Soil carbon sequestration and biological activity in Conservation Agriculture systems in North Italy

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Introduction

A Life project called HelpSoil has been started to compare Conservation Agriculture systems with conventional “arable” agriculture in North Italy (http://www.lifehelpsoil.eu). To this purpose 20 experimental sites have been selected all over the Po plain, where agronomic and environmental indicators are monitored. Each site is arranged with two test plots, respectively cultivated under conservation and conventional practices. Different soil types and mean annual precipitation characterize the sites; crop rotations include winter (wheat and barley) and summer cereals (maize and sorghum), soybean and seeding of cover crops in the conservation managed test plots. Conservation practices mainly consist of no-till soil management. The main part of farms where study sites occur are irrigated; some of them are dairy farms and soils are fertilized with manure applications. A first soil sampling was carried out in the 2014 after the harvest of summer crop, providing three replications per plot. Results of this trial showed that SOC (Soil Organic Carbon) stock is considerably higher in Conservation Agriculture farming systems. Earthworms abundance, QBS-ar index based on presence/absence of microarthropodes and IBF index (Soil Biological Fertility Index) based on microbial activity were also detected to study the soil biological activity and biodiversity. All indicators pointed out a positive and often considerable effect of Conservation Agriculture methods and a strong correlation with differences in SOC content. However a second soil survey is planned by the project in the autumn 2016 to verify data and trends over the time.

1. Material and methods

Farms where the experimental sites occur are characterized by different soil types (Figure 1), classified as Luvisols, Vertisols, Cambisols and Fluvisols (IUSS-WRB, 2007). Soils have a clay content in the topsoil ranging from 7 to 49 %, and a pH from 5,6 to >8.

Figure 1: Soil Map of Italy (1:1.000.000) and location of HelpSoil demonstrative farms
The cropping systems included winter cereals, such as wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.), alfalfa (*Medicago sativa* L.) and summer crops, such as maize (*Zea mays* L.) mainly produced for silage, soybean [*Glycine max* (L.) Merr.] and sorghum (*Sorghum vulgare* Pers.). Rice (*Oryza sativa* L.) is cultivated in one of the demonstrative farms. Winter cover crops, formed by cereals (Italian Raygrass, Triticale) or a mix of different species (Vetch, Rye, Italian Raygrass, Radish) were sowed in the study sites managed under conservation practices. The mean annual precipitation in the area is ranging from about ~650 mm/year to more than 1000 mm/year.

Conservation practices consist of no tillage in the most farms (73%) and of strip-tillage or minimum tillage in the others (23%) and include improved crop rotations, permanent land cover with crop residues and cover crops. Mould board plough followed by secondary tillage to prepare the seed beds instead identifies conventional practices.

Each experimental site is arranged with two test plots, respectively managed under conservation and conventional practices. In some sites more replications occur.

Three monitoring units per test plot corresponding to an area of 20 x 20 m were used in this study (Figure 2). Within each monitoring unit, a cross-sampling scheme was used, resulting in nine sub-sampling points. Soil subsamples were collected to a 30 cm depth in autumn 2014 after the end of the cropping season using a soil auger. Subsamples were bulked together in a single composite sample per monitoring unit (Stolbovoy *et al*., 2007). This resulted in three soil composite samples per plot leading to an overall total of 130 samples. Soil samples were air dried, sieved at 2 mm and analysed for SOC concentration using the Dumas method.

Undisturbed samples, using a cylinder with a minimum volume of 100 cm$^3$, were extracted from the centre of each monitoring unit to quantify BD (bulk density). Samples were collected at a depth of 0-15 and 15-30 cm in the conservation plots and from the middle (at a depth of 10-20 cm) of the ploughed horizon in conventional plots. SOC stock was quantified according to Batjes (1996)

$$SOC\ stock = OC \cdot BD \cdot t \cdot (1 - RM) \cdot \frac{1}{10}$$
where SOC stock is given in t/ha, OC is the SOC concentration (g/kg) BD is the bulk density (g/cm$^3$), t is the layer thickness (cm), RM is the mass proportion of rock fragment content (dimensionless).

Soil samples were also analysed for TOC (Total Organic Carbon, using Springer-Klee method), carbon of the microbial biomass, basal and cumulative respiration, metabolic quotient and mineralization quotient, that are the parameters considered for the computation of IBF – Index of Soil Biological Fertility (Benedetti et al., 2006). According to the IBF methodology, a score is assigned to each parameter and then the algebraic sum of the scores leads to rank the soils in 5 classes of biological fertility (Table 1).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Score</th>
</tr>
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<tbody>
<tr>
<td>organic matter (%)</td>
<td>1 1-1,5 1,5-2 2-3  &gt;3</td>
</tr>
<tr>
<td>microbial biomass carbon (ppm)</td>
<td>&lt;100 100-200 200-300 300-400  &gt;400</td>
</tr>
<tr>
<td>basal respiration (ppm)</td>
<td>&lt;5 5-10 10-15 15-20  &gt;20</td>
</tr>
<tr>
<td>cumulative respiration (ppm)</td>
<td>&lt;100 100-250 250-400 400-600  &gt;600</td>
</tr>
<tr>
<td>metabolic quotient (/h)</td>
<td>&gt;0,4 0,3-0,4 0,2-0,3 0,1-0,2 &lt;0,1</td>
</tr>
<tr>
<td>mineralization quotient (%)</td>
<td>&lt;1 1-2 2-3 3-4  &gt;4</td>
</tr>
</tbody>
</table>

The sum of the scores of each parameter gives the class of biological fertility according to the following scheme:

<table>
<thead>
<tr>
<th>Total score</th>
<th>I alarm stress</th>
<th>II pre-alarm stress</th>
<th>III medium</th>
<th>IV good</th>
<th>V high</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-12</td>
<td></td>
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<tr>
<td>13-18</td>
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<td>19-24</td>
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<tr>
<td>25-30</td>
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</table>

Table 1: IBF – Index of Soil Biological Fertility methodology

To assess the the soil biological activity and biodiversity two indexes based on the presence of earthworms and arthropods in the soil populations were selected. To this purpose, the same sampling design implemented for SOC was used, collecting in this case 1 sample per monitoring unit. Samples were drawn from the soil surface separately for the determination of earthworms and arthropods, each having a volume of 25 cm$^3$ and 10 cm$^3$ respectively.

Clods were manually broken up to extract earthworms and assess their density.

The index used to assess soil quality with respect to arthropods is the Biological Index of Soil Quality (QBS/ar), which is obtained by summing the eco-morphological indexes (EMI) of the taxa found (Parisi et al., 2001). The extraction of the arthropods was carried out using Berlese-Tullgren selectors; after the extraction, a stereo microscope was used for classifying and counting. The data collected were processed according to the QBS method.

2. Results and discussion

SOC stock data are here shown comparing the results achieved from two groups of farms. The first group (A) is given by the experimental sites where the test plots were under their respective conservation and conventional soil management practices for at least 8-10 years; instead the second group (B) is formed by the sites where conservation practices was introduced since 3-5 years before the time of soil sampling.

The result of the trial (Figure 3) for group A on average showed an higher SOC stock in the conservation plots (77.9 t/ha) compared to that of the respective conventional plots (67.7 t/ha), with an overall difference of 15%.

For the group B the average difference was of about 5% with conservation plots showing an average SOC stock of 61.4 t/ha and conventional managed plots of 58.5 t/ha.

Moreover clay soils (Vertisols and Vertic Cambisols) have been found to seem more
responsive to SOC accumulation compared to other soil types. However results provided a strong variability depending on the site under study. This may be because soil, and more generally pedoclimatic conditions, as well as the crop management may have a determinant influence on the variation of SOC stocks (Sleutel et al., 2006). In spite of that the first soil sampling provided with the Helpsoil project encourages to support the assumption that cropland can actually be managed using conservation practices to sequester carbon and increase SOC stocks (Basch et al., 2012).

Figure 3: SOC stock in the conservation plots compared to that of the conventional plots

With respect to the IBF index, both conservation and conventionally ploughed plots were classified into the class IV (good) or III (medium), on average showing a very similar total score (respectively 17.3 and 17.2). Nevertheless, further investigations are needed to verify the sensitivity of the Index as a whole rather than its single parameters to the variation of soil tillage practices.

Figure 4: earthworms density and QBS/ar index pointed out in the test plots

On the contrary all the experimental sites showed an abundance of earthworms significantly higher in the conservation plots than in the ploughed fields (on average, respectively 15.1 and 6.5 earthworms per 25 cm³). This evidence, as well as the higher
presence of arthropods (on average the QBS/ar accounted for 77.1 points for the conservation plots and for 58.9 points for the conventionally managed plots), points out the importance of soil fauna indicators to get valuable information on the health status of the soil and, indirectly, of the agroecosystem of which it is a part (Figure 4).

3. Conclusions

This study is carried out in the frame of a Life+ project named “HelpSoil” (LIFE12 ENV/IT/000578). The project is aimed at monitoring indicators of soil ecosystem functions and assessing the capacity of Conservation Agriculture to restore agro-ecosystems to a more sustainable and productive state.

To this purpose the dissemination of such practices to foster an agriculture durable and capable to produce larger ecosystem services in the North Italy is provided. Farmers and "stakeholders" are actively involved in this process, in order to identify viable solutions and optimize environmental benefits in each specific local situation.

However, in despite of the character of the project that is mainly addressed to demonstrative actions, scientific methodologies are used in the monitoring activities.

Moreover, the results here presented are preliminary. Data indeed were collected from the first soil sampling planned in the project, whereas a second soil survey will occur in the autumn 2016 to verify results and trends over the time.

Anyhow the results achieved to date already support the improvement of knowledge concerning the potential of conservation management practices to sequester organic carbon into cropland soils in the Po plain of Italy. Data collected seem in particular to confirm (Brenna et al., 2010) that, together with no-tillage, a wide use of intercropping and cover crops as well as diversified crop rotations using a variety of crop species is determinant for the accumulation of SOC and the enhancement of soil biodiversity and vitality.

The activities illustrated in this study are in any case addressed to identify reliable indicator to assess the impact of soil management practices and their effect on climate change mitigation and adaptation as a part of a broader strategy providing a contribution to control global warming and to enhance beneficial soil natural biological processes.

References


