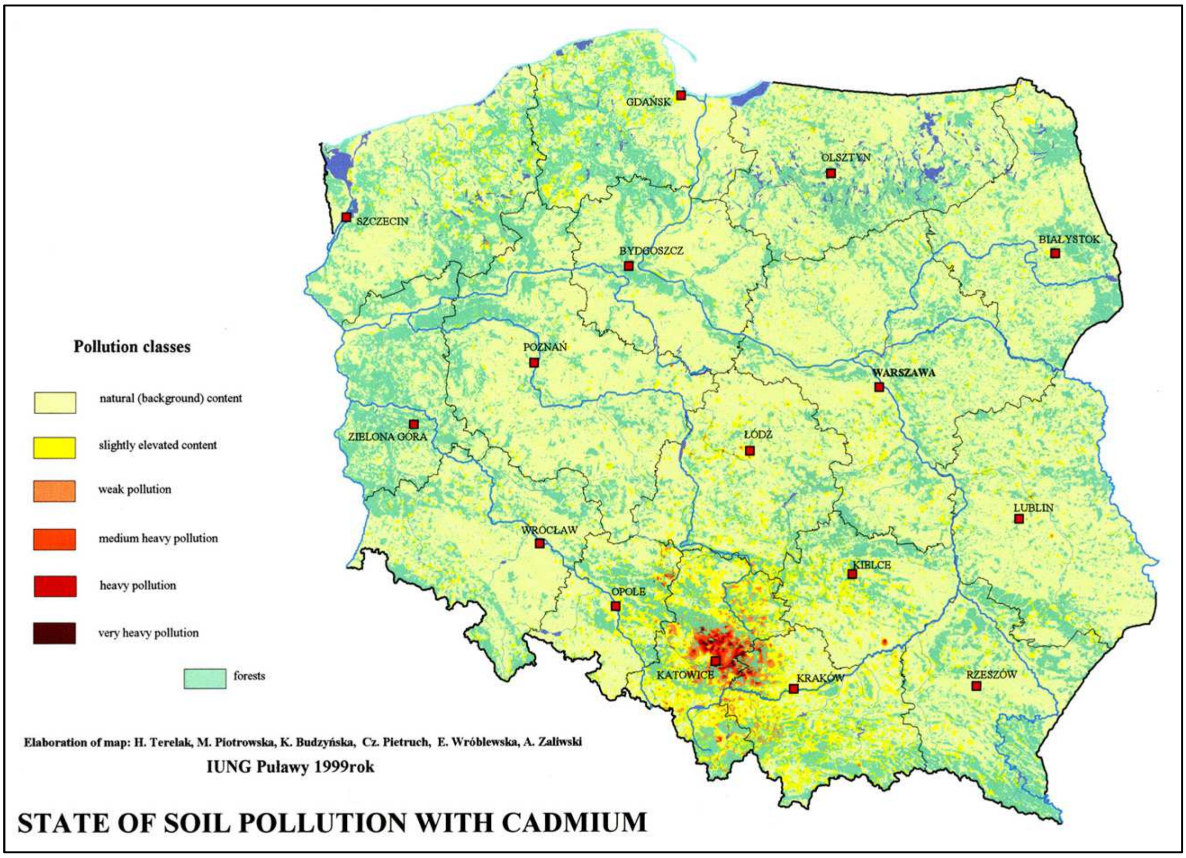

Figure 6. Total cadmium content classes as based on the guideline indicative values (Kabata-Pendias et al, 1993).

The new data gathered in ongoing national soil monitoring program did not indicate any significant metal accumulation processes within last 15 years (Figure 7) .

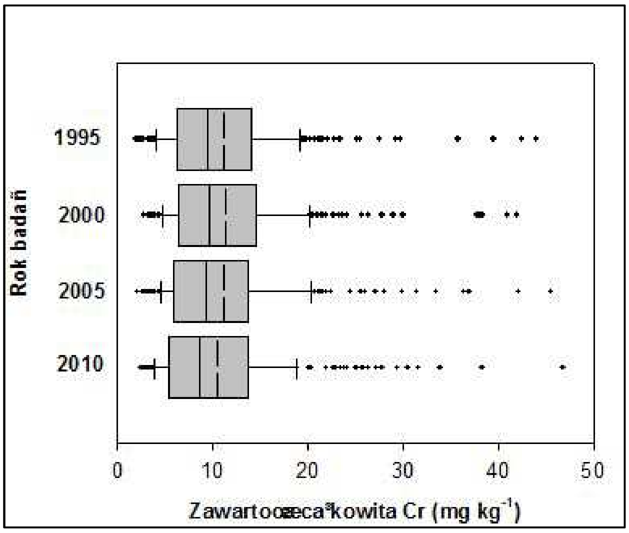

Figure 7. Statistics for total chromium contents in soil in different periods of national monitoring program (216 monitoring locations)

Salinity, **landslides** and **floods** do not pose any significant threat to soil resources in Poland.

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Soil degradation problems in Spain

Authors: Gema Guzman**,** Tom Vanwalleghem, Juan Vicente Giráldez

University of Cordoba, Spain

Introduction

Adverse climatic conditions, irregular terrain with steep slopes, parent material and long periods of land misuse are the main factors responsible for land degradation in the Mediterranean (Kosmas et al., 2000). The main soil degradation processes which will be discussed in the following, are water erosion, salinization, reduced fertility and compaction. Lower crop yields, climatic change, loss of bio-diversity and scarcity of good quality water resources can be affected by soil degradation. These processes include physical, chemical and biological actions that affect the soil capacity for self-regulation and productivity (Lal et al. 1989). Although soil and climate characteristics play an important role, soil degradation is mainly caused by inappropriate use and management of soil and water resources.

The frequently arid or semi-arid climate with rainfall concentrated in few events, usually in the autumn and spring, scarcity of vegetation cover, and eroded and shallow soils in several areas lead to soil degradation processes (de Paz et al. 2006). Mediterranean ecosystems are fragile and any alteration of the system, albeit by natural processes, could lead to soil degradation. In fact, human pressure is accelerating these processes and causing rapid loss of soil productivity. Soils under Mediterranean conditions develop slowly and have little capacity to recover (de Paz et al. 2006). Soil organic matter, nutrient supply, soil vegetation cover and soil compaction are critical for soil degradation in these environments and they must be managed appropriately in order to ensure continuous soil rehabilitation since the most significant influence to soil quality parameters is land use on the main soil quality parameters (Dunjó et al. 2003).

Water erosion

Land degradation is a common phenomenon in the Mediterranean semiarid terrains, where physical loss of soil by water erosion and the associated loss of soil nutrient status is identified as the dominant problem (Thornes, 1995).

Mediterranean environments are particularly prone to soil erosion due to high rainfall intensity, the low average annual precipitation, the fragility of many soils (low organic matter content, poor nutrient content), the presence of steep slopes, and the long history of landscape transformation, including deforestation, forest fires, frequent land-use changes and cultivation in extreme topographic and climatic conditions (García-Ruiz, 2010).

The main effects caused by erosion are the loss of agricultural and forest soil fertility, increased degradation of vegetation cover, and a decrease in natural hydrologic control. While erosion can lead to emission of trace gasses into the atmosphere, deposition can bury and sequester some of the carbon (Lal et al. 2001). Areas of high erosion rates are mostly small and localized (except the valley of the Guadalquivir and to a lesser extent on the northern Meseta) (Figure 1; Source:Kirkby et al. 2003).

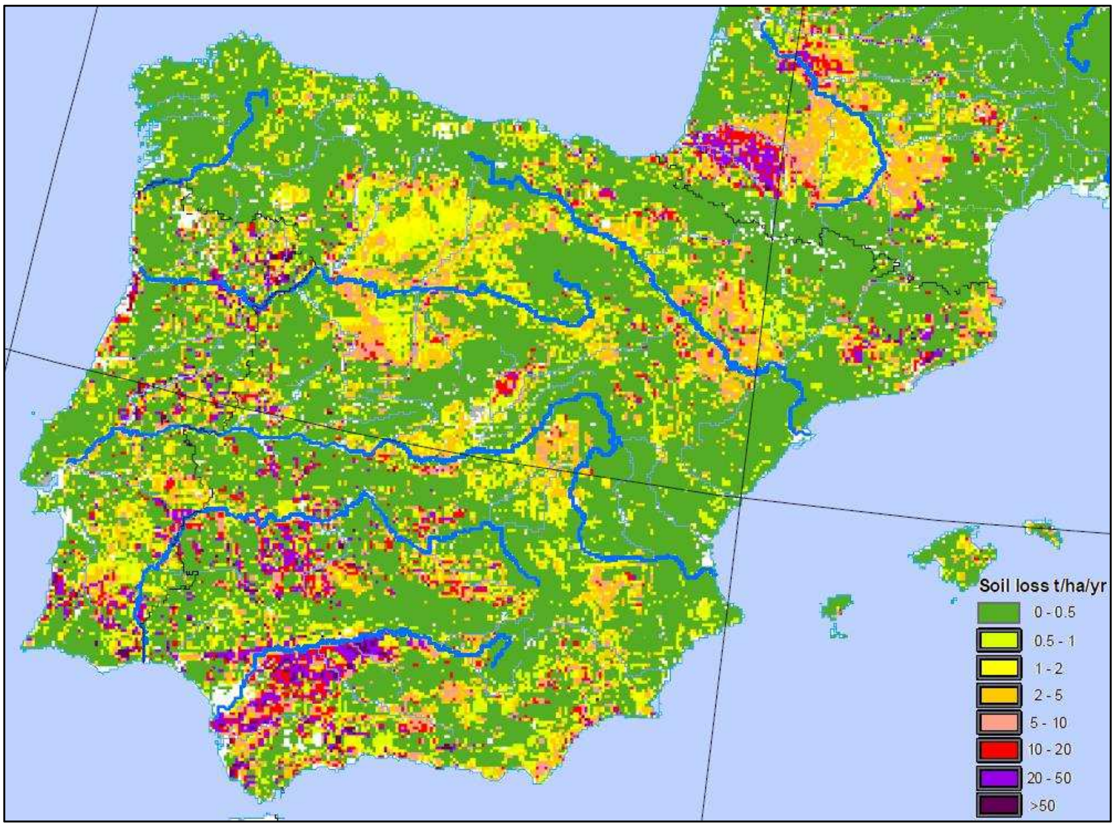

Figure 1 PESERA: Pan European Soil Erosion Risk Assessment Map within Spain. http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/esb_rr/n16_ThePeseraMapBkLet52.pdf.

Salinization

Soil salinization arises due to concentration of soluble salts at or near the soil surface and it is usually associated with low fertility. Salts accumulate by primary and secondary processes that alter the soils physicochemical properties and lead to direct and indirect soil degradation.

Irrigating with the resultant contaminated groundwater has induced soil salinization based on water quality and doses (Schofield et al. 2001). Soil salinization is mainly an arid-zone problem leading to land desertification. It reduces soil quality, limits the growth of crops, agricultural productivity, biodiversity, soil deterioration, moisture regime and biogeochemical cycles of elements. The control of this problem involves inventorying, mapping, and monitoring soil salinity, which requires cost-effective, rapid, and reliable methods for determining soil salinity in the field, and rapid, specific data-processing methods.

The areas with salinization problems in Spain are given in Figure 2.

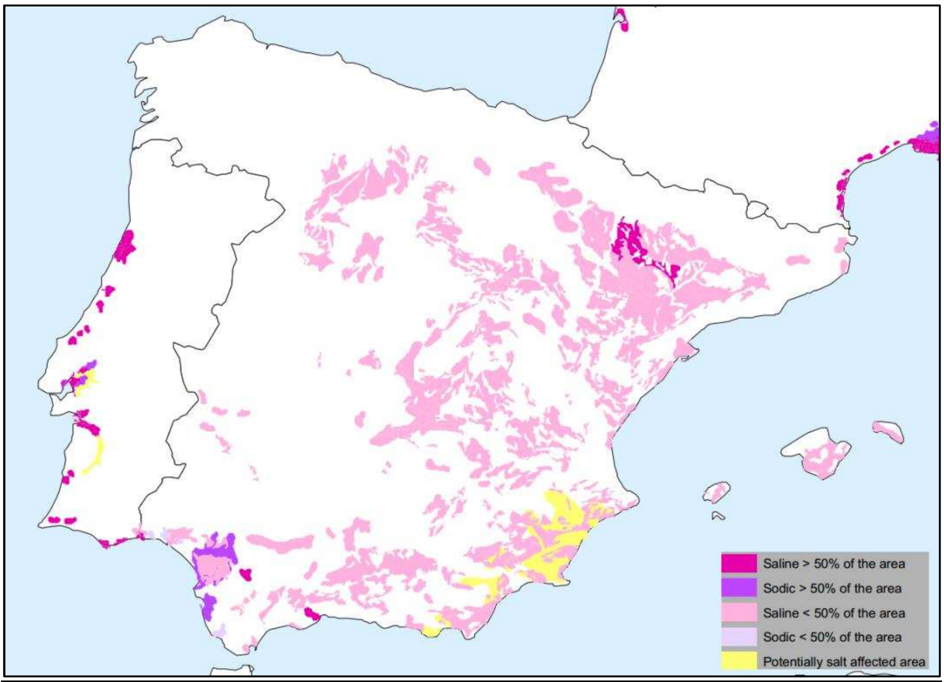

Figure 2 Map showing the area distribution of saline, sodic and potentially salt affected areas within Spain. http://eusoils.jrc.ec.europa.eu/library/themes/salinization/Resources/salinisation.pdf.

Reduced fertility

Soil fertility is a complex quality of soils that is closest to plant nutrient management. The rapid loss of soil organic matter and the consequences in terms of physical soil properties were considered to be important factors in soil degradation. Soil degradation processes after vegetation removal in semiarid zones can be enhanced in a short time period. Vital soil properties such as structural stability, organic carbon content or bulk density tended to deteriorate and result in irreversible soil degradation in semiarid areas (Albaladejo et al. 1998).

The main land areas in Spain with a high sensitivity to desertification and to drought as defined by the sensitivity to desertification index (SDI), are given in Figure 3.

Low soil fertility is considered the main reason for abandoning agricultural fields and this land abandonment may lead to deteriorating or improving conditions of plant cover depending on the soil and climate conditions of the area (Kosmas et al. 2000). Several factors are responsible for a decline in soil organic matter and many of them relate to human activity: conversion of grassland, forests and natural vegetation to arable land; deep ploughing of arable soils; drainage, fertiliser use; tillage of peat soils; crop rotations with reduced proportion of grasses; soil erosion; and wild fires (Kibblewhite et al. 2005).

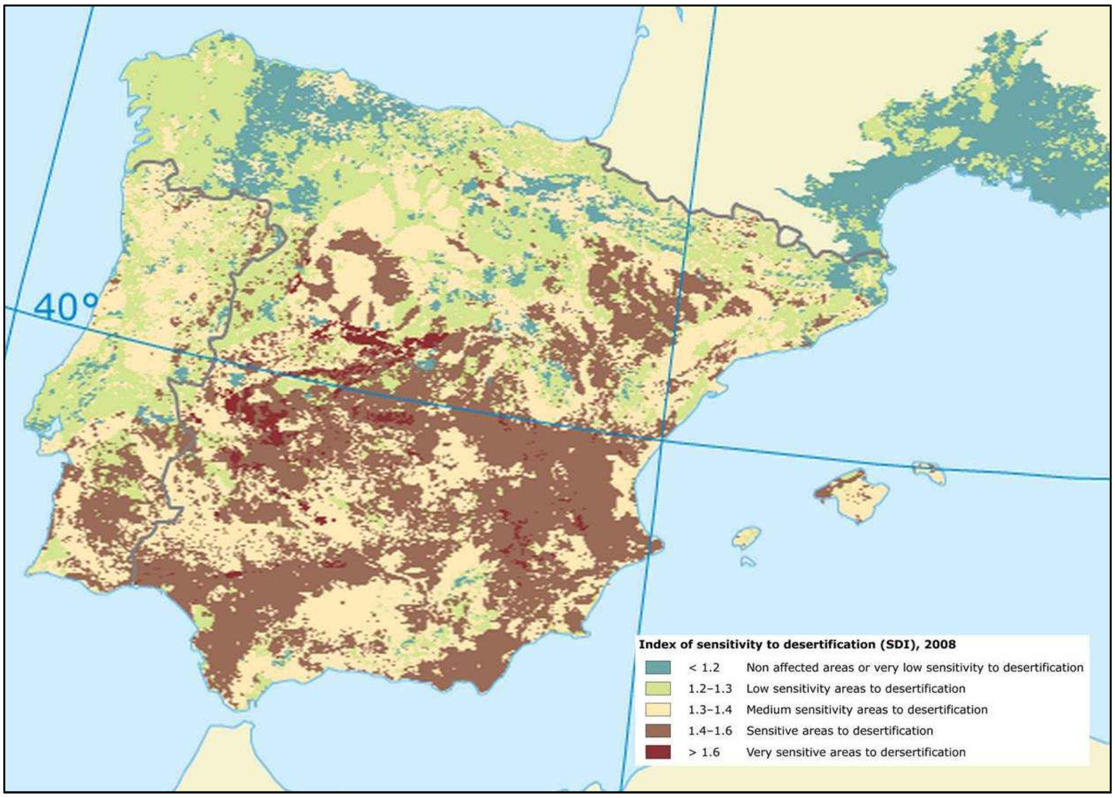

Figure 3 Map showing the sensitivity to desertification and drought as defined by the sensitivity to desertification index (SDI) based on soil quality, climate and vegetation parameters http://eusoils.jrc.ec.europa.eu/SOER2010/images/Map%202.9%20Soil_SO113_v1.png.

Compaction

Soil compaction occurs in a wide range of soils and climates. It is exacerbated by low soil organic matter content and use of tillage or grazing at high soil moisture content. Soil compaction increases soil strength and decreases soil physical fertility through decreasing storage and supply of water and nutrients, which leads to additional fertilizer requirement and increasing production cost. A detrimental sequence then occurs of reduced plant growth leading to lower inputs of fresh organic matter to the soil, reduced nutrient recycling and mineralisation, reduced activities of micro-organisms, and increased wear and tear on cultivation machinery (Hamza and Anderson, 2005).

The main land areas in Spain that are susceptible to soil compaction, are given in Figure 4.

Increasing soil organic matter through stubble retention, green and brown manure application and/or addition of plant or animal organic matter from external sources is important for decreasing the bulk density of the soil and for acting as a buffer to prevent or lessen the transmission of compaction to the subsoil from external loads acting on the topsoil.

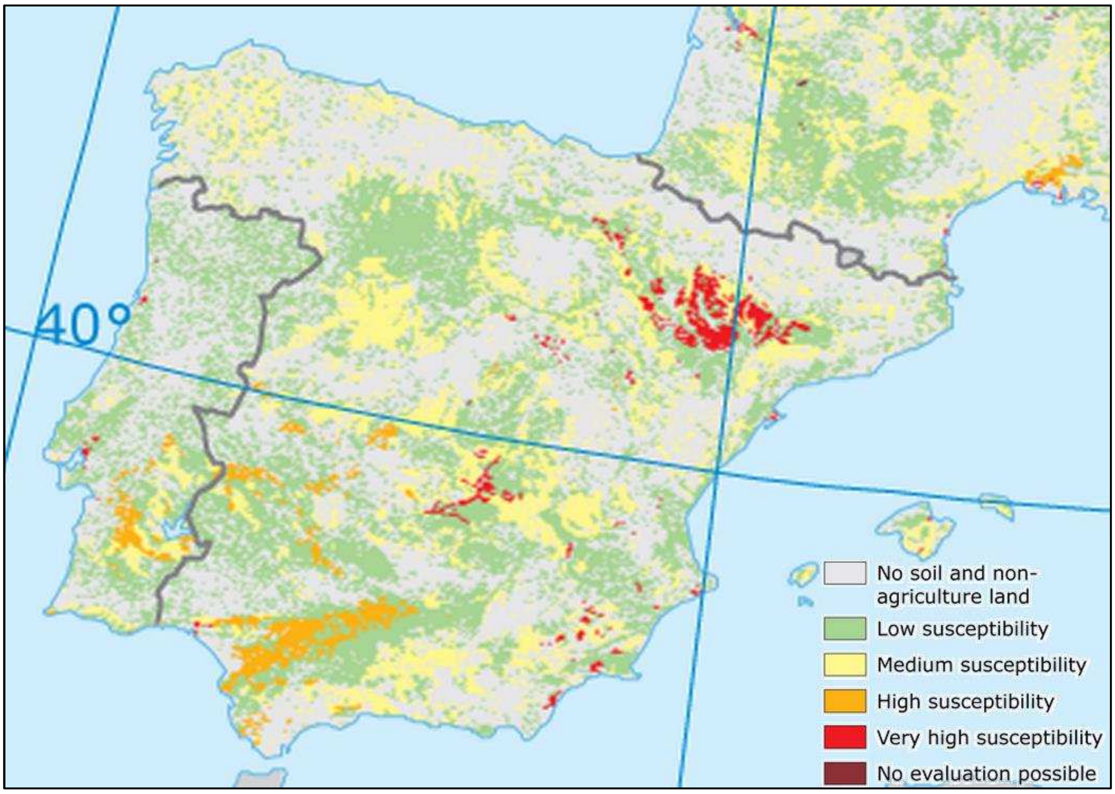

Figure 4 Natural susceptibility of agricultural soils to compaction based on soil properties and water regime. Susceptibility to compaction does not mean that a soil is compacted. *http://eusoils.jrc.ec.europa.eu/SOER2010/images/Map2-5_SO107_map.png*.

Conclusions

In Spain, desertification is mainly associated with soil erosion, particularly in natural and semi-natural systems. The main erosion problems are not found in natural environments but in agricultural systems, especially in marginal agricultural areas on steep slopes and with bad agricultural practices and also in intensively irrigated lands.

The main desertification problem in Spain is generated by unsustainable water management. The current expansion of irrigated lands outside the areas suited for agriculture is increasing the intensity of aquifer exploitation, already causing serious problems of salinization, the loss of springs and wetlands and associated biodiversity, and the exhaustion of non-renewable groundwater resources (Martínez Fernández and Esteve, 2005).

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