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Soil carbon sequestration for climate food security and ecosystem services

Proceedings of the International conference
27-29 May 2013 Reykjavik Iceland

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Abstract
The international conference SOIL *CARBON SEQUESTRATION for climate, food security and ecosystem services* – linking science, policy and action (SCS2013) took place in Reykjavik Iceland on 27. – 29. May 2013. The conference was organized by the Soil Conservation Service of Iceland, the Agricultural University of Iceland and the Joint Research Centre of the European Commission (Collaboration Agreement No 31059) in partnership with a group of international and UN agencies, universities and non-governmental organizations. The scientific soil community acknowledges that there is an urgent need to communicate better the value of soil carbon to a broader public. The message so far has not actively reached the media, the public and policy makers. The SCS2013 conference brought together a broad spectrum of soil carbon experts, in order to link science, policy and action on soil carbon sequestration issues. Approximately 200 people from 40 countries from all continents attended the conference: young and high level scientists; present and future leaders in restoration and land management; administrators and policymakers. The conference received extensive media coverage, both in Iceland and globally. Despite coming from different countries and backgrounds, with varied scientific interests and convictions, the overall message was that soil and soil management, specifically soil carbon, needs be a substantial part of the solution in mitigating climate change, ensuring food security and providing ecosystem services. Furthermore soil conservation, preservation and restoration could be considered as "win-win" processes for meeting other goals. The SCS2013 conference represented an excellent example of bridge between scientists, land managers and policy makers. The EC was actively involved in the conference and is still willing to bridge the communication gap between science and policy and to continue to act as interface. The conference proceedings aim to present how the potential role of soil carbon sequestration has been discussed along different sessions (forest/ cropland/ revegetation/ desertification/ wetland/ rangeland/ verification) and from different perspectives.

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A Joint Publication

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Assessing change of topSoil Organic Carbon due to Common Agricultural Policy (CAP)

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Introduction

Emilia-Romagna (ER) is one of the main agricultural regions of Italy and the protection of soil, as provided by EU policies and adopted by the regional government, is intended to play a strategic role for sustainable development. The Regional Rural Development Programme (RDP 2007-2013, Reg (CE) 1698/2005) promotes the preservation and the storage of Soil Organic Carbon (SOC) through Agri-environmental Payments (Measure 214) directed to farmers.

Agri-environmental payments may influence directly or indirectly SOC, due to its complex behaviour. Several projects have been funded by the Region ER to investigate the current state of soil quality and the impact of agri-environmental policy. The evaluation requires the knowledge of (i) the actual SOC stock, (ii) the nature and effects of interacting factors (e.g.: micro-climate, soil properties, crop rotations etc.) and (iii) a thorough knowledge of farm management.

Efficacy and efficiency of farming actions may change as a consequence of soil types, land use and local conditions. An evaluation of this variability and related effects is necessary to select actions targets and provide their successful fine tuning.

To better evaluate the effects of agri-environmental commitments on SOC dynamics the following processes need to be studied: SOC storage capacity of meadows; effect of land use change from arable land to grassland; rates of SOC accumulation; SOC content as influenced by integrated or organic agriculture compared to conventional farms.

Soil surveys co-ordinated by Emilia-Romagna Administration began in 1976 and mapping has been carried out at different scales on various themes: geology, land use, soils, salinity and more (http://ambiente.regione.emilia-romagna.it/geologia/temi/geologia-en). The Regional Soil Information System is the knowledge base where the information on soils are organized and contains data collected as a joint venture by two regional services: Agricultural Extension Service and Geological, Seismic and Soil Survey.

In 2011 ER Region started a new project in the Po plain to investigate the capacity to accumulate OC by different soils and to evaluate how SOC can be affected by Agri-environmental Measures of RDP. In three years of activity a new inventory of 1800 geo-referenced topsoil samples has been conducted. By the end of 2012, 1200 samples were ready for a first analysis. In this study a subset of collected data has been statistical analysed to characterise SOC content of three different Soil Functional Groups and to assess the impact on SOC of different soil management system.

1. Context of the studied area

Emilia-Romagna Region is in the northern part of Italy and covers an area of 22.124 km^2. Utilized Agricultural Area (UAA) reaches 10.627 Km^2, meanly located in the Po plain, north to the Apennine Chain (Table 1). Arable crops occupy 65% of the plain and one third of the hilly area (100-600 m asl). Temporary or permanent grassland are widespread through the hilly area, respectively with

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40% and 15% of UAA, and even more in mountain area (above 600 m) with 41% and 48% of UAA (Fig. 1).

Table 1 Land use of Emilia Romagna Region in different altimetric area (ha). General Census of Agriculture 2010 - ISTAT

	UAA (Utilized Agricultural Area) ha				UAA
	Arable crops	Temporary grass (forage land)	Permanent grassland	Permanent crops	
Plain	462.539	135256	16.440	97.347	711.583
Hill	82.279	99.969	37.293	30.134	249.675
Mountain	9.369	41.158	48.826	2.149	101.505
Total region	554.187	276.384	102.561	129.631	1.062.763

Different agri-environmental actions are included in RDP 2007-2013. In 2012, 144.638 ha, 13% of regional UAA, were managed on a voluntary basis under one or more agri-environmental contracts (Fig. 2) that have a specific influence on SOC.

Compared to the conventional agricultural management, the RDP introduces additional commitments, described as follows: integrated (action 1) and organic farming (action 2) are the most important actions (more than 90.000 ha in total) aimed at reducing the chemical inputs, introducing arable crops rotation and increasing the use of organic fertilization. Another action is no tillage and extensive grazing (action 8) which include conservation of existing meadows and transforming of arable crops in permanent grassland, with low fertilization and reducing grazing livestock load. Other actions have a more targeted approach aimed at increasing soil organic matter through distribution of organic fertilizers (action 4), increasing winter cover of soils (cover crops – action 3), conservation of natural and semi-natural area in the agricultural landscape (action 9) and set-aside for environmental purposes (action 10).

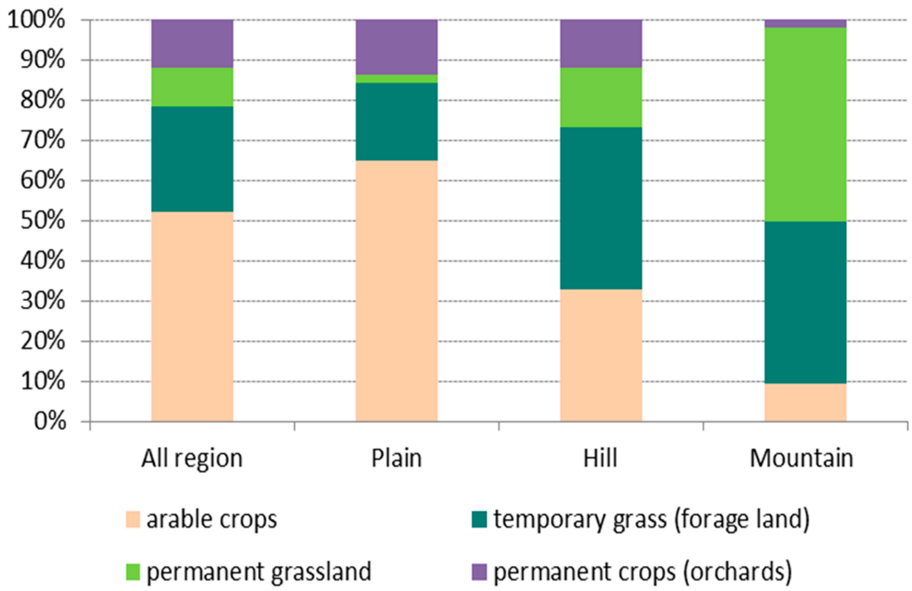

Figure 1 Land use of Emilia Romagna Region shares in different altimetric area (per cent of UAA). General Census of Agriculture 2010 – ISTAT.

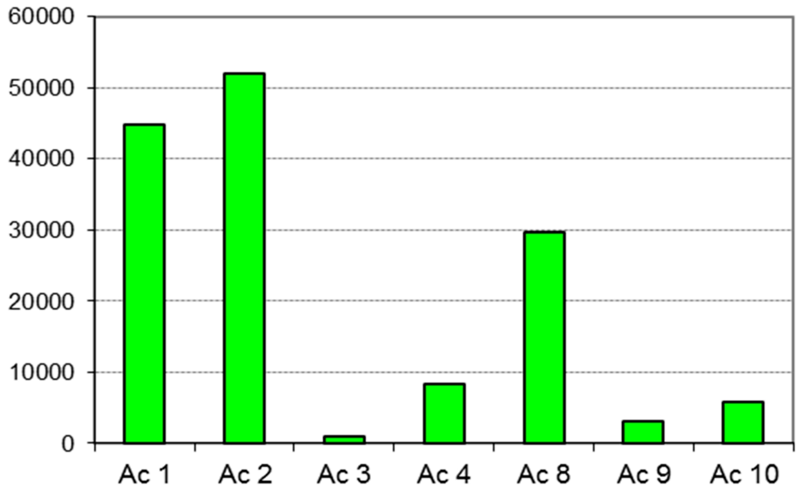

Figure 2 Selected Agri-environmental actions affecting SOC: area (ha) under contract in Emilia Romagna Region, 2012

A soil map at 1:50.000 scale, available in the Po plain area, defines 218 STUs (Soil Typological Units) to describe soil variability (http://ambiente.regione.emilia-romagna.it/geologia/temi/suoli/cartografie).

In order to show a trend of top-SOC distribution all over the region, these STUs have been grouped in 13 Soil Functional Groups (SFGs), based on a selection of soil-specific characteristics that are likely to affect SOC status and dynamics: top-soil textural class, drainage class, slope, presence of organic horizon and floods. As a result a first map of top-Soil Organic Carbon Stock was obtained in 2010 using soil map delineations and land use classification as parameters to optimize a geostatistical approach (Ungaro et al.). The map shows a SOC stock mean value of 63 Mg*ha^{-1}, 8 Mg ha^{-1} in terms of Carbon Potential Sequestration and 5 Mg ha^{-1} as Potential Carbon Loss, with a spatial variability related to soil types, land use and soil management (Fig. 3).

Three SFGs have been taken into account in this study. They are described as follow (Fig. 4):

A – soils in interfluvial area: soils with a high clay content affected, to varying degrees, by shrinking and swelling which produces large, deep cracks in the soil; Ap texture fine (C, SiC, SC), moderately well drained to poorly drained. Mainly Calcic Vertisols and Vertic Cambisols (Gleyc), according to WRB. Typically they are in interfluvial bottom land artificially drained;

E - soils of distributary channels: they display a reorganization of soil particles, attributable to animal and plant organisms, and are characterized by deposition at depth of calcium carbonate, leached from the surface by the water. Ap texture medium-fine (SiCL. CL, SCL), well drained to moderately well drained. Mainly Haplic Cambisols and Haplic Calcisols, according to WRB;

M – coastal plain soils: are characterized by a relatively shallow groundwater table, problematic drainage (seasonal surplus of water) Ap texture coarse (S, LS), moderately drained to poorly drained. Mainly Endogleyic Arenosols according to WRB.

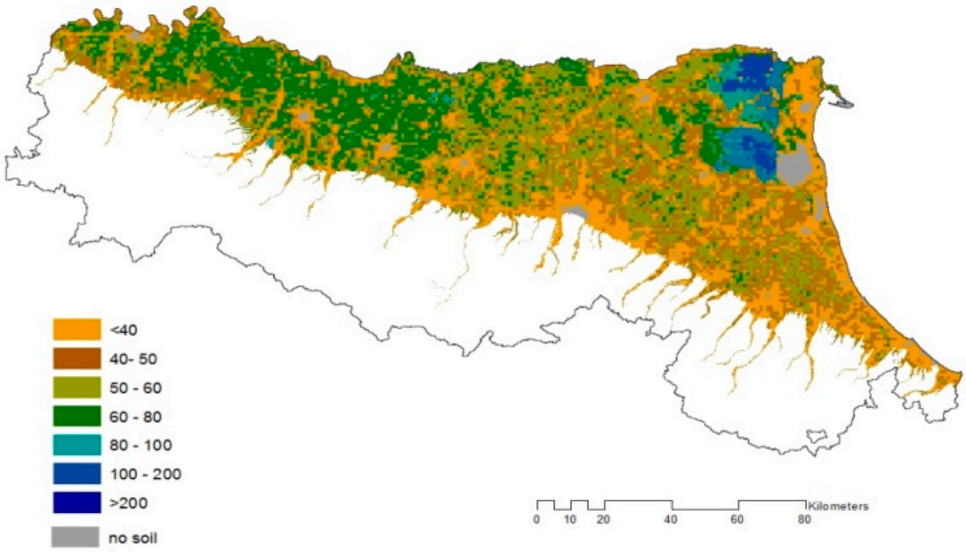

*Figure 3. Top-SOC Stock of Emilia-Romagna Plain (Mg*ha^{-1})*

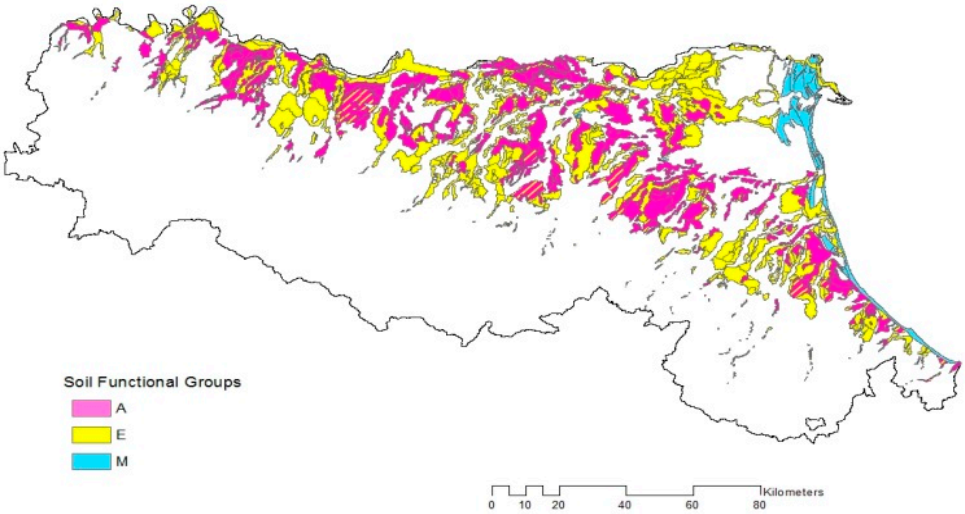

Figure 4. Regional distribution of A, E, and M Soil Functional Groups

1.1. Soil sampling and statistical analysis

The project started in 2011 provides, in three years of activity, an inventory of 1800 geo-referenced topsoil samples with soil type and land use description and routine laboratory analysis. The study area is located in the Po plain. By the end of 2012, 1200 samples were ready and a subset was used in this analysis (Fig. 5).

Data collected have been included in the regional Soil Information System and linked to a Soil Typological Unit (STU) of regional catalogue. For each site the following analytical data are available for the first 30 cm of soil: textural fractions, sand, silt and clay, according to USDA particle size (ISO11277 method); pH (ISO 10390); soil organic matter (ISO 10694 method).

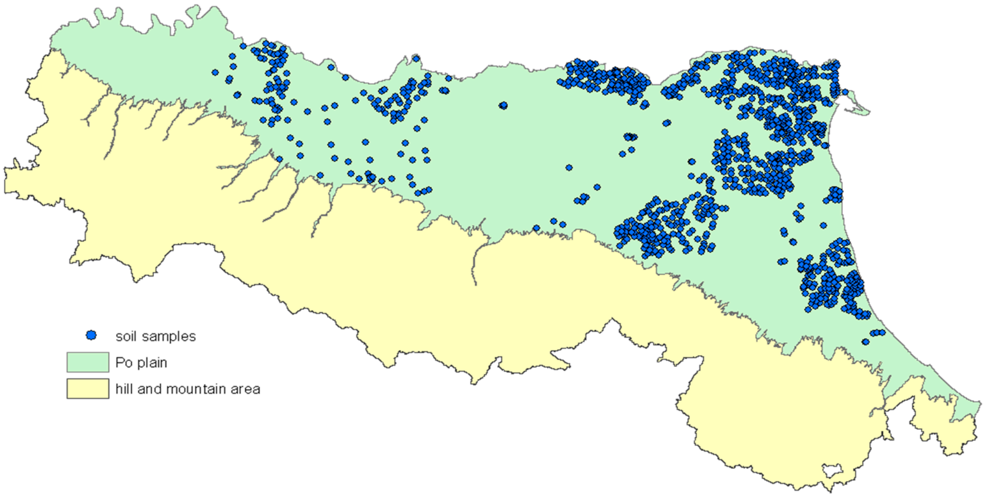

Figure 5. Regional distribution of soil sampling points collected in 2011 and 2012.

2. SOC in different SFGs

To assess soil specific OC content 679 samples, linked to “A”, “E” and “M” SFGs, were selected from the inventory. Selection depends on three land use classes: arable crop, temporary grassland (forage) and permanent grassland (minimum 30 years old meadows).

According with analytical data, “A”, “E” and “M” SFGs are well distinguished (Table 2). The significant difference of SOC content among the groups (Fig. 6) is connected to the soil type, land use and management. The SFG A shows the highest content of OC, due to the high clay content, while SFG M has the lowest value, as a consequence of coarse texture.

Beside SFG M data set do not include permanent grassland use. 2010 ISTAT General Census of Agriculture confirms the low occurrence of this land use class in Ferrara (FE) and Ravenna (RA) eastern provinces where SFG M is widespread. On the contrary permanent grassland and forage land are instead common in Parma (PR) and Reggio Emilia (RE) provinces where A and E SFGs are prevalent (Fig. 7, 4). This distribution depends on livestock sector, typically concentrated in the western part of the region.

Table 2 Descriptive statistics of the data set for A, E and M SFGs.

	A (Num Obs = 278)				E (Num Obs = 307)				M (Num Obs = 94)			
	sand%	silt%	clay%	SOC%	sand%	silt%	clay%	SOC%	sand%	silt%	clay%	SOC%
Mean	8,86	46,4	44,7	1,58	18,36	52,3	29,4	1,36	76,73	13,6	9,71	1,02
std dev	1,45	2,35	2,74	0,58	10,16	8,54	7,38	0,57	10,86	8,23	4,29	0,42
Min	5	39	35	0,41	8	22	10	0,33	26	2	2	0,33
Median	9	46	45	1,51	14	55	32	1,24	80	11,5	9,5	0,91
Max	18,5	56	51	4,52	64	70	39	4,2	96	54	27	2,19

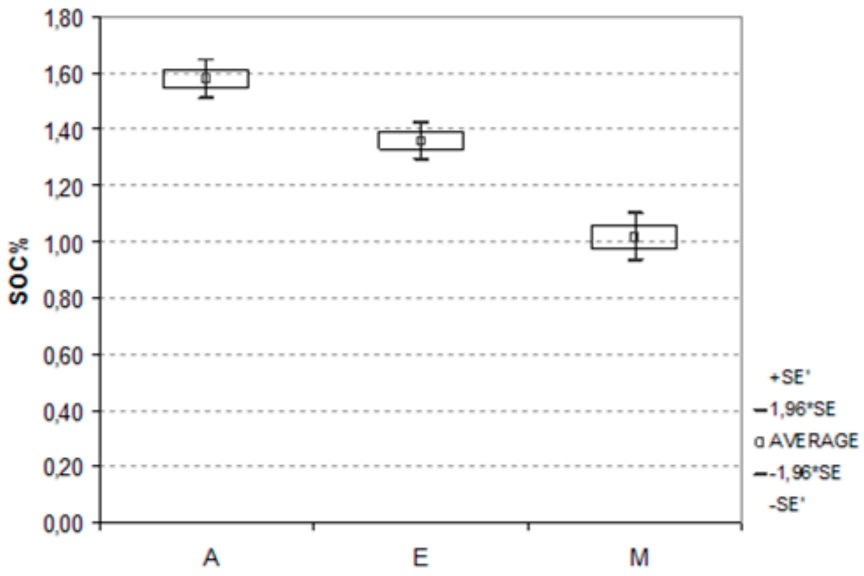

Figure 6. SOC%: mean values and mean confidence intervals for the three SFGs

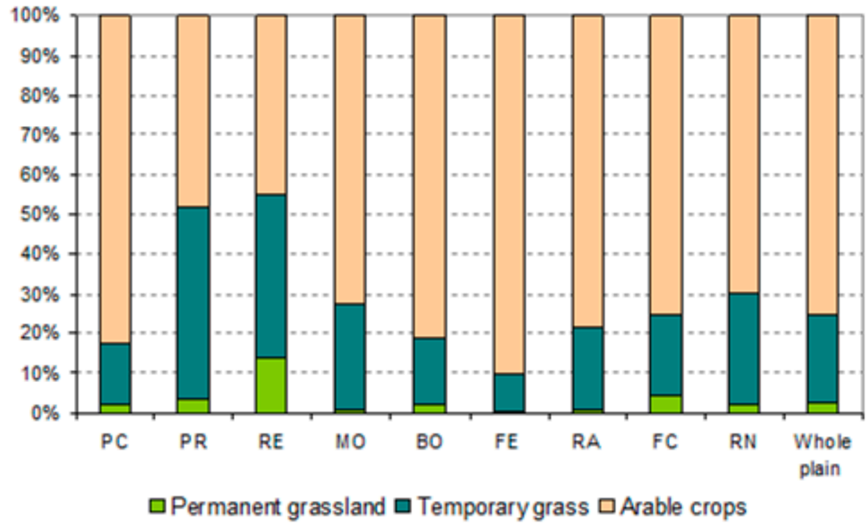

Figure 7. Land use share in the provinces of Emilia Romagna plain (per cent of UAA, ISTAT 2010.)

2.1. SOC in different cropping system

To evaluate the impact of RDP on SOC two Regional Farm Database (Applications Managing System and RDP Evaluation Primary Data) have been used to obtain information on soil management concerning arable land, temporary grassland and permanent grassland (meadows), under contract for one of the selected agri-environmental actions.

A subset of 112 samples have been selected for A and E SFGs. These data were used to define OC storage capacity of meadows, the effect of land use change from arable land to grassland, the rates of SOC accumulation and carbon potential sequestration, as a consequence of soil types and management system.

Permanent grasslands cover 16.440 ha of the Po Plain, mainly over Parma and Reggio Emilia provinces where small dairy farms, connected with Parmesan cheese production, are located (Table 1 and Fig. 7). A part of these meadows are unploughed over 30 years, irrigated and managed exclusively through mowing and fertilizing. They are characterized by a high biodiversity and inserted in an intensive agricultural matrix.

Temporary grassland usually regards long crop rotations with 3-5 years of alfalfa, followed by two years with annual crops. No soil tillage operation is scheduled while alfalfa occupies the single field.

Arable land is ploughed every year and different crops are always in rotation (winter wheat, maize, sugar beet, tomato, etc.).

In both SFGs, statistical analysis confirms the strong influence of no-tillage over the years to enhance OC storage capacity. As expected, the permanent grassland reaches the highest value that is significantly different from the other two crop systems. Temporary grassland shows values of SOC % higher than arable land, even if difference is not so evident (Table 3 and Fig. 8).The role of organic fertilization, as a determinant for SOC, is still under observation and will be analyzed at the end of the project.

Table 3 SOC %: descriptive statistics of data subset for SFGs A and E in the three cropping systems

	A			E		
	Permanent grassland	Temporary grass	Arable land	Permanent grassland	Temporary grass	Arable land
Num Obs	11	21	27	11	22	20
Mean	3,91	1,63	1,45	3,4	1,33	1,17
std dev	0,44	0,41	0,27	0,65	0,29	0,35
Min	3,12	0,94	0,94	2,17	0,63	0,49
Median	4,08	1,56	1,5	3,52	1,37	1,19
Max	4,52	2,62	2,02	4,2	1,68	1,93

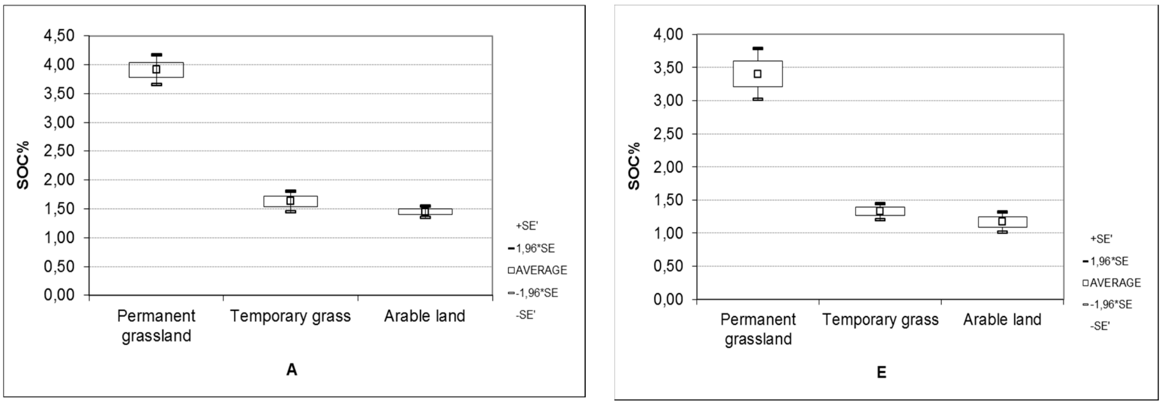

Figure 8. SOC%: mean values and mean confidence intervals of data subset for A and E SFGs in the three cropping systems

SOC mass fraction can be converted using bulk density (BD) in SOC Stock (Mg*ha^{-1}) for a certain soil volume using the follow expression SOC (Mg*ha-1) = SOC% * BD * depth * 100.

BD regional data from Regional Soil Survey are available (May2013). BD average values is 1,42 Mg*m^{-3} for SFG A and 1,52Mg*m^{-3} for SFG E, while for permanent grassland topsoil BD average value is 0,95 Mg*m^{-3}.

Table 4 shows SOC Stock of the SFGs A and E. Values are calculated by a simple approach using SOC and BD mean value for a depth of 30 cm of soil.

*Table 4 SOC stock (Mg*ha^{-1}) of the A and E SFG in the three cropping systems*

	permanent grassland	temporary grass	arable land
A	111,41	69,44	61,77
E	96,93	60,61	53,33

Conclusions

Local soil data assessment is essential to define SOC stock and SOC dynamics and to understand how far agricultural policy can affect SOC.

This analysis confirms the influence of soil types on OC storage capacity. In Emilia-Romagna plain, soils with high clay content (SFG A) show a mean value of 1,58% OC that is significantly different from medium-fine texture soils (SFG E) with a mean value of 1,36% OC and even more from coarse soils (SFG M), 1,02% OC. SOC depends also on land use and soil management: suitable local conditions like rainy climate or irrigation availability, higher water capacity, dairy farms especially if involved in traditional productions (e.g. Parmesan cheese), are factors that brings to the concentration of permanent grassland in some areas. This land use is concentrated where A and E SFGs are dominant, while in areas characterised by SFG M permanent grassland is not present.

To assess RDP actions impact, three cropping systems have been analysed for A and E SFGs. The strong influence of no-tillage over the years is evident in permanent grassland where meadows are unploughed over 30 years. The meadows reach mean values of 3.9 OC% in SFG A and 3.1 OC% in SFG E. Temporary grass, characterized by 3-5 years of alfalfa without tillage, shows higher mean value compared to systems ploughed every year, even if the influence of organic fertilization is still under observation and need to be subject to further analysis.

In terms of SOC stock, soils under RDP actions could store on average up to 111 $Mg*ha^{-1}$ OC in SFG A and 96 $Mg*ha^{-1}$ OC in SFG E. Changes from arable land to temporary grassland can lead to gain nearly 8 $Mg*ha^{-1}$ OC in SFG A and 7 $Mg*ha^{-1}$ OC in SFG E.

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