Soil Carbon Data in Cropland and Grassland in the Mediterranean Region

Deliverable D7/A5

Project MediNet

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We note however that the methodology, the selection of data for compilation, views and opinions expressed in this report are of the responsibility of the authors, and do not necessarily reflect the views of any individual participating at the workshop.

Agustin Rubio Sanchez	Boštjan Mali	Carlo Trotta
Cinzia Chiriacò	Colas Robert	Cristina García Diaz
Dimitris Triantakonstantis	Domenico Vitale	Franca Ciccarelli
George Theophanous	Giacomo Certini	Iordanis Tzamtzis
João Paulo Marques	Kostas Bithas	Letizia Atorino
Lúcio do Rosário	María del Mar Esteban García	María José Sanz
Marina Vitullo	Melina Menelaou	Raul Zornoza
Riccardo Valentini	Simona Castaldi	Simone Rossi

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1 Introduction

The main objective of this report[1] is to propose new default coefficients for the reporting of emissions and removals for soil organic carbon (SOC) in cropland and grasslands, within the Greenhouse Gases inventory and reporting obligations under the UNFCCC and its Kyoto Protocol, and the related EU decisions and regulations (Decision 529/2013/EU, Regulation EU 525/2013).

The main carbon pools in cropland and grassland are living biomass and soil organic carbon. As data for SOC for croplands and grasslands are very poor, the main objective of this study is to identify sources of information to improve default factors for the soil organic carbon pool in the Mediterranean area.

Sections 2 and 3 describe the methodology used and provides a review of existing information on SOC in cropland and grassland types and respective management practices available from the Mediterranean countries considered in Project MediNet (Figure 1).

Figure 1: Area of Intervention of Project MediNet

Section 4 describes the results obtained for SOC stock in cropland and grassland, particularly for annual crops, permanent crops (olive trees, vineyards and fruit trees), pasture and shrubland, and uses the results from the previous section to propose new coefficients for reporting emissions and removals from SOC in croplands (annual and permanent crops), grassland and shrubland.

Finally, section 5 makes an overview of the results and identifies information gaps and areas for further work to improve the quality of the estimates in future inventory methodologies.

[1] This report is the fifth report of Project MediNet and is the final deliverable of action A5 “Gains and Losses in Soil Organic Carbon”

2 Methodology / Soil Profiles Databases

The first step of this action consisted on the identification, collection and organisation of data on SOC concentration and other useful parameters needed to calculate the SOC stock from cropland and grassland for all MediNet countries. When possible, additional information was also identified (e.g. management practices, site features). For this purpose, a literature soil profile database was created by using data found in the relevant scientific literature, while other three soil profile databases were obtained by contacting their authors or by retrieving them directly from the Internet. These three databases were: the CARBOSOL database, containing data from Spain (Llorente et al. 2017); the SeisNET Database, with specific data from Andalusia (De la Rosa et al. 2001); and the INFOSOLO database, containing data from Portugal (Ramos et al. 2017).

2.1 Databases Description

2.1.1 Literature Database

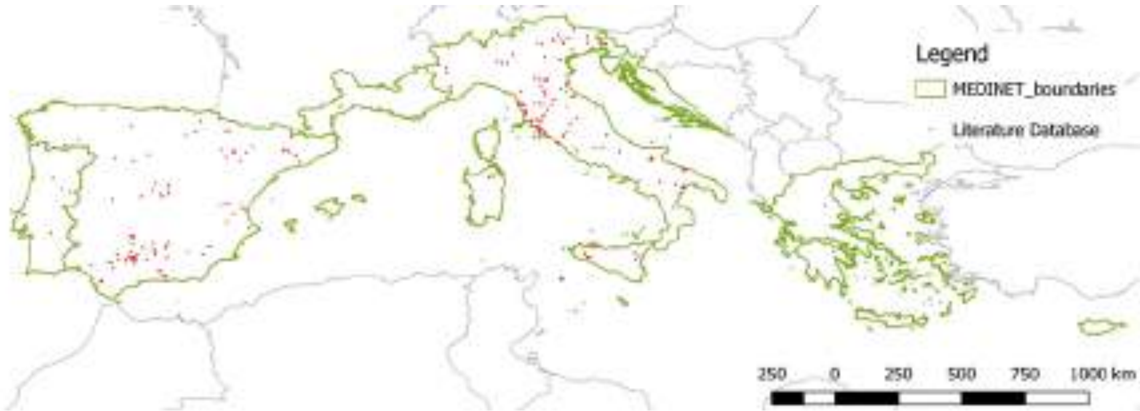
The literature database was created collecting all the relevant data included in the following sources:

- GHG Inventory Reports of MediNet countries;
- Scientific literature (peer reviewed papers on national and international journals);
- Grey literature (project reports, master thesis, congress proceedings, etc.);
- Direct information requests to paper's authors and focal points of Project MediNet;

Papers were considered relevant if they contained soil data collected in MediNet countries and related to important crops in the region[2].

A total of 166 papers, containing 766 soil profiles, corresponding to 1187 soil entries (i.e. layers or horizons), were identified and processed in the following phases. The variables extracted from the collected papers are described in the following section. The location of the database soil profiles is indicated in Figure 2.

Figure 2: Location of the Soil Profiles Contained in the Literature Database



2.1.2 CARBOSOL Database

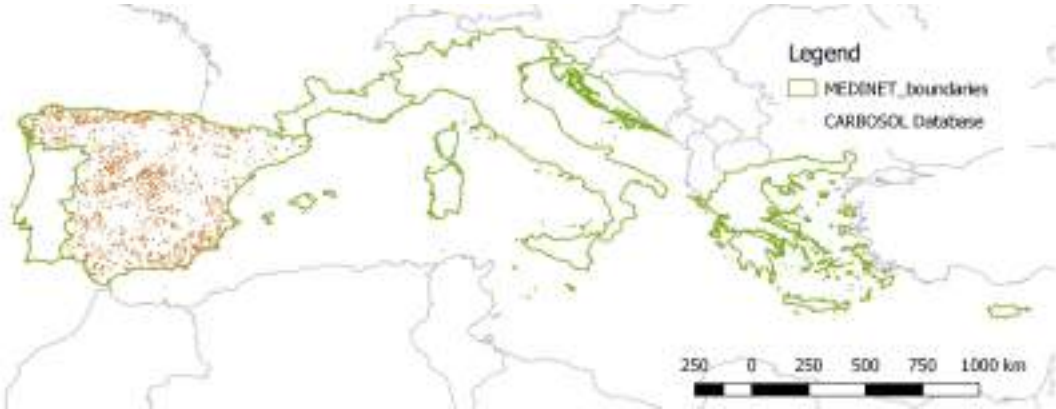
The CARBOSOL Database has been developed by the CARBOSOL Collaborative Network Project and, currently, represents the largest standardized soil data compilation in Spain. The database is freely available and aims to be a useful research tool to increase knowledge of Spanish soils, especially around the study of the soil organic carbon stocks, the dynamic of soil organic matter and its determinant factors.

The CARBOSOL Database contains data of physical and chemical properties of 6609 georeferenced soil profiles in Spain associated to a related analytical dataset of 22100 horizons compiled from 635 soil studies. The database provides a wealth of information on soil organic matter content, its distribution along the profile and its associated determinants: such as soil type, lithology, topography and land cover. It also includes broad

[2] Defined in the 2nd report of project MediNet: "Selection of Cropland and Grassland Types and Management Systems for Further Consideration in Project MediNet"

physical and chemical characteristics of the profiles and its associated horizons. The location of the database entries is indicated in Figure 3.

Figure 3: Location of the Soil Profiles Contained in the CARBOSOL Database



2.1.3 SeisNET Database

SeisNet (Spanish Soil Information System on the Internet) collects the results obtained in the Implementation of three research projects (MIMAM-CSIC, FAO-CSIC and SIDASS), co-ordinated by the MicroLEIS group of IRNAS (Instituto de Recursos Naturales y Agrobiología de Sevilla), in the period 1999-2001. All data were freely available from the Internet[3].

The database was developed compiling the existing information useful to understand the current state of quality and degradation of soils in Andalusia and contains information for 1043 soil profiles, comprising a set of 3472 horizons/layers. The location of the database entries is indicated in Figure 4.

Figure 4: Location of the Soil Profiles Contained in the SeisNET Database

The SeisNet system is structured in three levels of information, from lower to greater detail:

- Level 1: First Approach to Soils;
- Level 2: Digital Atlas of Soil Countries and;
- Level 3: On-line Soil Database.

[3] http://evenor-tech.com/banco/seisnet/seisnet.htm

2.1.4 INFOSOLO Database

The INFOSOLO database is the first attempt to develop a soil information system for Portugal, suitable to compile soil data produced in the country, with the aim to support stakeholders and land managers in decision-making.

The INFOSOLO database includes soil data from 3461 soil profiles, comprising a set of 9934 horizons/layers studied across the country between 1966 and 2014. Data was obtained from scattered soil surveys, research projects, and academic studies carried out by public Portuguese and other European institutions, with a series of validation tests and harmonisation which were performed to access and improve the quality and consistency of the overall data. The location of the database entries is indicated in Figure 5.

Figure 5: Location of the Soil Profiles Contained in the INFOSOLO Database

2.2 MediNet Database Fields

The second step consisted in the creation of a common and harmonised database joining the data from the four different databases, by extracting all the relevant information contained in the papers and in the three different databases that could be useful for the purposes of Project MediNet.

As expected, for the literature database, different papers focused on different aspects and addressed problems and questions that were not always fully aligned with the Project's objectives. As a consequence, their information was not homogeneous and presented a challenge in terms of organisation.

All information was collected in a database, keeping the information as close as possible to the format used in the original source. For that reason, the database had to contain an extensive number of fields. However, this format also allowed an easier implementation of Quality Assurance/Quality Control procedures (details provided in section below).

The list of information that was searched in each paper is listed below. However, it should be noted that not all papers contained all the information listed:

- Horizon nomenclature;
- Upper depth (cm);
- Lower depth (cm);
- Particle-size fractions of fine soil (% of the less than 2 mm fraction): total sand, silt, and clay content;
- Organic Carbon content (%). Preferably, based on the Dry Combustion and Walkley and Black (1934); analytical procedures (see also Tinsley 1950);
- Dry Bulk Density (g cm^{-3});
- Geographical location;
- Land use category (Cropland, Grassland);
- MediNet Land use subcategory (i.e. Annual crops, Olive trees, Vineyards, Fruit Trees, Pasture and Shrubland);
- Management information (e.g. tillage vs. no tillage; type of irrigation; type of fertilization, etc.).

In Table 1 is reported a detailed explanation of the entire variables considered for the extraction of data from the papers used to create the Literature database.

Table 1: MediNet Soil Database Variables

Field Name	Description
WGS_84_dec_Latitude	Geographical coordinates of the site
WGS_84_dec_Longitude	Geographical coordinates of the site
Country	Country of the study
Region	Region of the study
Province	Province of the study
Locality	Locality of the study
Horizon	FAO nomenclature
Top Depth	Upper horizon depth (cm)
Bottom Depth	Lower horizon depth (cm)
Sand	Sand 0.05-2 mm, % oven dry weight (at 105 °C)
Silt	Silt 0.002-0.05 mm, % oven dry weight (at 105 °C)
Clay	Clay <0.002 mm, % oven dry weight (at 105 °C)
Bulk Density	Bulk Density g cm^{-3} measured
Rock fragments	Stone content as mass %
SOC	Organic Carbon content %
Method for SOC	Dry combustion; Walkley Black; others
Year	Year of sampling
Altitude	Site altitude m a.s.l.
Category	IPCC category (cropland, grassland)
Sub-category	MediNet subcategory (annual crops, rice, olive trees, vineyards, pasture, shrubland)
Type of Crop	Crop cultivated in the study area (e.g. cereal, type of fruit tree)
Management practice	Tillage, no tillage, reduced tillage, cover crop
Management regime	Conventional farming, organic farming
Irrigation	Irrigation, no irrigation
Plantation Age	Age of plantation in case of perennial crops
Cultivar	Type of cultivar in case of perennial crops
Fert/Herb	Type of fertilizers/herbicides applied (chemical; organic)
Training System	Training system in case of perennial crop
Soil Type	Soil classification (WRB or USDA)
Reference	Reference to the study

The existing three databases were already structured with the fields considered in the literature database, except for the management information, which was not provided in any of the other three databases. Only irrigation was provided for the annual crops category in the CARBOSOL and INFOSOLO databases.

2.3 Database Harmonisation and Gap Filling

In each of the four databases, the soil profiles were collected in diverse situations (location, soil type, year/time of the year, number and classification of soil layers, soil depth sampled, etc.), leading to the need of harmonise existing data and, in some cases, gap fill missing variables that would allow the calculation of SOC on a per hectare basis.

The calculation of SOC (tC ha^{-1}) was done following Equation 1.

Equation 1: Calculation of Soil Organic Carbon per Hectare

$$SOC = SOC\% \times BD \times \left(1 - \frac{VS}{100}\right) \times LD \quad [1]$$

Where:

SOC: soil organic carbon (tC ha^{-1})
SOC%: soil organic carbon concentration for given depth (%)
BD: dry bulk density (t m^{-3})
VS: volume of stones (%)
LD: Depth of soil layer (m)

SOC is expressed in tonnes of Carbon per hectare (tC ha^{-1}). This choice was done since most activity data are expressed in hectares and so it is the most useful format. The harmonisation and gap filling done on all those variables is detailed in the following sections.

2.3.1 Land use data

Except for the Literature database, in which the data were included only if it was possible to extract the land use, in all the other three databases the land use data were already reported in the original format, allowing for an easy attribution to one of the different MediNet categories (Table 2).

Table 2: Land use categories in the MediNet Database

IPCC Category	MediNet Category
Croplands	Annual Crops
	Olive Trees
	Vineyards
	Fruit Trees
Grasslands	Pasture
	Shrubland

2.3.2 Soil Depth

Following the 2006 IPCC default for soil depth, the database was harmonised to reflect soil organic carbon on the first 30 cm of soil depth.

Given the large heterogeneity in the thickness of the layers from the soil profiles considered, most of the profiles had to be harmonised and aggregated to make them comparable.

The harmonisation to a single 0-30 cm layer process was based on the following steps:

1. Calculation of SOC stocks separately for each layer of each profile according to Equation 1.
2. For each profile all SOC stocks for layers up to 30 cm were added together. Where the last layer had a lower depth higher than 30 cm only a proportion of the SOC stock of that layer was considered (see example in text box).

Example of harmonization process to 0-30cm

Layer	SOC tC ha^{-1}
0-5 cm	15
5-20 cm	14
20-45 cm	10

SOC[0-30] = 15 + 14 + (10/25 x 10) = 33 tC ha^{-1}

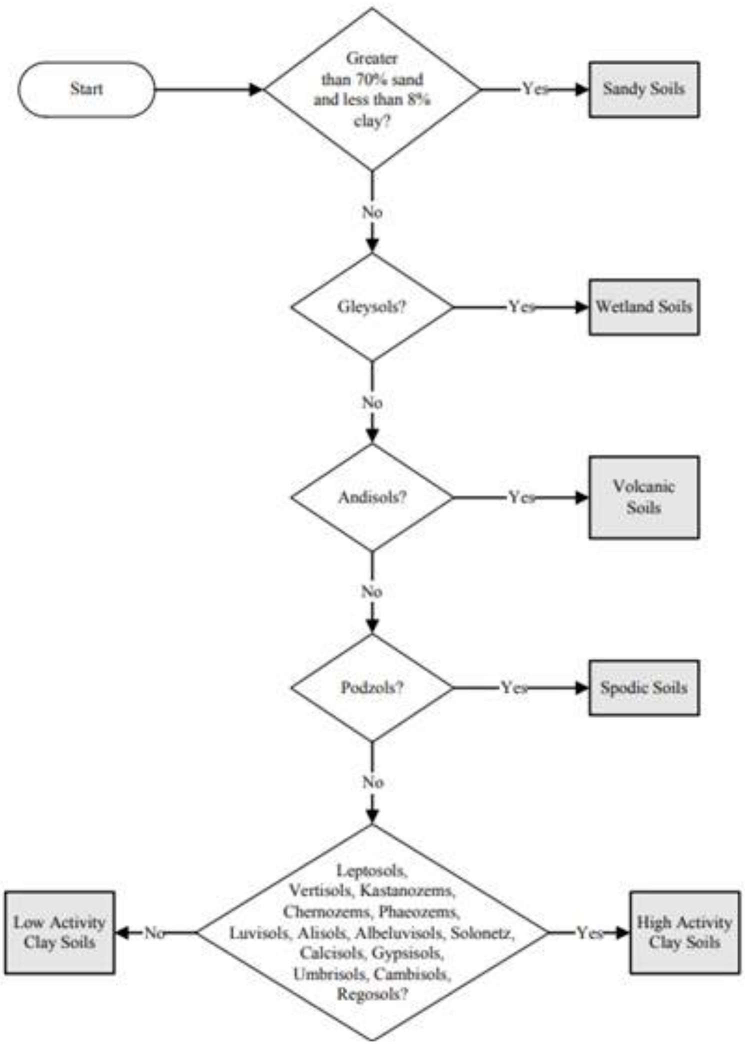
2.3.3 IPCC Climate zones

The IPCC 2006 GL suggests that data should be stratified by climate zones and suggests a grouping of climate zones. A digital map of IPCC Climate Zones was available from JRC[4] and was used to attribute climate information to each of the sample contained in the MediNet Database, by crossing the information available from the map with the point coordinates. The software QGIS version 2.18.16 (http://www.qgis.org) was used to manage and process that information.

2.3.4 IPCC Soil types

The IPCC 2006 GL suggests that data should be stratified by soil types and suggests a particular grouping of soil types. It also provides a decision tree to convert the classification used by the World Reference Base with the IPCC soil types (see Figure 6)[5].

Figure 6: IPCC 2006 Decision Tree to convert WRB Soil Classification to IPCC Soil Types



The sand content used for the first step of the decision tree was the one provided by the MediNet Database, while the soil type was provided by the original reference, or, where that was not available, from the crossing

[4] http://eusoils.jrc.ec.europa.eu/projects/RenewableEnergy/

[5] Figure 3A.5.4 on 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Chapter 3.

of point coordinates with the digital map of WRB classification provided by the European Soil Database v2.0/ESDAC[6]. The software QGIS 2.18.16 (http://www.qgis.org) was used to manage and process that information.

2.3.4.1 Organic soils

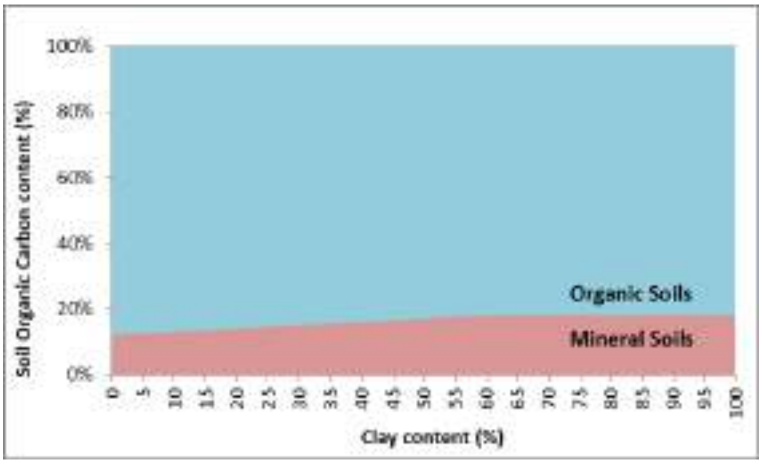
The IPCC 2006 Guidelines provides objective criteria for identifying organic soils in its Volume 4, Chapter 3, Annex 3A.5 “Default climate and soil classifications”.

> Soils are classified in order to apply reference C stocks and stock change factors for estimation of soil C stock changes, as well as the soil N_2O emissions (i.e., organic soils must be classified to estimate N_2O emissions following drainage). Organic soils are found in wetlands or have been drained and converted to other land-use types (e.g., Forest Land, Cropland, Grassland, Settlements). Organic soils are identified on the basis of criteria 1 and 2, or 1 and 3 listed below (FAO 1998):
>
> 1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.
> 2. Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).
> 3. Soils are subject to water saturation episodes and has either:
>   a. At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay; or
>   b. At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay; or
>   c. An intermediate, proportional amount of organic carbon for intermediate amounts of clay.

In all data sources used it was not possible to determine if soils are subject to water saturation episodes or not, and so the identification of organic soil on the basis of criterion 2 was not possible.

Therefore, organic soils were identified by criterion 1 and by applying the quantitative thresholds described in IPCC’s criterion 3 (see Figure 7) on the assumption that those soils are subject to saturation episodes. This assumption is considered valid as the points identified as “organic” are located in areas of “Warm Temperate Moist” and “Cool Temperate Moist” climates, i.e., the wetter types of climate present in the MediNet Region.

Figure 7: IPCC 2006 Guidelines criterion 3 thresholds for classification of organic soils



Only 45 out of 4980 soil profiles were classified as organic soils (0.9%). This suggests that organic soils are not a particularly relevant feature in Mediterranean soils. Due to the low number of plots, no specific analysis on organic soils was conducted in this report.

[6] https://esdac.jrc.ec.europa.eu/resource-type/datasets

2.3.5 Bulk Density

Bulk densities values were available for 2032 soil layers in the 0-30 cm depth, while for 3215 soil layers, contained in the same depth, there was not any bulk density value. In particular bulk density was not reported for: a) 1778 out of 3151 layers (56%) in the CARBOSOL database; b) 1428 out of 1580 layers (90%) in the SeisNET database; c) 9 out of 5665 layers (0.2%) in the INFOSOLO database and; d) 486 out of 1709 layers (28%) in the Literature database. Where bulk density measurements were not available they were estimated using a pedotransfer function.

Two approaches were followed depending on data availability.

For profiles where Organic Carbon and Mineral Fractions (Clay, Silt, Sand) were available, the approach used in the Soil Profile Analytical Database of Europe of the European Soil Database v2 (SPADE/M)[7] was followed (Equation 2):

Equation 2: General Equation for Bulk Density Estimation based on Organic Carbon and Mineral Fractions

$$BD = a + b \times \ln Clay\% + c \times \ln Sand\% + d \times \ln SOC\% \qquad [2]$$

where,
BD = Bulk Density (t m^{-3})
a, b, c, d coefficient derived from the fitting of the bulk density function to real data
Clay% = the percentage of clay in the specific layer
Sand% = the percentage of sand in the specific layer
SOC% = the percentage of soil organic carbon in the specific layer

The equation was fitted using all soil profiles/layers[8] in the 4 databases (2032 layers) for which Bulk Density, Organic Carbon and Mineral Fractions (percentages of Clay, Silt, Sand) were available. The equation was fitted to better reflect the original database and crop type. Specifically, the fitting was done following the Cross-validation procedure, with the process that was iterated 100 times according to the following steps:

1. All the layers were randomly divided in two groups with 80% and 20% of the total samples;
2. 80% sample were used to fit the best coefficient combination;
3. The quality of the coefficient combination was tested on the remaining 20% of the samples.

The parameters to be used in Equation 2, resulting from the best fitting for each category, are presented in Table 3.

Table 3: Parameters for Equation 2 resulting from the fitting of the equation using MediNet Databases

Category	a	b	c	d	N layers[9]	Mean Average Error[10]
Annual Cops	1.317	-0.054	0.055	-0.054	685	0.13
Olive Trees	1.169	-0.047	-0.053	0.100	202	0.13
Vineyards	1.342	-0.040	0.038	0.011	106	0.13
Fruit Trees	1.158	-0.086	0.092	-0.067	46	0.10
Pasture	1.564	-0.056	-0.026	-0.097	577	0.14
Shrubland	1.350	-0.054	0.023	-0.094	564	0.14

[7] Hannam JA, Hollis JM, Jones RJA, Bellamy PH, Hayes SE, Holden A, Van Liedekerke MH and Montanarella L. (2009). SPADE-2: The soil profile analytical database for Europe, Version 2.0 Beta Version March 2009. Unpublished Report, 27pp. https://esdac.jrc.ec.europa.eu/content/spadem

Hiederer R, Jones RJA, Daroussin J. (2006). Soil Profile Analytical Database for Europe (SPADE): Reconstruction and Validation of the Measured Data (SPADE/M). Geografisk Tidsskrift, Danish Journal of Geography 106(1). p. 71-85.

[8] Layers below 30 cm depth were not considered.

[9] Number of data points used to fit the equation (80% of total samples).

[10] Note the MAE is expressed in the same unit of the bulk density (t m^{-3})

For profiles where only Organic Carbon (OC) was available (i.e. where information on mineral fractions was not included), a bivariate relationship of OC and bulk density was used, and three types of models can be distinguished:

Equation 3: General Equations for Bulk Density Estimation based on Organic Carbon

a) Transformation of OC (logarithmic)

- $BD = a \times LN(OC) + b$

b) Transformation of bulk density (logarithmic or power variable)

- $BD = e^{(a \times OC + b)}$

c) Reciprocal

- $BD = (a \times OC + b)^{-1}$

The model of using a linear regression between the log-transformation of bulk density and SOC content is conceptually comparable to the relationship used by Ruehlmann and Körschens (2009). The reciprocal functions are largely derived from Adams (1973) with a fixed value for bulk density of the mineral material. Adams (1973) uses a value of 0.311 g cm^{-3} as a default for the bulk density of organic matter, whereas Rawls (1983) used a default of 0.244 g cm^{-3} and Rawls and Brakensiek (1985) a value of 0.224 g cm^{-3}.

The equations were fitted using all soil profiles/layers[11] in the 4 databases (2032) for which Bulk Density and Organic Carbon were available. The three equations were adjusted to better reflect the crop type. Specifically the fitting was done following the Cross-validation procedure, with the process that was iterated 100 times according to the following steps:

1. All the layers were randomly divided in two groups with 80% and 20% of the total;
2. 80% sample were used to fit the best coefficient combination;
3. The quality of the coefficient combination was tested on the remaining 20% of the samples;

The parameters to be used in Equation 3, resulting from the best fitting for each category, are presented in Table 4.

Table 4: Parameters for Equation 3 fitted using MediNet Databases

Category	Model	a	b	N layers[12]	Mean Average Error[13]
Annual Cops	Reciprocal	0.049	0.687	685	0.13
Olive Trees	Logarithmic	-0.115	1.389	202	0.14
Vineyards	Logarithmic	0.010	1.369	106	0.13
Fruit Trees	Logarithmic	-0.048	1.281	46	0.10
Pasture	Reciprocal	0.025	0.749	577	0.14
Shrubland	Logarithmic	-0.102	1.278	564	0.15

[11] Layers below 30 cm depth were not considered.

[12] Number of data points used to fit the equation (80% of total samples).

[13] Note the MAE is expressed in the same unit of the bulk density (t m^{-3})

2.3.6 Abnormal values

The MediNet database was cleaned removing possible abnormal values. Initially, it was checked that no negative SOC stock values were present. Then, all the values with SOC stock higher than the 95th percentile were checked for the parameters used to calculate the SOC stock. This was done going back to the raw data in the original database. Data were corrected when possible (e.g. mistake in recording a C concentration or other value) and removed from the original data when we were not certain of the quality of the raw data (e.g. an annual crop on a sandy soil with a stock of 200 t C ha^{-1}). All the procedures were developed in the R-studio software (R Core Team 2016).

2.4 Quality Assurance / Quality Control

The data collection and harmonisation procedures described above contain multiple opportunities that can lead the user to make mistakes, which, in turn, could limit the quality of the information contained in the database. These may include:

- Lack of understanding of what the scientific paper describes;
- Mistakes in transposing data from the papers to the databases;
- Mistakes in recording the correct unit of measurement;
- Mistakes in the use of correction factors (unit conversions, default values, etc.).

In order to limit these possibilities, the following procedures were implemented:

- Random check of about 10% of the studies. It consisted on a second read of the selected papers by another person who checked possible mistakes made in the database compilation and harmonisation procedures;
- Checks of "abnormal values". It consisted on the identification and check of possible outliers.

3 Methodology / LUCAS Topsoil Database

3.1 Database Description

LUCAS stands for the Land Use and Coverage Area frame Survey. EUROSTAT has carried out this survey every 3 years since 2006 to identify changes in land use and cover in the European Union. In 2009, a soil module was introduced, whereby soil samples were collected in a subset of LUCAS sample plots. This module was repeated in the 2015 LUCAS Survey, but data for this sample is not yet available.

LUCAS 2009 Topsoil Data was retrieved from the JRC Website[14] and the summary of available data is described in Table 5.

Table 5: Summary of Data Available from the LUCAS Topsoil Database 2009

	Available Details
Point Identifiers	Point identifier, soil sample identifier, GPS measured latitude and longitude
Soil Attributes	Clay content (%), silt content (%), sand content (%), coarse fragments (%); pH (H_2O), pH($CaCl_2$); Organic carbon content (g kg^{-1}); Carbonates $CaCO_3$ content (g kg^{-1}); Nitrogen content (g kg^{-1}), phosphorous content (mg kg^{-1}), potassium content (mg kg^{-1}) Cation exchange capacity (cmol(+) kg^{-1});

Each point corresponds to a composite soil sample representative of the first 20 cm of soil, regardless of soil type and horizons present in those 20 cm.

[14] https://esdac.jrc.ec.europa.eu/content/lucas-2009-topsoil-data

3.2 Database Harmonisation and Gap Filling

The LUCAS Topsoil Database does not contain all the information required for estimating soil Carbon stocks and needed to be completed for the purposes of MediNet. The following sections describe the approaches used to fill in the missing information and/or correct some problems found in the original data.

3.2.1 Land use data

Land-use data for LUCAS Sample Plots is not available from the Topsoil Database, but is available from the core LUCAS Land-Cover database that contains the land-use/land-cover information. The two databases can be linked via the Point Identifier, which is common in the 2 databases.

Land-use/land-cover data is available at 3 different levels of disaggregation and a correspondence between the LUCAS and MediNet classifications was made, as shown in Table 6.

Table 6: Land-cover data available from LUCAS Database

Level 1	Level 2	Level 3	MediNet Classification
A00-Artificial Land	A10-Built-up areas	A11-Buildings with one to three floors	NA
		A12-Buildings with more than three floors	
		A13-Greenhouses	
	A20-Artificial non-build areas	A21-non build-up area features	
		A22-non build-up linear features	
B00-Cropland	B10-Cereals	B11-Common wheat	Cropland / Annual Crops
		B12-Durum wheat	
		B13-Barley	
		B14-Rye	
		B15-Oats	
		B16-Maize	
		B17-Rice	
		B18-Triticale	
		B19-Other cereals	
	B20-Root Crops	B21-Potatoes	
		B22-Sugar beet	
		B23-Other root crops	
	B30-Non-Permanent Industrial Crops	B31-Sunflower	
		B32-Rape and turnip rape	
		B33-Soya	
		B34-Cotton	
		B35-Other fibre and oleaginous crops	
		B36-Tobacco	
		B37-Other non-permanent industrial crops	
	B40-Dry Pulses, vegetables and flowers	B41-Dry pulses	
		B42-Tomatoes	
		B43-Other fresh vegetables	
		B44-Floriculture and ornamental plants	
		B45-Strawberries	
	B50-Fodder Crops	B51-Clovers	

Level 1	Level 2	Level 3	MediNet Classification
		B52-Lucerne	
		B53-Other Leguminous and mixtures for fodder	
		B54-Mix of cereals	
		B55-Temporary grasslands	
	B70-Permanent Crops: Fruit Trees	B71-Apple fruit	Cropland / Fruit Trees
		B72-Pear fruit	
		B73-Cherry fruit	
		B74-Nuts trees	
		B75-Other fruit tree and berries	
		B76-Oranges	
		B77-Other citrus fruit	
	B80-Other Permanent Crops	B81-Olive groves	Cropland / Olive Trees
		B82-Vineyards	Cropland / Vineyards
		B83-Nurseries	Cropland / Annual Crops
		B84-Permanent industrial crops	
D00-Shrubland	D10-Shrubland with sparse tree cover	D10-Shrubland with sparse tree cover	Grassland / Shrubland
	D20-Shrubland without tree cover	D20-Shrubland without tree cover	
E00-Grassland	E10-Grassland with sparse tree/shrub cover	E10-Grassland with sparse tree/shrub cover	Grassland / Pastures
	E20-Grassland without tree/shrub cover	E20-Grassland without tree/shrub cover	
	E30-Spontaneously re-vegetated surfaces	E30-Spontaneously re-vegetated surfaces	
F00-Bare land	F00-Bare land	F00-Bare land	Bare Land
G00-Water areas	G10-Inland water bodies	G10-Inland water bodies	NA
	G20-Inland running water	G20-Inland running water	
	G30-Coastal water bodies	G30-Coastal water bodies	
	G50-Glaciers, permanent snow	G50-Glaciers, permanent snow	
H00-Wetlands	H10-Inland wetlands	H11-Inland marshes	NA
		H12-Peatbogs	
	H20-Coastal wetlands	H21-Salt marshes	
		H22-Salines	
		H23-Intertidal flats	

Data for categories (and their subcategories) A00-Artificial Land, G00-Water Areas and H00-Wetlands were not further considered due to an insufficient number of points with soil data in the MediNet Region (see Table 7).

Table 7: Number of Soil Samples in LUCAS per MediNet Category in the MediNet Region

MediNet Classification	LUCAS Classification	N Plots
Cropland / Annual Crops	B11, B12, B13, B14, B15, B16, B17, B18, B19, B21, B22, B23, B31, B32, B33, B34, B35, B36, B37, B41, B42, B43, B44, B45, B51, B52, B53, B54, B55, B84	2203
Cropland / Olive Trees	B81	414
Cropland / Vineyards	B82	265
Cropland / Fruit Trees	B71, B72, B73, B74, B75, B76, B77, B83	215
Grassland / Pasture	E10, E20, E30	838
Grassland / Shrubland	D10, D20	284
Bare Land	F00	273
NA	A00, G00, H00	20

3.2.2 Corrections of Point Coordinates

The LUCAS Database contains GPS coordinates (GPS_LAT, GPS_LONG). However 12 points were identified with the same (invalid) coordinates (GPS_LAT = 40,0000; GPS_LONG = -9,00000). In those cases, the coordinates from the core LUCAS Database (land-use/land-cover data) for the same point ID were used (TH_LAT, TH_LONG).

3.2.3 Country/Regional data

Country/region data for LUCAS Sample Plots is not available from the Topsoil Database, but is available from the core LUCAS Land-Use/Land Cover database. The two databases can be linked via the Point Identifier, which is common in the 2 databases.

Points are identifiable by NUT0, NUT1 and NUT2 level.

In the 2009 dataset all MediNet countries are represented, except for Cyprus and Malta. All available soil plots from these countries were considered, except for the case of France, for which only the points from NUT1 FR8 (Mediterranean) were considered and the case of Slovenia, which only the points from NUT2 SI04 (Western Slovenia) were considered (Figure 8).

Figure 8: Location of the Soil Samples Contained in the LUCAS Topsoil Database

3.2.4 IPCC Climate zones

The IPCC suggests that data should be stratified by climate zones and suggests a grouping of climate zones. A digital map of IPCC Climate Zones was available from JRC[15] and was used to attribute climate information to each of the LUCAS sample points, by crossing the information available from the map with the point

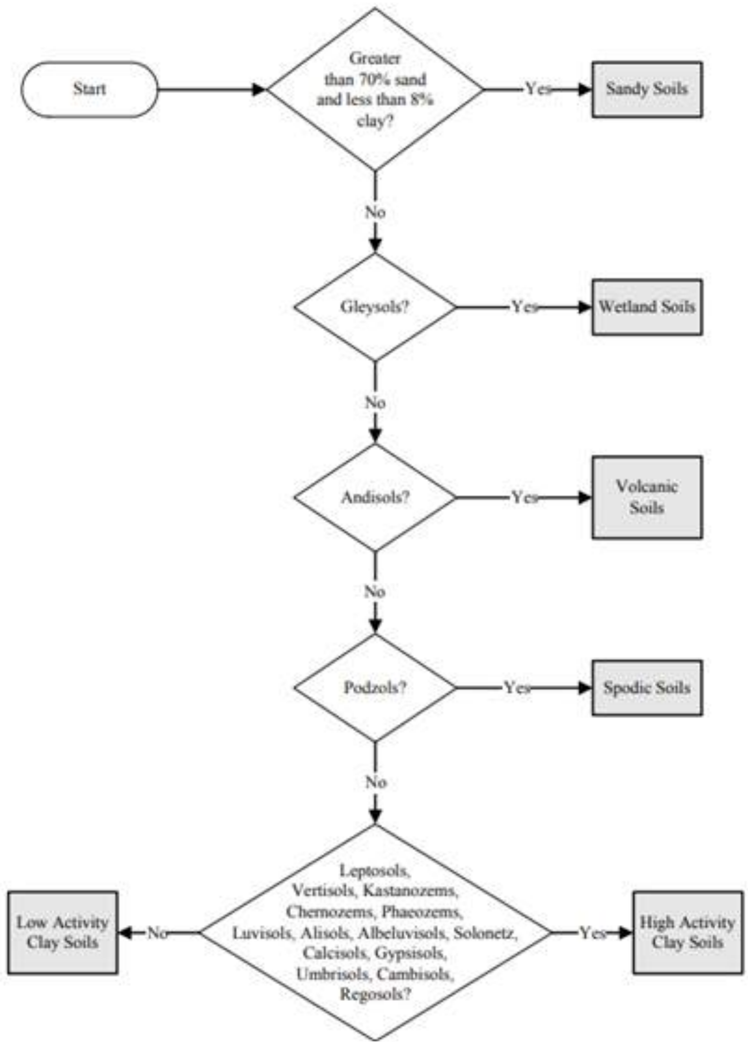
[15] http://eusoils.jrc.ec.europa.eu/projects/RenewableEnergy/

coordinates. The software QGIS version 2.18.16 (http://www.qgis.org) was used to manage and process that information.

3.2.5 IPCC Soil types

The IPCC suggests that data should be stratified by soil types and suggests a particular grouping of soil types. It also provides a decision tree to convert the classification used by the World Reference Base with the IPCC soil types (see Figure 9)[16].

Figure 9: IPCC 2006 Decision Tree to convert WRB Soil Classification to IPCC Soil Types



The sand content used for the first step of the decision tree was the one provided by LUCAS Topsoil, while the soil type was derived from the digital map of WRB classification provided by the European Soil Database v2.0 / ESDAC[17], by crossing the information available from the map with the point coordinates. The software QGIS 2.18.16 (http://www.qgis.org) was used to manage and process that information.

3.2.5.1 Organic soils

The IPCC 2006 Guidelines provides objective criteria for identifying organic soils in its Volume 4, Chapter 3, Annex 3A.5 "Default climate and soil classifications".

[16] Figure 3A.5.4 on 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Chapter 3.

[17] https://esdac.jrc.ec.europa.eu/resource-type/datasets

> Soils are classified in order to apply reference C stocks and stock change factors for estimation of soil C stock changes, as well as the soil N_2O emissions (i.e., organic soils must be classified to estimate N_2O emissions following drainage). Organic soils are found in wetlands or have been drained and converted to other land-use types (e.g., Forest Land, Cropland, Grassland, Settlements). Organic soils are identified on the basis of criteria 1 and 2, or 1 and 3 listed below (FAO 1998):
>
> 1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.
> 2. Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).
> 3. Soils are subject to water saturation episodes and has either:
>   a. At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay; or
>   b. At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay; or
>   c. An intermediate, proportional amount of organic carbon for intermediate amounts of clay.

LUCAS Topsoil Database does not provide data by horizon and so the application of criterion 1 is not possible. Likewise it is not possible to determine from the LUCAS database if soils are subject to water saturation episodes or not. As a consequence, organic soils were identified by applying the quantitative thresholds described in IPCC's criterion 3, on the assumption that those soils are subject to saturation episodes. This assumption is considered valid as the points identified as "organic" are located in areas of "Warm Temperate Moist" and "Cool Temperate Moist" climates, i.e., the wetter types of climate present in the MediNet Region.

Only 22 out of 5195 soil points contained organic soils (0.42%). This suggests that organic soils are not a particularly relevant feature in Mediterranean soils. Due to the low number of plots, no specific analysis on organic soils was conducted in this report.

3.2.6 Bulk Density

Bulk density was not measured and is not provided by in the LUCAS Topsoil Database. It was therefore necessary to estimate bulk density from the existing information, mostly share of clay, silt and sand and soil organic carbon.

The equations with the parameters derived using the MediNet Database as described in section 2.3.5 were used for the different MediNet subcategories (see Equation 2 and Table 3).

3.2.7 LUCAS harmonization to 0-30 cm depth

To harmonize the LUCAS database to the 0-30 cm depth so to have a comparison with the MediNet database and to add the LUCAS data to the MediNet database, we used a conversion factor derived from the MediNet database. For each category in the MediNet database, having the SOC stock for both 0-30 and 0-20 cm depth, the amount of SOC stored in the 20-30 cm depth was estimated as a fraction of the total amount stored in the 0-20 cm compartment. The resulting values are reported in Table 8 for each of the MediNet categories. No significant differences were observed deriving the conversion factors for the same categories but dividing all the points according to moist and dry climates.

Table 8: Conversion factors to report LUCAS data to 0-30 cm depth based on 0-20 cm estimates. Values in brackets represent the standard deviation

Annual crops	Olive Trees	Vineyards	Fruit Trees	Pasture	Shrubland
1.99 (±1.80)	1.43 (±1.02)	1.54 (±1.24)	1.66 (±1.15)	1.29 (±1.13)	1.16 (±1.19)

The conversion factors in Table 8 were applied to each point (0-20 cm depth) from LUCAS in each MediNet category of the LUCAS database.

3.2.8 Abnormal values

The MediNet database was cleaned removing possible abnormal values. Initially, it was check that no negative SOC stock values were present. Then, all the values with SOC stock higher than the 95th percentile were checked for the parameters used to calculate the SOC stock. This was done going back to the raw data in the original database. Data were corrected when possible (e.g. mistake in reporting a C concentration value) and removed from the original data when we were not certain of the quality of the raw data (e.g. an annual crop on a sandy soil with a stock of 200 t C ha^{-1}). All the procedures were developed in the R-studio software (R Core Team 2016).

4 Results Consolidated MediNet Database

4.1 Introduction

This section presents the results of the consolidated data from the MediNet Literature Database, CARBOSOL, INFOSOLO, SeisNET and the LUCAS Topsoil Database, all harmonised to 0-30 cm depth. The Consolidated MediNet Database consists of 8537points, distributed across all countries of the Mediterranean Basin (Figure 10).

Figure 10: Spatial distribution of the MediNet and LUCAS points in all the MediNet countries

Carbon Stocks in cropland and grassland may be affected by a number of different factors, such as:

1. Land-Use

Land-use (and its associated management practices) determines to a large extent the Carbon Stocks in soils. The diversity of crop types in the Mediterranean is quite big and so there was a need to aggregate them for the purposes of data presentation and (at a later stage) development of emission factors. All points without land-use information were discarded from the analysis. For the purposes of data presentation, Land-use data was aggregated as shown in Table 9.

Table 9: Land use categories in the Consolidated MediNet Database

IPCC Category	MediNet Category
Croplands	Annual Crops
	Olive Trees
	Vineyards
	Fruit Trees
Grasslands	Pastures
	Shrublands

2. Climate Zone

Climate, and in particular precipitation, is one of the major drivers of primary productivity in the Mediterranean and therefore affects also SOC stocks. As described in Sections 2.3.3 and 3.2.4 all data points were classified according to the IPCC Climate Zones. The analysis of the data showed that the major differences occurred between moisture regimes (i.e. dry vs moist) rather than temperature changes (i.e. warm vs cool vs tropical). Most of the region is represented in 5 climate zones, which were aggregated for data presentation as follows:

- Moist climates: all points located in areas of Warm Temperate Moist; Cold Temperate Moist;
- Dry climates: all points located in areas of Warm Temperate Dry; Cold Temperate Dry; Dry Tropical.

3. Soil Type

Soil types and textures affect the way SOC is accumulated and how it decays. As described in Sections 2.3.4 and 3.2.5 all data points were classified according to the IPCC Soil Types. However, soils in the Region are strongly dominated by "High Activity Clay Soils", i.e. the number of points in other soil types is very limited for a meaningful comparison between different soil types. Further, data suggests that the climate impacts are much more significant than the impact of different soil types. For these reasons, data per soil type is presented, but no specific analysis of the effect of soil type on SOC was performed.

4. Management Practices

There are usually different ways of producing the same crop (e.g. seeding/planting densities; irrigation or rainfed; crop residue management; type of fertilization; tillage practices and intensity; etc.), which affect differently SOC stocks and may lead to different emission factors.

Most of the points in the database did not contain management information or contained only very limited management information of the respective crop. It was therefore not possible to determine the impacts of different management practices in the measured SOC stocks.

5. Land-use History

Changes in land-use in the same location affect SOC stocks in the soils for extended periods of time of that particular location; the IPCC considers that changing land-uses will take a default of 20 years to stabilise from the typical "old" land-use Carbon Stock to the typical "new" land-use SOC stock.

None of the database points contained information about land-use history. It was therefore not possible to determine if the measured SOC stocks were affected by the land-use history of each plot.

Section 4.2 presents the results as averages of all points with a similar combination of crop/soil/climate types, whenever the number of points allowed for that disaggregation to occur[18]. It also presents for each land-use considered:

- the number of data samples and the average of all recorded Soil C Stocks and the averages of SOC stocks in Moist and Wet Climates per crop type;
- their percentile distribution and confidence interval;
- the number of data samples and the average of all recorded SOC stocks for each combination of crop/soil/climate which contained more than 20 samples;
- the number of data samples and the average of all recorded SOC stocks for each country and the averages of SOC stocks in Moist and Wet Climates per crop type and country.

Section 4.3 presents 3 sets of emission factors resulting from changing between crop types (calculated as difference in SOC stocks):

(1) based on averages per crop type only;

(2) based on averages per crop type in moist climates;

(3) based on averages per crop type in dry climates.

4.2 Results per Crop Type

4.2.1 Annual Crops

The Consolidated MediNet Database contained 4308 soil samples on Annual Crops. The calculated SOC stocks in Annual Crops were on average 50.64±0.41 tC ha^{-1} in the first 30 cm of soil (Table 10). There are no significant differences per soil type, but climate seems to be an important factor, with drier climates having significantly

[18] Data were only presented where a minimum 20 points per relevant combination exists.

lower values than wetter climates (Table 11). The differences per country are explained by differences in the predominance of different climate zones, with France showing the highest average value and Spain the lowest values (Table 12).

Table 10: Percentiles and Average SOC stocks (tC ha^{-1}) in Annual Crops

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Annual Crops	4308	1.3	30.5	45.9	66.4	129.2	26.7	49.8	50.6	51.4	1.6%
Moist climates	1143	5.6	50.7	69.6	92.6	129.2	27.7	69.8	71.5	73.1	2.2%
Dry climates	3165	1.3	27.2	39.6	55.6	127.1	21.9	42.4	43.1	43.9	1.8%

Table 11: Distribution of Average SOC stocks (tC ha^{-1}) in Annual Crops per Climate Zone and Soil Type

	Climatic Region										C Stock per soil type	
	1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
Soil Type	N	C	N	C	N	C	N	C	N	C	N	C
2 Sandy Soils	235	69.7	91	31.2			1	-			**327**	**58.9**
4 Volcanic Soils	1	-	2	-							**3**	-
5 Spodic Soils	9	-	4	-							**13**	-
6 High Activity Clay Soils	662	69.8	2750	44.2	31	61.4	19	-	52	37.0	**3514**	**49.1**
7 Low Activity Clay Soils	197	81.4	199	37.0	4	-			41	29.2	**441**	**56.2**
8 Other Areas	4	-	6	-							**10**	-
C Stock per climate type	**1108**	**71.8**	**3052**	**43.4**	**35**	**60.1**	**20**	**54.0**	**93**	**33.6**	**4308**	**50.6**

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 12: Distribution of Average SOC stocks (tC ha^{-1}) in Annual Crops per Country and Climate Zone

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Annual Crops	159	48.1 (1.6)	2134	43.4 (0.5)	27	65.3 (4.3)	729	53.7 (0.8)	1259	61.2 (0.9)	0	-
Moist climates	6	-	88	60.6 (2.7)	9	-	231	56.5 (1.3)	809	77.0 (1.0)	0	-
Dry climates	153	47.8 (1.6)	2046	42.6 (0.5)	18	-	498	52.4 (1.5)	450	32.7 (0.7)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

4.2.2 Olive trees

The consolidated MediNet Database contained 917 soil samples on Olive Trees. The calculated SOC stocks in Olive Trees were on average 38.50±0.64 tC ha^{-1} in the first 30 cm of soil (Table 13). There are no significant differences per soil type or climate region (Table 14). The values for Spain and Portugal appear to be somewhat lower than the values for Greece and Italy (Table 15).

Table 13: Percentiles and Average SOC stocks (tC ha^{-1}) in Olive Trees

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Olive Trees	917	1.9	24.2	35.1	50.4	96.0	19.5	37.2	38.5	39.7	3.3%
Moist climates	56	10.8	33.6	49.5	70.9	95.0	22.6	45.1	51.0	56.9	11.6%
Dry climates	861	1.9	23.8	34.5	49.2	96.0	19.0	36.4	37.7	39.0	3.4%

Table 14: Distribution of Average SOC stocks (tC ha^{-1}) in Olive Trees per Climate Zone and Soil Type

			Climatic Region										C Stock per soil type	
			1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
			N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2	Sandy Soils	6	-	30	19.6					5	-	41	24.7
	4	Volcanic Soils			2	-							2	-
	5	Spodic Soils												
	6	High Activity Clay Soils	44	48.9	717	39.4					29	37.3	790	39.8
	7	Low Activity Clay Soils	6	-	52	33.4					26	22.7	84	32.2
	8	Other Areas												
C Stock per climate type			56	51.0	801	38.3					60	29.4	917	38.5

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 15: Distribution of Average SOC Stocks (tC ha^{-1}) in Olive Trees per Country and Climate Zone

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Olive Trees	80	56.2 (2.4)	487	34.0 (0.8)	2	-	135	47.8 (1.4)	205	36.6 (1.4)	0	-
Moist climates	2	-	0	-	0	-	12	-	40	51.3 (3.9)	0	-
Dry climates	78	56.1 (2.4)	487	34.0 (0.8)	2	-	123	47.5 (1.5)	165	33.0 (1.3)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

4.2.3 Vineyards

The consolidated MediNet Database contained 552 soil samples on Vineyards. The calculated SOC stocks in Vineyards were on average 37.28±0.83 tC ha^{-1} in the first 30 cm of soil (Table 16). There are no significant differences both per soil type and climate (Table 17). The differences per country are probably explained by differences in the predominance of different climate zones, with France showing the highest and Slovenia the lowest values (Table 18).

Table 16: Percentiles and Average SOC stocks (tC ha^{-1}) in Vineyards

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Vineyards	552	1.3	21.9	33.3	50.1	97.5	19.6	35.6	37.3	38.9	4.4%
Moist climates	170	3.7	21.2	45.1	60.1	97.5	22.3	40.5	43.9	47.2	7.6%
Dry climates	382	1.3	22.3	30.8	45.1	92.4	17.4	32.6	34.3	36.1	5.1%

Table 17: Distribution of Average SOC stocks (tC ha^{-1}) in Vineyards per Climate Zone and Soil Type

			Climatic Region										C Stock per soil type	
			1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
			N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2	Sandy Soils	23	44.2	16	-					1	-	40	33.0
	4	Volcanic Soils												
	5	Spodic Soils	4	-	1	-							5	-
	6	High Activity Clay Soils	91	42.6	355	35.2	19	-					465	36.4
	7	Low Activity Clay Soils	33	54.8	7	-							40	50.2
	8	Other Areas			2	-							2	-
C Stock per climate type			151	45.7	381	34.4	19	-			1	-	552	37.3

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 18: Distribution of Average SOC stocks (tC ha^{-1}) in Vineyards per Country and Climate Zone

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Vineyards	6	-	220	29.3 (1.1)	37	46.1 (2.5)	96	46.7 (1.9)	137	45.3 (1.9)	25	17.8 (0.5)
Moist climates	0	-	5	-	0	-	30	49.2 (3.2)	108	47.9 (2.1)	25	17.8
Dry climates	6	-	215	28.5 (1.0)	37	46.1 (2.5)	66	45.6 (2.4)	29	35.5 (3.6)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

4.2.4 Fruit trees

The consolidated MediNet contained 338 soil samples on Fruit Trees. The calculated SOC stocks in Fruit Trees were on average 43.26±1.13tC ha^{-1} in the first 30 cm of soil (Table 19). There are no significant differences both per soil type and climate (Table 20). The differences per country are probably explained by differences in the predominance of different climate zones, with Greece showing the highest and Spain the lower values (Table 21).

Table 19: Percentiles and Average SOC stocks (tC ha^{-1}) in Fruit Trees

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Fruit Trees	338	4.6	26.7	41.5	56.6	100.3	20.8	41.0	43.3	45.5	5.1%
Moist climates	41	8.0	36.8	57.5	72.3	100.3	24.7	48.3	55.8	63.4	13.5%
Dry climates	297	4.6	26.4	40.2	53.6	98.3	19.7	39.3	41.5	43.8	5.4%

Table 20: Distribution of Average SOC stocks in Fruit Trees per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	4	-	13	-							17	-
	4 Volcanic Soils												
	5 Spodic Soils												
	6 High Activity Clay Soils	25	58.7	245	43.4	4	-			7	-	281	44.8
	7 Low Activity Clay Soils	8	-	20	37.8					11	-	39	38.8
	8 Other Areas			1	-							1	-
C Stock per climate type		37	55.4	279	42.3	4	-			18	-	338	43.3

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 21: Distribution of Average SOC stocks (tC ha^{-1}) in Fruit Trees per Country and Climate Zone

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Fruit Trees	20	54.5 (4.4)	188	36.7 (1.4)	4	-	86	51.2 (2.0)	39	48.9 (3.8)	1	-
Moist climates	1	-	3	-	1	-	10	-	25	48.9 (4.5)	1	-
Dry climates	19	-	185	35.9 (1.3)	3	-	76	50.8 (2.1)	14	-	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

4.2.5 Pasture

The consolidated MediNet Databases contained 1410 soil samples on Pasture category. The calculated SOC stocks in Pasture were on average 64.45±1.06 tC ha^{-1} in the first 30 cm of soil (Table 22). There are no significant differences per soil type, but wetter climate regions seem to have significantly higher values than drier ones (Table 23). The differences per country are probably explained by differences in the predominance of different climate zones, with Spain, France and Portugal showing the higher and similar values and Greece the lowest values (Table 24).

Table 22: Percentiles and Average SOC stocks (tC ha^{-1}) in Pasture

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Pasture	1410	2.8	33.5	55.1	88.4	183.4	39.7	62.4	64.4	66.5	3.2%
Moist climates	587	3.3	57.8	80.6	112.5	183.4	38.1	82.3	85.4	88.4	3.6%
Dry climates	823	2.8	28.0	39.3	63.3	181.8	33.6	47.2	49.5	51.8	4.6%

Table 23: Distribution of Average SOC stocks (tC ha^{-1}) in Pasture per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	40	89.7	32	35.8	1	-			2	-	75	65.2
	4 Volcanic Soils			1	-							1	-
	5 Spodic Soils	2	-	7	-	6	-					15	-
	6 High Activity Clay Soils	319	77.8	723	49.6	165	97.3	19	-	2	-	1231	63.9
	7 Low Activity Clay Soils	48	90.3	31	45.0	2	-			3	-	84	72.4
	8 Other Areas			3	-	1	-					4	-
C Stock per climate type		409	80.4	797	48.8	175	97.0	19	-	7	-	1410	64.4

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 24: Distribution of Average SOC stocks (tC ha^{-1}) in Pasture per Country and Climate Zone

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Pasture	89	42.7 (2.8)	677	65.3 (1.6)	30	69.7 (5.9)	344	63.7 (1.9)	260	68.1 (2.4)	10	-
Moist climates	17	-	243	91.1 (2.6)	11	-	144	77.8 (2.9)	162	84.2 (2.9)	10	-
Dry climates	72	39.9 (2.8)	434	50.9 (1.8)	19	-	200	53.6 (2.2)	98	41.5 (2.4)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

4.2.6 Shrubland

The consolidated MediNet Databases contained 1012 soil samples on Shrubland category. The calculated SOC stocks in Shrubland were on average 72.48±1.58 tC ha^{-1} in the first 30 cm of soil (Table 25). There are no significant differences per soil type, but wetter climate regions seem to have significantly higher values than drier ones (Table 26). The insufficient amount of samples in most countries, except for Spain and Italy, does not allow for comparisons between them (Table 27).

Table 25: Percentiles and Average SOC stocks in Shrubland

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Shrubland	1012	2.6	32.1	61.0	100.4	226.7	50.4	69.4	72.5	75.6	4.3%
Moist climates	408	2.9	61.2	96.0	133.2	226.7	53.1	96.6	101.7	106.8	5.1%
Dry climates	604	2.6	25.5	43.4	70.3	211.0	37.3	49.8	52.8	55.7	5.6%

Table 26: Distribution of Average SOC stocks (tC ha^{-1}) in Shrubland per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	12	-	31	24.3	4	-	3	-	5	-	55	62.7
	4 Volcanic Soils			2	-							2	-
	5 Spodic Soils	3	-	1	-	6	-					10	-
	6 High Activity Clay Soils	238	102.1	491	55.2	133	95.2	21	54.1	6	-	889	74.0
	7 Low Activity Clay Soils	7	-	40	38.2	4	-			4	-	55	49.9
	8 Other Areas	1	-									1	-
C Stock per climate type		261	104.2	565	52.3	147	97.3	24	57.8	15	-	1012	72.5

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 27: Distribution of Average SOC stocks (tC ha^{-1}) in Shrubland per Country and Climate Zone

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Shrubland	57	56.6	704	72.0 (2.0)	23	59.5	169	85.0 8 (3.23)	57	60.5	1	-
Moist climates	7	-	290	106.5 (3.2)	10	-	71	106.1 (5.8)	29	67.4 (7.8)	1	-
Dry climates	50	53.9 (4.0)	414	47.9 (1.9)	13	-	98	71.2 (3.0)	28	53.5 (5.4)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Alongside land-use, climate type seems to have a significant impact, with dry climates present in the region (i.e. Warm Temperate Dry, Cool Temperate Dry and Tropical Dry) showing significantly lower values than wetter climates (i.e. Warm Temperate Moist and Cool Temperate Moist).

Most profiles were concentrated in High Activity Clay Soils, but the results suggest much smaller differences between soil types than between climate types.

4.3 Proposed C Stocks and C Stock Change Factors in Mediterranean Countries

The Emission Factors proposed in this section are based on the general equation for the Stock-Change Method as described in IPCC 2006 Guidelines, Volume 4, Chapter 2 (see Equation 4).

Equation 4: Calculation of Stock-Change Emission Factors

$$EF_{A \rightarrow B} = \frac{SOC_B - SOC_A}{D}$$

Where:

$EF_{A \rightarrow B}$ = Emission/Removal Factor from the conversion of Land-Use A to Land-Use B (tC ha^{-1} y^{-1});

SOC_A = Soil Organic Carbon Stock of Land-Use A (tC ha^{-1});

SOC_B = Soil Organic Carbon Stock of Land-Use B (tC ha^{-1});

D = Time dependence of Soil Organic Carbon Stock Change (years).

As mentioned above, 3 sets of emission factors are proposed:

(1) based on averages per crop type only;

(2) based on averages per crop type in moist climates;

(3) based on averages per crop type in dry climates.

Emission Factors (1) are proposed for general use in the Mediterranean Countries, while Emission Factors (2) and (3) are recommended for use whenever activity data allows for the identification of land-use changes in each broad climate zone.

4.3.1 All climate zones in Mediterranean Countries

Table 29 presents a summary of the data on SOC stock per Land-Use Category as described in section 4.2, while Figure 11 shows the dispersion of information for each land-use and highlights significant differences (Pairwise Wilcoxon test $p<0.05$) between different land-use categories.

Differences between the average C Stocks are generally statistically significant, except for the differences between Pasture and Shrubland and between Olive Trees and Vineyards.

Table 28: Soil Carbon Stocks per Land-Use Category / all climate zones

IPCC Category	MediNet Category	N Samples	Average SOC Stock tC ha^{-1}	U (%)
Croplands	Annual Crops	4308	50.6	1.6
	Olive Trees	917	38.5	3.3
	Vineyards	552	37.3	4.4
	Fruit Trees	338	43.3	5.1
Grasslands	Pasture	1410	64.5	3.2
	Shrubland	1012	72.5	4.3

Figure 11: Box plot showing the distribution of the soil profiles contained in the Consolidated MediNet Database between the different categories. Different letters on top of the bars indicate a significant difference (p<0.05). The numbers below each box represents the numbers of samples considered for each category.

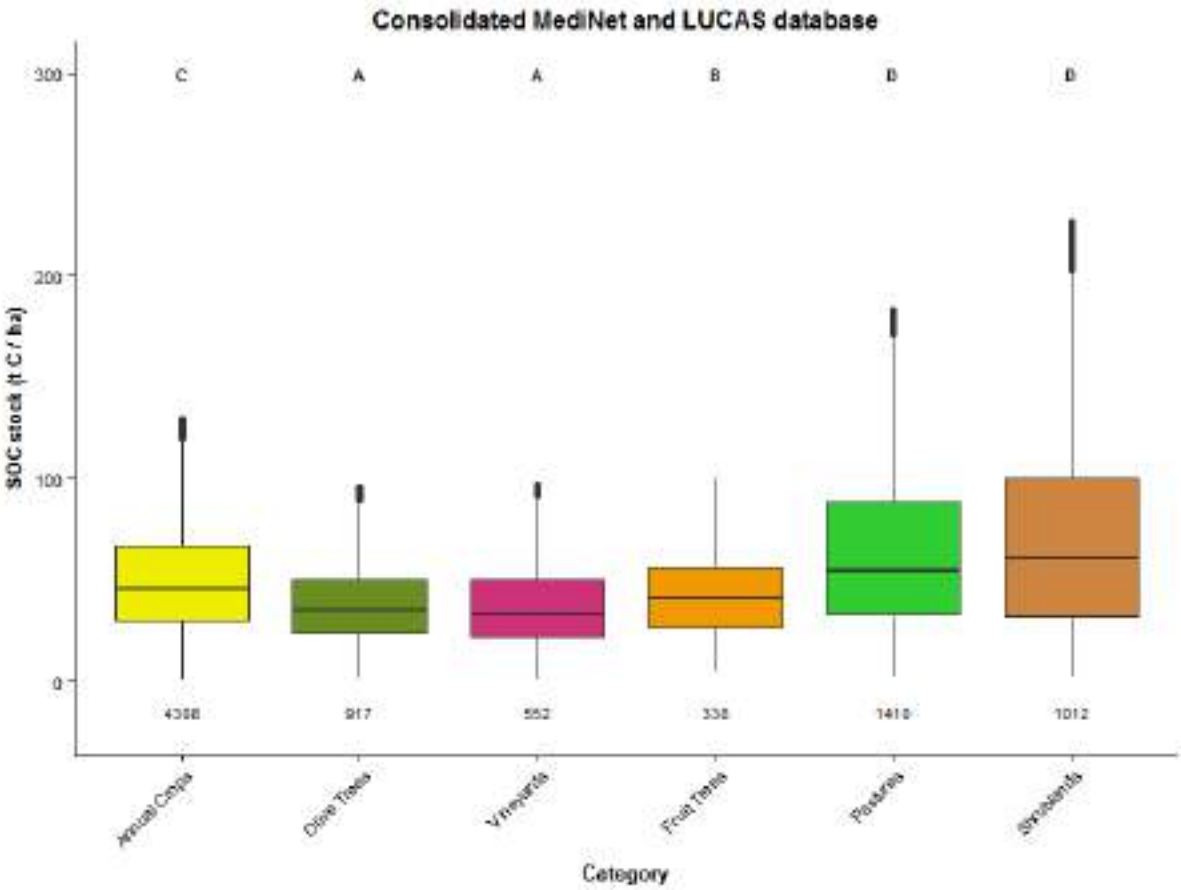


Table 29 shows the annual change in SOC stock considering 20 years of transition period. The changes that are not significantly different are highlighted in grey.

Table 29: Annual change in SOC considering 20 years of transition period. In grey the changes that are not significant

Emission Factor tC $ha^{-1} y^{-1}$		To					
		Annual Crops	Olive Trees	Vineyards	Fruit Trees	Pasture	Shrubland
From	Annual Crops		-0.61	-0.67	-0.37	0.69	1.09
	Olive Trees	0.61		-0.06	0.24	1.30	1.70
	Vineyards	0.67	0.06		0.30	1.36	1.76
	Fruit Trees	0.37	-0.24	-0.30		1.06	1.46
	Pasture	-0.69	-1.30	-1.36	-1.06		0.40
	Shrubland	-1.09	-1.70	-1.76	-1.46	-0.40	

4.3.2 Moist Climates

Table 30 presents a summary of the data on SOC stock per Land-Use Category considering only the Moist climates.

Table 30: Soil Carbon Stocks per Land-Use Category / Moist climate zones

IPCC Category	MediNet Category	N Samples	Average SOC Stock tC ha^{-1}	U (%)
Croplands	Annual Crops	1143	71.5	2.3
	Olive Trees	56	51.0	11.6
	Vineyards	170	43.9	7.6
	Fruit Trees	41	55.8	13.5
Grasslands	Pasture	587	85.4	3.6
	Shrubland	408	101.7	5.0

Table 31: shows the annual change in SOC stock in moist climates, considering 20 years of transition period. The changes that are not significantly different are highlighted in grey.

Table 31: Moist climates annual change in SOC considering 20 years of transition period. In grey the changes that are not significant

Emission Factor tC $ha^{-1} y^{-1}$		To					
		Annual Crops	Olive Trees	Vineyards	Fruit Trees	Pasture	Shrubland
From	Annual Crops		-1.02	-1.38	-0.78	0.70	1.51
	Olive Trees	1.02		-0.35	0.24	1.72	2.54
	Vineyards	1.38	0.35		0.60	2.07	2.89
	Fruit Trees	0.78	-0.24	-0.60		1.48	2.29
	Pasture	-0.70	-1.72	-2.07	-1.48		0.82
	Shrubland	-1.51	-2.54	-2.89	-2.29	-0.82	

4.3.3 Dry Climates

Table 32 presents a summary of the data on SOC stock per Land-Use Category considering only the dry climates.

Table 32: Soil Carbon Stocks per Land-Use Category / Dry climate zones

IPCC Category	MediNet Category	N Samples	Average SOC Stock tC ha^{-1}	U (%)
Croplands	Annual Crops	3165	43.1	1.8
	Olive Trees	861	37.7	3.4
	Vineyards	382	34.3	5.1
	Fruit Trees	297	41.5	5.4
Grasslands	Pasture	823	49.5	4.6
	Shrubland	604	52.7	5.6

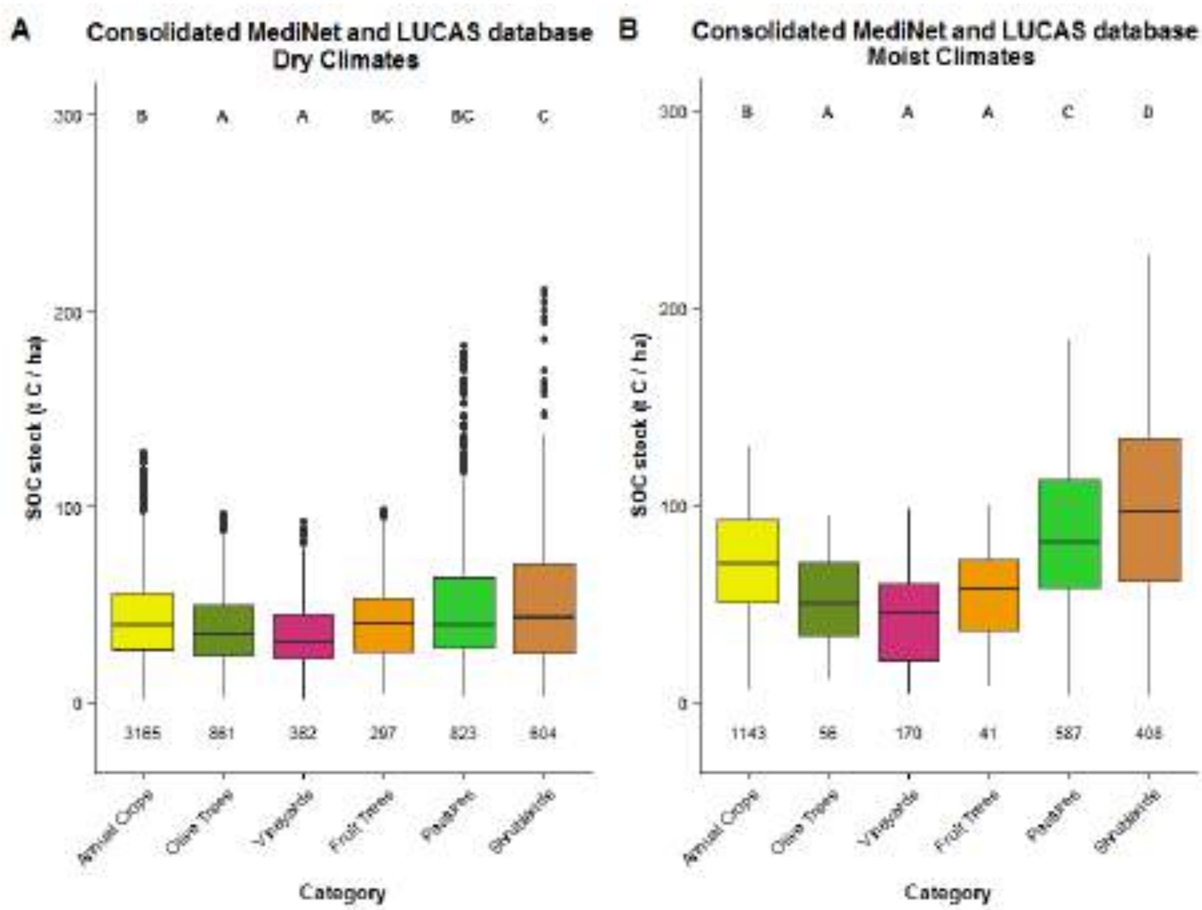
Table 33 shows the annual change in SOC stock in dry climates, considering 20 years of transition period. The changes that are not significantly different are highlighted in grey.

Table 33: Dry climate annual change in SOC considering 20 years of transition period. In grey the changes that are not significant

	Emission Factor $tC\ ha^{-1}\ y^{-1}$	To					
		Annual Crops	Olive Trees	Vineyards	Fruit Trees	Pasture	Shrubland
From	Annual Crops		-0.27	-0.44	-0.08	0.32	0.48
	Olive Trees	0.27		-0.17	0.19	0.59	0.75
	Vineyards	0.44	0.17		0.36	0.76	0.92
	Fruit Trees	0.08	-0.19	-0.36		0.40	0.56
	Pasture	-0.32	-0.59	-0.76	-0.40		0.16
	Shrubland	-0.48	-0.75	-0.92	-0.56	-0.16	

Figure 12, shows the dispersion of information for each land-use and highlights significant differences (Pairwise Wilcoxon test $p<0.05$) between different land-use categories, separated by dry (A) and moist climate (B).

Figure 12: Average SOC stock data for different MediNet Categories and considering the stratification based on climate (Dry vs. Moist). Different letters on top of the bars indicate a significant difference ($p<0.05$). The numbers below each box represents the numbers of samples considered for each category.



5 Information Gaps and Possibilities for Further Improvement

The tables below (see Table 34 and Table 35) show the comparison between the calculations of the SOC applying the default method of the IPCC 2006 (Eq. 2.25, Ch.2, Vol. 4) with the SOCref related to the most representative combination of soil type and climate for the Mediterranean regions (Table 2.3 of IPCC 2006 Ch.2, Vol. 4): High activity Clay in Warm Temperate dry (38 tC ha^{-1}) and moist (88 tC ha^{-1}) and Low Activity Clay in Warm Temperate dry (24 tC ha^{-1}) and moist (63 tC ha^{-1}).

The three factors related to the land use (F_{LU}), inputs (F_I), and management (F_{MG}) were selected from table 5.5 of IPCC 2006 Ch.5, Vol. 4, with the purpose to calculate the SOC applying the most representative management and inputs regimes in the Mediterranean area, and compare them with the average SOC stock resulting from the consolidated MediNet database (M+L).

Table 34: Comparison of SOC stock between MediNet and IPCC 2006 Default Values for Annual Crop (tC ha^{-1})

	F_{LU}: long T cultivated F_I: medium input F_{MG}: full tillage	F_{LU}: Long T cultivated F_I: high input F_{MG}: no tillage	M+L
HAC+WTdry	30.4	34.8	44.2
HAC+WTmoi	60.7	77.5	69.8
LAC+WTdry	19.2	22.0	37.0
LAC+WTmoi	43.5	55.5	81.4

HAC – high activity clay soils; LAC – low activity clay soils; WTdry - warm temperate dry; WT moist – warm temperature moist
Long T cultivated = represents area that has been continuously managed for >20 yrs.
Medium input = when all crop residues are returned to the field.
High input = Represents significantly greater crop residue inputs over medium C input cropping systems due to additional practices (e.g. production of high residue yielding crops, use of green manures, cover crops).
Full tillage = Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g. <30%) of the surface is covered by residues.
No tillage = Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.

Table 35: Comparison of SOC stock between MediNet and IPCC 2006 Default Values for Perennial Crops (tC ha^{-1})

	F_{LU}: perennial/tree crop F_I: medium input F_{MG}: reduced tillage	F_{LU}: perennial/tree crop F_I: high input without manure F_{MG}: no tillage	Vineyard (M+L)	Olive Trees (M+L)	Fruit Trees (M+L)
HAC+WTdry	38.8	43.5	35.2	39.4	43.4
HAC+WTmoist	95.0	112.3	42.6	48.9	58.7
LAC+WTdry	24.5	27.5	28.6	33.4	37.8
LAC+WTmoist	68.0	80.4	54.8	62.0	58.0

HAC – high activity clay soils; LAC – low activity clay soils; WTdry - warm temperate dry; WT moist – warm temperature moist
Medium input = when all crop residues are returned to the field.
High input without manure = Represents significantly greater crop residue inputs over medium C input cropping systems due to additional practices (e.g. production of high residue yielding crops, use of green manures, cover crops).
Reduced tillage = Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with >30% coverage by residues at planting.
No tillage = Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.

However, although we believe that the use of the proposed values will constitute an improvement there are still limitations in the current values and opportunities for further improvements that should be explicitly acknowledged (see Table 36).

Table 36: Main Improvements to the Default Values to be Further Elaborated

Limitation	Description *Recommendation*
Data consistency	• *Increase the amount of data for the subcategories under represented*
Stratification	• *Keep the data in a disaggregated format so to allow for different types of stratification*
Management practices	• Improve the information on the different management practices

Annex I: Results from MediNet Soil Profiles Database and LUCAS Topsoil Database

In this annex, and for information only, we present separately the results for SOC stocks from the Database of Soil Profiles (as described in section 2 Methodology / Soil Profiles Databases) and for the LUCAS Topsoil Database (as described in section 3 Methodology / LUCAS Topsoil Database).

MediNet Soil Profiles Database

The distribution of the points contained in the MediNet Soil Profiles Database indicates significant differences (Pairwise Wilcoxon test $p<0.005$) between Pasture and Shrubland land-use categories. In the perennial crop category, Vineyards are significantly different from both Olive tree and Fruit Tree subcategories. Finally, Annual Crops are significantly different from all the other categories (Figure 13).

Figure 13: Box plot showing the distribution of the soil profiles contained in the MediNet Database between the different categories. Different letters on top of the bars indicate a significant difference ($p<0.05$). The numbers below each box represents the numbers of samples considered for each category.

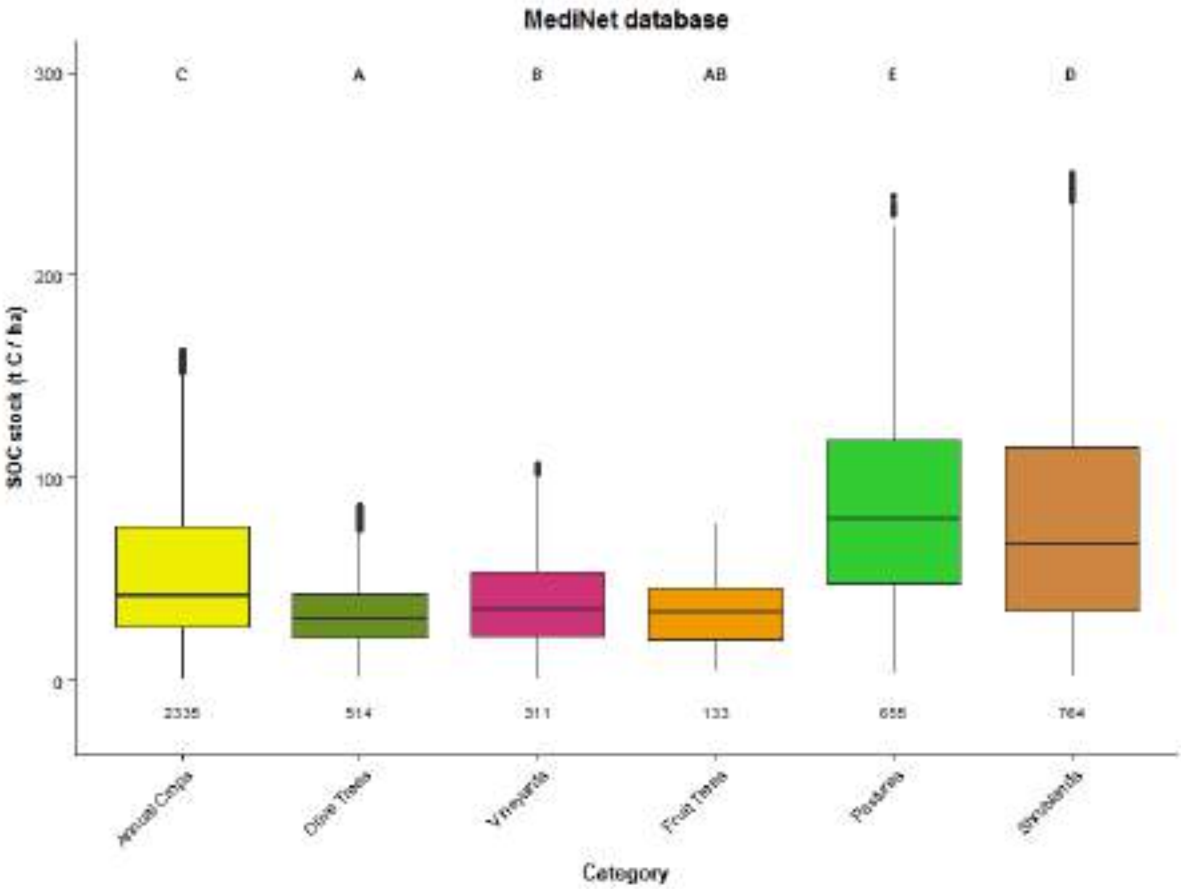


Table 37 shows the annual change in SOC stock considering 20 years of transition period. The changes that are not statistically significant ($p<0.05$ - Pairwise Wilcoxon Rank Sum Tests) are highlighted in grey.

Table 37: Annual change in SOC considering 20 years of transition period. In grey the changes that are not significant

SOC stock change tC ha^{-1} y^{-1}		to					
		Annual Crops	Olive Trees	Vineyards	Fruit Trees	Pasture	Shrubland
from	Annual Crops	-	-1.02	-0.73	-0.98	1.68	1.34
	Olive Trees	1.02	-	0.28	0.03	2.70	2.36
	Vineyards	0.74	-0.28	-	-0.24	2.42	2.08
	Fruit Trees	0.98	-0.03	0.24	-	2.66	2.33
	Pasture	-1.68	-2.69	-2.42	-2.66	-	-0.34
	Shrubland	-1.34	-2.36	-2.08	-2.33	0.34	-

Annual Crops

The MediNet Soil Profiles Database contained 2335 soil samples on Annual Crops. The calculated SOC stocks in Annual Crops were on average 54.26±0.01 tC ha^{-1} in the first 30 cm of soil (Table 38). There are no significant differences per soil type, but climate seems to be an important factor, with drier climates having significantly lower values than wetter climates (Table 39). The differences per country are probably explained by differences in the predominance of different climate zones, with Portugal showing the highest and Spain the lowest values (Table 40).

Table 38: Percentiles and Average SOC Stocks (tC ha^{-1}) in Annual Crops

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Annual Crops	2335	1.3	26.1	42.1	76.5	163.1	36.5	**52.8**	**54.3**	**55.7**	2.7%

Table 39: Distribution of Average SOC stocks in Annual Crops per Climate Zone and Soil Type

		Climatic Region											
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry		C Stock per soil type	
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	264	77.9	72	27.7			1	-			337	67.0
	4 Volcanic Soils	1	-									1	-
	5 Spodic Soils	10	-	1	-							11	-
	6 High Activity Clay Soils	491	80.9	983	33.3	19	-	12	-	34	31.6	1539	49.0
	7 Low Activity Clay Soils	228	90.0	179	35.5	4	-			35	24.9	446	62.7
	8 Other Areas			1	-							1	-
C Stock per climate type		994	82.1	1236	33.3	23	58.0	13	-	69	28.2	2335	54.3

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 40: Distribution of Average SOC stocks (tC ha^{-1}) in Annual Crops per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Annual Crops	2	-	808	29.2 (0.8)	0	-	201	41.3 (1.2)	1326	64.8 (1.1)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Olive Trees

The MediNet Soil Profiles Database contained 514 soil samples on Olive trees. The calculated SOC stocks in Olive trees were on average 33.89±0.03 tC ha^{-1} in the first 30 cm of soil (Table 41). It is difficult to determine the effect of climate because Olive trees are mainly located in dry climates (Table 42). The SOC stock distribution between countries shows the highest value in Italy and the lowest in Spain (Table 43).

Table 41: Percentiles and Average SOC stocks (tC ha^{-1}) in Olive Trees

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Olive Trees	514	1.9	21.1	31.2	42.6	86.4	17.8	32.4	33.9	35.4	4.5%

Table 42: Distribution of Average SOC stocks (tC ha^{-1}) in Olive Trees per Climate Zone and Soil Type

		Climatic Region											
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry		C Stock per soil type	
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	6	-	30	19.6			5	-			41	24.7
	4 Volcanic Soils												
	5 Spodic Soils												
	6 High Activity Clay Soils	20	45.6	352	35.2					27	35.1	399	35.7
	7 Low Activity Clay Soils	4	-	47	31.0					23	22.3	74	29.3
	8 Other Areas												
C Stock per climate type		30	48.0	429	33.6			5	-	50	29.2	514	33.9

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 43: Distribution of Average C Stocks (tC ha^{-1}) in Olive trees per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Olive trees	11	-	299	31.4 (1.0)	0	-	32	41.4 (2.6)	164	34.8 (1.3)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Vineyards

The MediNet Soil Profiles Database contained 311 soil samples on Vineyard category. The calculated SOC stocks in Vineyards were on average 39.49±0.07 tC ha-1 in the first 30 cm of soil (Table 44). There are no significant differences per soil type, but climate seems to be an important factor, with drier climates having significantly lower values than wetter climates (Table 45). The SOC stock distribution between countries shows the highest value in Portugal and the lowest in Slovenia (Table 46).

Table 44: Percentiles and Average SOC stocks (tC ha^{-1}) in Vineyards

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Vineyards	311	1.3	21.6	35.5	53.9	107.3	21.8	37.1	39.5	41.9	6.1%

Table 45: Distribution of Average SOC stocks (tC ha^{-1}) in Vineyards per Climate Zone and Soil Type

		Climatic Region											
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry		C Stock per soil type	
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	26	51.0	15	-					1.0	-	42	38.2
	4 Volcanic Soils												
	5 Spodic Soils	4	-									4	-
	6 High Activity Clay Soils	63	47.1	149	35.4	13	-					225	37.7
	7 Low Activity Clay Soils	33	54.8	7	-							40	50.2
	8 Other Areas												
C Stock per climate type		126	50.0	171	33.6	13	-			1.0	-	311	39.5

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 46: Distribution of Average SOC stocks (tC ha^{-1}) in Vineyards per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Vineyards	0	-	102	31.1 (1.7)	3	-	24	49.6 (2.3)	125	49.7 (2.1)	25	17.8 (0.5)

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Fruit Trees

The MediNet Soil Profiles Database contained 133 soil samples on Fruit trees. The calculated SOC stocks in Fruit Trees category were on average 34.59±0.12 tC ha^{-1} in the first 30 cm of soil (Table 47). Most points in the fruit trees are located in dry climates with no significant differences between soil types (Table 48). The SOC stock distribution between countries shows the highest value in Italy and the lowest in Spain (Table 49).

Table 47: Percentiles and Average SOC stocks (tC ha^{-1}) in Fruit Trees

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Fruit Trees	133	4.6	20.8	34.0	46.2	76.8	16.6	31.8	34.6	37.4	8.2%

Table 48: Distribution of Average SOC stocks (tC ha^{-1}) in Fruit Trees per Climate Zone and Soil Type

	Climatic Region											
	1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry		C Stock per soil type	
Soil Type	N	C	N	C	N	C	N	C	N	C	N	C
2 Sandy Soils	4	-	12	-							16	-
4 Volcanic Soils												
5 Spodic Soils												
6 High Activity Clay Soils	7	-	69	33.6					3	-	79	34.1
7 Low Activity Clay Soils	8	-	20	37.8					10	-	38	38.9
8 Other Areas												
C Stock per climate type	19	-	101	33.5					13	-	133	34.6

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 49: Distribution of Average SOC stocks (tC ha^{-1}) in Fruit Trees per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Fruit Trees	0	-	85	29.1 (1.5)	0	-	21	44.7 (2.5)	27	44.0 (3.7)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Pasture

The MediNet Soil Profiles Database contained 655 soil samples on Pasture. The calculated SOC stocks in Pasture were on average 87.84±0.08 tC ha^{-1} in the first 30 cm of soil (Table 50). There are not significant differences in term of soil type, while for climate some significant differences are observed (Table 51). The differences per country are probably explained by differences in the predominance of different climate zones, with Italy showing the highest and Spain the lowest values (Table 52).

Table 50: Percentiles and Average SOC stocks (tC ha^{-1}) in Pasture

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Pasture	655	3.3	47.9	80.4	119.1	239.5	52.5	83.8	87.8	91.9	4.6%

Table 51: Distribution of Average SOC stocks (tC ha^{-1}) in Pasture per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	42	95.2	29	41.6	1	-	1	-			N	C
	4 Volcanic Soils									2	-	75	74.6
	5 Spodic Soils	1	-	6	-								
	6 High Activity Clay Soils	144	95.0	185	73.9	141	111.7	18	-			7	-
	7 Low Activity Clay Soils	50	95.2	28	41.0	2	-					491	92.0
	8 Other Areas									2	-	82	76.3
C Stock per climate type		237	94.8	248	66.7	144	111.6	19	-	4	-	655	87.8

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 52: Distribution of Average SOC stocks (tC ha^{-1}) in Pasture per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Pasture	3	-	384	86.5 (2.9)	0	-	94	96.7 (4.4)	174	86.9 (3.4)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Shrubland

The MediNet Soil Profiles Database contained 764 soil samples on Shrubland. The calculated SOC stocks in Shrubland Category were on average 81.12±0.07 tC ha^{-1} in the first 30 cm of soil (Table 53). There major differences are observed between different types of climate (Table 54). In term of countries, we only have more than 20 samples for Italy (the highest value) and Spain (Table 55).

Table 53: Percentiles and Average SOC stocks (tC ha^{-1}) in Shrubland

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Shrubland	767	2.6	34.8	67.3	115.3	250.7	58.6	77.0	81.1	85.3	5.1%

Table 54: Distribution of Average SOC stocks (tC ha^{-1}) in Shrubland per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils	13	-	31	24.3	5	-	4	-	5	-	58	71.8
	4 Volcanic Soils												
	5 Spodic Soils	5	-	6	-							11	-
	6 High Activity Clay Soils	163	122.6	332	59.6	120	102.3	20	54.0	5	-	640	83.8
	7 Low Activity Clay Soils	7	-	40	38.2	4	-			4	-	55	49.9
	8 Other Areas												
C Stock per climate type		188	124.7	409	55.8	129	103.8	24	65.5	14	-	764	81.1

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 55: Distribution of Average SOC stocks (tC ha^{-1}) in Shrubland per Country

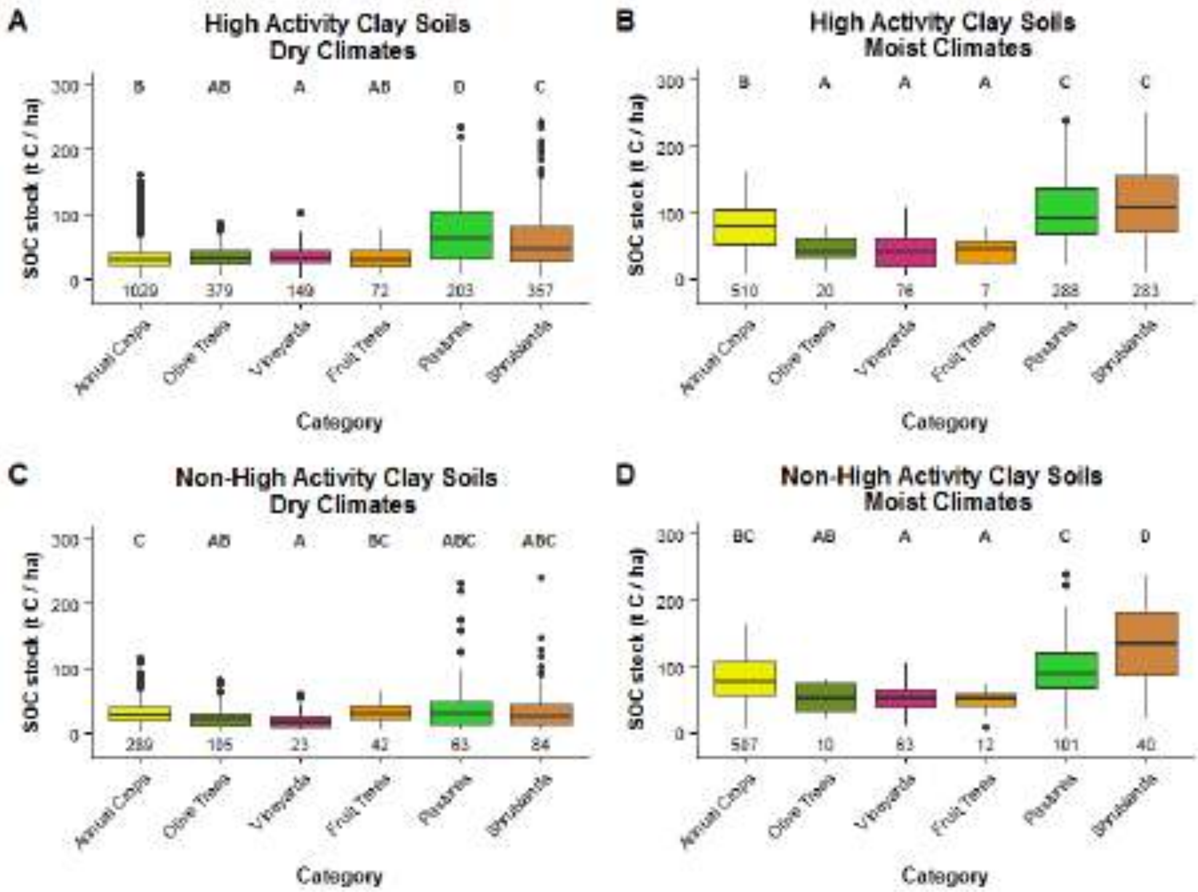
	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Shrubland	0	-	629	78.0 (2.4)	0	-	130	98.3 (3.6)	4	-	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Alongside land-use, climate type seems to have a significant impact, with dry climates present in the region (i.e. Warm Temperate Dry, Cool Temperate Dry and Tropical Dry) showing significantly lower values than wetter climates (i.e. Warm Temperate Moist and Cool Temperate Moist).

Most profiles were concentrated in High Activity Clay Soils (HAC), but the results suggest much smaller differences between soil types than between climate types (Figure 14).

Figure 14: Average SOC stock data considering the soil (HAC vs. other soil types) and the climate (Moist vs. Dry)



LUCAS Topsoil Database

The distribution of the points contained in the LUCAS Topsoil Database indicates significant differences (Pairwise Wilcoxon test $p<0.05$) for different land-use categories. In particular, the Pasture category shows significant differences from Annual Crop, and within the three Perennial Crop subcategories, Vineyards are significantly different from both Olive Trees and Fruit Trees (Figure 15).

Figure 15: Box plot showing the distribution of the soil profiles contained in the LUCAS Database between the different categories. Different letters on top of the bars indicate a significant difference (p<0.05). The numbers below each box represents the numbers of samples considered for each category.

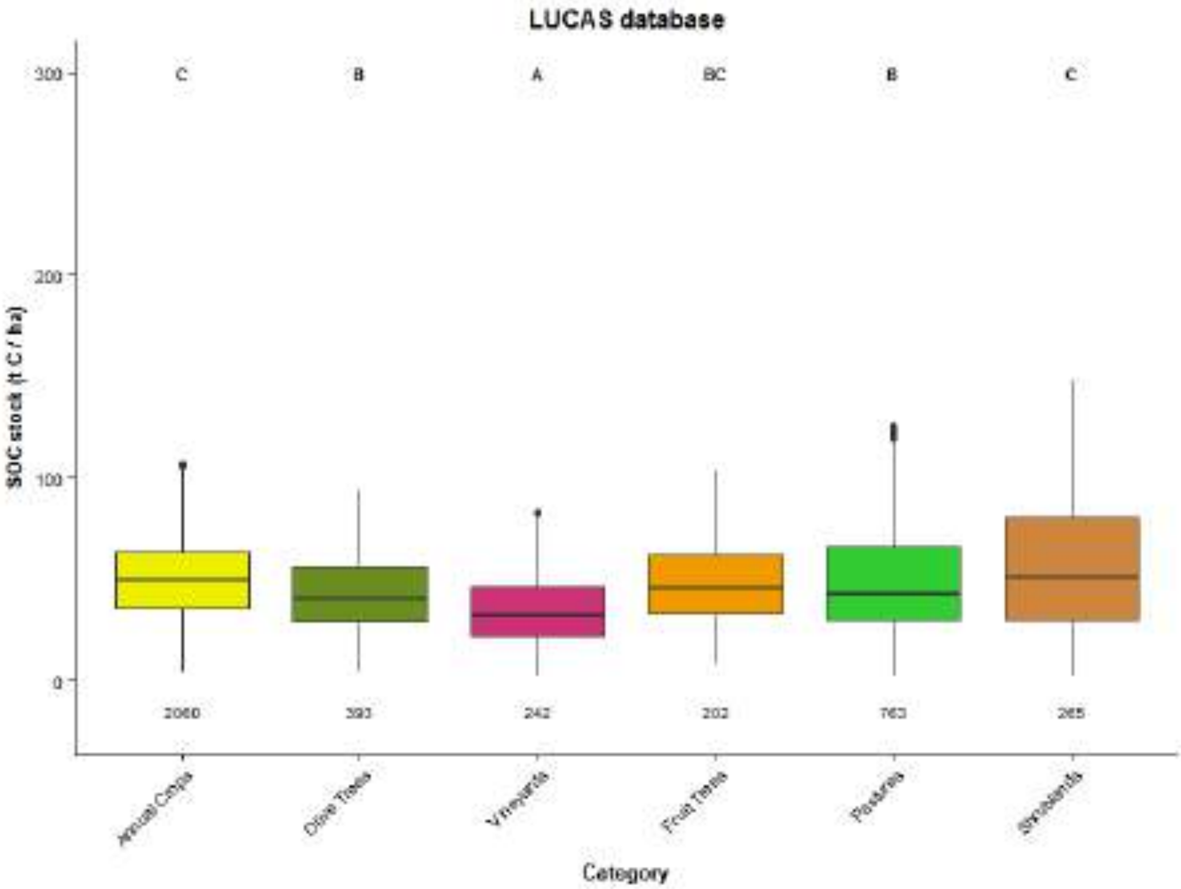


Table 56 shows the annual change in SOC stock considering 20 years of transition period. In grey are reported the changes that are not significantly different in term of SOC stock. The most significant changes are observed for the change between the Vineyards category and all the other categories ($p<0.05$ - Pairwise Wilcoxon Rank Sum Tests). Annual Crops and Shrubland categories are not significantly different, while they differ from the Pasture category.

Table 56: Annual change in SOC considering 20 years of transition period. In grey the changes that are not significant

SOC stock change tC ha^{-1} y^{-1}		to					
		Annual Crops	Olive Trees	Vineyards	Fruit Trees	Pasture	Shrubland
from	Annual Crops		-0.39	-0.80	-0.13	-0.10	0.34
	Olive Trees	0.39		-0.41	0.25	0.29	0.73
	Vineyards	0.80	0.41		0.66	0.69	1.14
	Fruit Trees	0.13	-0.26	-0.66		0.03	0.47
	Pasture	0.10	-0.29	-0.69	-0.02		0.44
	Shrubland	-0.34	-0.73	-1.14	-0.47	-0.44	

Annual Crops

LUCAS Topsoil Database contained 2060 soil samples on Annual Crops. The calculated SOC stocks in Annual Crops were on average 51.0±0.01 tC ha^{-1} in the first 30 cm of soil (Table 57). There are no significant differences per soil type, but climate seems to be an important factor, with drier climates having significantly lower values than wetter climates (Table 58). The differences per country are probably explained by differences in the predominance of different climate zones, with France showing the highest and Greece the lowest values (Table 59).

Table 57: Percentiles and Average SOC stocks (tC ha^{-1}) in Annual Crops

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Annual Crops	2060	4.0	36.2	49.5	63.9	106.9	20.3	50.1	51.0	51.9	1.7%

Table 58: Distribution of Average SOC stocks (tC ha^{-1}) in Annual Crops per Climate Zone and Soil Type

			Climatic Region								C Stock per soil type	
			1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
			N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2	Sandy Soils			19	-							19	-
Soil Type	4	Volcanic Soils			2	-							2	-
Soil Type	5	Spodic Soils			3	-							3	-
Soil Type	6	High Activity Clay Soils	213	59.9	1750	49.8	12	-	8	-	18	-	2001	51.0
Soil Type	7	Low Activity Clay Soils			20	50.1					6	-	26	51.1
Soil Type	8	Other Areas	4	-	5	-							9	-
C Stock per climate type			217	60.0	1799	49.7	12	-	8	-	24	49.0	2060	51.0

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 59: Distribution of Average SOC stocks (tC ha^{-1}) in Annual Crops per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Annual Crops	154	47.1 (1.5)	1318	48.6 (0.6)	27	65.3 (4.3)	517	57.7 (0.8)	44	49.2 (3.3)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Olive Trees

LUCAS Topsoil Database contained 393 soil samples on Olive Trees. The calculated SOC stocks in Olive Trees were on average 43.14±0.04 tC ha^{-1} in the first 30 cm of soil (Table 60). There are no significant differences per soil type or climate region (Table 61). The values for Spain and Portugal appear to be somewhat lower than the values for Greece and Italy (Table 62).

Table 60: Percentiles and Average SOC stocks (tC ha^{-1}) in Olive Trees

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Olive Trees	393	4.1	29.1	40.9	56.1	93.4	18.8	41.3	43.1	45	4.3%

Table 61: Distribution of Average SOC stocks (tC ha^{-1}) in Olive Trees per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils												
	4 Volcanic Soils			2	-							2	-
	5 Spodic Soils												
	6 High Activity Clay Soils	22	47.9	361	42.8					2	-	385	43.2
	7 Low Activity Clay Soils			3	-					3	-	6	-
	8 Other Areas												
C Stock per climate type		22	47.9	366	42.9					5	-	393	43.1

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 62: Distribution of Average SOC stocks (tC ha^{-1}) in Olive Trees per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Olive Trees	66	52.5 (2.5)	186	37.5 (1.2)	2	-	103	49.7 (1.6)	36	37.0 (3.4)	0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Vineyards

LUCAS Topsoil Database contained 242 soil samples on Vineyards. The calculated SOC stocks in Vineyards were on average 35.0±1.2 tC ha^{-1} in the first 30 cm of soil (Table 63). There are no significant differences per soil type, but wetter climate regions seem to have significantly higher values than drier ones (Table 64). The differences per country are probably explained by differences in the predominance of different climate zones, with France showing the highest and Spain the lowest values Table 65).

Table 63: Percentiles and Average SOC stocks (tC ha^{-1}) in Vineyards

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Vineyards	242	2.7	22.3	46.3	83.2	107.3	17.3	32.8	35.0	37.2	6.2%

Table 64: Distribution of Average SOC stocks in Vineyards per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Typ	2 Sandy Soils			1	-							1	-
	4 Volcanic Soils												
	5 Spodic Soils			1	-							1	-
	6 High Activity Clay Soils	29	35.3	203	34.4	6	-					238	35.0
	7 Low Activity Clay Soils												
	8 Other Areas			2	-							2	-
C Stock per climate type		29	35.3	207	34.4	6	-					242	35.0

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 65: Distribution of Average SOC stocks in Vineyards per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Vineyards	6		118	27.8 (1.3)	33	46.2 (2.2)	68	43.2 (2.2)	17		0	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Fruit Trees

LUCAS Topsoil Database contained 202 soil samples on Fruit Trees. The calculated SOC stocks in Fruit Trees were on average 48.27±0.10 tC ha^{-1} in the first 30 cm of soil (Table 66). There are not enough data to evaluate if soil type and climate regions are significant differences (Table 67). The differences per country are probably explained by differences in the predominance of different climate zones, with Greece showing the highest and Spain the lowest values (Table 68).

Table 66: Percentiles and Average SOC stocks (tC ha^{-1}) in Fruit Trees

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Fruit Trees	202	8.6	33.4	46.1	62.2	104.0	20.9	45.4	48.3	51.2	6.0%

Table 67: Distribution of Average SOC stocks (tC ha^{-1}) in Fruit Trees per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2 Sandy Soils			1	-							1	-
	4 Volcanic Soils												
	5 Spodic Soils												
	6 High Activity Clay Soils	15	-	176	47.4	4	-			4	-	199	48.4
	7 Low Activity Clay Soils									1	-	1	-
	8 Other Areas			1	-							1	-
C Stock per climate type		15	-	178	47.3	4	-			5	-	202	48.3

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 68: Distribution of Average SOC stocks in Fruit Trees per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Fruit Trees	20	54.5 (4.4)	102	42.3 (1.8)	5	-	64	52.7 (2.5)	10	-	1	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Pasture

LUCAS Topsoil Database contained 763 soil samples on Pasture category. The calculated soil Carbon stocks in Pasture were on average 48.87±0.03 tC ha^{-1} in the first 30 cm of soil (Table 69). There are no significant differences per soil type, but wetter climate regions seem to have significantly higher values than drier ones (Table 70). The differences per country are probably explained by differences in the predominance of different climate zones, with France showing the highest and Portugal the lowest values (Table 71).

Table 69: Percentiles and Average SOC stocks (tC ha^{-1}) in Pastures

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Pasture	763	2.8	30.2	42.5	65.7	125.7	26.5	47.0	48.9	50.8	3.9%

Table 70: Distribution of Average SOC stocks (tC ha^{-1}) in Pasture per Climate Zone and Soil Type

		Climatic Region										C Stock per soil type	
		1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cool Temperate Moist		4 Cool Temperate Dry		12 Tropical Dry			
		N	C	N	C	N	C	N	C	N	C	N	C
Soil Typ	2 Sandy Soils			4	-							4	-
	4 Volcanic Soils			1	-							1	-
	5 Spodic Soils	2	-	6	-							8	-
	6 High Activity Clay Soils	166	64.1	540	42.7	31	72.8	3	-	2	-	742	48.8
	7 Low Activity Clay Soils			3	-					1	-	4	-
	8 Other Areas			3	-	1	-					4	-
C Stock per climate type		168	64.1	557	42.9	32	73.6	3	-	3	-	763	48.9

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 71: Distribution of Average SOC stocks (tC ha^{-1}) in Pasture per Country

	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Pastures	58	41.5 (3.2)	307	48.8 (1.6)	26	59.8 (4.2)	248	51.8 (1.6)	91	41.4 (2.1)	6	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Shrubland

LUCAS Topsoil Database contained 265 soil samples on Shrubland category. The calculated SOC stocks in Shrubland were on average 57.75±0.12 tC ha^{-1} in the first 30 cm of soil (Table 72). There are no significant differences per soil type, but wetter climate regions seem to have significantly higher values than drier ones (Table 73). The differences per country are probably explained by differences in the predominance of different climate zones, with Portugal showing the highest and Italy the lowest values (Table 74).

Table 72: Percentiles and Average SOC stocks (tC ha^{-1}) in Shrubland

	N	Min	P25	Median	P75	Max	St Dev	<conf int	C Stock	>conf int	U
Shrubland	265	2.9	30.5	51.1	81.1	148.7	33.9	53.7	57.8	61.8	7.1%

Table 73: Distribution of Average SOC stocks (tC ha^{-1}) in Shrubland per Climate Zone and Soil Type

			Climatic Region										C Stock per soil type	
			1 Warm Temperate Moist		2 Warm Temperate Dry		3 Cold Temperate Moist		4 Cold Temperate Dry		12 Tropical Dry			
			N	C	N	C	N	C	N	C	N	C	N	C
Soil Type	2	Sandy Soils												
	4	Volcanic Soils			2	-							2	-
	5	Spodic Soils			1	-							1	-
	6	High Activity Clay Soils	81	71.1	162	49.5	16	-	1	-	1	-	261	57.5
	7	Low Activity Clay Soils												
	8	Other Areas	1	-									1	-
C Stock per climate type			82	72.0	165	49.5	16	-	1	-	1	-	265	57.8

Note: Average C stocks are only shown where a minimum 20 samples have been collected.

Table 74: Distribution of Average SOC stocks (tC ha^{-1}) in Shrubland per Country

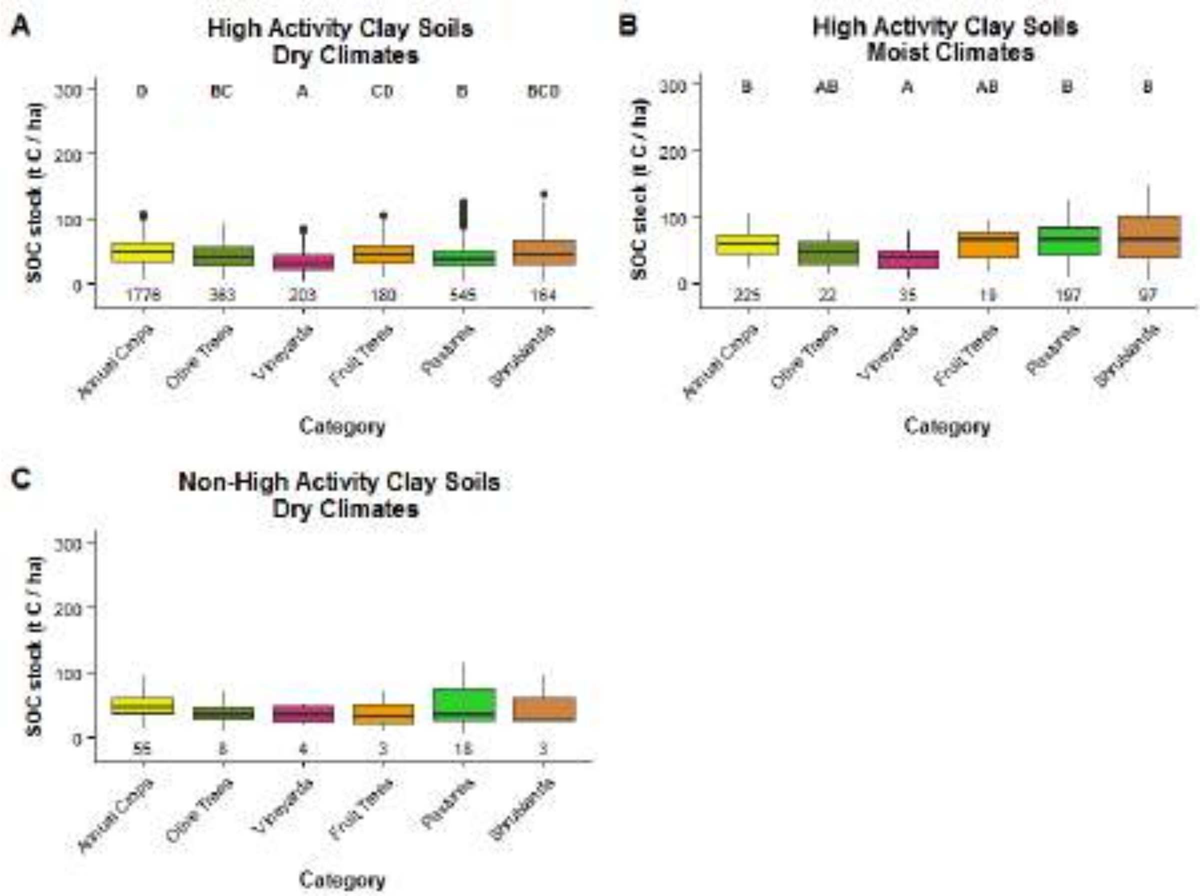
	Greece		Spain		France		Italy		Portugal		Slovenia	
	N	C	N	C	N	C	N	C	N	C	N	C
Shrubland	57	56.6 (3.9)	91	60.1 (4.0)	23	59.5 (6.8)	40	48.9 (4.2)	53	60.5 (5.0)	1	-

Note: Average C stocks are only shown where a minimum 20 samples have been collected.
Values in brackets represent the standard error of the mean in tC ha^{-1}.

Alongside land-use, climate type seems to have a significant impact, with dry climates present in the region (i.e. Warm Temperate Dry, Cool Temperate Dry and Tropical Dry) showing significantly lower values than wetter climates (i.e. Warm Temperate Moist and Cool Temperate Moist).

Most profiles were concentrated in High Activity Clay Soils, but the results suggest much smaller differences between soil types than between climate types (Figure 16).

Figure 16: Average SOC stock data considering the soil (HAC vs. other soil types) and the climate (Moist vs. Dry)



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Annex III: IPCC Protocol for expert elicitation

[text taken from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1: General Guidance and Reporting; Chapter 2: Approaches to Data Collection; Annex 2A.1 A protocol for expert elicitation]

Wherever possible, expert judgement should be elicited using an appropriate protocol. An example of a well-known protocol for expert elicitation, Stanford/SRI protocol, has been adapted and is described below.

• Motivating: Establish a rapport with the expert, and describe the context of the elicitation. Explain the elicitation method to be used and the reason it was designed that way. The elicitor should also try to explain the most commonly occurring biases to the expert, and to identify possible biases in the expert.

• Structuring: Clearly define the quantities for which judgements are to be sought, including, for example, the year and country, the source/sink category, the averaging time to be used (one year), the focus activity data, emission factor or, for uncertainty, the mean value of emission factors or other estimation parameter, and the structure of the inventory model. Clearly identify conditioning factors and assumptions (e.g., resulting emissions or removals should be for typical conditions averaged over a one-year period).

• Conditioning: Work with the expert to identify and record all relevant data, models, and theory relating to the formulation of the judgements.

• Encoding: Request and quantify the expert's judgement. The specific qualification will differ for different elements and be present in the form of a probability distribution for uncertainty, and an activity or emission factor estimate for activity data and emission factors. If appropriately managed, information on uncertainty (probability density function) can be gathered at the same time as gathering estimates of activity or emission factor. The section on encoding in Chapter 3 describes some alternative methods to use for encoding uncertainty.

• Verification: Analyze the expert's response and provide the expert with feedback as to what has been concluded regarding his or her judgement. Is what has been encoded really what the expert meant? Are there inconsistencies in the expert's judgement?

Possible Biases in Expert Elicitation

Elicitation protocols should be designed to overcome the biases that can be introduced by the rules of thumb (sometimes called heuristics) that experts use when formulating judgements. The most common unconscious biases introduced by rules of thumb are:

• Availability bias: This is basing judgements on outcomes that are more easily remembered.

• Representativeness bias: This is basing judgements on limited data and experience without fully considering other relevant evidence.

• Anchoring and adjustment bias: This is fixating on a particular value in a range and making insufficient adjustments away from it in constructing representative estimate.

To counteract the first two potential sources of biases, elicitation protocols should include a review of relevant evidence. In order to counteract the third potential source of bias, it is important to ask the expert to make judgments regarding extreme values first, before asking for judgments regarding the best estimate or central values for an uncertainty distribution.

There is also the possibility of more conscious biases:

• Motivational bias: is a desire by an expert to influence an outcome or to avoid contradicting prior positions on an issue.

• Expert bias: arises from an unqualified expert's desire to appear as a true expert in the field. This would typically lead to overconfident estimates of uncertainty.

• Managerial bias: is a situation in which an expert makes judgements that achieve organisational goals, rather than judgements that reflect the actual state of knowledge regarding an inventory input.

• Selection bias: occurs when the inventory compiler selects the expert who tells it what it wants to hear.

The best way to avoid these biases is to be careful in the selection of experts. Expert judgments can be elicited from individuals or groups. Groups can be useful for sharing knowledge and hence could be part of the motivation, structuring, and conditioning steps of the elicitation. However, group dynamics occasionally introduce other biases. Thus, it is usually preferable to elicit judgement on an individual basis. When eliciting judgments independently for a given quantity from two or more experts, it is possible that different views on distributions (or ranges) will be obtained. In some cases, the differences may not lead to a significant difference in the overall estimate for the inventory, such as when the inventory is not sensitive to the particular quantity. Thus, in these cases, disagreements among experts do not matter significantly to the overall assessment. However, when judgments differ, and when the quantity for the judgments is made is important to the overall inventory, there are two main approaches that can be used. One is to estimate resulting emissions or removals and perform the uncertainty analysis separately for each set of judgments and compare the results. The other is to ask the experts to weight the judgments and combine them into one assessment. The former approach is preferred where possible, but the latter is acceptable provided that the judgments are weighted and not averaged. The difference is that weighting enables sampling from each of the expert's estimations, whereas averaging can produce intermediate values that are not supported by any of the expert's judgement. A similar situation can occur when comparing predictions with alternative models, as described in the section of 'Combining Data Sets Numerically' in Section 2.2.3. The distinction between weighting and averaging is explained there. Although the development of weighting schemes can be complex, it is reasonable to start with assuming equal weights for each expert and refines the development of weights only as needed or as appropriate for a given situation.

Expert judgement documentation

The subjective nature of expert judgment increases the need for quality assurance and quality control procedures to improve comparability of emission and uncertainty estimates between countries. It is recommended that expert judgments are documented as part of the national archiving process, and inventory compilers are encouraged to review expert judgments, particularly for key categories. Table 2A.1 below shows an example of the document elements necessary to provide transparent expert judgment (Column 1) and an example of the data to record (Column 2).

Such documentation will save the compiler a considerable amount of time in reporting and documenting the inventory through the enhanced transparency of the inventory. More general text on documentation, checking and review of methods is included in Chapter 6, QA/QC and Verification, of Volume 1. These principles should also be applied to the use of expert judgement in inventory compilation and uncertainty assessment.

TABLE 2A.1
EXAMPLE OF DOCUMENTATION OF EXPERT JUDGEMENT

Documentation Element	Documentation Example
Reference number for judgement	*EJIPPU2005-001*
Date	*14th January 2005*
Name of expert(s) involved	*Dr Anne N Other*
Experts' background (references, roles, etc.)	*Nitric Acid Process emissions and abatement industrial expert*
The quantity being judged	*National emission factor for emissions of N_2O from Nitric Acid Plant*
The logical basis for judgement, including any data taken into consideration. This should include the rationale for the high end, low end, and central tendency of any uncertainty distribution	*An absence of measurement data for 9 out of the 10 Nitric Acid plant. The single plant estimate has been recommended as the basis for a national factor to be applied to national nitric acid production.*
The result: e.g., activity value, emission factor or for uncertainty the probability distribution, or the range and most likely value and the probability distribution subsequently inferred	*8.5 kgN_2O/tonne nitric acid produced for 1990 – 2003*
Identification of any ***external reviewers***	*Nitric Acid Trade Association*
Results of any external review	*See document: e:/2003/ExpertJudgement/ EJIPPU2005-001.doc*
Approval by inventory compiler specifying date and person	*25th January 2005, Dr S.B Else*

Annex IV: WS Report

MediNet Participatory Workshop on Soil Data and Soil Emission Factors for Cropland

The third workshop of Project MediNet was held in Hotel Salus Terme in Viterbo, Italy the 14th of June 2018.

The general objective of the workshop was to receive feedback from participants on the methodologies and results used by the project and to receive guidance on the refinement of the deliverables and main conclusions of the project.

Participants were selected and invited on the basis of their personal capacity and on the basis of their expertise in one or more of the following fields: experience in estimation of emissions and removals in cropland and in inventory compilation; experience in statistics compilation; knowledge in soil organic carbon in cropland and grassland; involvement in the IPCC work on guidance for reporting. A list of participants is provided at the end of this report.

It focused on the work already carried out under MediNet related to the collection of activity data, and the development of soil organic carbon emission factors for cropland and grassland.

The workshop was designed to allow as much interaction between participants as possible, so as to maximise their input and contribution. Participants were asked to participate freely and, to facilitate that, were given guarantees that the workshop report would contain references to the discussions held, but not contain attribution of opinions or views (Chatman House rules).

The main results of the work done are summarised below. All documents mentioned in this report are available at the site of Project MediNet (http://www.lifemedinet.com). The summary is of the responsibility of the Project Team and does not necessarily reflect the views of each of the participants.

Agenda 14th of June | ***Documents and Presentations Distributed at the Workshop***

9:30 – 9:50 Welcome to Participants

9:50 – 10:10 Project MediNet

Opening of the works (Prof. Giuseppe Scarascia-Mugnozza – MediNet Team) and a brief presentation (Tommaso Chiti – MediNet Team) about the MediNet project was made with the objective to familiarise the participants with the project.

01 Project MediNet - general presentation.pdf

Agenda 14th of June — ***Documents and Presentations Distributed at the Workshop***

10:10 – 10:40 IPCC Methodology: Soil Organic Carbon Emission Factors

A brief presentation (Guido Pellis) about key IPCC reporting concepts was made with the objective to familiarize the participants with the reporting approaches that Member States are required to use for the purpose of estimating Emission and Removals in cropland and grassland.

02 IPCC Reporting Methods.pdf

11:10 – 12:45 National Experiences in Soil Organic Carbon reporting for Cropland and Grassland

Representatives from participant countries were asked to make a brief presentation about their country experiences in reporting cropland and grassland emissions and removals.
Presentations from Cyprus (Melina Menelaou), Greece (Iordanis Tzamtzis), Slovenia (Boštjan Mali), Spain (Maria del Mar Esteban Garcia), Italy (Marina Vitullo) and Portugal (Paulo Canaveira) were made.

03 Experience of Cyprus.pdf

04 Experience of Greece.pdf

05 Experience of Slovenia.pdf

06 Experience of Italy.pdf

14:00 – 15:00 MediNet Report on Soil Organic Carbon Data

MediNet’s report on soil organic carbon data was presented (Tommaso Chiti – MediNet Team). It describes the methodology and the results of the literature survey on soil organic carbon data in copland and grassland categories.
A report on the same topic was prepared and sent to participants in advance of the Workshop.

07 MediNet Report SOC.pdf

15:00 – 16:00 Group Work on Soil Organic Carbon Data

  

Participants were divided in groups and asked to comment on the potential and limitations of different data sets for use as activity data to report cropland and grassland.

The following questions were made to guide de discussions:

1. Comment on the methodology and propose improvements.
2. Possible use of data in the inventories.
3. Can the results be treated as default data for the SOC in the Mediterranean countries? What is the best aggregation/result format?
4. Discuss and propose research or further work needs.

16:30 – 17:00 Report back and Conclusions

A rapporteur from each of the groups presented the conclusions of his or her group. This was followed by a "plenary" group discussion on possible WS conclusions and/or recommendations.

On Comment on the methodology and proposed improvements (Question 1), participants commented/suggested the following:

Comments

- The proposed methodology appears to be transparent;
- The results appear to be relevant and should be submitted to the IPCC database.

Improvements

- Possibly harmonize the SOC stock also for 0-10 cm and 10-20 cm of depth;
- The stratification should consider also different soil types, not only the IPCC soil classification;
- The data should be provided also in a disaggregated format so to allow for a different stratification;
- Insert the uncertainty for the SOC stock per country;
- Improve the information on management practices;
- Further improve the amount of data for those country with a low number of points on some of the subcategories (e.g. data from France soil survey (RMQS); Biosoil project; SPADE database);
- Associate qualitative information to the data.

On the possible use of the data in the inventories (Question 2) participants commented/suggested the following:

- The groups agreed that the data could be possibly used in the next inventory, at least in those cases where data are currently unavailable;
- The data can be useful to estimate soil carbon stock changes for changes between subcategories in a same land use.

On the possible use of the SOC data as a default and on the best aggregation of the data (Question 3) participants commented/suggested the following**:**

- The data could substitute the values currently applied (coming from literature) for land use change;
- The consolidated MediNet-LUCAS database was definitely the best aggregation proposed.

On further reserch needs (Question 4) participants commented/suggested the following:

- To possibly produce some guidelines on how to treat the data for people that want to contribute to the database adding additional data;

- To have the database freely available to scientists for further elaborations and use;
- Further improve the information on management practices;
- Identify the key drivers of the soil carbon variability;
- The use of the data for model calibration.

17:00 – 17:15: Networking with other projects (Diverfarming, Desert-adapt, Olive4Climate, Climatree)

Participants representing other related projects were invited to share their project's experiences and to identify areas where possible cooperation with project MediNet could be reinforced. Three LIFE projects, Olive4Climate (Antonio Brunori), ClimaTree (Kostas Bithas), and Desert-Adapt (Simona Castaldi), one Horizon 2020 project, Diverfarming (Raul Zornoza) presented their views.

08 LIFE Climatree.pdf
09 LIFE Desert-Adapt.pdf

17:15 – 17:30 Closure of the Workshop and Next Steps

The workshop was closed with a note acknowledging and thanking all participants for their active engagement.
It was agreed that a Workshop Summary Report would be produced and distributed to all participants and posted on the project's website and that the MediNet reports on Soil Organic Carbon Data will be updated to reflect the contributions made during the Workshop.

20:00-22:00 Workshop Dinner

WS List of Participants

Country	Name
Cyprus	George Theophanous
Cyprus	Melina Menelaou
France	Colas Robert
Greece	Dimitris Triantakonstantis
Greece	Iordanis Tzamtzis
Greece	Kostas Bithas
Italy	Cinzia Chiriacò
Italy	Dario Papale
Italy	Franca Ciccarelli
Italy	Giacomo Certini
Italy	Giuseppe Scarascia-Mugnozza
Italy	Guido Pellis
Italy	Letizia Atorino
Italy	Luca Regni
Italy	Lucia Perugini
Italy	Marina Vitullo
Italy	Riccardo Valentini
Italy	Simona Castaldi
Italy	Tommaso Chiti
JRC	Simone Rossi
Slovenia	Boštjan Mali
Spain	Cristina García Diaz
Spain	María del Mar Esteban García
Spain	María José Sanz
Spain	Raul Zornoza
Portugal	Ana Pina
Portugal	João Paulo Marques
Portugal	Lúcio do Rosário
Portugal	Paulo Canaveira
Portugal	Sara Manso
Portugal	Tiago Morais

Annex V: Project MediNet

Project focus

Improve the transparency, consistency, comparability, completeness and accuracy of cropland and grassland reporting of emissions and removals in Mediterranean Countries

Project objectives:

1. Compilation and systematization of existing knowledge and data with relevance for reporting croplands and grasslands emissions in Mediterranean conditions, in particular for mineral soil and above ground biomass of perennial crops
2. Sharing experiences and approaches in reporting croplands and grasslands emissions in Mediterranean conditions
3. Exploring the possible use of common methods and/or reference data and/or data sets for reporting purposes
4. Identifying information and research gaps
5. Enhance the participation and involvement of agriculture stakeholders in climate change mitigation and adaptation

Actions and means involved

To accomplish its objectives, MediNet will involve public Institutions and Universities from different countries in the Mediterranean basin working specifically on themes related to Agriculture and emissions and removals reporting. For this purpose, different Actions of the project will involve both the Institutions with the official responsibilities of reporting on Cropland and Grassland emissions and removals at National level, and the Institutions/Universities working in specific themes related to Grassland and Cropland management.

The establishment of the MediNet network, involving Italy and Portugal as beneficiaries of the project, and Spain, Greece, France, Malta, Cyprus, Croatia, Slovenia as stakeholders, will allow identifying, sharing and maximising the potential of existing knowledge that can be used for reporting purposes. The identification of gaps in data at National level and the adoption of solution to fill these gaps coming from the experience gained by other Mediterranean counties is an aim of the MediNet project. The main objective of the MediNet network is to increase the knowledge on the effect that different management activities applied to croplands (e.g. conventional agriculture, biological, reduced tillage, other) and grasslands (e.g. grazed, mowed, sown, other) have on the soil organic carbon (SOC) and biomass C stocks.

This represents a crucial and necessary point, needed to allow for an identification of new and more specific factors to be related to different management activities for cropland and grassland management in the Mediterranean area. As a result, more accurate, complete and consistent estimates of C gain and losses due to emission and removal from Cropland and Grassland will be provided at National level. The sharing of reporting experiences and of specific solutions for reporting (i.e., methodologies, activity data and emission factors) will also allow for increased comparability across Mediterranean Countries.

A preliminary action characterizes the Institutional arrangements (Institution and data provision) for each country involved in MediNet (Actions A.1). Subsequently, the preliminary Action A.2 will select the types of Management Systems for Cropland and Grassland to be used in subsequent Actions. The core of MediNet will be expressed through Actions A.3, A.4 and A.5, that will specifically identify the type of data and methodologies present in the different Institutions/Universities necessary to report emissions and covering three main topic areas:

- Activity data for Cropland and Grassland under different management types and the area that is annually subject to a land use/management change: methodologies and data sharing;
- Assessment of the contribution of the above and below ground biomass of perennial crops to annual Carbon gains and losses: data available and gaps.
- Soil organic carbon stock and variations in mineral soils under different management options for Cropland and Grassland: data available and gaps;

To accomplish the purposes of MediNet, specific workshops will be held during the course of the project involving both the Institutions doing the emission & removal estimations and the Institutions/Universities working on Cropland and Grassland related themes. People from other LIFE and non-LIFE projects will be also invited so to possibly increase the exchange of data and of experiences. Specifically, the workshops will follow the specific themes treated in Actions A.3, A.4 and A.5, and will be focused on: a) Cropland and Grassland areas that are subject to a change in management; b) SOC data for the different types of management used in

Cropland and Grassland; c) contribution of above ground biomass and deadwood from perennial crops. The workshops are included in the implementation Actions rather then in the communication Actions since they aim specifically at allowing for a wider exchange of data, rather than on communicating project results.

An important part of the project is devoted to increase project visibility and in sharing of information among partners and stakeholders. A project website (Action B1) will be created soon after the beginning of the project to specifically widespread information useful for stakeholders (e.g. Institutions) and the general public. To allow information to be spread widely a Facebook page with the LIFE logo will be also created allowing for a wider visibility of the proposed Actions and of the project results (Action B1). Twice per year, the status of the progress made on the different themes treated by the project will be published on the webpage.

Brochures reporting the results/decisions of the specific workshops will be made available soon after their conclusion on the project website. Networking with other projects will also represent an important part of the project (Action B2) allowing collecting information useful for the project.

A Farmer's day (Action B3 and B4) will be organized in each of the two countries (Italy and Portugal) to involve farmers and provide capacity building on agriculture and climate change, the opportunities for improved climate management practices in each of the Rural Development Programmes and share information on specific themes such has the effectiveness of the application of good managements practices (e.g. reduce tillage; organic fertilizers) aimed at soil conservation and to increase soil fertility. Questionnaires will be spread among farmers so to evaluate the uptake and quality of implementation of these practices. The involvement of stakeholders in those workshops, particularly farmers and/or their representative organisations, represents a crucial and fundamental part of the project. All the outputs of the farmer's day will be available on the website of the project (Action B1). A Layman's report (Action B5) and Board Notices (Action B6) will be also performed so to allow for a wider visibility of the project structure and its results, particularly among the general public.

Expected results

The main results expected at the end of the project are the following:

1. Increased knowledge on the soil organic carbon data for at least the top 30 cm (if possible 50 or 100 cm depth) of mineral soil for different crops/grassland management types from each Mediterranean country involved in MediNet. A database will be created to collect all the information correlating the average SOC content and stock to the different management activities applied for Cropland and Grassland.
2. Improved default emission factors in SOC as a result of land management change in Cropland and Grassland for use in Mediterranean conditions, to replace the IPCC tier 1 default factors and to increase the number of management practices that are currently used for reporting purposes at National level.
3. Increased knowledge on the contribution from the above ground biomass of perennial crops and from deadwood to annual emissions and removals. A database will be created to collect all the information and to relate the carbon in the above ground biomass of perennial crops to the different management activities applied for Cropland and Grassland.
4. Creation of a network of stakeholders to be used for monitoring the agriculture contribution to climate change in the Mediterranean area.