Potential carbon sequestration of Lombardy soils (Italy)

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Abstract
Lombardy soils have a high potential capacity to incorporate considerable amount of carbon, if carbon (C) saving land management is adopted. However, the certification of the changes of soil organic carbon (SOC) stock over the time is needed on the basis of transparent and cost effective methodologies. To this purpose, the soil sampling protocol recently proposed by the European Commission's Directorate General Joint Research Centre (JRC) of Ispra has been tested comparing three different land management occurring on the same soil type. Results showed a huge potential SOC sequestration rate ranging from 3,5 and 4,2 tC/ha/year and suggested the soil involvement in land-based C management practice can be actually feasible, even if the influence of soil mass on estimates of carbon storage should be in particular studied in more detail.

Key Words
Sampling protocol, uncertainty, reproducibility, CO_2 storage

Introduction
SOC stored in the upper 30 cm of the Lombardy soils is about 130 millions of tons. Nevertheless, this pool is varying according to bioclimatic conditions, soil types and land use (Brenna *et al.,* 2004). Due to historical cultivation the SOC is low in particular on the Po Plain, where cropland shows a mean content of 57 t/ha with level below 30-40 t/ha in some areas of the western and southern parts of Lombardy (Figure 1).

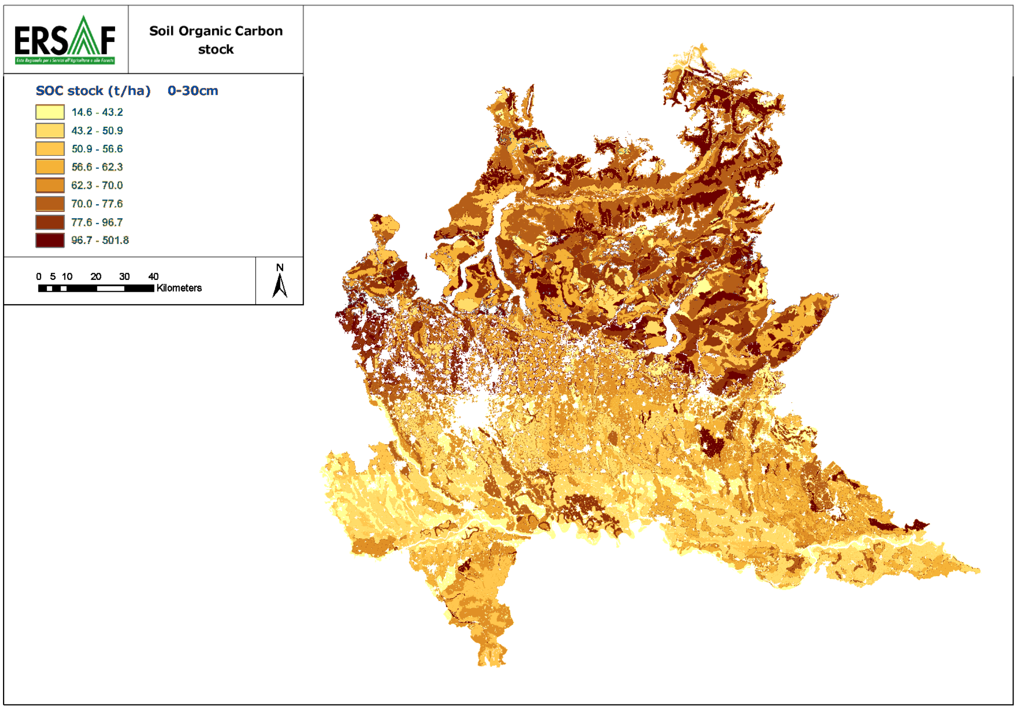

Figure 1. Soil organic carbon stock in Lombardy.

This amount of C is close to the content of the inertial fraction. Therefore these soils show a considerable capacity to re-gain a large amount of C under C saving management regime, e.g.reduced tillage and reduction of soil disturbance leading to decrease of mineralization of the crop residues, increase of organic input into soil, control of soil erosion, etc. In other words, C sequestration could become a big challenge as well as a relevant opportunity for agriculture of the region.
In fact increasing SOC by 0,1% (for example from 2 to 2,1%) in the ploughed layers of croplands (nearly 900.000 ha in Lombardy), could make the regional soil C stock to grow by over 3 million of tons, that are equivalent to a CO_2 storage of 10 million of tons.

Hence, the certification of the changes of SOC stock over the time is needed on the basis of common, simple, transparent and cost effective methodologies.
To this purpose, a soil sampling protocol, referred to a new method named "Area-Frame Randomised Soil Sampling"(AFRSS), has been recently proposed by the European Commission's Directorate General Joint Research Centre (JRC) of Ispra (Stolbovoy *et al*. 2005 and 2007).
The protocol follows the general requirements of the International Standard (ISO 2002) and is consistent with the principles of the IPCC Good Practice Guidance (IPCC 2003).
However, to bring any new method in practice does request considerable validation efforts; this validation is essential to set up boundary conditions for the method and to adjust the latter to a practical field survey.
In this study the protocol has been tested comparing three different land management occurring on the same soil type in one of the ERSAF (Regional Agency for Agriculture and Forests) experimental farms.
The test has been carried out in the frame of a wider research programme aimed at developing a regional soil C monitoring system and identifying suitable indicators and methodologies to upgrade information about the Lombardy SOC stock change and the SOC potential sequestration.

Methods

The validation test has been achieved in a farm located in the south-eastern part of Lombardy on the so called "Main Level of the Po Plain" (Late Pleistocene). The site is characterized by a nearly level surface (slope 0,2%), mean annual rainfall is about 650-700 mm (Figure 2).

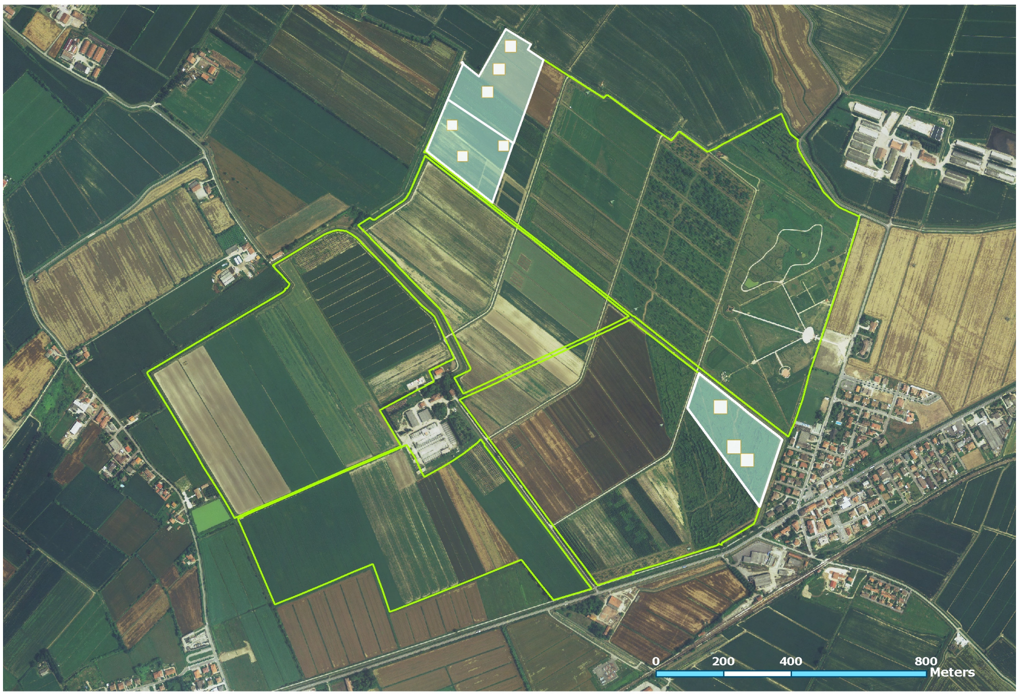

Figure 2. Aerial photograph of the ERSAF farm and localization of the testing plots, bounded by white lines.

Three testing plots standing for as many different types of land management have been identified. All of them have been cultivated in the pass with cereals (maize and winter cereals) for a long time. Currently the first plot is still cultivated with cereals (test plot identified as "cropland"), the second plot is occupied by a Short Rotation Forestry ("SRF") since 2004. The third plot is used as a forest plantation planted in the 2003 ("young forest"). The plantation includes "slow-growing" trees (oaks, hornbeams, ...), so that soil has been mainly covered by herbaceous vegetation till now.
The testing plots occur on the same soil type, classified as Endogley-Hypercalcic Calcisol (WRB 2006); the soil is developed on calcareous silt – fine sandy fluvial sediments, is moderately well drained, alkaline with a $CaCO_3$ content in the topsoil ranging from 4,1 to 26,8%, whereas a relatively shallow water table is around a depth of 100 cm. Rock fragments are lack in the soil profile and on the surface.
According to the AFRSS method, a template based on a grid with 100 cells resulted from 'modified random sampling' with a distance threshold has been considered and adapted to the testing plots (Figure 3).
Then three cells ("sampling sites") have been selected within each plot. Within the cells a "cross-sampling scheme" has been adopted, so that 9 sub-samples have been collected and mixed in a single composite sample for the SOC laboratory analysis. Also samples for the determination of bulk density have been taken.

The target of the AFRSS method is the estimate of the changes in SOC stock and its standard error, but the assessment of the reproducibility (R) of the sampling method, that is site-specific and corresponds to the minimum detectable SOC stock change, is also proposed.

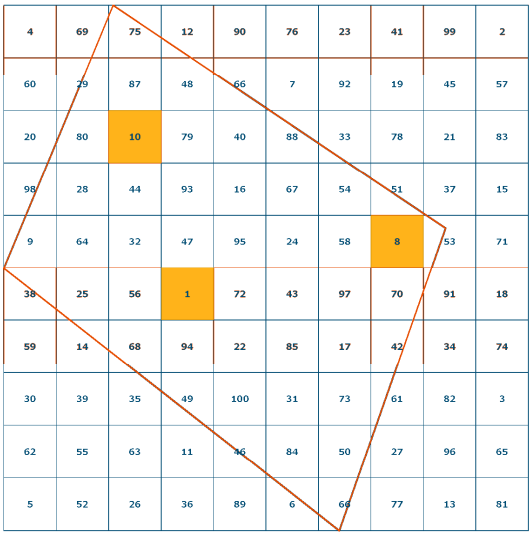

Figure 3. Adaptation of the template to the "cropland" plot

Therefore a second sampling has been performed with the same criteria on other three cells shifted for 5 m far from the first ones, to assess the reproducibility of the sampling result, that in practice simulates the error of the average coming from the mistake of the second sampling sites positioning, due to the inherent variability of soil characteristics over short distances, which is not tackled by the method.
Following the IPCC guidelines (IPCC 2003) suggesting one standard soil depth (0-30cm) for all soil types in different land cover classes, for the computation of SOC stock a soil thickness of 30 cm has been considered. For the determination of bulk density, undisturbed samples with a minimum volume of 100 cm^3 cylinder have been taken. Soil samples have been taken by auguring and composite samples analyzed in the laboratory for the SOC content with Walkley-Black method.

Results

Laboratory analysis show low SOC content, ranging from 10,90 g/kg ("cropland") to 11,89 g/kg ("SRF") and 13,79 g/kg ("young forest") on average. Bulk density is lower for "cropland" (1,17 g/cm^3) than for "SRF" (1,46 g/cm^3) and "young forest" (1,43 g/cm^3).
These measured data lead to a mean soil C density (SCD) of 3,81 kgC/m^2 for "cropland", 5,22 kgC/m^2 for "SRF" and 5,92 kgC/m^2 for "young forest".
The test provided a coefficient of variation (CV) around 6-8% for all the plots and reproducibility (R) values close to 5% for "cropland" and "SRF" and higher (9%) for "young forest" (Table 1).

PLOT	n samples	Mean SCD (Kg/m2)	Stand. Dev	CV (%)	R (%)
Cropland	6	3,81	0,33	8,75	5,77
SRF	6	5,22	0,34	6,47	4,48
Young forest	6	5,92	0,46	7,76	9,14

Table 1. Mean soil carbon density (SCD), standard deviation, coefficient of variability and reproducibility (R) pointed out by the test

The test results show a huge difference in SCD between "cropland" and the land management of the other tested plots. Clearly, the computation of the changes in SOC stock and the detection of the uncertainty are not applicable for a one time sampling. Nevertheless, assuming the same starting SOC content when all the plots were cultivated and no change in the cropland over the time, these differences, of about 21 tC/ha between "cropland" and "young forest" and 14,1 tC/ha between "cropland" and "SRF", would lead to a very impressive potential soil carbon sequestration rate ranging from 3,5 and 4,2 tC/ha/year, that should be attributed only to change in land use, being the soil the same in all the plots.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Conclusion

Obviously, the evaluation of uncertainty is crucial for any estimates and as a general opinion (Batjes 1996), SOC stock variability is in fact large, leading to doubts for the implementation of SOC management procedures. However, this assumption is provisional and the results of the validation test described in this study can contribute to the discussion concerning the uncertainty of SOC detection and the feasibility to develop an effective method to certify the change of SOC.

As already reported in previous studies (Stolbovoy *et al.*2007), also in this test all the soils show a similar pattern with a standard deviation of SOC stock less in the sampling sites having high SOC content. This finding suggests the uncertainty of SOC change expects to be less where the SOC enrichment occurs and should be considered a favorable argument to support soil involvement in the C sequestration practice.

Furthermore the validation test highlighted the difference in bulk density of the soil plots accounts for 40% and for 67% of the total observed change of SCD. The tested methodology basically involves calculating SOC stock in a given soil volume, as the product of bulk density, depth, and OC concentration. However, when soils are being compared on an equivalent soil volume basis, only if the average bulk density in all of the plots does not change much the evaluation of the SOC stocks will not be strongly affected; but, because overall variation in bulk density is common when land use systems are modified, or when tillage practices change (eg. till and no-till), it could induce some mis-interpretation of experimental results due to a computation of the SOC amount referred to different soil masses.

Recent publications (Ellert and Bettany 1995, Gifford and Roderick. 2003) indicate a serious and persistent lack of awareness about the influence of soil mass on estimates of nutrient storage.

Instead, according to these researchers, the SOC computation on the basis of an "equivalent soil mass" method could be very accurate, drastically reducing the standard error and allowing finding also small statistically detectable differences in soil organic carbon content.

Moreover, the application of the "equivalent soil mass" method would not require bulk density measurements, that are really time consuming and often providing practical sampling difficulties.

Thus, as a further step the test of a sampling approach based on the "equivalent soil mass" method to verify if it can lead to a sound reduction in the uncertainty of the results and an improvement on the SOC change estimation as well, taking in account the cost effectiveness, has been already planned.

However the study results encourage the soil involvement in land-based C management practice is actually feasible and uncertainty of the SOC change verification in mineral soils should not be considered as a constraint for its certification.

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