



REGIONE DEL VENETO



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

DAFNAE

Dipartimento di Agronomia Animali
Alimenti Risorse naturali e Ambiente

VENETO  AGRICOLTURA 



CONSERVATION AGRICULTURE

8 years

of experiences in Veneto Region





REGIONE DEL VENETO



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

DAFNAE
Dipartimento di Agronomia Animali
Alimenti Risorse naturali e Ambiente

VENETO  
AGRICOLTURA

CONSERVATION AGRICULTURE

8 years of experiences in Veneto Region

This publication collects the results of a series of projects conducted over the years 2011-2018 and partly still in progress, by the Veneto Region, Veneto Agricoltura and the University of Padua.

The following **Projects** are particularly noteworthy:



LIFE+ HELPSOIL – Improving soils quality and strengthening the adaptation to climate change through sustainable techniques of Conservation Agriculture (LIFE12 ENV/IT/000578) www.lifehelpsoil.eu/



Monitamb-214-I – Regional Program for monitoring the effects of the application of 2007-2013 RDP Measures (Measure 214/i Agro-compatible management of agricultural land “Action 1 - Adoption of conservation farming techniques” and “Action 2 - Continuous land cover”) and RDP 2014-2020 (Measure 10.1.1 - Agronomic techniques with reduced environmental impact Multi-year notice)



LIFE+ AGRICARE – Introducing innovative precision farming techniques in AGRiculture to decrease CARbon Emissions (LIFE13 ENV/IT/000583) www.lifeagricare.eu



RECARE – Preventing and Remediating degradation of soils in Europe through Land Care (Programma FP7-ENVIRONMENT - Specific Programme “Cooperation”: Environment, including Climate Change) grant agreement No. 603498 www.recare-project.eu

The publication was coordinated by a **working group** consisting of:



Regione del Veneto, Direzione Agroambiente – Veneto Region, Agrienvironment Directorate - *Barbara Lazzaro, Irene Martini*



Veneto Agricoltura – Veneto agency for innovation in the primary sector - *Lorenzo Furlan, Francesca Chiarini, Renzo Converso, Annalisa Fellin, Stefano Gambetta, Paolo Giacobbi, Renzo Rossetto, Serenella Spolon* - with particular reference to the editing of the Sheets: 0 “Techniques adopted and farm characteristics”, 1 “Yields of crops in rotation”, 9 “Integrated protection against pests: insects, gastropods, birds”, 10 “Mycotoxins in maize and wheat grains”, 11 “Evolution of flora and weed management”, 12 “Soil biodiversity: earthworms”, 13 “Soil biodiversity: mesofauna”, 14 “Soil biodiversity: microbiota and enzymes”, 15 “Sowing and harvesting machinery”, 16 “Fertilizer and liquid manure distribution techniques”, 17 “Decomposers”, 18 “Cover crops” and 19 “Economic balance: costs and revenues”



DAFNAE (Dipartimento di Agronomia, Animali, Alimenti, Risorse naturali e Ambiente) Università di Padova – (Department of Agronomy, Animals, Food, Natural Resources and the Environment) University of Padua - *Francesco Morari, Ilaria Piccoli* - with particular reference to the editing of Sheets 3 “Evolution of Soil Organic Carbon content”, 4 “Greenhouse gas emissions into the atmosphere”, 5 “Water dynamics in soil: hydraulic properties and water balance”, 6 “Effects on soil physical properties: compaction and porosity”, 7 “Distribution and properties of roots in the soil” and 8 “Impact on water quality”; *Paolo Carletti* - with particular reference to the editing of the Sheet 14 “Soil biodiversity: microbiota and enzymes”

Authors or co-authors of specific sheets are:

Nicola Colonna (ENEA) in Sheet 2 “Consumption of fossil fuels: diesel”

Cristina Menta (Dipartimento di Scienze Chimiche, della Vita e della Sostenibilità Ambientale dell’Università di Parma - Department of Chemical Sciences, Life and Environmental Sustainability of the University of Parma) in Sheet 13 “Soil biodiversity: mesofauna”

Donato Loddo (Istituto per la Protezione Sostenibile delle Piante - Consiglio Nazionale delle Ricerche - Institute for Sustainable Plant Protection - National Research Council) in Sheet 11 “Evolution of flora and weed management”

Vladimiro Toniello e *Maurizio G. Paoletti* (Dipartimento di Biologia dell’Università degli Studi di Padova - Department of Biology of the University of Padua) on the taxonomic classification of the species belonging to the Lumbricidae family used in the editing of Sheet 12 “Soil biodiversity: earthworms”

Luigi Sartori - (TESAF - Dipartimento Territorio e Sistemi Agro-Forestali dell’Università di Padova - Department of Territory and Agro-Forestry Systems of the University of Padua) in the review of the Sheets 15 “Sowing and harvesting Machinery”, 16 “Fertilizer and liquid manure distribution techniques” and 17 “Decompactors”

Anna Trettenero (Trettenero Farm) in Sheet 20 “My experience in Conservation agriculture”

Special thanks particularly to

Francesco Fagotto, Francesco Salmaso, Paolo Giacobbi (Veneto Agricoltura) for the execution of the field trials

Isadora Benvegnù, Giulia Florio, Francesco Fracasso, Sebastiano Pavan, Alberto Sartori, Erica Sartori and Roberto Solone (Veneto Agricoltura employees) for data collection and data processing activities

Editorial coordination: *Stefano Barbieri* (Veneto Agricoltura)

Text revision: *Stefano Barbieri, Francesca Chiarini, Federica Dal Molin, Lorenzo Furlan* (Veneto Agricoltura)

Graphic layout: *Federica Mazzuccato*

Translation of texts by Alison Garside and Studio Moretto Group, Brescia

Publication edited by:

Veneto Agricoltura – Agenzia veneta per l’innovazione nel settore primario - Veneto agency for innovation in the primary sector

Viale dell’Università, 14 - 35020 Legnaro (PD)

Tel. 049 8293711 - Fax 049 8293815

e-mail: ricerca@venetoagricoltura.org

www.venetoagricoltura.org

Reproduction of texts, tables, graphics, etc. subject to authorization by Veneto Agricoltura, citing the details of the publication, is acknowledged.

Finished printing in June 2019 by the Veneto Region at the Regional Press Centers

ISBN code 978-88-6337-209-0

INDEX

| | |
|---|----|
| INTRODUCTION | 5 |
| Conservation agriculture and its application in Veneto | |
| SHEET 0 | 7 |
| Techniques adopted and farm characteristics | |
| PART ONE | 9 |
| CONSERVATION AGRICULTURE AND ECOSYSTEM SERVICES | |
| SHEET 1 | 10 |
| Yields of crops in rotation | |
| SHEET 2 | 14 |
| Consumption of fossil fuels: diesel | |
| SHEET 3 | 18 |
| Evolution of Soil Organic Carbon content | |
| SHEET 4 | 22 |
| Greenhouse gas emissions into the atmosphere | |
| SHEET 5 | 27 |
| Water dynamics in soil: hydraulic properties and water balance | |
| SHEET 6 | 31 |
| Effects on soil physical properties: compaction and porosity | |
| SHEET 7 | 36 |
| Distribution and properties of roots in the soil | |
| SHEET 8 | 41 |
| Impact on water quality | |
| SHEET 9 | 48 |
| Integrated protection against pests: insects, gastropods, birds | |
| SHEET 10 | 52 |
| Mycotoxins in maize and wheat grains | |
| SHEET 11 | 58 |
| Evolution of flora and weed management | |
| SHEET 12 | 64 |
| Soil biodiversity: earthworms | |
| SHEET 13 | 69 |
| Soil biodiversity: mesofauna | |
| SHEET 14 | 74 |
| Soil biodiversity: microbiota and enzymes | |
| PART TWO | 79 |
| LAND MANAGEMENT IN CONSERVATION AGRICULTURE | |
| SHEET 15 | 80 |
| Sowing and harvesting Machinery | |
| SHEET 16 | 83 |
| Fertilizer and liquid manure distribution techniques | |
| SHEET 17 | 86 |
| Decompactors | |
| SHEET 18 | 88 |
| Cover Crops | |
| PART THREE | 93 |
| CONSERVATION AGRICULTURE PROFITABILITY | |
| SHEET 19 | 94 |
| Economic balance: costs and revenues | |
| SHEET 20 | 97 |
| My experience in Conservation agriculture | |

INTRODUCTION

CONSERVATION AGRICULTURE AND ITS APPLICATION IN VENETO

Since 2010, following the Health check reform of CAP, Regione del Veneto (Veneto Region Government) has decided to pursue the opportunity to implement a new action in the framework of the Rural Development Programme (RDP), in support of conservation agronomic techniques for preservation of the soil structure.

The motive behind this decision stemmed from scientifically demonstrated evidence that on the one hand, particularly in Europe, soils were undergoing progressive degradation phenomena due to the use of intensive tillage techniques, and on the other, that farmers were expressing the need for a more attentive adaptation of production processes to the ever-changing commodities market conditions, and the aids connected to the single payment scheme.

The literature of the sector, since the early 2000s, noted how agricultural soils would be subject to a series of degenerative processes such as the reduction of organic carbon content, reduction of biodiversity, water, wind and mechanical erosion, because of tilling, compaction, salinization and sodification of the soil. Conventional agronomic techniques therefore seemed to be difficult to sustain in terms of both related burdens on arable crop farms and the need to protect agricultural land.

At the same time, new possibilities have emerged from the Community's agroenvironmental schemes measures, connected to the need for changing the approach to the agronomic techniques that, even in Veneto, was consolidated in a system characterized by high management costs and a strong impact on soil, which is a hardly renewable resource.

Therefore, Veneto has been the first region in Italy to believe in the possibility of a reasonable number of farms starting a new beneficial practice, through tools provided by agro-environmental payments from the RDP. The choice was a clear one from the very beginning, as it was characterized by the introduction of the no-tillage technique, which involves no soil tillage and non-inversion of the soil layers. This choice, while highlighting some problems in the first cultivation cycles, has seen some interesting results emerge over time, as demonstrated by the Monitamb-214-I Project conducted by Veneto Agricoltura for the monitoring of the RDP measures, especially in terms of connected ecosystem services.

The RDP measure, activated in 2010, included the core principles of sod seeding, in the form of specific commitments made by applicant farms: a single seeding on non-ploughed soil, adoption of appropriate crop rotation, continuous coverage of the soil. These three elements were supplemented by binding instructions on how to implement the specific commitments, as well as to make them controllable by the Paying Agency.

At the end of the 2007-2013 RDP, Regione Veneto reintroduced Conservation agriculture for the 2014-2020 planning period. The commitments have basically confirmed the characteristic elements of this agronomic technique, adapting these obligations to the evidence that has emerged over time, especially in consideration of the issues faced by farmers directly in the fields.

Over the considered planning periods, the participation of 83 farms in the Conservation agriculture system has been consolidated, for a total of about 2,400 hectares. The relative importance of the results achieved with this type of intervention lies mainly

in the overall changes that these farms have had to make, meaning that they faced problems of different types and at different levels, especially during the first few years of their commitment.

Achieving satisfactory results for the farm and important ecosystem services for the agro-ecosystem depends on various factors: the type of farm equipment (the availability of sod seeders, the possibility or irrigation, etc.), the type of environment (sandy or loamy soils, silty soils, etc.) and knowledge-related factors (e.g., the skills required to face difficult situations). The optimum combination of the aforementioned elements is essential for such an advanced practice not to be a challenge, but rather a real opportunity for the future.

As all far-reaching changes, the introduction of sod seeding has involved uncertainty, difficulties and needs for adaptation. At the same time, new stimuli have emerged from the involved farms' experiences that can become drivers to better adapt, the 'conservation system' to the Veneto agricultural reality, improving performance and increasing the amount of land involved.

One of the most interesting factors for the study and optimal application of Conservation agriculture is time, meaning the necessary number of years before being able to bring corporate profits up to the same level as that achieved with the usual technique. Opinions on this aspect are not univocal, also because economic analyses for immediate estimates (gross marketable production, costs of the means of production) come into play, as well as other elements such as the medium- and long-term ecosystem services, which are more complex to evaluate.

The increase in organic matter, which remains fundamental for improving the soil structure, is a slow natural process; at the beginning of the adoption of no-tillage, especially in silty soils, the disadvantages of starting with a low amount of organic matter, with no energy-intensive techniques such as ploughing to compensate for them, have an appreciable negative impact, also on yields. However, in the long term, establishing optimum levels of organic carbon distinctive to each soil may allow for a much more favourable cost benefit analysis, provided that adequate initial investments are made in terms of a significant supply of organic matter.

In this context, the proposal was made to participate in the LIFE+ HelpSoil Project with the regions of the Po Valley was developed, in order to satisfy the need for knowledge of the different aspects of this practice. The project ended in 2017; the partners were Regione Lombardia acting as the project leader, Regione Friuli-Venezia Giulia, ERSAF, Regione Piemonte, Regione Emilia Romagna, CRPA, the Regione Veneto and Veneto Agricoltura, with Kuhn Italia S.p.A. as the co-financing body. In this context, Regione Veneto has launched a specific institutional collaboration with DAFNAE, University of Padova, concerning in particular analysis of the water cycle and carbon cycle management. Water and energy consumption were monitored for comparison with traditional irrigation methods, as well as the organic matter content and biological fertility of soils, which were monitored by taking samples in "test fields" of the project's demonstration farms.

This publication summarizes and aims to disseminate the outcomes of the work (LIFE+ Helpsoil and Monitamb 214I) performed for the monitoring of the aforesaid measures, in order to make them available to all those farmers who intend to implement Conservation agriculture on their own farms.

SHEET 0

TECHNIQUES ADOPTED AND FARM CHARACTERISTICS

The analysis and data reported in this text are the results of **8 years of experiments** (2011 - 2018), conducted on three demonstration pilot farms of Veneto Agricoltura (ValleVecchia, Diana, Sasse Rami), and other two commercial farms taking part in the Helpsoil Project, adopting conservation farming techniques.

Conservation agriculture has been defined by the FAO (www.fao.org/ag/ca, 2004) as an agricultural system that promotes farm production, optimizing the use of resources and helping to mitigate soil deterioration through integrated management of soil water and existing biological resources, together with external production factors.

The three fundamental pillars of Conservation agriculture are:

- Minimum mechanical soil disturbance, avoiding deep movement of the soil, in particular tillage, in order to preserve the structure, soil fauna and organic matter;
- Keeping the soil permanently covered (with cover crops, crop residues and protective grassland) to protect the soil and reduce weeds;
- Intercropping and crop rotation that support the soil microorganisms and fight weeds, pests and plant diseases.

More specifically, between the soil management techniques included in the definition of Conservation agriculture (minimum tillage, no-till seeding and strip tillage), the protocol applied in this study refers to **no-tillage (i.e. sod seeding)**, together with at least one annual decompaction operation, combined with permanent soil cover by means of seeding cover crops.

On the three Veneto Agricoltura farms, Conservation agriculture was compared to Conventional agriculture consisting of ploughing followed by the subsequent operations (weeding, harrowing) and without cover crops.

Each farm applied both types of soil management on two adjacent or very close fields (1-1.5 hectares each), and with similar soil conditions (Table 0.1).

| Characteristics | Unit of Measurement | Farm | | |
|----------------------------------|---------------------|--------------|-----------|------------|
| | | VALLEVECCHIA | DIANA | SASSE RAMI |
| Sand | g/100 g | 34.2 | 8.3 | 18.4 |
| Silt | g/100 g | 42.6 | 66.1 | 57.8 |
| Clay | g/100 g | 23.2 | 25.6 | 23.8 |
| USDA soil texture classification | | silt | silt loam | silt loam |
| Organic matter content | g/100 g | 1.7 | 1.5 | 1.4 |

.....
Table 0.1 - Soil characteristics of the test plots.

Each field was subjected to the same crop rotation – wheat (*Triticum aestivum* L.) - oilseed rape (*Brassica napus* L.) - maize (*Zea mays* L.) - soybean (*Glycine max* (L.) Merr.) with non-coinciding starting dates, so as to have all four crops at the same time on each farm, each year. After the first few years, the 4-year rotations were changed to **3-year rotations** without the oilseed rape, because of the difficulties, with sod seeding, in achieving sufficient emergence density, with inevitable poor yield performance. Indeed, in order to achieve good germination and a subsequent adequate plant density, the small size of rape seeds requires careful seed bed preparation, so as to guarantee a uniform and superficial depth of seeding, difficult to obtain with no-tillage, which in most cases has an irregular surface.

In Conservation agriculture, **permanent soil cover** was guaranteed by autumn cover crops (barley (*Hordeum vulgare* L.) + vetch (*Vicia sativa* L.) /barley/wheat) and summer cover crops (sorghum, *Sorghum vulgare* Pers. var. *sudanense*) planted after the main crop.

The land on the three farms was cultivated according to the same **cultivation protocol**, which involved the use of the same fertilizers and the same varieties for each crop, with an increase in seeding density in Conservation agriculture plots (maize 8.5 seeds/m² as compared to 7.5 in Conventional agriculture; for soybean, 48 seeds/m² as compared to 44; for wheat, 500 seeds/m²

as compared to 450 seeds/m²). In addition to various other agronomic parameters, the grain production of the rotated crops was recorded for each of the plots.

An in-depth analysis on the **characteristics of the Veneto Agricoltura pilot farms**, testing sites and the **cultivation protocols used**, is reported in the LIFE+ HelpSoil Project publication “The experience of twenty project farms”, in particular pages 21, 29, 37 (<http://bit.ly/2B8mx7g>).

The experiments took place as part of the **Veneto Agricoltura Programme of Activities** and were then implemented and sustained by various projects, in particular the **LIFE+ HelpSoil Project** (www.lifehelpsoil.eu/) which involved all the regions of the Po Valley under the coordination of the Lombardy Regional Authority, and the **LIFE+ Agricare Project** (www.lifeagricare.eu/it), which strengthened the contribution of Conservation agriculture, with the support of precision techniques, to the reduction of climate-altering gases and soil protection. Finally, a particular contribution was made by the regional project “**Monitamb-214-I**”, which monitored the effects of the application of agri-environmental measures supported by the RDP¹.

The analysis recorded in the data sheets that make up this publication refers, in general, to the period 2011-2018. Certain results, precisely because they are recorded as part of specific projects, refer to a different time frame, but are still within the framework of long-term crop management conducted for eight years on the same fields, concerning the pilot and demonstration farms of Veneto Agricoltura.

Within the scope of the LIFE+ Helpsoil Project, the experiments engaged two private farms in Veneto: Pasti Marco Aurelio and S. Ilario – Miana Serraglia, whose characteristics are outlined on pages 25 and 33 of the aforementioned publication (<http://bit.ly/2B8mx7g>).

¹ RDP 2014-2020:

(Measure 10.1.1 -

Agronomic techniques with low environmental impact Multiannual call for applications 2015 <http://bit.ly/2RSmZRn>)

RDP 2007-2013:

Measure 214/i Agri-compatible management of agricultural areas: Action 1 “Adoption of Conservation agriculture techniques” and Action 2

“Permanent soil cover”.



PART ONE

**CONSERVATION
AGRICULTURE
AND ECOSYSTEM
SERVICES**

SHEET 1

YIELDS OF CROPS IN ROTATION

This sheet examines the production performance achieved in the wheat-maize-soybean rotation on the three Veneto Agricoltura demonstration pilot farms, where the long-term experiments were performed to compare Conservation agriculture (CONS) and Conventional agriculture (CONV), as outlined in sheet 0.

The following graphs (Fig. 1.1) show the production at the commercial moisture for the three crops of the final rotation, on the three farms, according to the two cultivation methods applied. During the eight years of the survey, the production performance of CONS was always lower than CONV (Figures 1.2 and 1.3).

Figure 1.1 - Average production (\pm standard error) of the three crops on the three Veneto Agricoltura farms with the two cultivation systems over the eight year trial period (2011-2018).

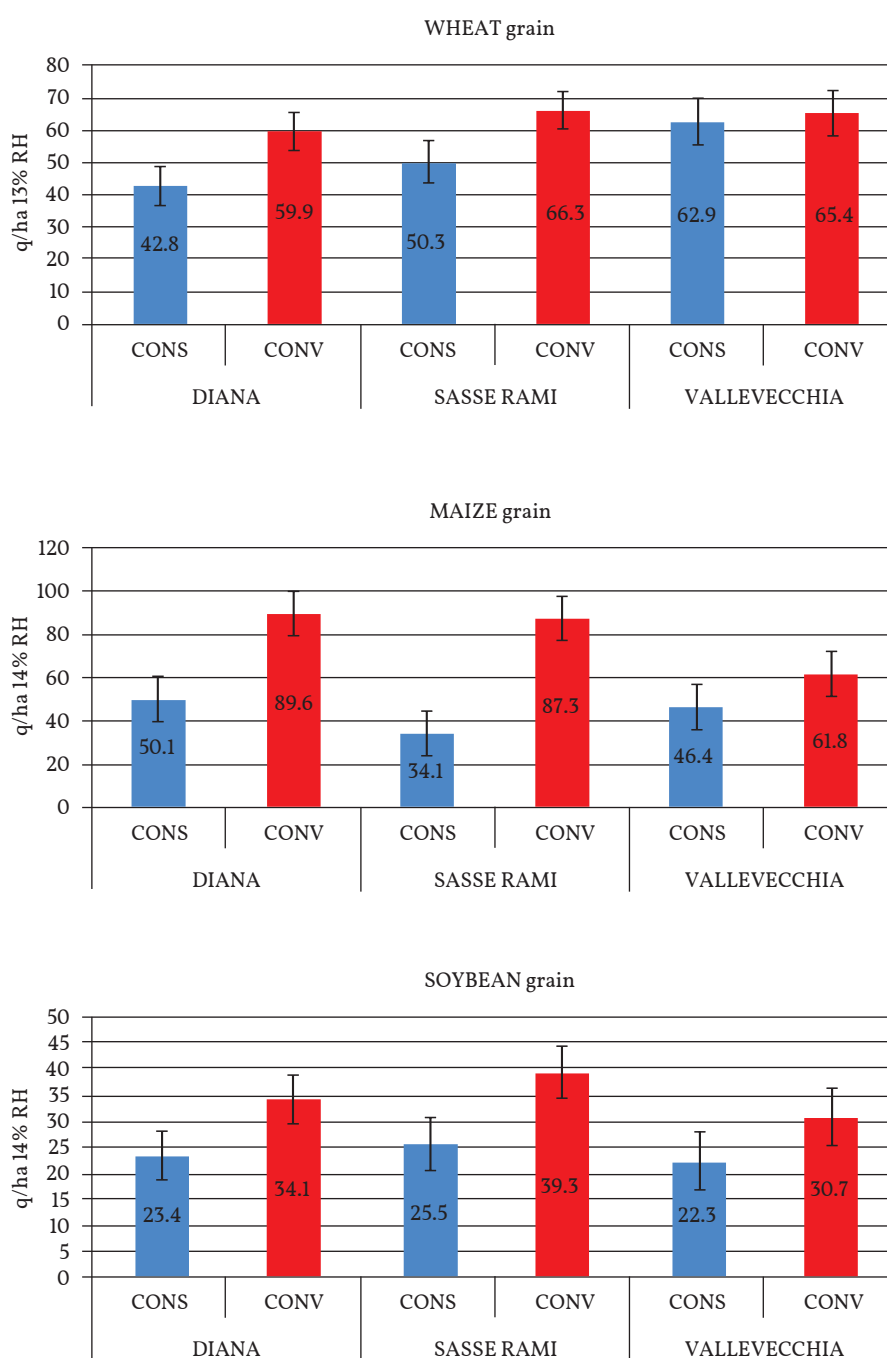


Figure 1.2 - Average production of the three crops with the two cultivation systems over the eight year trial period (2011- 2018).

From now on, in Figures, numbers with the same letter do not differ according to Tukey test ($p \leq 0.05$)

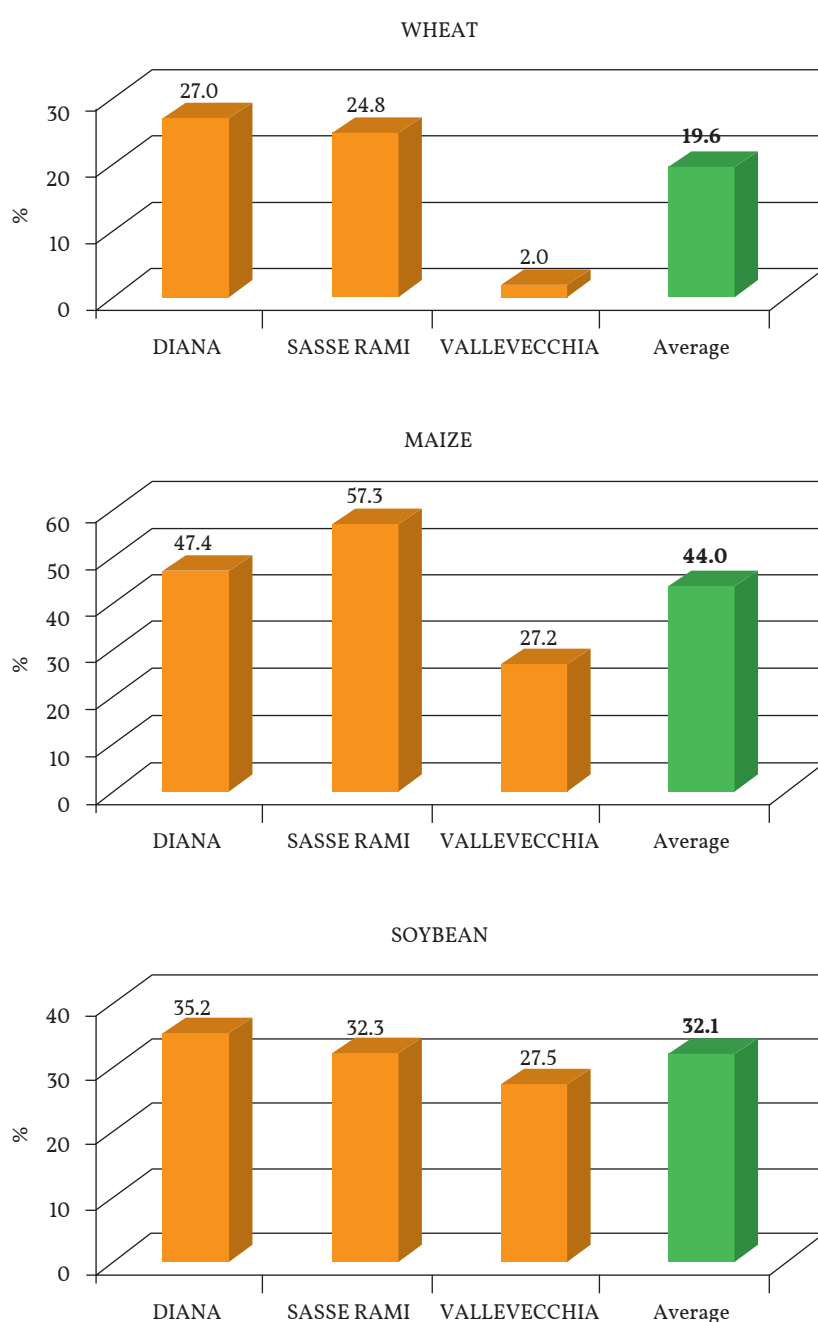
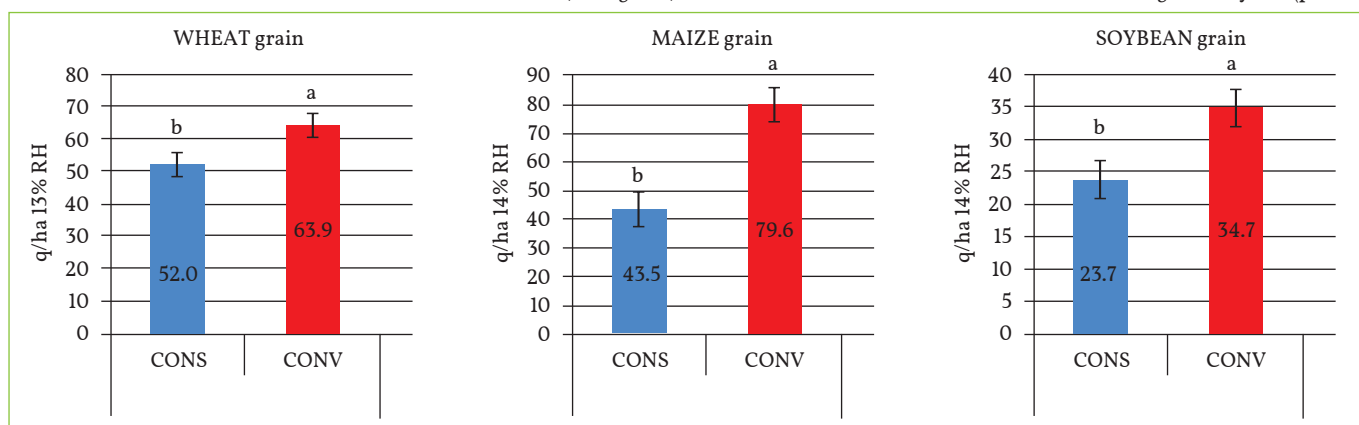


Figure 1.3 - Percentage reduction of the yield of the 3 crops cultivated using Conservation agriculture, as compared to the crops cultivated using conventional techniques over the eight year trial period (2011-2018).

Wheat cultivated on Conservation agriculture produced on average 19.6% less than the crops grown on land conventional agriculture, proving to be the crop less affected by the effects of sod seeding (Fig. 1.3). Soybean cultivated with Conservation agriculture recorded yields that were on average 32.1% lower than that cultivated using conventional methods. Maize was the most affected crop, with decreases in production from 27.2% to 57.3% depending on the farm (an average of 44%). At the ValleVecchia farm, characterized by high sand content and loamy texture, the negative effects of Conservation agriculture on grain yields proved to be more limited for all crops with respect to the other farms.

This shows that the agronomic parameter that most affected Conservation agriculture yields was probably soil compaction, especially in silty soils, further aggravated by the low organic matter content. In addition there was the high density of weeds in no-tillage that reduced the competitiveness of the crop, already poorly developed because of the effect of soil compaction.

.....
Photo 1.1 - No-till seeded,
poorly developed maize
in silty soil.



Furthermore, poor maize emergence (-22% on average) in CONS negatively influenced the crop performances, despite the higher seeding density (Fig 1.4). Moreover, this aspect is non-recoverable as maize plants are not subject to tillering or branching, unlike the other two crops. In no-till soils, the seed may find physical conditions that are unsuitable for germination or emergence. From field observations, the seeding furrow can remain open, and the poor seed-to-soil contact prevents the germination or following seedling rooting. Instead, in the more moist areas of the field with a higher silt content, the soil swelling sometimes led to the seedlings being crushed and in turn devitalized (Photo 1.2). Moreover, in these conditions, the seed is more exposed to the risk of predators, such as birds and soil insects. The lower emergence density results in a greater proportion of bare soil, which allows the weeds, already in higher quantities, to develop freely. Therefore, the final yield may be comprised if weeds are not adequately controlled with weeding. Even in cases where the final plant densities in Conservation agriculture were similar to those in Conventional agriculture, there was a significant yield reduction.

In order to reduce the aforementioned problems within the scope of the conservation farming techniques adopted (in this particular case, no-till seeding), we must first of all have a suitable no-till planter, which must be properly calibrated (see Sheet 15). It is important to wait until

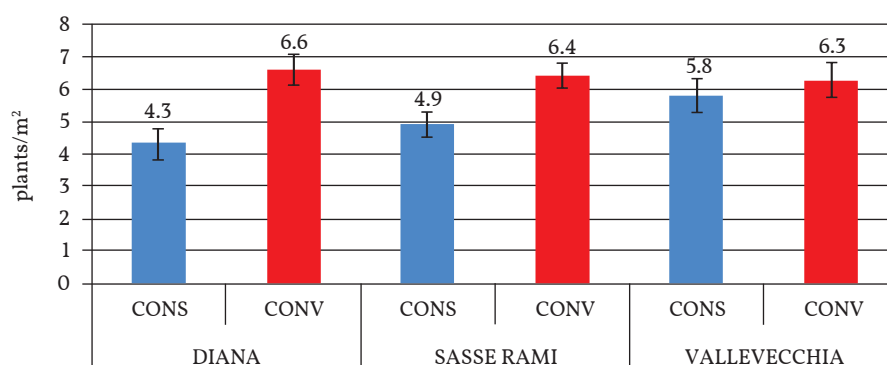


Figure 1.4 - Emergence density for maize on the three pilot farms over the 8-year trial period (2011-2018) (From now on, in the Figures, bars are mean \pm standard error).



Photo 1.2 - 'Crushed' maize seedling on no-till silty soil.

the soil is in the best possible moisture conditions, in order to limit the risk of leaving open furrows. It is also important to have the possibility to irrigate, where necessary, insofar as no-till soils tend to be more compacted and to limit root depth, with the consequent reduction in the plants' ability to absorb water (see Sheet 5).

Final considerations

The problems that emerged, and that affect yield performance, are linked primarily to the initial soil conditions, particularly in terms of the low organic matter content that does not facilitate good soil structure, especially in soils with high silt content. Increasing the organic matter in soil is a naturally slow process, but remains a fundamental objective of Conservation agriculture and a basis for all other soil improvements. At the outset of the adoption of no-till seeding methods, particularly in silty soils, the disadvantages of initial low organic matter content, not compensated for by strongly impacting techniques such as ploughing, have a notable negative impact. However, in the long term, the establishment of specific optimal levels of organic matter for each soil is likely to improve agronomic results, starting with yields, when faced with lower input of production factors.

SHEET 2

CONSUMPTION OF FOSSIL FUELS: DIESEL

Energy consumption

One of the main items of expenditure in an agricultural venture is the diesel used to run the various cultivation operations. The use of tractors and specialized machinery entails high fuel consumption per hectare of land, which significantly impacts the farm's financial and environmental balance sheet.

Conservation techniques reduce the number of passages and/or the traction effort, and therefore significantly reduce the consumption of diesel fuel.

Replacing traditional ploughing methods by no-tillage (sod seeding) or minimum tillage and the use of combination machines, which can perform several operations in a single passage, allows diesel fuel consumption to be reduced by 50% or more, according to the type of soil and crop, compared to traditional techniques.

Experimental results from the Veneto Agricoltura pilot farms

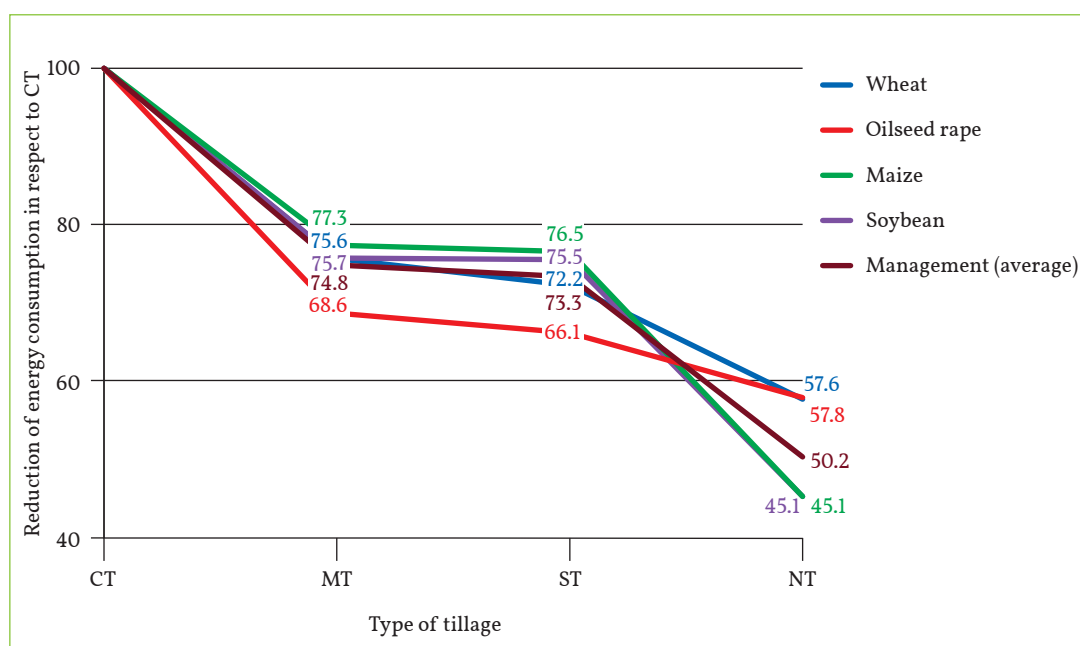
Since 2015, the pilot demonstration farm of Veneto Agricoltura, located in ValleVecchia of Caorle (province of Venice), has been conducting different experimental activities within the LIFE+ Agricare project (www.lifeagricare.eu). Conservation agriculture was used for four different crops (wheat, oilseed rape, maize, soybean), as well as three different techniques. No-tillage (NT), minimum tillage (MT) and strip tillage (ST) were compared with conventional tillage (CT), which includes ploughing and the normal sequence of operations, carried out separately. Conservation soil management showed immediate benefits in terms of diesel fuel savings (Tab. 2.1) for all crops with consumption reduction peaks of more than 50%.

Table 2.1 - % diesel fuel savings after two years of testing, compared to conventional controls for each crop and technique.

| Crop/Technique | MT | ST | NT |
|----------------|-------|-------|-------|
| Wheat | -24.4 | -27.8 | -42.4 |
| Oilseed rape | -31.4 | -33.9 | -42.2 |
| Maize | -22.7 | -23.5 | -54.8 |
| Soybean | -24.3 | -24.5 | -54.9 |

No-tillage has shown higher savings, followed by strip tillage and minimum tillage. The difference between the crops is related to the specific technique used, and in particular, to the difference between fertilization and irrigation levels.

Figure 2.1 - Direct energy consumption (diesel+lubricant) per crop and the entire cropping system, and comparison with conventional tillage (CT=100).



In terms of absolute value, the results are specific to the tests and machines used at the Valle-Vecchia experimental farm; however, similar results may be obtained by any farmer who uses the same conservation techniques; shifting from the plough to moving, rotating machinery that till the surface or just cut a furrow to sow the seed, reduces the traction effort and therefore diesel fuel consumption, in addition to decreased machine use time. Expenditure per crop cultivation is thus significantly reduced; however, in order to assess the cropping system as a whole, the additional spending on cover crops, which are an essential element of Conservation agriculture, must also be taken into account.

Energy expenditure on cover crops

The expenditure on fossil-fuel energy for cover crops was limited to the use of tractors for soil preparation and seeding, and was 2300 MJ, with a percentage incidence of 17% in MT and ST tests, and 25% for NT.

For more extensive knowledge of the energy consumption associated with a particular crop or cropping system, the gross energy requirement must also be considered.

Gross Energy Requirement

Diesel fuel and lubricants are the two fossil-origin elements that are directly used for cultivation, but there are also other relevant energy expenditures to be considered to assess a crop: these are the so-called 'hidden' or indirect costs. Fertilizers, seeds and protection products (pesticides, herbicides) are all inputs that require energy to be produced, packaged and supplied to the farm. If we were to also include the 'hidden' energy costs in the different technical inputs, the energy balance sheet of the crop would change significantly.

The gross energy requirement of the crops tested at ValleVecchia has been found to vary according to the crop and techniques used. The results show an energy requirement of 28880 MJ per hectare for maize, 21830 MJ for wheat, 14260 MJ for oilseed rape and 12570 MJ for soybean; these figures show the different energy intensity of the different crops and, in the case of soybean, the importance of the absence of nitrogen fertilizers. The graphs in Figure 2.2 show how the percentage in weight of energy hidden in indirect consumption is very important for wheat and oilseed rape, whereas the situation is significantly different with maize and completely overturned with soybean.

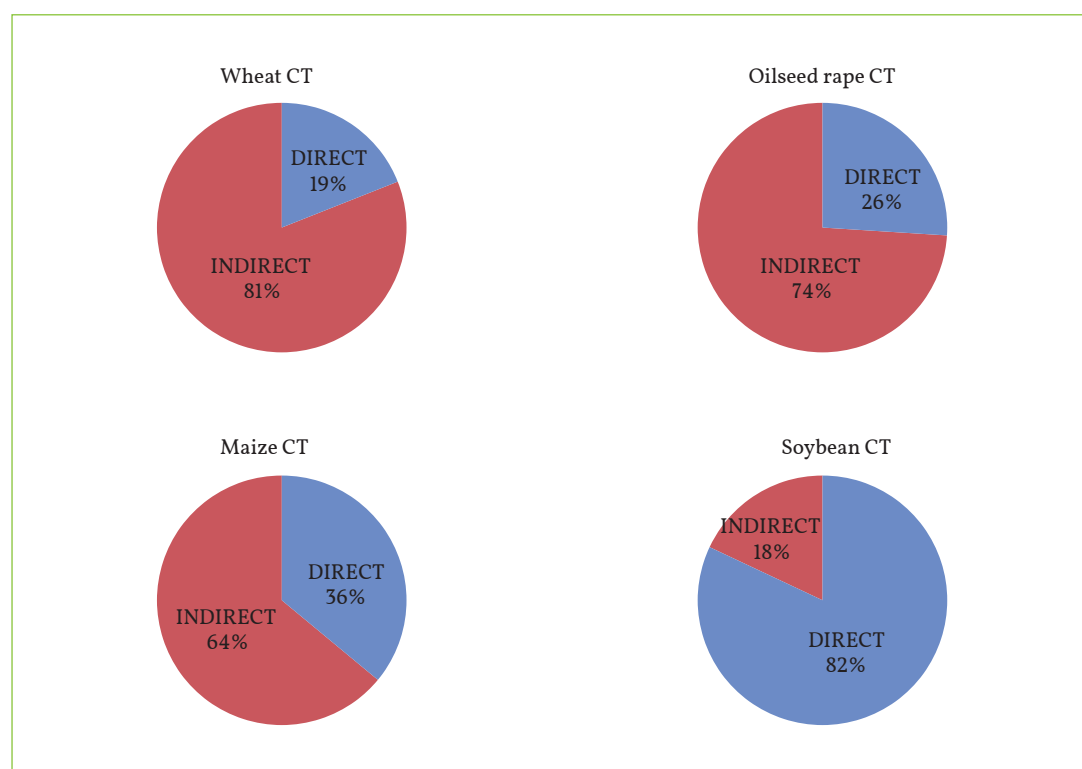
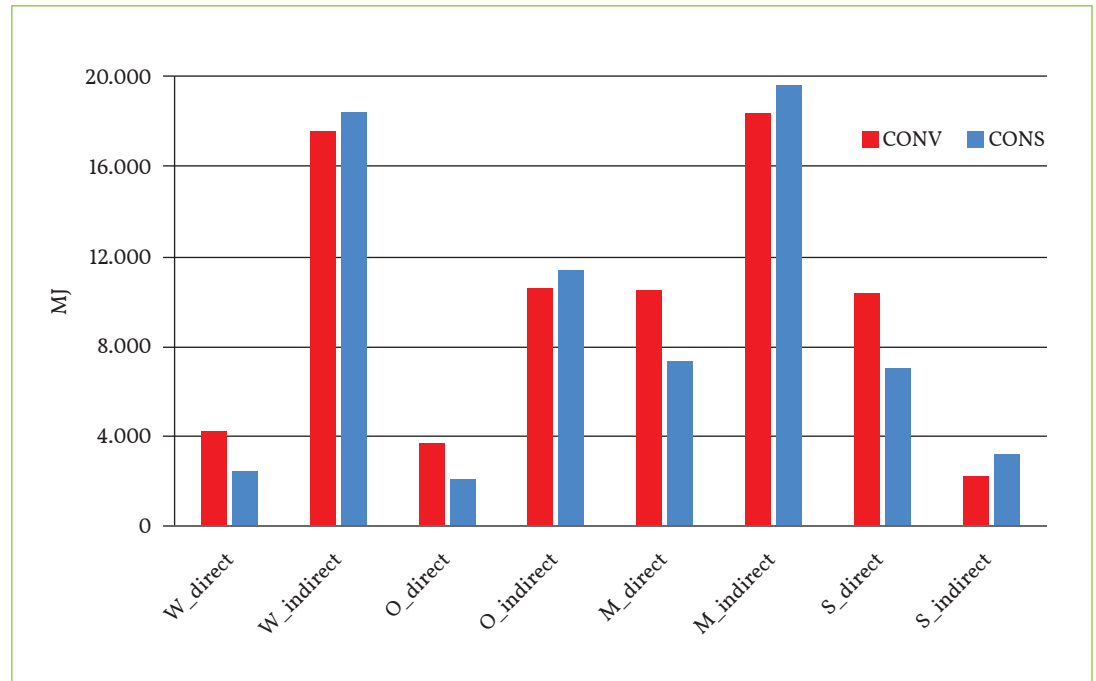


Figure 2.2 - Direct and indirect energy consumption percentage weight per crop with conventional tillage.

Upon shifting from ploughing to conservation techniques, the direct consumption of energy (diesel fuel essentially) decreases, while indirect energy consumption slightly increases, mainly because of energy expenditure connected to weeding (Fig 2.3). The tests conducted at ValleVecchia showed that the use of herbicides, which in fact partially replaces the weed control function of ploughing, actually entails a higher energy expenditure of about 2-3000 MJ per hectare, therefore partly counterbalancing the benefits of diesel fuel savings. Thus, considering that expenditure for weeding is higher than that for cover crops, Conservation agriculture entails tangible, albeit not large, savings on energy.

Figure 2.3 - Direct and indirect energy consumption (mean values over two years) per crop W = Wheat, O = Oilseed rape, M = Maize, S = Soybean with conventional tillage (CONV) compared with the no tillage (CONS).



At ValleVecchia, Conservation agriculture was also tested in an integrated manner by applying Precision Farming, which led to further energy savings, reaching 11% on average of two-year testing. The optimization of the machine manoeuvres and paths, made possible by assisted driving, allows to decrease both machine use time and the distances travelled, therefore leading to further savings on diesel fuel.

The results obtained can be better understood and evaluated by analyzing, apart from just the gross energy requirement, the Net Energy Ratio (NER), which correlates energy expenditure with the production outputs. The energy expenditure per unit of product obtained (MJ/t), or even better per unit of energy obtained (MJ/MJ), taking the LCV (Lower Calorific Value) as a reference, and the grain of the biomass produced by the crop. This index allows to see whether Conservation agriculture is actually more energy-efficient than traditional techniques as it also integrates yield results.

Over the two testing years, in the pedoclimatic conditions of ValleVecchia, the energy efficiency of the conservation techniques was lower - even if only slightly - compared to conventional tillage; this was due to the outputs being lower on average.

The information and experience gained at ValleVecchia lead us to think that over time, the application of conservation techniques, could lead to remove or reduce the production gap and also improve the net energy ratio, as a consequence; this is due to the farmers' greater experience, improvement of techniques and the cumulative effects of organic matter conservation. The integration of precision farming techniques as well, with consequent diesel fuel savings and optimization of inputs, provided that a variable distribution of inputs is applied, altogether tend to improve results and energy efficiency compared to conventional techniques.

BIBLIOGRAPHY

- AA.VV., 2010: Come si valuta l'efficienza delle colture da biomassa. AGRICOLTURA. pag. 95-97
- AA.VV., 2014 LINEE GUIDA per l'applicazione e la diffusione dell'Agricoltura Conservativa. Progetto LIFE+ HelpSoil (LIFE 12 ENV/IT/000578)
- Bonari E., Mazzoncini M., Peruzzi A., Silvestri N., 1992: Valutazioni energetiche di sistemi produttivi a diverso livello di intensificazione colturale. Informatore Agrario 1/92 suppl., 11-25
- Borin M., Menini C., Sartori M., 1997: Effects of tillage systems on Energy and Carbon balance in north eastern Italy. Soil and Tillage Research, 40 209-226
- Casali E., 2016: L'Agricoltura Conservativa: le tecniche in Rivista di Agraria.org. <http://www.rivistadiagricoltura.org/articoli/anno-2016/lagricoltura-conservativa-le-tecniche/>
- Pisante M., (editor) 2007: Agricoltura blu. La via italiana dell'Agricoltura Conservativa. Edagricole, Bologna pp 187-257
- Triolo L., Mariani A., Tomarchio L., 1984: L'uso dell'energia nella produzione agricola vegetale in italia: Bilanci energetici e considerazioni metodologiche. ENEA RT/FARE/84/12



SHEET 3

EVOLUTION OF SOIL ORGANIC CARBON CONTENT

Soil Organic Carbon (SOC) constitutes 58% of the organic matter found in soils and is of both agronomic and environmental relevance. In fact, SOC is the main indicator of soil quality and fertility, and is the second global carbon pool.

Conservation agriculture is a cropping system able to increase the soil carbon stock in the upper 30 cm soil profile, by about 0.57 ± 0.14 t of Carbon (C) per hectare per year.

This effect is primarily due to minimum disturbance of the soil and its aggregates, greater organic C input from crop residues, and diversification of crops (rotation and cover crop).

Recent studies have shown, however, that the advantage in comparison to the arable systems is zeroed when the stock is calculated also including the SOC in the deep soil layers; indeed, Conservation agriculture changes SOC distribution in the soil profile with higher values at the surface and lower in the deep layers.

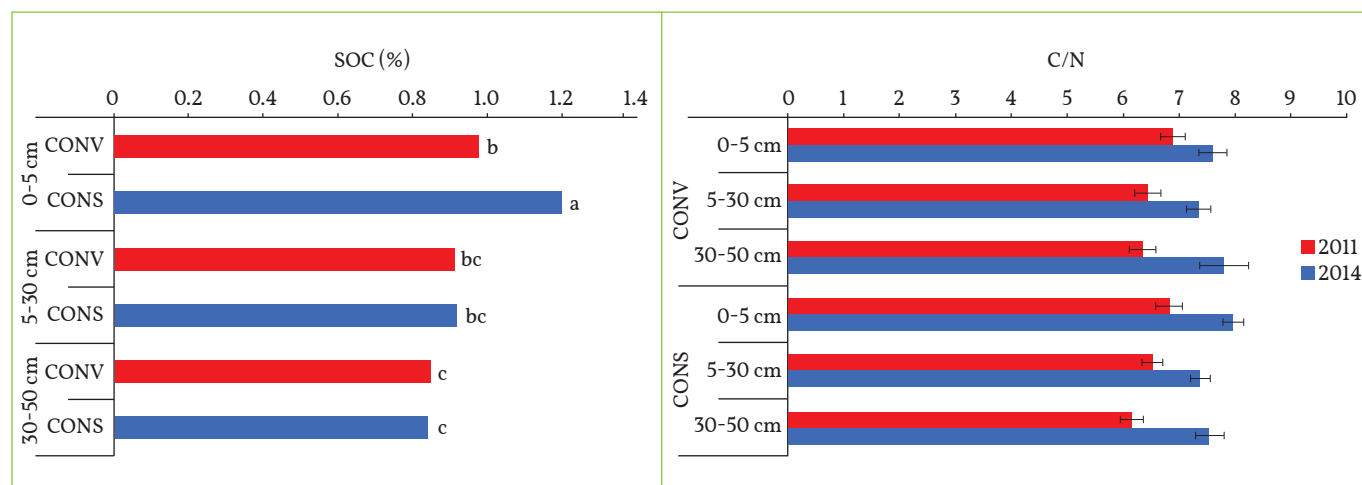
Regardless of the soil carbon stock, Conservation agriculture has a positive effect on the quality of organic matter, as it increases the humus content and activity of the soil microbial biomass.

Experimental results of the Veneto Agricoltura pilot farms

Conservation agriculture has increased the mean concentration (%) of SOC in the 0-50 cm profile (0.99% compared to 0.91% of Conventional agriculture), mainly due to the accumulation of SOC at the surface layer: 0-5 cm, 1.20% compared to 0.98% of Conventional agriculture (Fig. 3.1).

In addition, the concentration at Sasse Rami and ValleVecchia was found to also be positively correlated to the clay content, thus highlighting the presence of the physical protection mechanisms leading to the formation of organic-clayey complexes. The mean values of C/N (Fig. 3.1) ranged from 6.5 in 2011 to 7.6 in 2014, without significant differences according to agronomic management and sampling layers.

Figure 3.1 - Left: SOC (%) concentration of SOC in the different layers. Right: C/N ratio in the different layers. Mean data in 2011 and 2014, and for the three experimental sites. CONV = conventional; CONS = conservation.



In the 2010-2014 period, Conservation agriculture affected the SOC stock distribution within the soil profile, which increased by 0.85 and 0.57 t C per hectare in the 0-5 cm and 0-30 cm layers, and decreased by 0.69 t C per hectare in the 0-50 cm layer. Compared to Conventional agriculture, the increment was 0.36 t C per hectare per year at 0-5 cm and 0.22 t C per hectare

per year in the upper 0-30 cm. However, no significant differences were observed in the 0-50 cm profile.

The factors that modified the SOC distribution were:

- A) no tillage in Conservation agriculture, with the consequent accumulation of residues on the surface;
- B) soil layer inversion by ploughing in Conventional agriculture, with consequent burial of residues in depth;
- C) root apparatus development and C input from crop residues on the soil surface;
- D) texture, with a positive effect of clay and a negative effect of sand.

The reported results refer to a short-term period (3 years). However, according to the DNDC model, SOC in silt loam soil of the Veneto plain would be affected by long-term dynamics longer than 20 years. Therefore, 20 years might be the minimum time span to observe significant differentiation between conservation and conventional systems (Fig. 3.2).

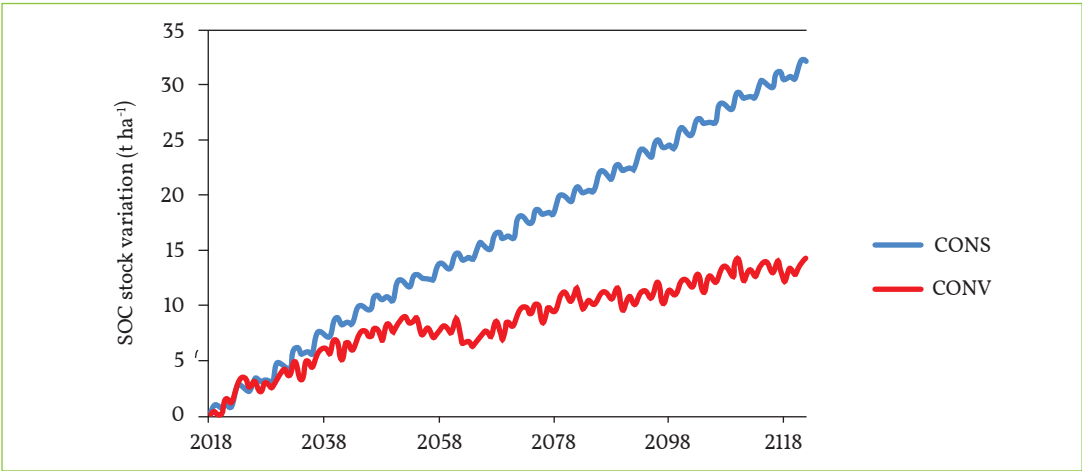


Figure 3.2 - DNDC model simulation of SOC stock variation over 2018-2118 years at SasseRami. 0-50 cm profile.

Over the three years trial period, Conservation agriculture affected the ratio between the humic fractions, with a reduction of the light component (low molecular weight humic matter fractions) in favour of the medium molecular weight component (Fig. 3.3). Instead, microbial activity did not show a clear trend according to the agronomic practice. The microbial C and N content averaged around 170 mg per kg and 10 mg per kg, respectively.

| | 0-5 cm | 0-30 cm | 0-50 cm |
|------|--------|---------|---------|
| CONV | -0.23 | 0.08 | 1.18 |
| CONS | 0.85 | 0.57 | -0.69 |

Table 3.1 - SOC stock variation (t/ha) from 2011 to 2014 within the soil profile.

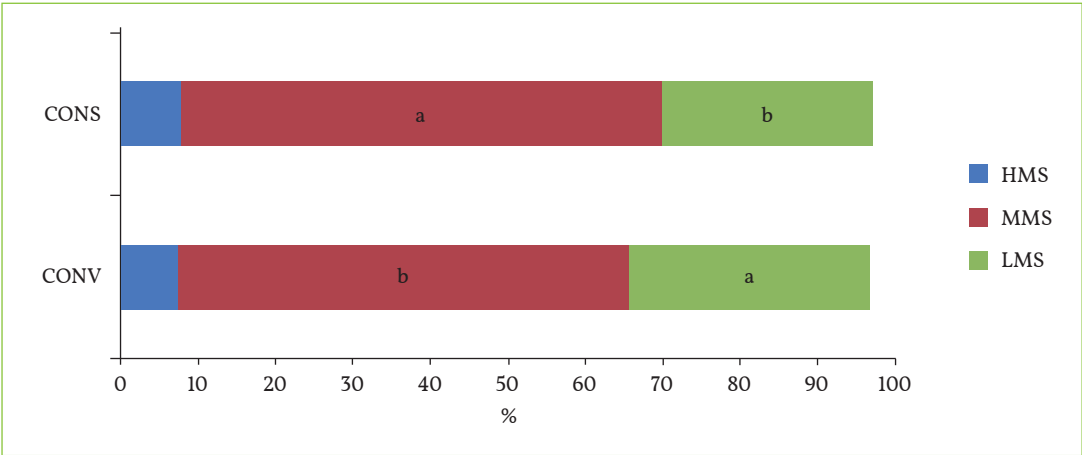
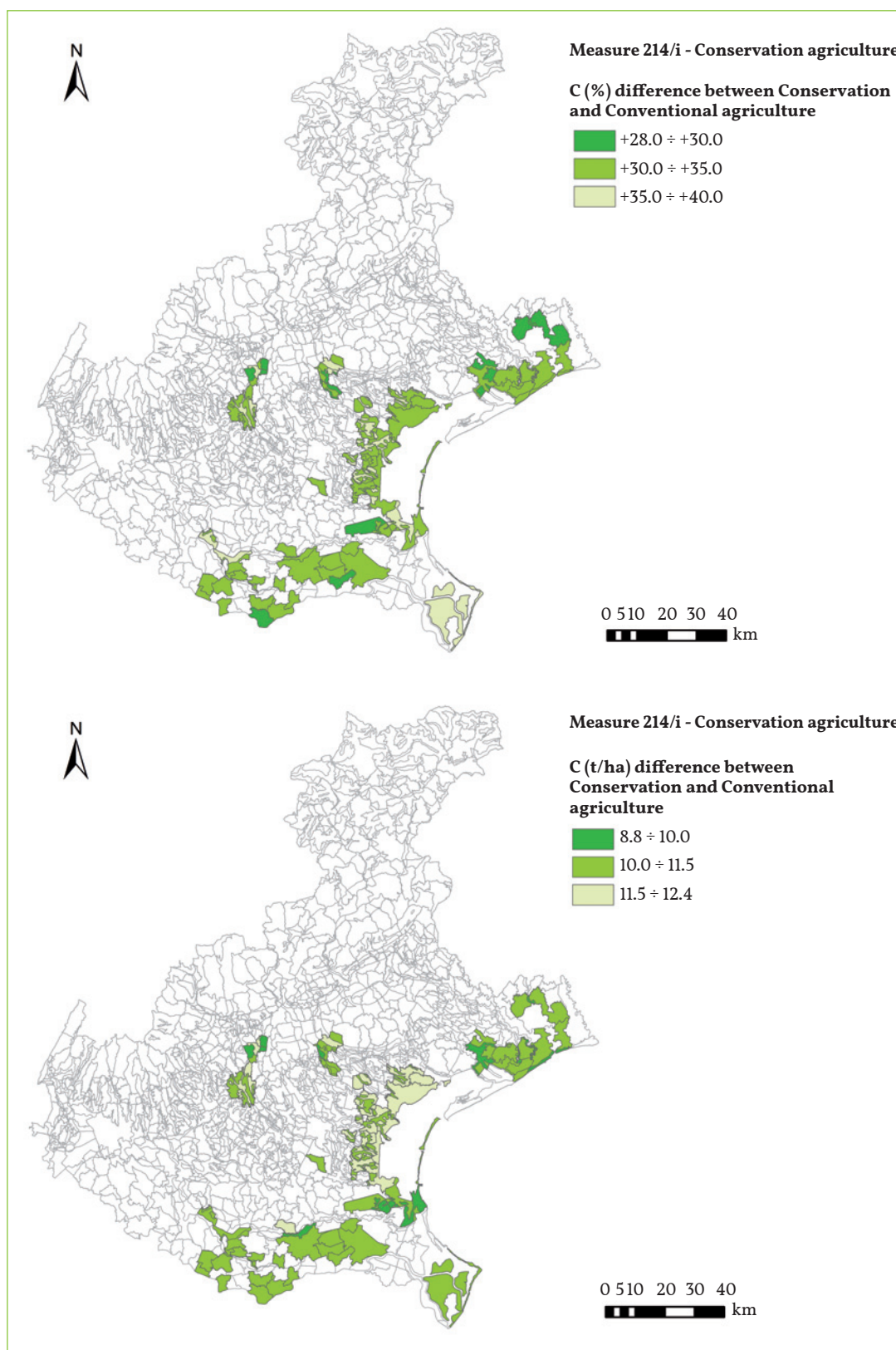


Figure 3.3 - Distribution of humic matter fractions between treatments. HMS = high molecular weight humic substances; MMS = medium molecular weight humic substances; LMS = low molecular weight humic substances; CONV = conventional; CONS = conservation.

Conservation agriculture in Veneto as a result of the application of the RDP

In Veneto, the impact of Conservation agriculture on the SOC stock is affected by the interaction between agricultural management and pedoclimatic conditions. The 214/i Measure Action 1 (Conservation agriculture), applied for the first time in the 2007-2013 RDP, would have increased the SOC stock by $1.5 \text{ t ha}^{-1} \text{ y}^{-1}$ in the first 20 cm layer according to the DayCent model, with higher values in finer soils compared to sandy ones (Fig. 3.4). As the map clearly shows, the measure was mainly applied in the low Veneto plain.

Figure 3.4 - Soil carbon content difference in 2013 (t/ha - bottom; % - top) between cropping systems in which the 214/i Action 1 Measure was applied (Conservation agriculture) and conventional systems, during the first RDP (2007-2013). DayCent model simulations.



BIBLIOGRAPHY

- Camarotto, Dal Ferro, N., Piccoli, I., Polese, R., Furlan, L., Chiarini, F., Morari, F., 2018. Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain, *Catena*, 167, pp. 236-249.
- Dal Ferro, N., Cocco, E., Lazzaro, B., Berti, A., Morari, F., 2016. Assessing the role of agri-environmental measures to enhance the environment in the Veneto Region, Italy, with a model-based approach. *Agriculture, Ecosystems and Environment*, 232, pp. 312-325.
- Piccoli, I., Chiarini, F., Carletti, P., Furlan, L., Lazzaro, B., Nardi, S., Berti, A., Sartori, L., Dalconi, M.C., Morari, F. 2016. Disentangling the effects of Conservation agriculture practices on the vertical distribution of soil organic carbon. Evidence of poor carbon sequestration in North- Eastern Italy. *Agriculture, Ecosystems and Environment*, 230, 68-78.



SHEET 4

GREENHOUSE GAS EMISSIONS INTO THE ATMOSPHERE

The agricultural sector accounts for 7% of greenhouse gas (GHGs) emissions into the atmosphere, thus constituting Italian second main GHGs emission source after the energy sector (ISPRA, 2010). Carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) are GHGs that are mainly regulated by the agronomic management of soils, although they are also strongly influenced by local conditions (soil, weather, etc.). The ability to mitigate their effect on climate change depends on the total balance of these three gases, as well on their global warming potential, which is 300 times higher than that of CO₂ for nitrous oxide and 30 times higher for methane.

Carbon dioxide (CO₂) and methane (CH₄)

CO₂ emission is influenced by both short- and long-term phenomena. In the short term, the action of tillage is predominant on microbial activity, whereas in the long term, the general effects of the cropping systems prevail over the soil chemical, physical and biological quality. In the first days after ploughing, CO₂ peaks are usually recorded, because the tillage stimulates the microbiological activity by breaking up aggregates and soil conditions are more oxidative. Overall, emissions produced by conventional systems can be 40% higher than those of Conservation agriculture.

The effect on CH₄ emissions has not yet been sufficiently investigated; according to some authors, Conservation agriculture either positively or negatively influences the release of gas depending on the aerobiotic/anaerobiotic conditions of the soil.

Nitrous oxide (N₂O)

In general, the greater water content and reduced aerobiosis of Conservation agriculture systems cause an increase in N₂O emission compared to arable systems, notably on soils with poor water conductivity following intense rainfall. The phenomenon is evident, especially during the transition period from a conventional system to a conservation one, when the structure of the soil has not yet reached its equilibrium. On the contrary, in stabilized systems or well aerated soils, the impact on emissions is negligible, or even lower than that of ploughed soil.

Soil properties and gas transport

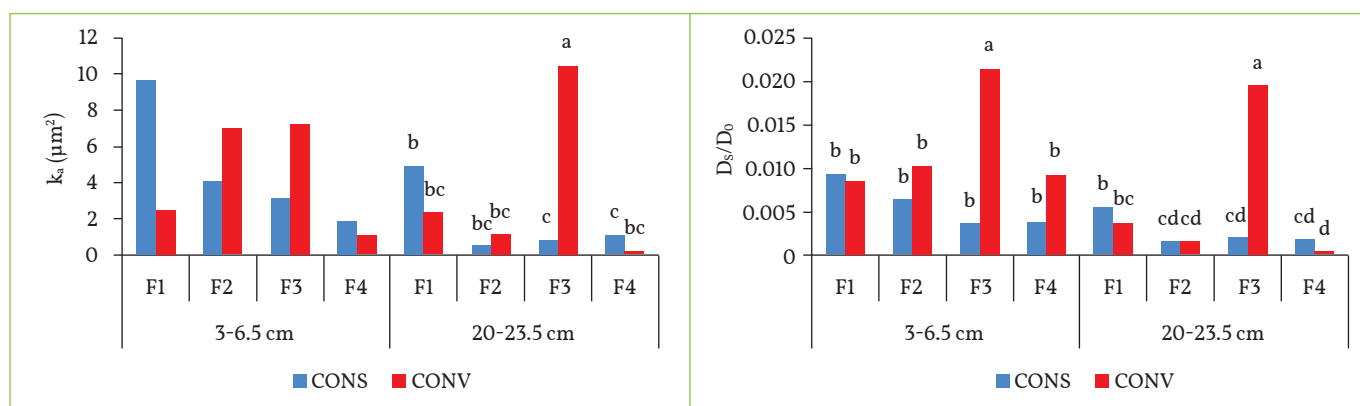
In Conservation agriculture, anaerobic conditions also depend, in addition to external factors (e.g., rainfall, shallow water table), on the soil structure. The formation of large, vertically oriented and not very convoluted pores would be linked to the transport and exchange of high gas volumes with the atmosphere and therefore, to a lower anaerobic condition. The exchange in deep soil is instead favoured by total porosity, regardless of the size of the pores and degree of their interconnection. Soil compaction reduces gas transport from the soil to the atmosphere and vice versa, therefore decreasing the oxygen concentration of the soil.

Experimental results from the Veneto farms

Gas transport capacity

Conservation agriculture has not affected the gas transport capacity of the soil at the 3-6.5 cm and 20-23.5 cm layers. (Fig. 4.1), which in general, was low. This result suggests that regardless of the agronomic practice, soils of the low Veneto plain are poorly aerated. Conservation agriculture has only reduced the soil gas transport capacity at the Miana Serraglia farm; this is a result of subsoil compaction, which is linked to a reduction in the average diameter and a greater tortuosity of pores.

Figure 4.1 - Air permeability (left) and gas diffusion (right) in ValleVecchia (F1), Diana (F2), MianaSerraglia (F3) and Sasse Rami (F4). The results obtained after 5 years from the conversion to Conservation agriculture in 3-6.5 cm (L1) and 20-23.5 cm (L2) layers. The higher the value of these properties, the greater the gas transport capacity of the soil.



DNDC model simulation of Greenhouse gases balance

At the Sasse Rami farm, the DNDC model was used for a simulation of GHGs release in both the short (2 years) and long term (100 years). In the short term, Conservation agriculture has promoted a reduction of nitrous oxide flow (Tab. 4.1), from 5.07 kg N-N₂O/ha to 3.1 kg N-N₂O/ha, while the CO₂ balance was negative, which suggests the occurrence of C accumulation (C sequestration). Contrary to what was expected, accumulation was higher in the conventional system. CH₄ emissions were similar in the two systems, on average -0.84 kg C/ha and -0.86 kg C/ha, reflecting the prevalence of CH₄ degradation by micro-organisms.

Generally, according to the GHGs balance, Conservation agriculture would have a mitigating effect in the short term (-116 kg C-CO₂ eq/ha) compared to the conventional system, which has a net emission of 388 kg C-CO₂ eq/ha, caused by a greater release of nitrous dioxide.

On the contrary, the opposite results were observed in the long term, where N₂O emissions in Conservation agriculture (on average, 2 kg N-N₂O kg per hectare) were independent from the simulated climactic scenario (A1B, A2, B1). This behaviour was only partly counterbalanced by the greater carbon sequestration capacity of Conservation agriculture, about 300 kg C-CO₂ kg per hectare compared to the 65 kg C-CO₂ kg per hectare of conventional systems. Instead, methane emissions showed negative values.

Overall, the long-term conditions show a potential positive contribution to emissions in both systems, due to the high nitrous dioxide emissions (Tab. 4.2). These data are particularly interesting because they allow different dynamics to be identified as a function of the time scale. Nevertheless, it should be remembered that these results come from a single site and model-based simulations and therefore need to be validated in the long term.

| Treatment | Year | N ₂ O (kg N ha ⁻¹) | CH ₄ (kg C ha ⁻¹) | CO ₂ ^a (kg C ha ⁻¹) |
|-----------|------|--|---|--|
| CONS | 2016 | 1.96 (±0.03) | -0.78 (±0.004) | -2118.7 (±5.6) |
| | 2017 | 4.24 (±0.04) | -0.90 (±0.005) | 75.3 (±4.9) |
| CONV | 2016 | 4.10 (±0.07) | -0.70 (±0.004) | -1309.0 (±4.8) |
| | 2017 | 6.04 (±0.06) | -0.81 (±0.005) | -951.2 (±7.8) |

^a Net CO₂: difference between C outflows and inflows. CONS = Conservation agriculture, CONV = Conventional agriculture

| Climactic Scenario | Treatment | CO ₂ (kg C ha ⁻¹ yr ⁻¹) | N ₂ O (kg N ha ⁻¹ yr ⁻¹) | CH ₄ (kg C ha ⁻¹ yr ⁻¹) | GWP ^b (kg eq. CO ₂ ha ⁻¹ yr ⁻¹) |
|--------------------|-----------|--|---|--|---|
| A1B | CONS | -314.9 (±84.8) | 6.9 (±0.3) | -1.1 (±0.02) | 2134.2 (±454.8) |
| | CONV | -160.2 (±107.3) | 4.5 (±0.2) | -0.9 (±0.01) | 1553.0 (±488.9) |
| A2 | CONS | -300.0 (±81.6) | 7.0 (±0.4) | -1.1 (±0.02) | 2236.7 (±491.1) |
| | CONV | -158.2 (±114.9) | 4.7 (±0.2) | -1.0 (±0.01) | 1654.0 (±516.8) |
| B1 | CONS | -309.1 (±87.5) | 7.3 (±0.4) | -1.1 (±0.02) | 2347.4 (±512.7) |
| | CONV | 172.9 (±112.3) | 4.7 (±0.2) | -0.9 (±0.01) | 1602.5 (±507.2) |

^b GWP = global warming potential

Table 4.1 - GHGs emissions over 2016-2017 at Sasse Rami farm. DNDC model simulated data.

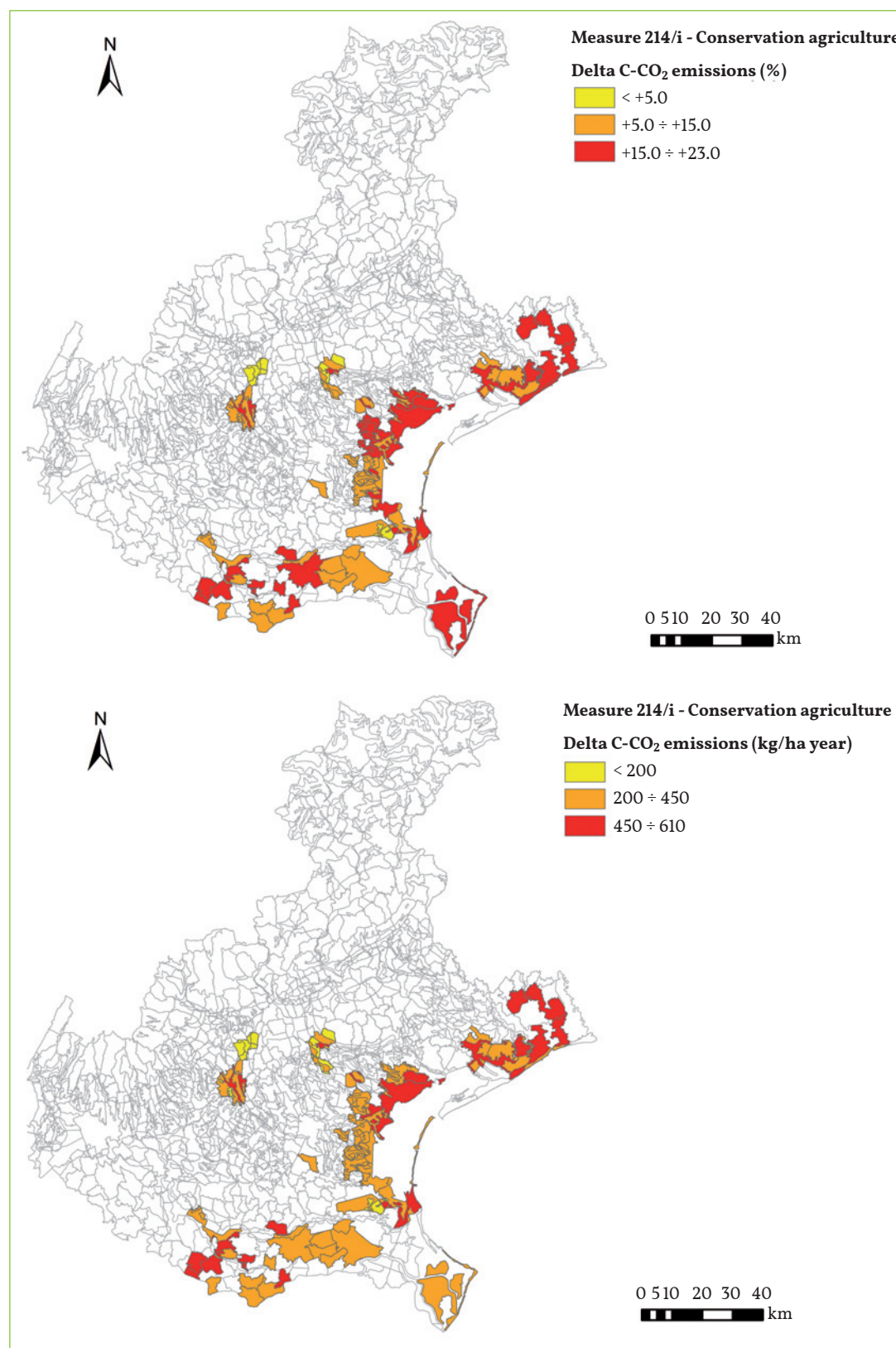
Table 4.2 - Long term simulated GHGs emissions at Sasse Rami (2018-2122). CONS = Conservation agriculture, CONV = Conventional agriculture.

Conservation agriculture in Veneto as a result of the application of the RDP

Over the 2007-2013 period, the impact of the 214/i Measure Action I worsened CO₂ emissions compared to conventional systems, because of both greater quantity of crop residues, and the improved biological activity induced in the soil by cover crops (Fig. 4.2). Altogether, though, the overall balance (outputs-inputs) is negative, with increments of CO₂ in the soil in the form of SOC.

(See Sheet 3, p. 18).

Figure 4.2 - Difference of C-CO₂ emissions (kg/ha year - bottom; % - top) between cropping systems in which the Measure 214/i Action 1 was applied, and conventional systems.



There was instead a decrease in nitrous dioxide emissions, with reductions according to the climate-soil interaction, which were higher than 0.5 kg N-N₂O compared to conventional systems. This is due to the cover crops nitrogen uptake as well as to the permanent soil covering. (Fig. 4.3).

Lastly, the differences in methane emissions simulated by the model were minimal, with values always lower than 0.5 kg per hectare per year (Fig. 4.4).

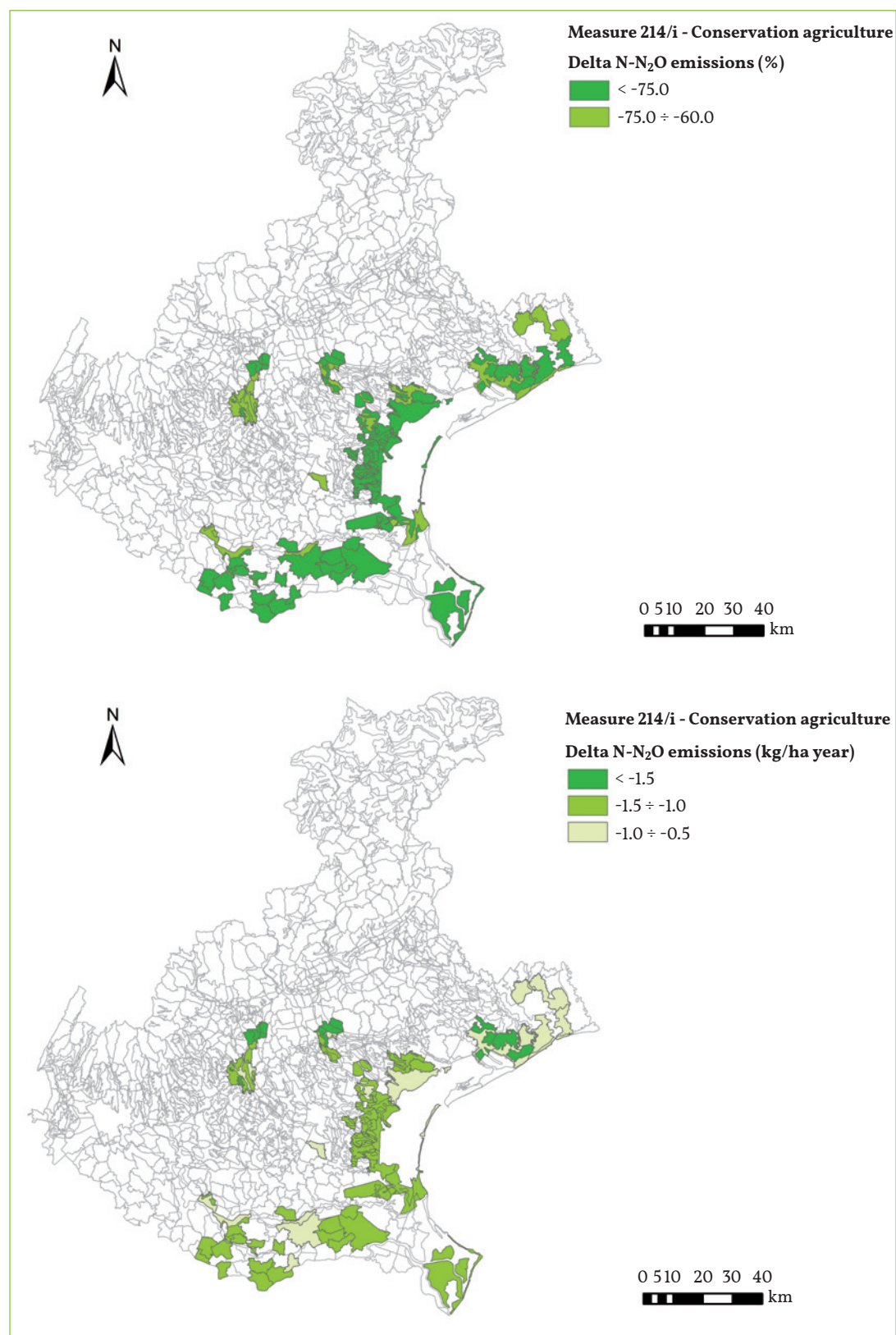
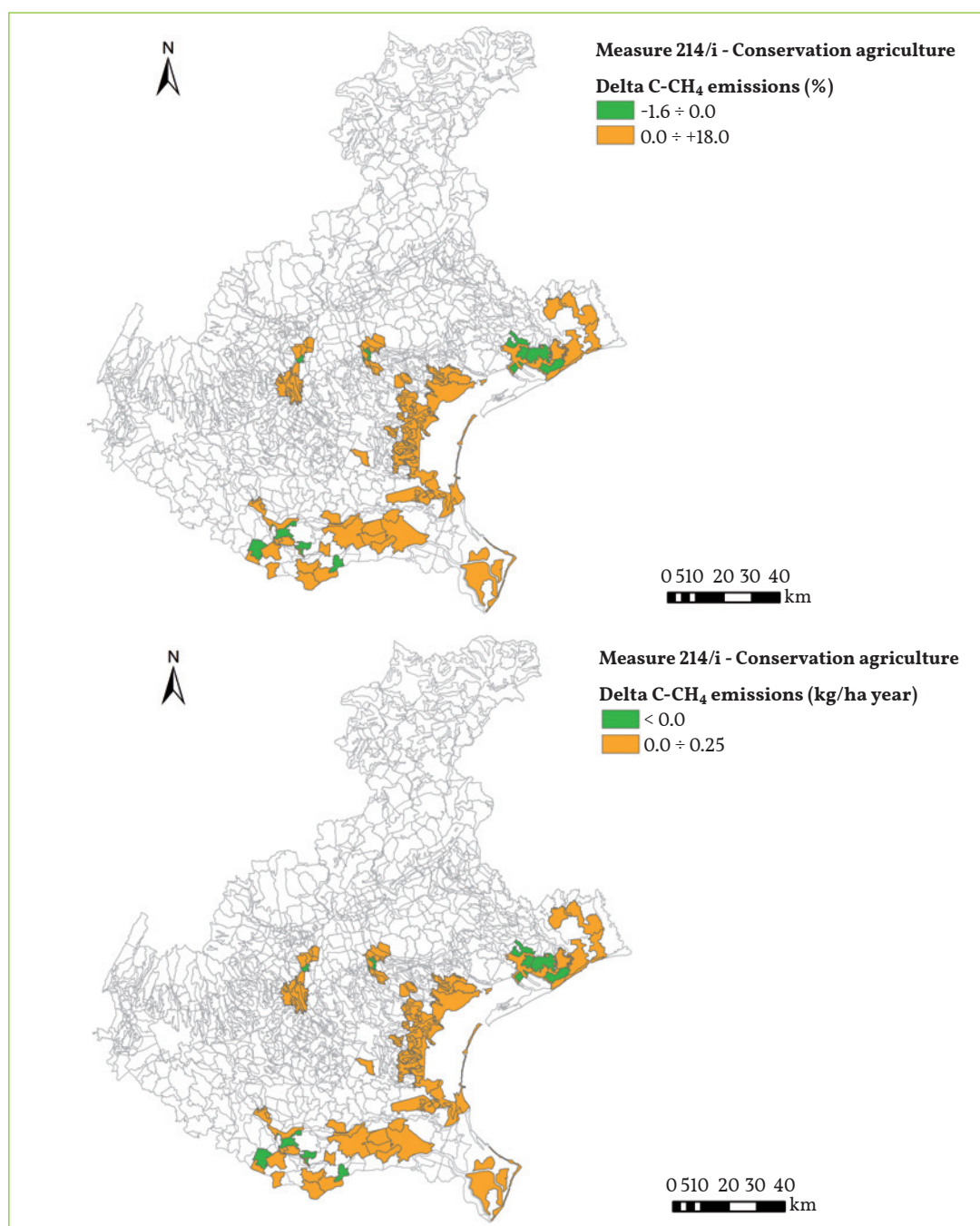


Figure 4.3 - Difference in N-N₂O emissions (kg/ha year - bottom; % - top) between cropping systems in which the Measure 214/i Action 1 was applied, and conventional systems.

Figure 4.4 - Difference of C-CH₄ (kg/ha year - bottom; % - top) between cropping systems in which the Measure 214/i Action 1 was applied, and conventional systems.



The overall balance of greenhouse gases in the field was found to be negative, confirming the mitigating actions of Conservation agriculture in the short term compared to conventional systems.

BIBLIOGRAPHY

- Camarotto, Dal Ferro, N., Piccoli, I., Polese, R., Furlan, L., Chiarini, F., Morari, F., 2018. Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain, Catena, 167, pp. 236-249.
- Dal Ferro, N., Cocco, E., Lazzaro, B., Berti, A., Morari, F., 2016. Assessing the role of agri-environmental measures to enhance the environment in the Veneto Region, Italy, with a model-based approach. Agriculture, Ecosystems and Environment, 232, pp. 312-325.
- Piccoli, I., Schjønnning, P., Lamandé, M., Furlan, L., Morari, F. 2017. Challenges of Conservation agriculture practices on silty soils. Effects on soil pore and gas transport characteristics in North-eastern Italy. Soil and Tillage Research, 172, pp. 12-21.

SHEET 5

WATER DYNAMICS IN SOIL: HYDRAULIC PROPERTIES AND WATER BALANCE

Hydraulic properties and dynamics of infiltration

The water retention curve and hydraulic conductivity represent the capacity of the soil to retain and conduct water. These properties are the basis of the biogeo-chemical cycles of soil and therefore influence the effects of Conservation agriculture on the environment.

In general, Conservation agriculture increases soil infiltration and hydraulic conductivity because it promotes the vertical development of macro-pores (e.g., biopores formed by earthworms).

Moreover, crop residues and the greater organic carbon content at the soil surface increase the stability of aggregates and consequently, also water conductivity. However, the results are not always consistent and in many cases, the formation of compact layers in Conservation agriculture is associated with lower infiltration and a greater surface runoff.

Conservation agriculture also increases the available water for crops, both because of the greater infiltration and the lower surface evaporation due to the mulching effect of residues. Moreover, water retention is facilitated by the higher organic matter content, but also in this case, results are not always consistent.

Experimental results from the Veneto Agricoltura pilot farms

Hydraulic Properties

In general, no differences were observed between conservation and conventional systems, with the exception of a greater variability observed in the latter, probably due to the effect of tillage on soil structure.

At the Diana Farm (Tab. 5.1), for example, the water content at saturation of the surface layers oscillated from 0.42-0.51 cm³/cm³ in the conventional system to 0.43-0.52 cm³/cm³ in the conservation system, with a mean value of 0.47 cm³/cm³. Field capacity and wilting point are 0.40 and 0.22 cm³/cm³ respectively, with more variable available water capacity in the conventional system (0.12-0.20 cm³/cm³) compared to the conservation system (0.17-0.21 cm³/cm³).

Table 5.1 - Diana Farm: values of volumetric water content (Theta) and hydraulic conductivity (K ins; cm/day) at different soil water potentials in the conventional system (CONV) and the conservation system (CONS).

| Diana Farm | Conventional | | | | | | Conservation | | | | | |
|------------|----------------------------------|---------|----------------------------------|---------|----------------------------------|---------|----------------------------------|---------|----------------------------------|---------|----------------------------------|---------|
| | CONV_1 | | CONV_2 | | CONV_3 | | CONS_1 | | CONS_2 | | CONS_3 | |
| Potential | Theta | K ins | Theta | K ins | Theta | K ins | Theta | K ins | Theta | K ins | Theta | K ins |
| cm | cm ³ /cm ³ | cm/d | cm ³ /cm ³ | cm/d | cm ³ /cm ³ | cm/d | cm ³ /cm ³ | cm/d | cm ³ /cm ³ | cm/d | cm ³ /cm ³ | cm/d |
| 0 | 0.46 | 0.40 | 0.51 | 55.00 | 0.42 | 4.5E-03 | 0.43 | 0.10 | 0.48 | 0.18 | 0.52 | 42.00 |
| 20 | 0.46 | 0.07 | 0.46 | 0.23 | 0.42 | 2.3E-03 | 0.43 | 0.02 | 0.48 | 0.03 | 0.50 | 1.12 |
| 40 | 0.45 | 0.05 | 0.44 | 0.08 | 0.42 | 1.9E-03 | 0.43 | 0.01 | 0.47 | 0.02 | 0.48 | 0.44 |
| 60 | 0.45 | 0.04 | 0.42 | 0.04 | 0.42 | 1.7E-03 | 0.42 | 0.01 | 0.47 | 0.02 | 0.47 | 0.22 |
| 100 | 0.44 | 0.02 | 0.40 | 0.02 | 0.42 | 1.4E-03 | 0.42 | 0.01 | 0.46 | 0.01 | 0.45 | 0.08 |
| 300 | 0.40 | 5.0E-03 | 0.36 | 2.7E-03 | 0.41 | 7.4E-04 | 0.39 | 1.6E-03 | 0.43 | 3.1E-03 | 0.40 | 7.2E-03 |
| 500 | 0.38 | 2.1E-03 | 0.34 | 1.1E-03 | 0.41 | 4.8E-04 | 0.37 | 6.7E-04 | 0.40 | 1.5E-03 | 0.37 | 2.1E-03 |
| 1000 | 0.34 | 5.4E-04 | 0.31 | 3.1E-04 | 0.39 | 2.2E-04 | 0.34 | 1.7E-04 | 0.36 | 5.0E-04 | 0.34 | 3.6E-04 |
| 2000 | 0.30 | 1.3E-04 | 0.29 | 9.1E-05 | 0.36 | 7.2E-05 | 0.30 | 3.7E-05 | 0.32 | 1.5E-04 | 0.30 | 6.1E-05 |
| 3000 | 0.28 | 5.2E-05 | 0.28 | 4.4E-05 | 0.34 | 3.3E-05 | 0.28 | 1.4E-05 | 0.29 | 7.7E-05 | 0.29 | 2.2E-05 |
| 5000 | 0.25 | 1.7E-05 | 0.26 | 1.8E-05 | 0.31 | 1.1E-05 | 0.25 | 4.3E-06 | 0.26 | 3.1E-05 | 0.27 | 5.8E-06 |
| 10000 | 0.22 | 3.6E-06 | 0.24 | 5.1E-06 | 0.26 | 2.0E-06 | 0.22 | 8.0E-07 | 0.23 | 9.1E-06 | 0.24 | 9.6E-07 |
| 15000 | 0.20 | 1.5E-06 | 0.23 | 2.4E-06 | 0.24 | 7.3E-07 | 0.20 | 3.0E-07 | 0.21 | 4.4E-06 | 0.23 | 3.4E-07 |

At ValleVecchia (Tab. 5.2) the differences between the systems were more remarkable due to the probable soil compaction in conservation systems: 0.40 cm³/cm³ in the conservation and 0.47 cm³/cm³ in conventional at saturation. On the contrary, the field capacity is higher in Conservation ag-

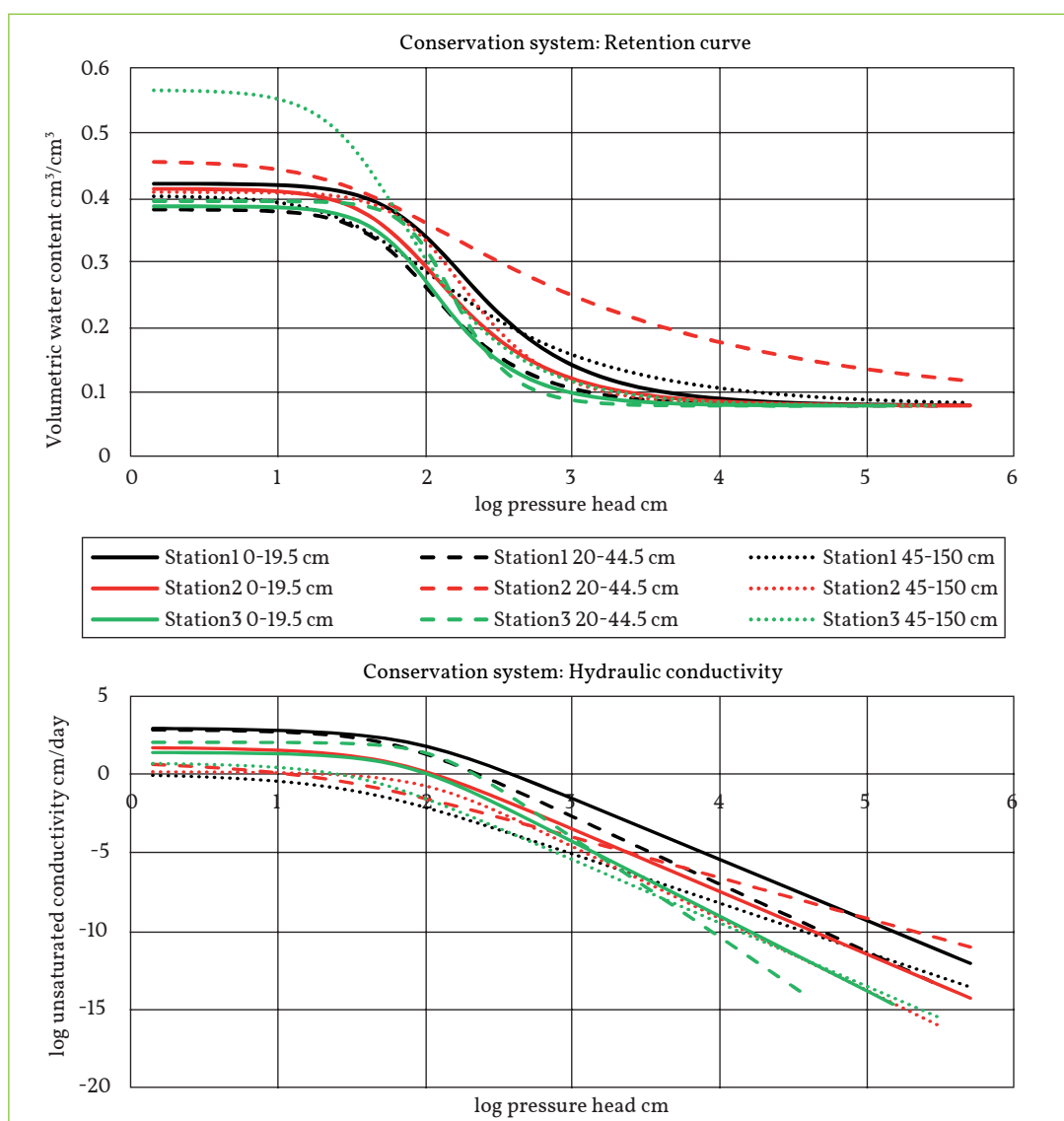
riculture (mean value $0.37 \text{ cm}^3/\text{cm}^3$) than in Conventional agriculture (mean value $0.34 \text{ cm}^3/\text{cm}^3$), as well as the water available for crops ($0.20\text{-}0.21 \text{ cm}^3/\text{cm}^3$ against $0.17\text{-}0.18 \text{ cm}^3/\text{cm}^3$).

Water retention also varies according to depth (Figures 5.1 and 5.2), even if not associated with treatment effect.

Table 5.2 - ValleVecchia Farm: values of volumetric water content (Theta) and hydraulic conductivity (K ins; cm/day) at different soil water potentials in the conventional system (CONV) and conservation system (CONS).

| ValleVecchia Farm | Conventional | | | | | | Conservation | | | | | |
|-------------------|---------------------------------|------------|---------------------------------|------------|---------------------------------|------------|---------------------------------|------------|---------------------------------|------------|---------------------------------|------------|
| | CONV_1 | | CONV_2 | | CONV_3 | | CONS_1 | | CONS_2 | | CONS_3 | |
| Potential cm | Theta cm^3/cm^3 | K ins cm/d | Theta cm^3/cm^3 | K ins cm/d | Theta cm^3/cm^3 | K ins cm/d | Theta cm^3/cm^3 | K ins cm/d | Theta cm^3/cm^3 | K ins cm/d | Theta cm^3/cm^3 | K ins cm/d |
| 0 | 0.44 | 6.50 | 0.47 | 3.50 | 0.40 | 1.05 | 0.40 | 0.04 | 0.40 | 0.11 | 0.40 | 0.06 |
| 20 | 0.45 | 0.52 | 0.45 | 0.27 | 0.40 | 0.21 | 0.40 | 0.01 | 0.40 | 0.04 | 0.40 | 0.03 |
| 40 | 0.44 | 0.27 | 0.44 | 0.14 | 0.39 | 0.13 | 0.40 | 0.01 | 0.40 | 0.03 | 0.40 | 0.02 |
| 60 | 0.43 | 0.17 | 0.43 | 0.09 | 0.39 | 0.09 | 0.40 | 0.01 | 0.40 | 0.02 | 0.40 | 0.02 |
| 100 | 0.41 | 8.3E-02 | 0.41 | 0.05 | 0.38 | 0.05 | 0.39 | 0.01 | 0.39 | 0.02 | 0.39 | 0.01 |
| 300 | 0.35 | 1.4E-02 | 0.35 | 0.01 | 0.34 | 6.3E-03 | 0.37 | 3.0E-03 | 0.37 | 0.01 | 0.38 | 5.6E-03 |
| 500 | 0.32 | 5.8E-03 | 0.32 | 4.9E-03 | 0.31 | 1.8E-03 | 0.35 | 1.9E-03 | 0.35 | 4.4E-03 | 0.36 | 3.2E-03 |
| 1000 | 0.29 | 1.6E-03 | 0.29 | 1.7E-03 | 0.27 | 2.7E-04 | 0.32 | 9.0E-04 | 0.31 | 1.9E-03 | 0.33 | 1.3E-03 |
| 2000 | 0.25 | 4.5E-04 | 0.25 | 5.6E-04 | 0.24 | 3.3E-05 | 0.28 | 4.1E-04 | 0.26 | 7.7E-04 | 0.28 | 4.8E-04 |
| 3000 | 0.23 | 2.1E-04 | 0.23 | 2.9E-04 | 0.22 | 9.4E-06 | 0.26 | 2.6E-04 | 0.24 | 4.4E-04 | 0.26 | 2.6E-04 |
| 5000 | 0.21 | 7.9E-05 | 0.21 | 1.3E-04 | 0.19 | 1.9E-06 | 0.23 | 1.4E-04 | 0.21 | 2.2E-04 | 0.23 | 1.1E-04 |
| 10000 | 0.19 | 2.1E-05 | 0.19 | 4.2E-05 | 0.16 | 2.1E-07 | 0.19 | 6.2E-05 | 0.17 | 8.2E-05 | 0.19 | 3.5E-05 |
| 15000 | 0.17 | 9.9E-06 | 0.17 | 2.2E-05 | 0.15 | 5.6E-08 | 0.17 | 3.9E-05 | 0.16 | 4.6E-05 | 0.17 | 1.8E-05 |

Figure 5.1 - Water retention curve and hydraulic conductivity measured at three depths in the conservation system at Sasse Rami.



Hydraulic conductivity is highly variable in both saturated and unsaturated soil; this variability does not make it possible to give a clear picture of the effects induced on hydraulic properties in Conservation agriculture. At Diana and Sasse Rami, the saturated hydraulic conductivity is higher in Conservation agriculture compared to Conventional agriculture, probably due to the presence of macropores in top layers, whereas at ValleVecchia the situation is the opposite with lower values in Conservation agriculture (0.13 cm/d compared to 2.3 cm/d). In saturated soil condition, hydraulic conductivity decreases by several orders of magnitude, with the progressive soil drying, but no marked difference between treatments was found, results being affected by high spatial variability (Fig. 5.1 and 5.2). In general, values decrease as depth increases.

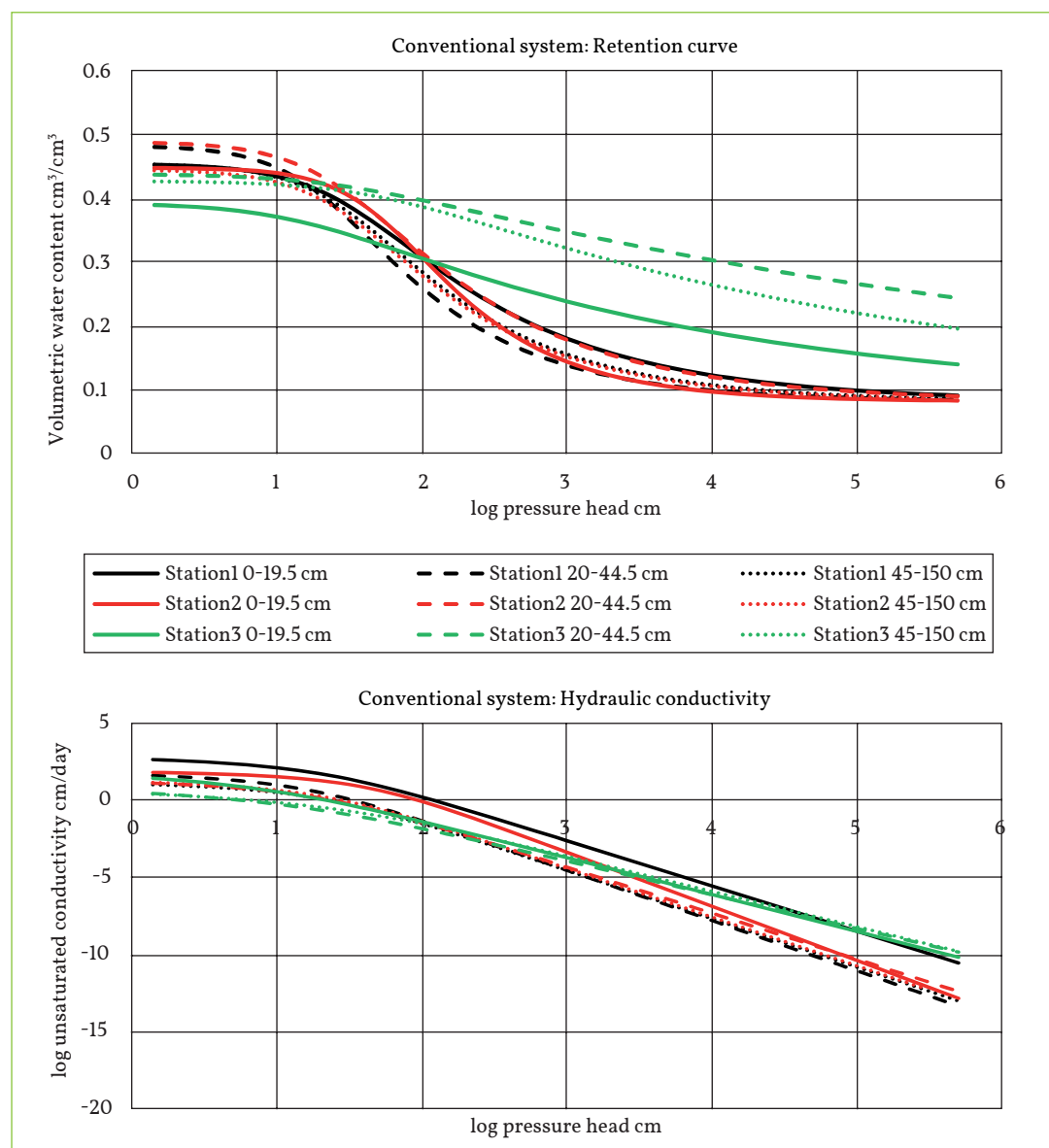


Figure 5.2 - Water retention curve and hydraulic conductivity measured at three depths in the conventional system at Sasse Rami.

Dynamics of infiltration

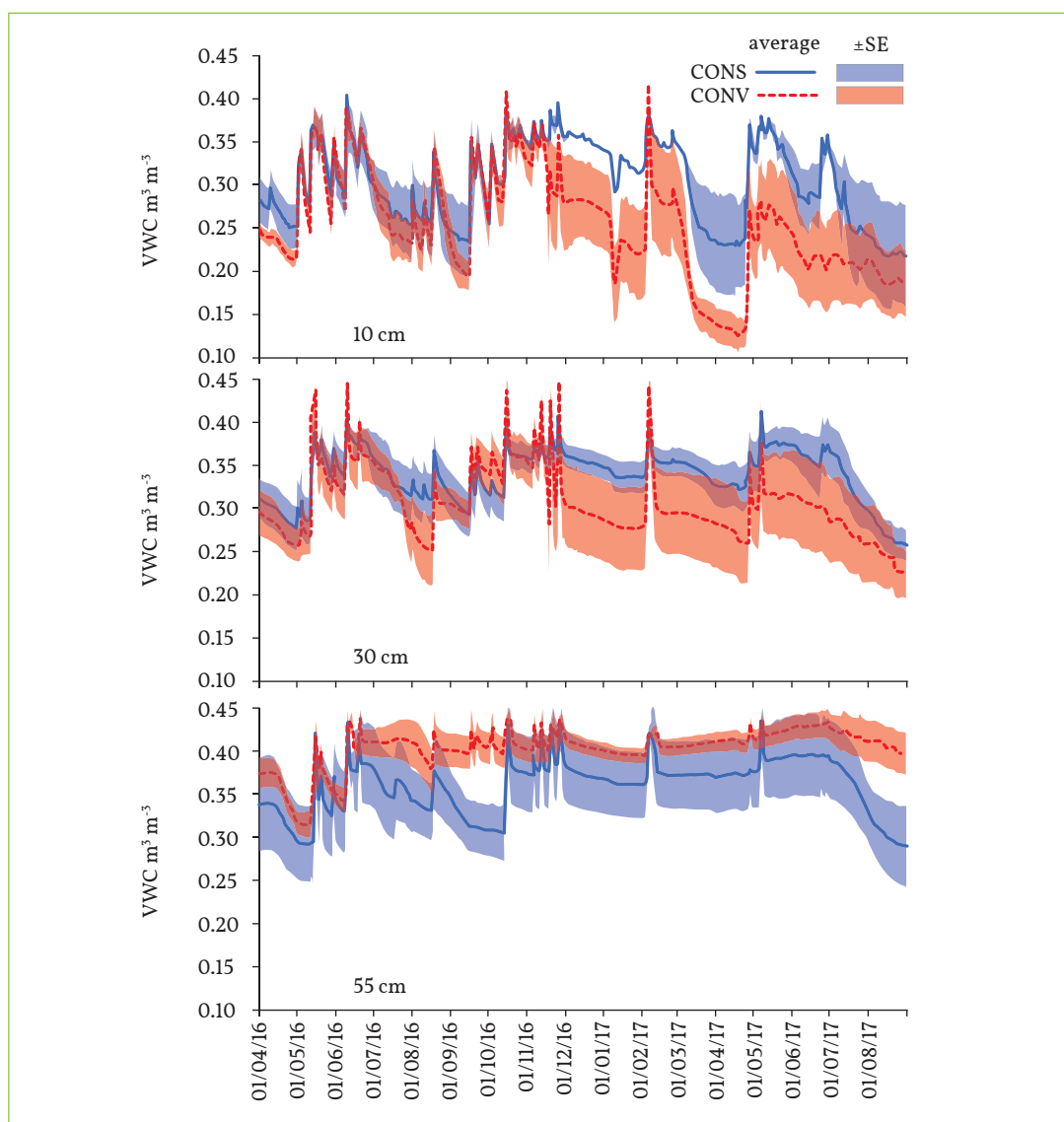
The effect of the interaction between hydraulic properties and soil cover management on the water balance has been simulated at the Sasse Rami farm with the Hydrus hydraulic model. The wheat crop cultivation from October 2017 to April 2018 was considered.

Despite the fact that infiltration is higher in the conservation system (49 mm vs 15.5 mm), percolation below the root zone is lower, equal to 19.5 mm, due to capillary rise (19 mm) also supported by the evapotranspiration of the cover crop (12.5 mm). The dynamics of water in the conservation system was probably affected more by the presence of the cover crop

(see sheet 7) than by hydraulic properties, especially at an advanced growth stage. The effect of macro- porosity does not seem that evident, especially considering such a limited time span; on the contrary, in the conventional system, preferential flow dynamics could be seen in freshly tilled soil.

Field monitoring of the water content (Fig. 5.3) finally allows the mulching effect of crop residues during the spring-summer season to be observed, with higher moisture content in the surface layers of conservation system.

Figura 5.3 - Water content along the soil profile at Sasse Rami in the conservation system (CONS) and conventional system (CONV).



BIBLIOGRAPHY

Camarotto, Dal Ferro, N., Piccoli, I., Polese, R., Furlan, L., Chiarini, F., Morari, F., 2018 . Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain, Catena, 167, pp. 236-249.

SHEET 6

EFFECTS ON SOIL PHYSICAL PROPERTIES: COMPACTION AND POROSITY

The effects of Conservation agriculture on soil structure depend on the time period considered:

- in the short term (weeks/months), compaction and fragmentation of the aggregates are generally observed;
- in the medium term (months/years), the high activity of macroinvertebrates (e.g., earthworms) may promote a vertically-oriented macropore network;
- in the long term (years/decades), the equilibrium achieved in the soil organic carbon (SOC) cycle allows the stabilization of soil structure.

Conservation agriculture also affects the quantity and distribution of pores, reducing the total porosity and shifting their distribution toward the meso- and micro-porous components, at the expense of the macro-porous component. The latter was formed by a small number of macropores, whose dimensions and connectivity were both higher than in conventional systems.

Experimental results from the Veneto farms

Bulk density, penetration resistance and electrical resistivity tomography

In general, after three years, no worsening of soil structure was found in the conservation systems. Bulk density has increased, even if generally not in a remarkable way: 1.45 g/cm^3 in Conservation agriculture compared to 1.43 g/cm^3 in Conventional agriculture. Only at the Miana Serraglia farm, particularly high values were recorded for Conservation agriculture in the 10-40 cm layer, i.e., 1.56 g/cm^3 compared to 1.39 g/cm^3 in Conventional agriculture. Instead, in the conventional system, bulk density peaked at 1.7 g/cm^3 below 40 cm-depth, which can be linked to the presence of a plough pan.

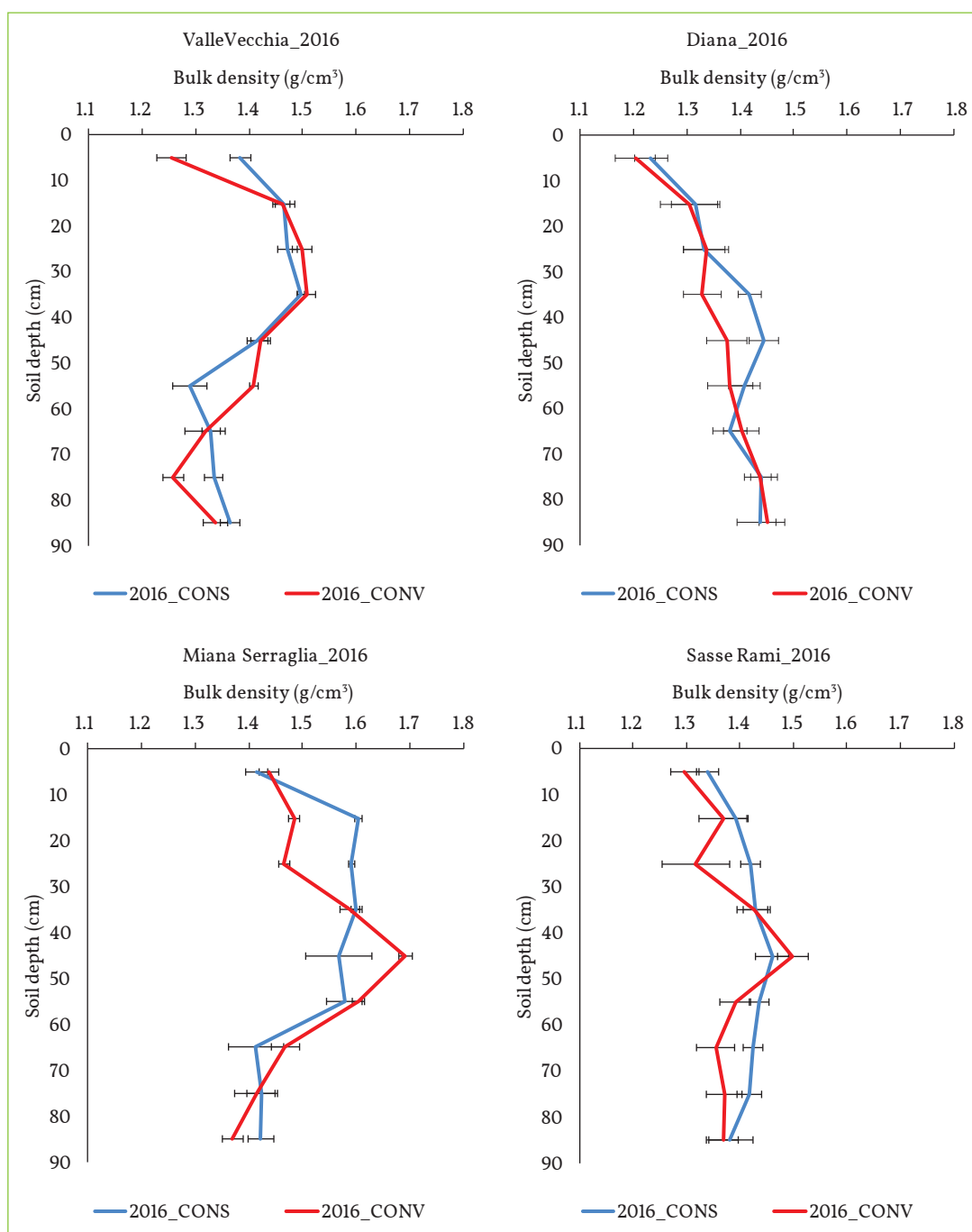
In the other farms, Conservation agriculture has not significantly increased bulk density, with 1.46 g/cm^3 for Conservation agriculture against 1.47 g/cm^3 for Conventional agriculture at Val-Vecchia, 1.41 g/cm^3 against 1.42 g/cm^3 at Diana and 1.44 g/cm^3 against 1.43 g/cm^3 at Sasse Rami respectively.

The distribution of bulk density within soil depth was also affected by the type of soil and its texture (Fig. 6.1), with higher values in the sandy layers compared to clayey ones.

The interaction between bulk density and water content has affected the soil penetration resistance, which was higher in Conservation agriculture during the summer seasons with low rainfall (e.g., in 2015) and in subsoil (10-20 cm). The increase in water content, especially in rainy seasons (e.g., spring 2016), corresponded to a decrease in penetration force, offsetting the differences between systems (Fig. 6.2).

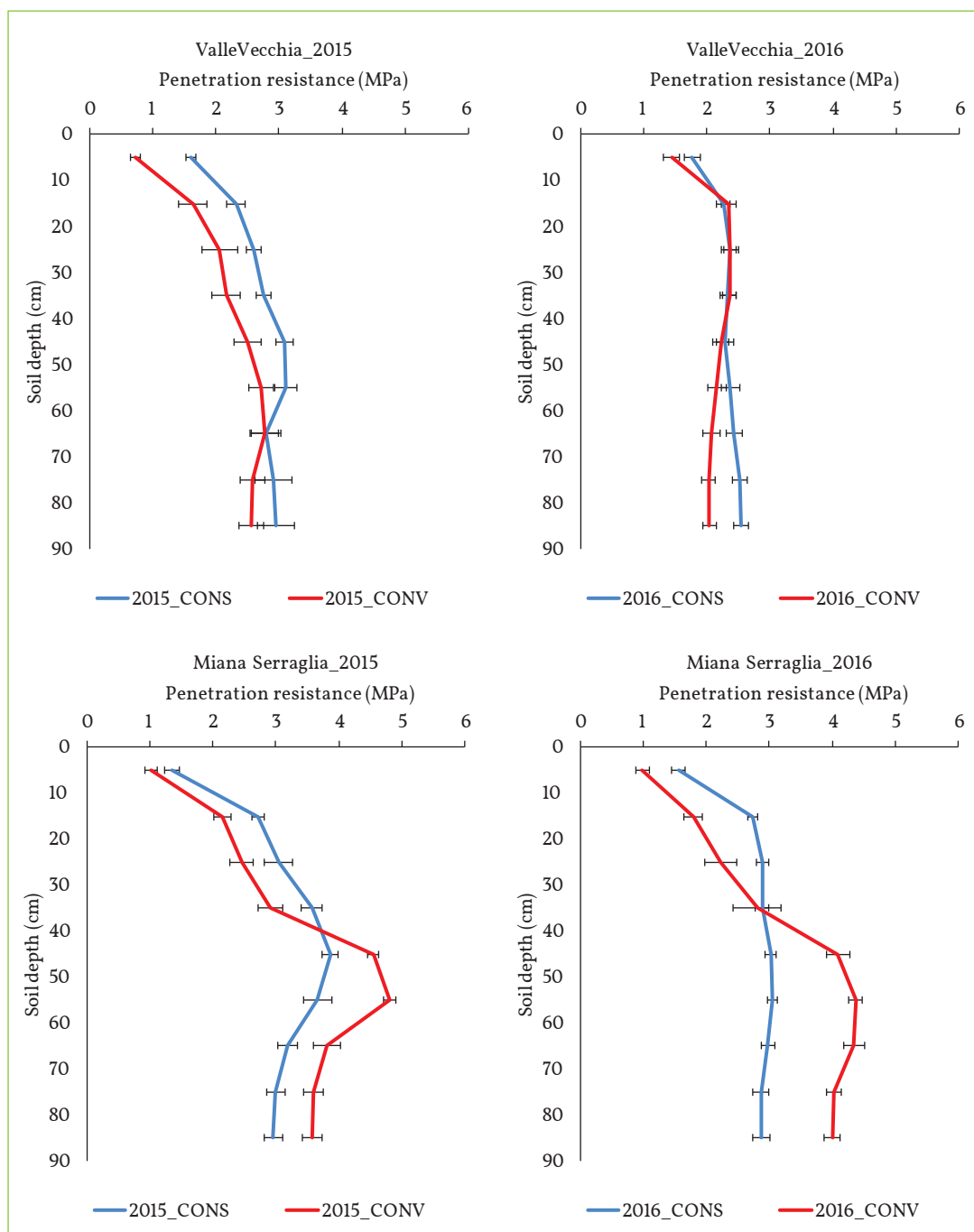
At the Miana Serraglia farm, characterized by coarser soil, analysis of penetration resistance mirrors that of bulk density, particularly in correspondence with the plough pan of the conventional system and the surface layer of the conservation system.

Figure 6.1 - Bulk density profiles 6 years after the RDP measures application, at the four pilot farms ValleVecchia, Diana, Miana Serraglia and Sasse Rami.



.....

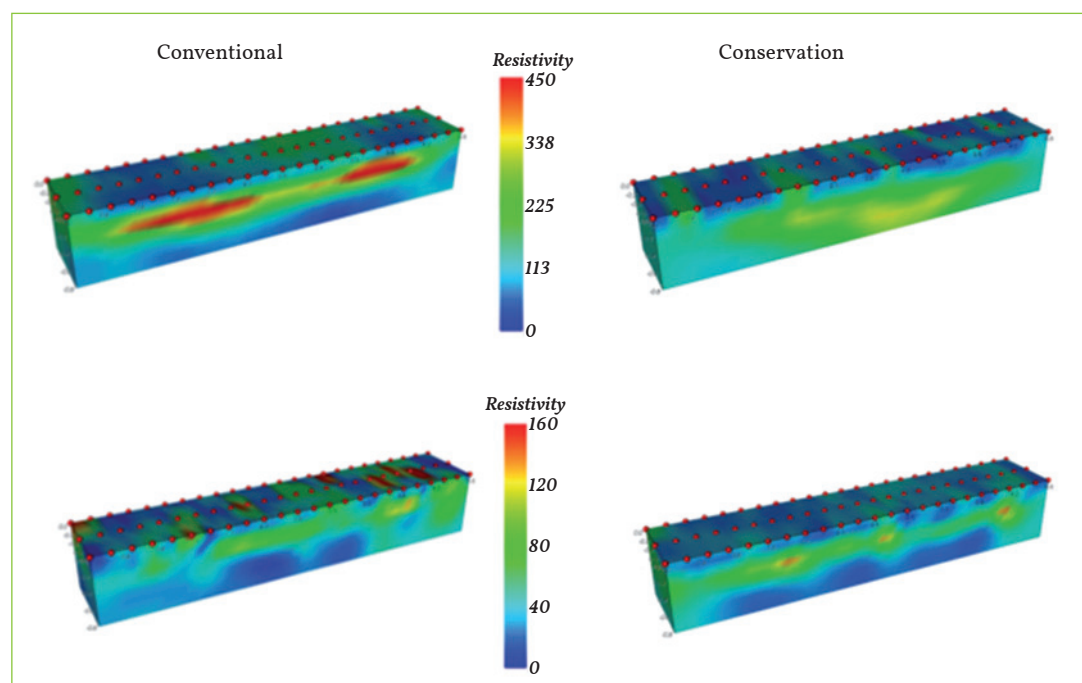
Figure 6.2 - Penetration resistance profiles at ValleVecchia (top) and Miana Serraglia (bottom), in the summer of 2015 (low water content, left) and in spring 2016 (high water content, right).



The special conditions of soils at Miana Serraglia conventional system were also shown by electrical resistivity tomography (ETR) where the plough pan was highlighted as a resistance peak, with variable values around 138 Ωm in 2014 (Fig. 6.3), 252 Ωm in 2015 and 200 Ωm in 2016.

In contrast, in the other farms no differences were observed between the two systems, as already shown by other physical properties (Fig. 6.3), with the exception of the influence of mulching on soil cracking.

Figure 6.3 - Electrical resistivity tomography in 2014 at Miana Serraglia farm (top) and Diana farm (bottom).



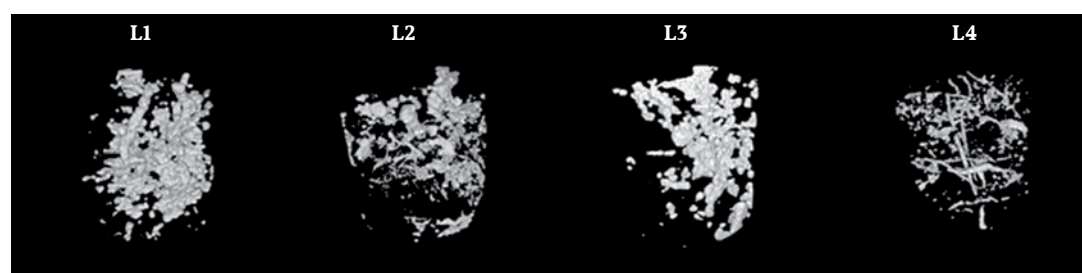
Pore architecture

Measuring total porosity using different analytical techniques (mercury porosimeter, X-ray, tomography, and core method) confirms bulk density results. The porosity between the two systems is similar, with an average of 32.8% in the conventional and 33.1% in the conservation one (core method), with a progressive decrease with soil depth.

In contrast, Conservation agriculture has changed pore distribution, increasing ultra-micro-pores (pores that promote the physical protection of organic matter) at the expense of meso-pores. The latter increase water retention within the range that can be used by crops.

Irrespective of the system used, the high silt content of Veneto plain soil affected soil porosity, with 90% of pores having dimensions less than 100 μm (micropores). This characteristic has a negative influence on water drainage and gas exchanges, thus facilitating soil water logging and anoxia.

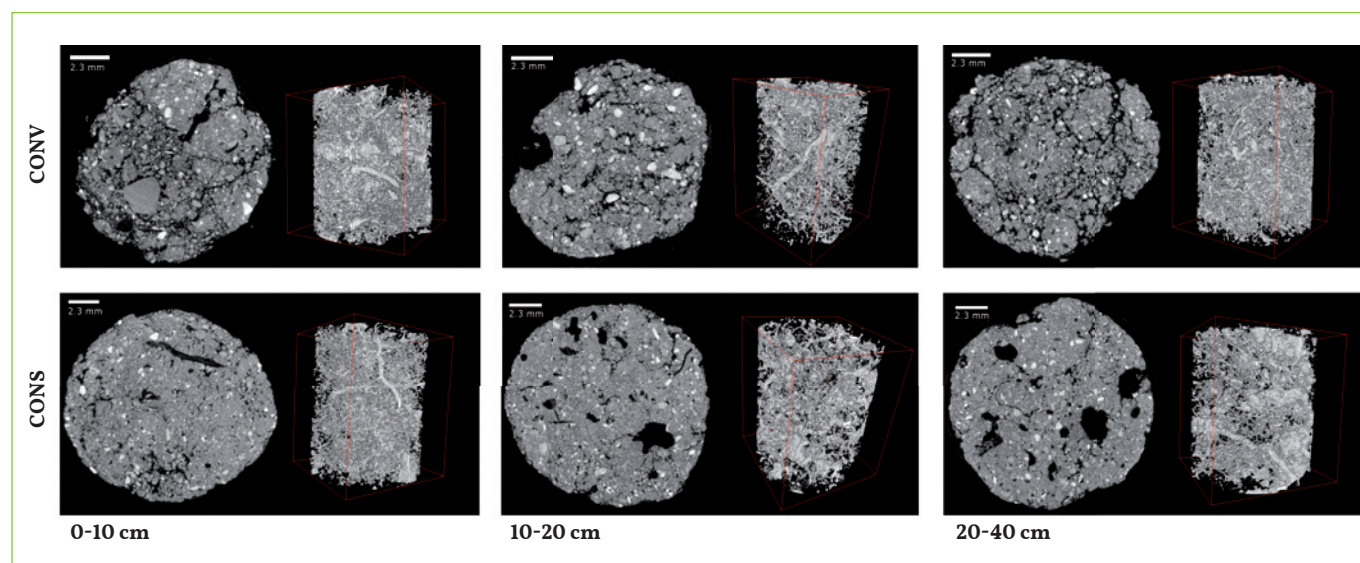
Figure 6.4 - Reduction of total porosity with depth. L1: 3-5.5 cm; L2: 12-14.5 cm; L3: 20-22.5 cm; L4: 45-47.5 cm.



Conservation agriculture has also influenced the spatial orientation of pores by increasing the vertical orientation, likely due to the activity of soil macrofauna. In the same way, this macrofauna has promoted the formation of circular pores both in ValleVecchia and in Miana Serraglia (year 2016). In contrast, conventional systems have been associated with higher cracking and fragmentation of the soil structure (Fig. 6.5).

In conclusion, it is evident that Conservation agriculture has modest effects on the soil physical properties and therefore, the reaction of soil to the introduction of conservation practices is slow. Conservation agriculture has positively influenced ultra-microporosity, which suggests that a virtuous cycle was initiated between organic matter and soil structure.

Figure 6.5 - 2D sections and 3D reconstructions of porosity measured by X-ray tomography at three depths at the MianaSerraglia farm in 2016. Above: CONV = Conventional, Below: CONS = Conservation.



BIBLIOGRAPHY

- Dal Ferro, N., Sartori, L., Simonetti, G., Berti, A. & Morari, F. 2014. Soil macro- and microstructure as affected by different tillage systems and their effects on maize root growth. *Soil and Tillage Research*, 140, 55–65.
- Piccoli, I., Camarotto, C., Lazzaro, B., Furlan, L. & Morari, F. 2017. Conservation agriculture had a poor impact on the soil porosity of veneto low-lying plain silty soils after a 5-year transition period. *Land Degradation and Development*, 28 (7), 2039-2050.

SHEET 7

DISTRIBUTION AND PROPERTIES OF ROOTS IN THE SOIL

In addition to performing a number of important agronomic functions, root systems are a source of Soil Organic Carbon (SOC) in agricultural systems. This is particularly important in conservation systems where the soil layers are not inverted, so the deep carbon input is of endogenous origin: soil micro and macrofauna and roots, due to the absence of tillage operations and soil layer inversion.

The effect of Conservation agriculture on root apparatus depends mainly on the degree of soil compaction, its water content and temperature. With an increase in soil compaction and penetration resistance, the root systems are usually stratified, concentrating the major part of biomass in the topsoil. The effects on diameter, however, are less consistent: according to some authors, it increases, while according to others, it decreases in order to reduce the resistance of the root apex during growth. The higher root stratification can also be boosted by the water content at the soil surface and the sub-optimal soil temperature in conservation systems. Usually, penetration resistance (see sheet 6) is used as an indicator of potential root growth, with optimal values below 1.5 MegaPascals (MPa) and being limiting above 2 MPa. Recent studies have suggested that the negative effect of conservation systems can be partially mitigated by the presence of large biological pores, which act as preferential channels for root growth. For this reason, the maximum upper limit for root growth can be raised from 2 MPa to 4.6-5.1 MPa.

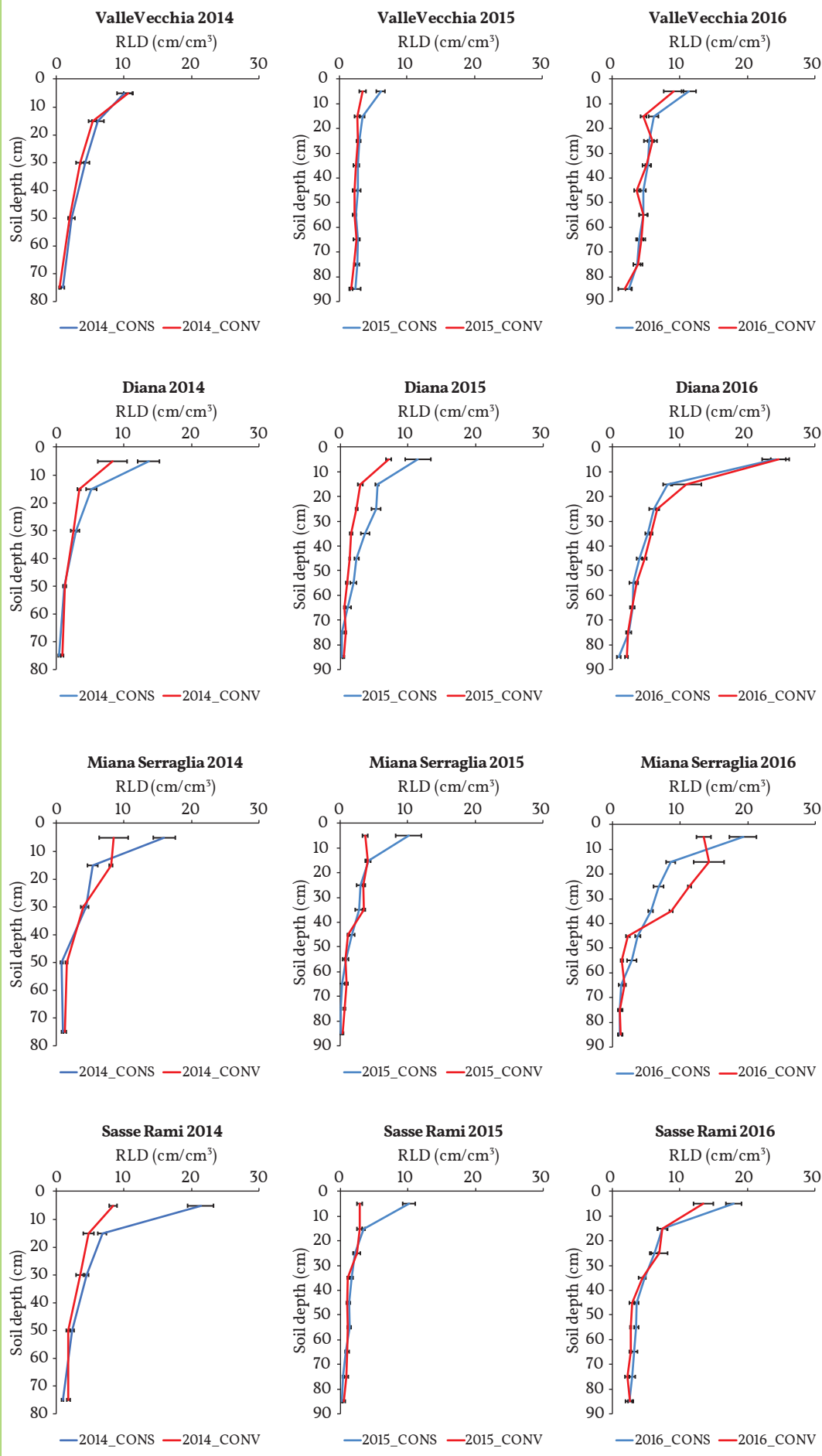
Experimental results from the Veneto farms

The application of Conservation agriculture on the silty soils of the Veneto region promoted the growth of root systems in the top 10 cm of soil, in particular for maize and soybean, with root density increasing by up to 100% in certain cases (Fig. 7.1). However, wheat seems to have suffered less from the effects of no-tillage, with negligible differences, or even improvements, as in the case of Miana Serraglia farm (Fig. 7.1).

In the deeper soil layers, the differences between the two cultivation systems were reduced, with the exception of wheat at Miana Serraglia, which shows higher root densities in the conservation system 0-40 cm-depth.

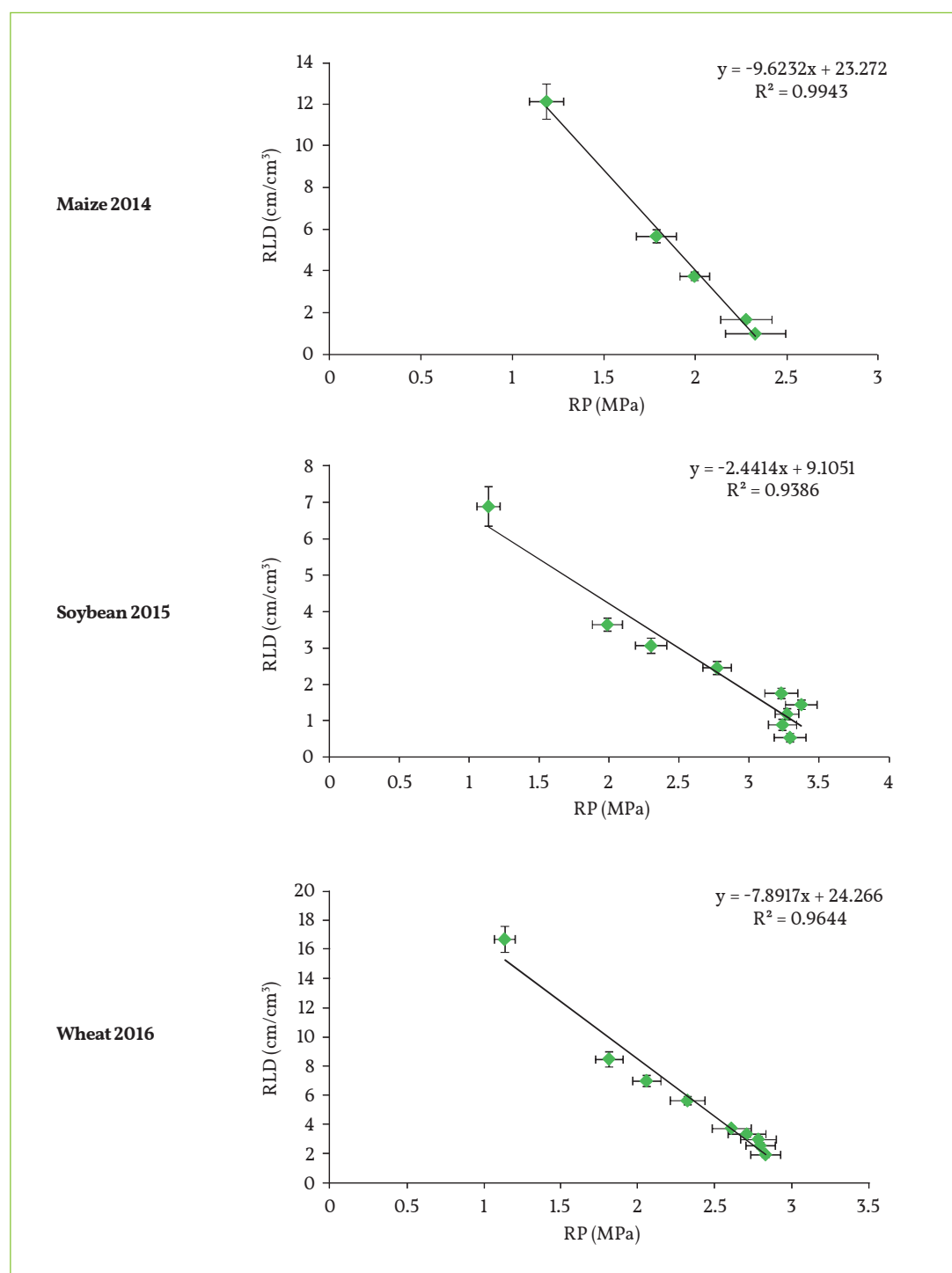
The greater root growth in topsoil can be attributed to different factors, such as sub-surface compaction, higher water content in the surface layers, soil temperature, the greater availability of nutrients due to the presence of crop residues at soil surface. Instead, it seems that the presence of compacted soil layers (>4 MPa), such as at Miana Serraglia, had no negative effect on development of the root system, confirming the hypothesis that roots might bypass compacted soil layers by using previously-existing paths (e.g. macropores).

Figure 7.1 - Distribution of the Root Length Density (RLD) for maize (2014), soybean (2015), and wheat (2016) at the ValleVecchia, Diana, Miana Serraglia and Sasse Rami farms.



Regardless of the type of treatment, soil resistance had a negative influence on the root density of the crops considered. Indeed, high resistances are associated with low root density, with minimum development of the root systems above 2.4, 3.4, and 2.8 MPa for maize, soybean, and wheat respectively (Fig. 7.2).

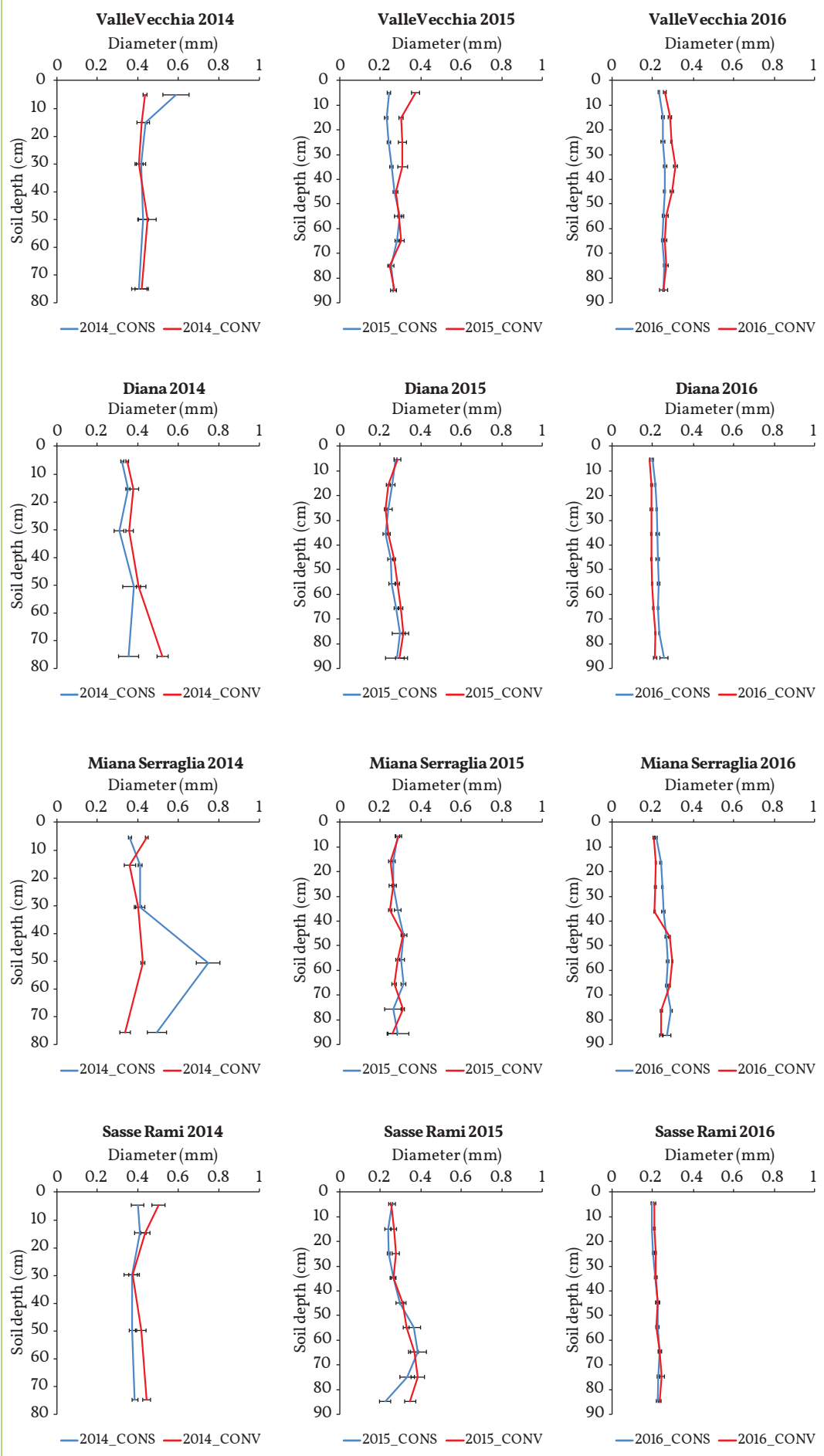
Figure 7.2 - Correlation between penetration resistance (RP) and Root Length Density (RLD) average per layer. The graphs show, on the top, maize cultivated in 2014, in the middle, soybean in 2015 and, on the bottom, wheat in 2016.



The average root diameter was affected by the type of crop, ranking as follows maize>soybean>wheat, while similar trends were shown between treatments, (Fig. 7.3). The only contrasting effect was seen at Miana Serraglia, where maize cultivated by Conservation agriculture displayed higher diameters below 40 cm-depth, while wheat cultivated according to conventional system showed a slight enlargement at the plough pan sole.

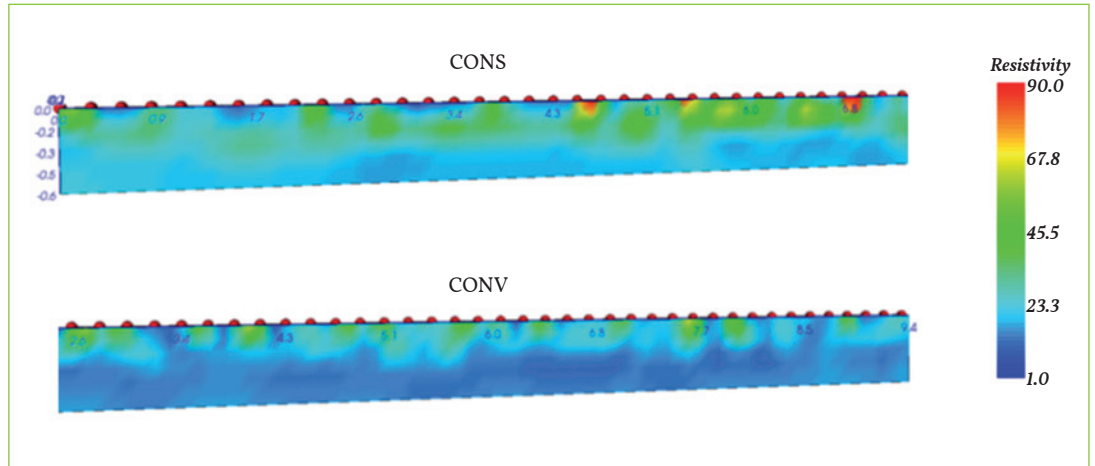
.....

Figure 7.3 - Distribution of average root diameter for maize (2014), soybean (2015), and wheat (2016) at the ValleVecchia, Diana, Miana Serraglia and Sasse Rami farms.



The structure and depth of the root systems also had significant effects on the soil water dynamics. The presence of cover crops in the Conservation agriculture led to an increase in evapotranspiration and consequently a reduction in water content in the soil root zone. This was also evidenced by the ERT performed at Sasse Rami farm, where conservation management was associated with higher resistivity values in the top layer (Fig. 7.4).

Figure 7.4 - Electrical Resistivity Tomography (ERT) in April 2018, with cover crop (top) and bare soil (bottom).



BIBLIOGRAPHY

- Dal Ferro, N., Sartori, L., Simonetti, G., Berti, A., Morari, F., 2014. Soil macro- and microstructure as affected by different tillage systems and their effects on maize root growth. *Soil & Tillage Research*. 140, pp. 55–65.
- Piccoli I., Dal Ferro N., Lazzaro B., Furlan L., Macolino S., Berti A., Morari F. Multi-electrode 3D resistivity survey on soil structure in Conservation agriculture. 2015. 7th International Congress of the European Society for Soil Conservation. Moscow (RUS), 18-22 May 2015.

SHEET 8

IMPACT ON WATER QUALITY

Conservation agriculture significantly influences the biochemical cycles of nitrogen and phosphorus, with considerable effects on the pollution of surface water and groundwater. Moreover, it has a direct effect on the transport mechanisms of the two phytonutrients, by modifying the water balance and, therefore, the percolation (vertical flow) and surface and sub-surface runoff.

Nitrogen

There is conflicting information on the effects of Conservation agriculture on nitrogen leaching. This variability depends on the soil type, climate, the use of cover crops during winter, etc.

According to some authors, the process is increased by preferential outflow through the macropores; according to others, however, the high efficiency of nitrogen use and the low concentration of mineral N in the soil reduces leaching in no-tillage systems.

However, the higher efficiency of nitrogen use in Conservation agriculture was not observed in a cold climate and sandy soil, because on the contrary conventional tillage enhanced root growth and consequently nitrogen absorption.

Phosphorous

Conservation agriculture has an undeniable effect on the mitigation of P loss in surface water, insofar as, by reducing the amount of erosion, it also reduces the transport of P associated with sediments. Reductions of over 30% have been observed by various authors, and in different contexts, as compared to losses in conventional systems. However, the surface layering of phosphorus in solution, produced by the mineralization of residues and the surface distribution of phosphate fertilizers, promotes the transport of soluble phosphorus, with increases up to 350%. Generally, however, the balance is in favour of conservation systems, because the transport associated with sediments is the principal pathway for removal of phosphorus from cultivation systems.

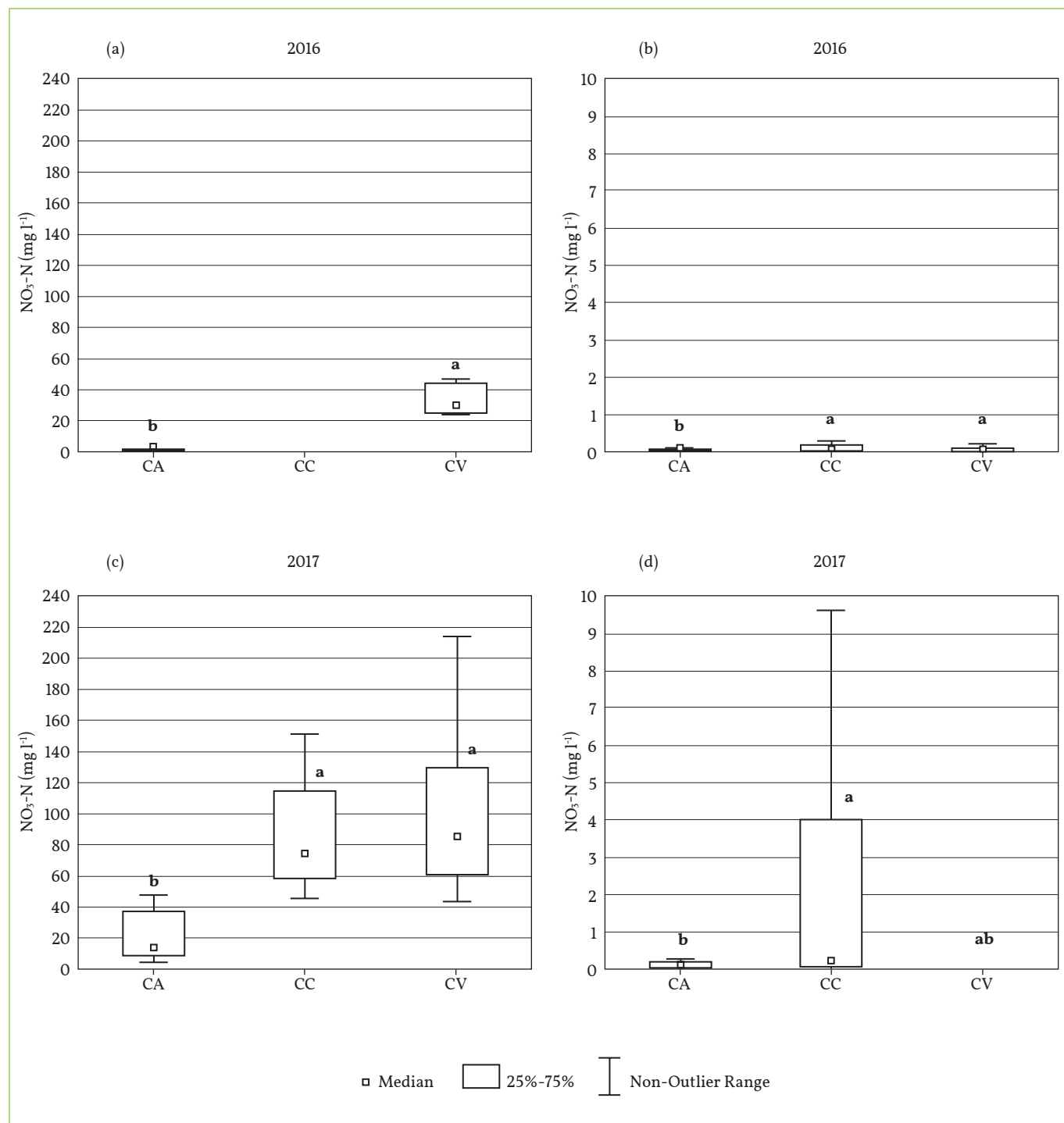
Experimental results from the Veneto Agricoltura pilot Farms

The evidence gathered at Sasse Rami from 2016 to 2017 showed that Conservation agriculture had a positive impact on the quality of percolation and groundwater (Fig. 8.1). In 2016, the median concentration of nitrate nitrogen was lower than 5 mg per litre in the percolating water in conservation plots, whereas it far exceeded 20 mg per litre in conventional systems. In 2017, there were also consistent differences observed between the cultivation systems: less than 20 mg per litre in Conservation agriculture and more than 80 mg per litre in conventional systems.



Such differences were also maintained in the average annual leaching values, with 3.5 kg per hectare in the conservation system and 58 kg per hectare in the conventional system. Overall, the reduced leaching also positively influenced the quality of the groundwater, even though the differences were smaller (Fig 8.1, right).

Figure 8.1 - Concentration of nitrate nitrogen (mg/l) in percolating water (a-c) and groundwater (b-d) in 2016-2017, in Conservation agriculture (CA), Conventional agriculture with cover crop (CC), and Conventional agriculture (CV).



Conservation agriculture in Veneto after the application of RDP

Conservation agriculture is one of the crop systems implemented from 2007 to 2013 in Veneto that potentially achieved the greatest Nitrogen Use Efficiency ($NUE = N_{\text{removed}}/N_{\text{input}}$), with median values simulated around 0.6, but with peaks >0.7 (Fig. 8.2).

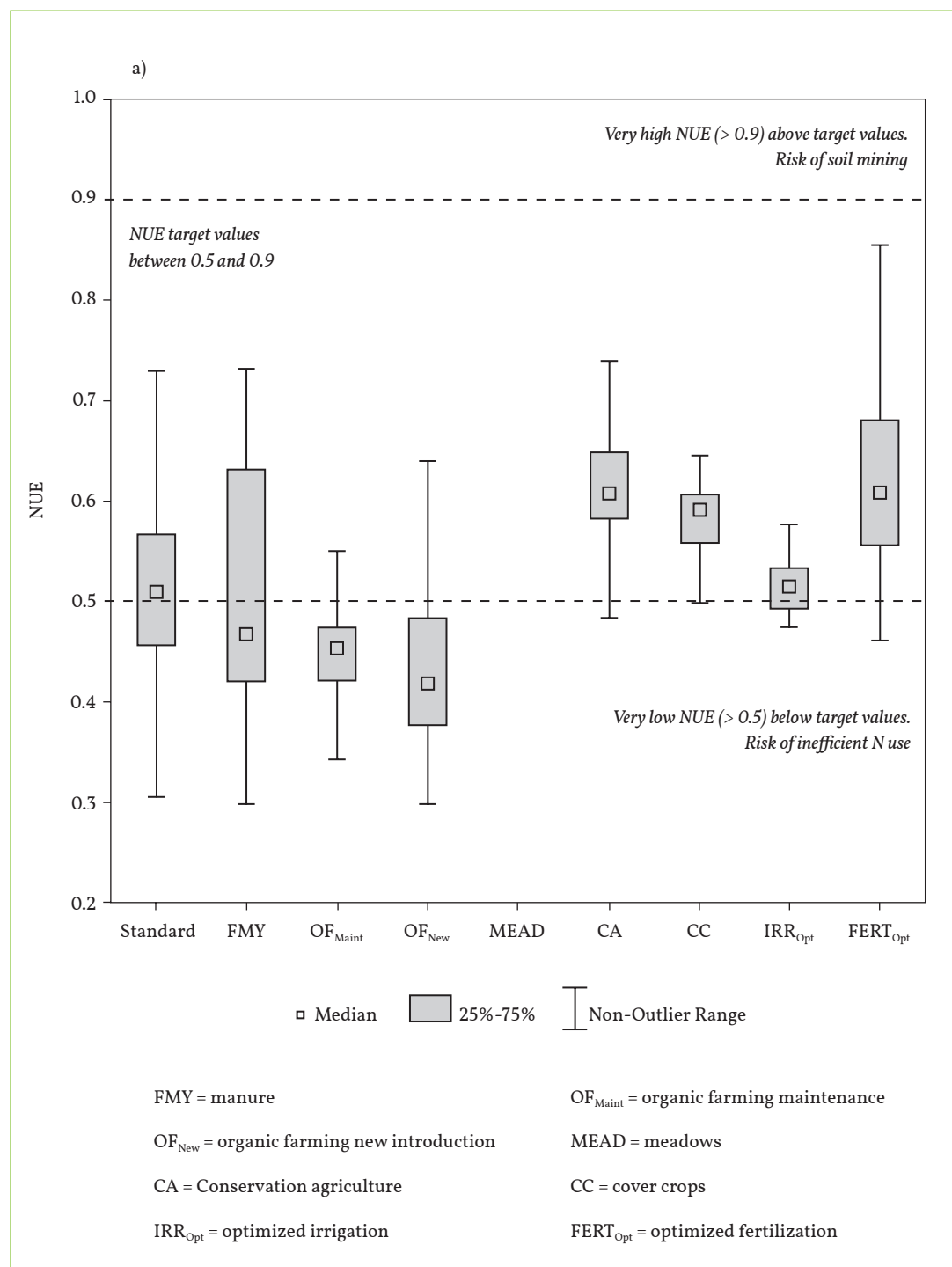
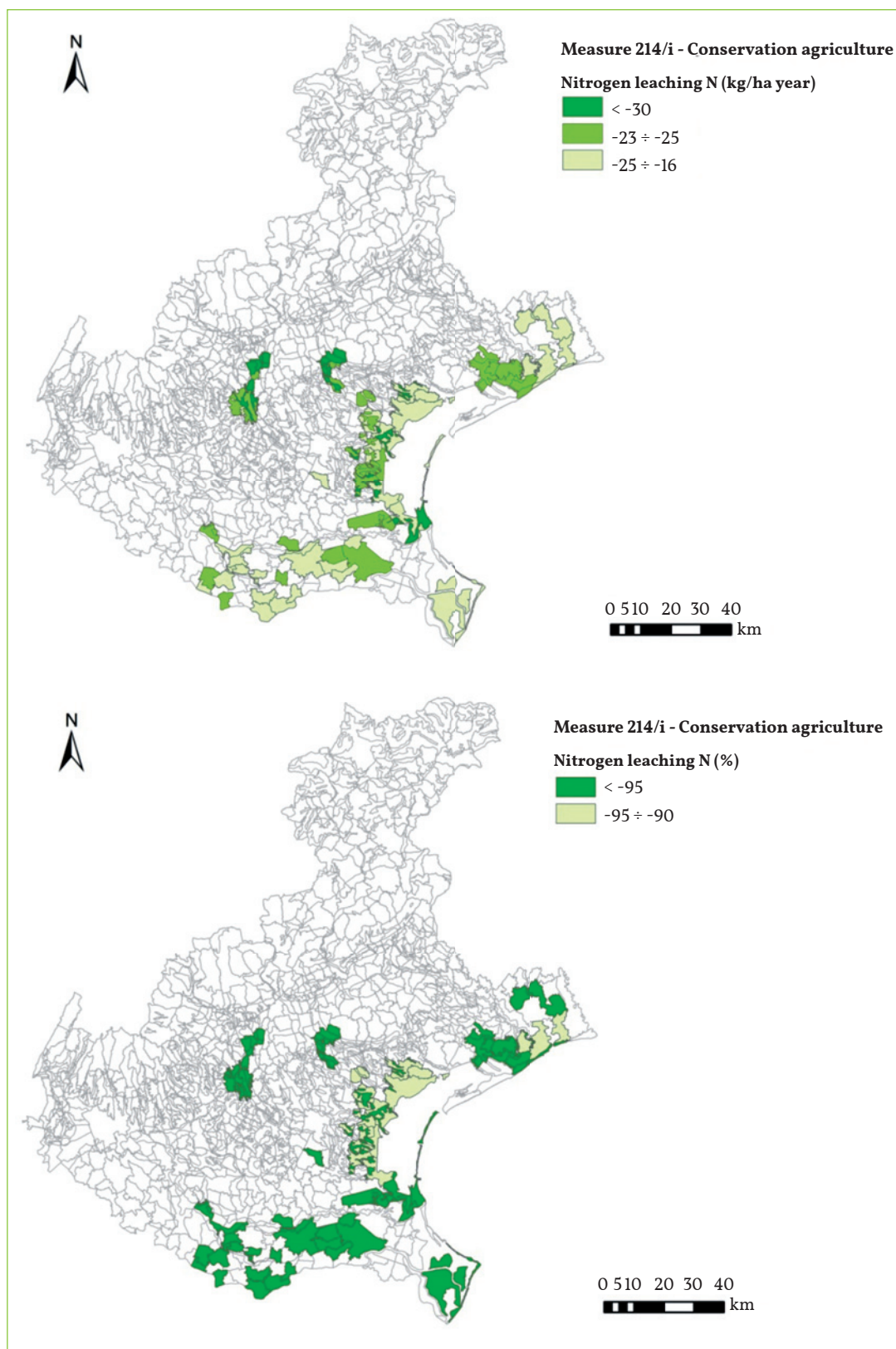


Figure 8.2 - Nitrogen Use Efficiency (NUE) in some agro-environmental measures simulated according to the RDP 2007-2013 (Standard = conventional; CA = Conservation agriculture).

Higher use efficiency also corresponds to lower simulated leaching, with decreases of over 16 kg per hectare per year, corresponding to reductions of over 95% (Fig. 8.3). The dynamics of phosphorus confirm those reported in the literature, i.e. the greater risk of phosphorus transport in solution in Conservation agriculture and the reduction of transport with sediment. The application of Conservation agriculture in some areas of the low Veneto

Figure 8.3 - Differences in nitrogen leaching (kg/ha year - top; % - bottom) between crop systems applying Conservation agriculture (Measure 214/i Action 1, RDP Regione Veneto 2007-2013) and conventional systems.



plain has indeed increased the concentration of organic phosphorus in the soil solution and, consequently its leaching into the groundwater (Fig. 8.4). The amount of this loss is still low: less than 0.01 kg per hectare per year, especially if compared with the loss of phosphorus particles. Indeed the loss of P particles was reduced to around 1 kg per hectare per year, with reductions of over 80% (Figure 8.5).

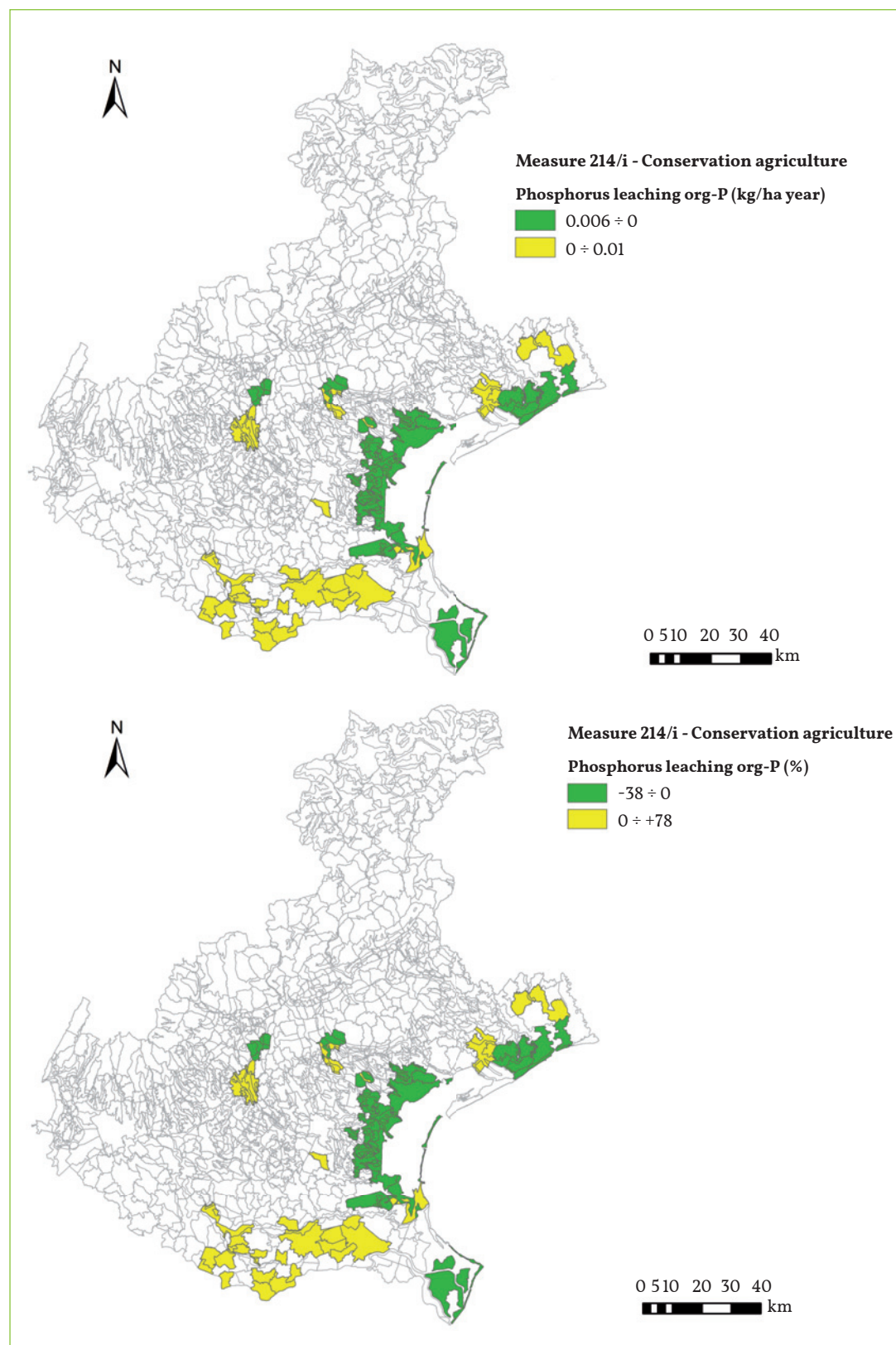
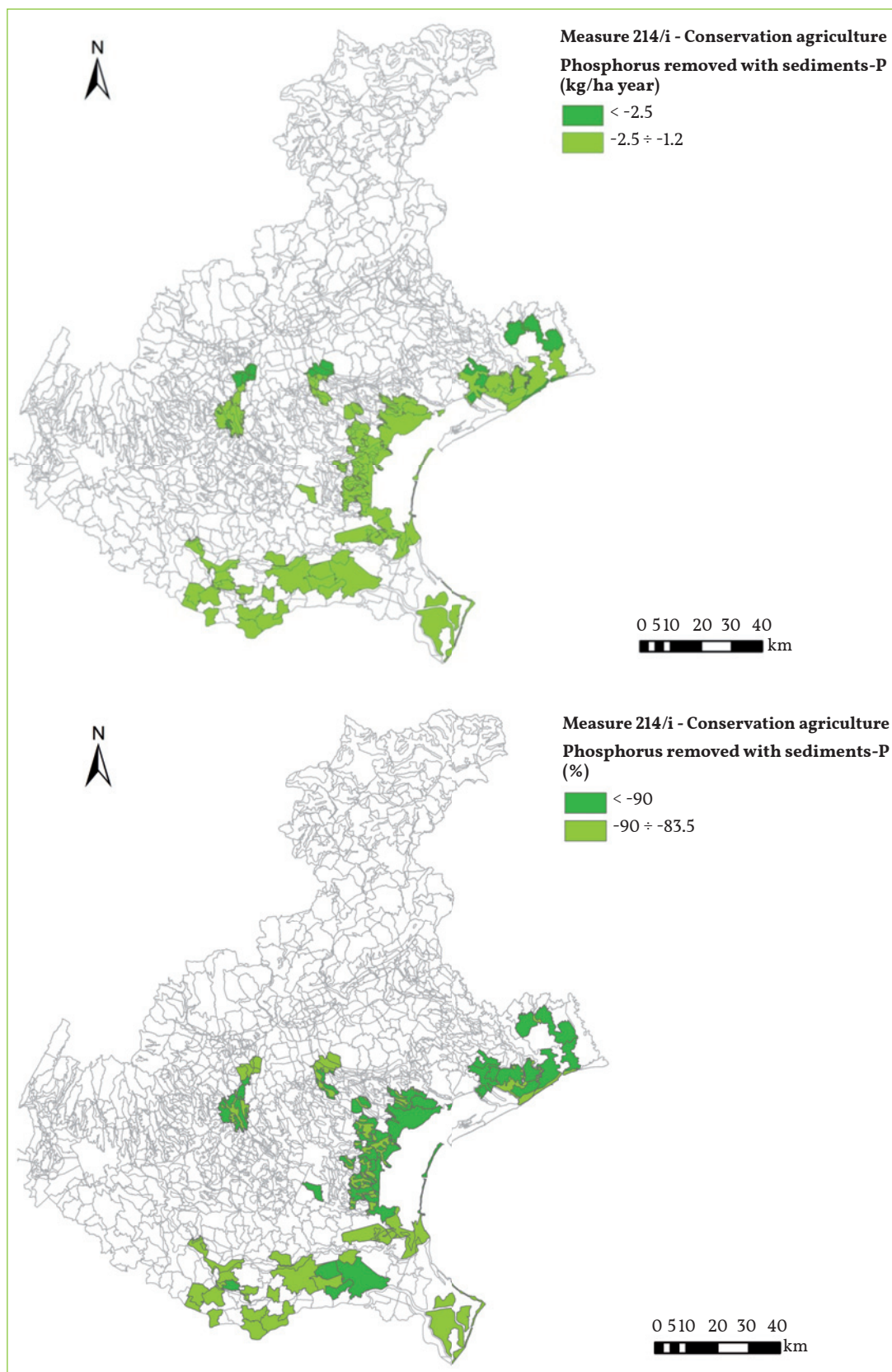


Figure 8.4 - Difference in organic phosphorus leaching (kg/ha year - top; % - bottom) between cultivation systems applying Conservation agriculture (Measure 214/i Action 1, RDP Regione Veneto 2007-2013) and conventional systems.

Figure 8.5 - Difference in phosphorus removed with sediments (kg/ha year - top; % - bottom) between cultivation systems applying Conservation agriculture (Measure 214/i Action 1, RDP Regione Veneto 2007-2013) and conventional systems.



BIBLIOGRAPHY

- Camarotto, Dal Ferro, N., Piccoli, I., Polese, R., Furlan, L., Chiarini, F., Morari, F., 2018. Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain, *Catena*, 167, pp. 236-249.
- Dal Ferro, N., Cocco, E., Lazzaro, B., Berti, A., Morari, F., 2016. Assessing the role of agri-environmental measures to enhance the environment in the Veneto Region, Italy, with a model-based approach. *Agriculture, Ecosystems and Environment*, 232, pp. 312-325.
- Dal Ferro, N., Cocco, E., Lazzaro, B., Berti, A., Morari, F., 2018. How to enhance crop production and nitrogen fluxes? A result-oriented scheme to evaluate best agri-environmental measures in Veneto Region, Italy. *Archives Of Agronomy And Soil Science*, vol 64. Issue 11.



SHEET 9

INTEGRATED PROTECTION AGAINST PESTS: INSECTS, GASTROPODS, BIRDS

Theoretically, the reduction of tilling operations in Conservation agriculture has, compared to ploughing, less impact on the population of harmful organisms. Therefore, one might initially expect there to be an increase in attacks of phytophages and diseases, at least until a new equilibrium is reached. In this context, the potentially more dangerous pests are gastropods (slugs, snails) and soil borne insects (particularly click beetles).

Gastropods: slugs and snails

Over the course of the trial period, data were systematically collected:

- 1) on monitoring methods and possible intervention thresholds;
- 2) on the incidence and severity of damage caused by gastropods.

The search for the best monitoring technique for tracking gastropods began in 2014, involving the maize-cultivated plots of the LIFE+ HELPSOIL project at the three pilot demonstration farms of Veneto Agricoltura (Diana - Treviso, Sasse Rami - Rovigo, ValleVecchia - Venice). The traps used and compared were:

1. Reversed bent tile (roof tile);
2. 18 cm flowerpot saucer above ground;
3. 18 cm flowerpot saucer buried up to the rim;
4. pit-fall trap.

The traps were primed with different concentrations of bait (beer):

- A. pure bait (trap filled with 100% beer);
- B. water-diluted bait (trap filled with 50% beer and 50% water) (Photo 9.1).

Photo 9.1 - Traps for gastropods used in the tests: 18 cm flowerpot saucer buried up to the rim (left), pit-fall trap (right).



All the traps secured a few catches, if at all (there were only some sporadic catches in the pit-fall traps) throughout the monitoring period (2014-2016). This is relevant, even if the traps were placed on ground that was crop-free (maize in precession) and only covered with crop residues and weeds, and even if soil humidity was very high.

Soils were also monitored with the YATLORf traps for click beetle adults, and it was noted that this type of trap is also able to significantly attract snails, at least of some species, and most probably because it provides them with an adequate shelter.

At ValleVecchia in particular, the mean data of catches in the test fields under conservation management and in those under conventional management for the three crops evaluated (wheat, maize, soybean) highlighted that the conservation management has significantly higher numbers of gastropods (Fig. 9.3), but they didn't seem to increase in the three years of monitoring. The snails caught were found to belong to the Helicidae family (*Helicella* spp., *Cernuella* spp.).



Photo 9.2 - YATLORf traps for click beetles were also used for the monitoring of gastropods and maize plant damaged by snails.

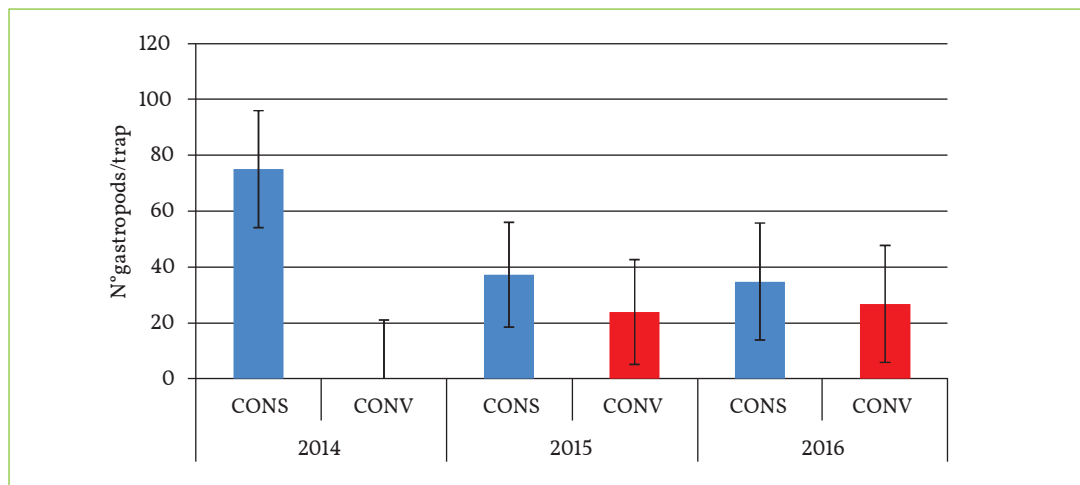


Figure 9.1 - Number of gastropods per trap in the test fields at ValleVecchia (4 pairs of no-till plots and conventional system plots) from 2014 to 2016.

Similarly, the incidence of plants with symptoms of damage by gastropods was higher in the no-till plots (27%) compared to those under conventional management (0-1%).

In summary, for certain sites, a significant increase in the gastropod population was highlighted in Conservation agriculture, and thus also symptoms of their presence. The limited number of findings, particularly with regard to the low incidence of serious damage, has not allowed a statistically significant analysis of gastropod damage thresholds. From a practical point of view, the number of plants showing symptoms of snail damage was appreciable when there were more than 100 individuals per trap in the YATLORf trap catches in the current or previous season. Monitoring and prevention (e.g., delaying sowing in the case of large populations) seem to be the basic protection tools, as specific treatment with registered baits is expensive and difficult to deploy on a field in the presence of very large populations.

In conclusion, a significant increase has been recorded in gastropod populations and symptoms of their presence with Conservation agriculture, particularly in no-till soil (Fig. 9.1), which is matched by an increase in the risk of damage. In fact, thirty year observations on thousands of hectares cultivated with maize in Conventional agriculture showed that the risk of serious damage, i.e. of damage capable of affecting yield levels, is close to zero. This risk still remains low in general on Veneto farms (less than 1% of the area cultivated with maize).

Underground pests (click beetles)

The larval density of click beetles in the soil was monitored in all the farms involved in this specification of the LIFE+ HELPSOIL project, in spring and/or autumn of the initial and final years of the project. For some plots, monitoring was continued for the entire duration of the project. The most harmful species were also monitored for adult individuals using YATLORf traps according to well-established surveying methods¹.

In general, larval density was low, and below the damage thresholds for the key species of the regions concerned. The catch levels of adult individuals in pheromone traps were also not particularly high (Tables 9.1, 9.2 and 9.3). The levels of damage from beetles and other pests (cutworms, other underground pests, viruses, seed and seedling fungal diseases) were found to be low and maize investment was good both in the fields under conservation management and in those under conventional management.

¹ See <http://www.venetoagricoltura.org/upload/Trappola%20YATLORf.pdf>.

Table 9.1 - Monitoring of click beetle (*Agriotes* spp.) population level in fields intended for crop protection trials in 2014.

| Farm | Region/prov | click beetle larvae / trap | | | | | | <i>Agriotes brevis</i> adults/trap | | <i>Agriotes sordidus</i> adults/trap | |
|----------------|-------------|----------------------------|------|--------------------|--------------|------|--------------------|------------------------------------|-------|--------------------------------------|-------|
| | | Conventional | | | Conservation | | | Conv. | Cons. | Conv. | Cons. |
| | | Mean | Sd | Prevailing sp. | Mean | Sd | Prevailing sp. | | | | |
| ValleVecchia** | Veneto/VE | 0.25 | 0.62 | <i>A. sordidus</i> | 0.33 | 0.49 | <i>A. sordidus</i> | 2 | 5 | 424 | 1041 |
| Sasse** | Veneto/RO | 0.33 | 0.49 | <i>A. sordidus</i> | 0.08 | 0.29 | <i>A. sordidus</i> | 2 | 15 | 272 | 513 |
| Diana** | Veneto/TV | 0.17 | 0.39 | <i>A. sordidus</i> | 1.33 | 1.50 | <i>A. sordidus</i> | 171 | 271 | 849 | 1097 |

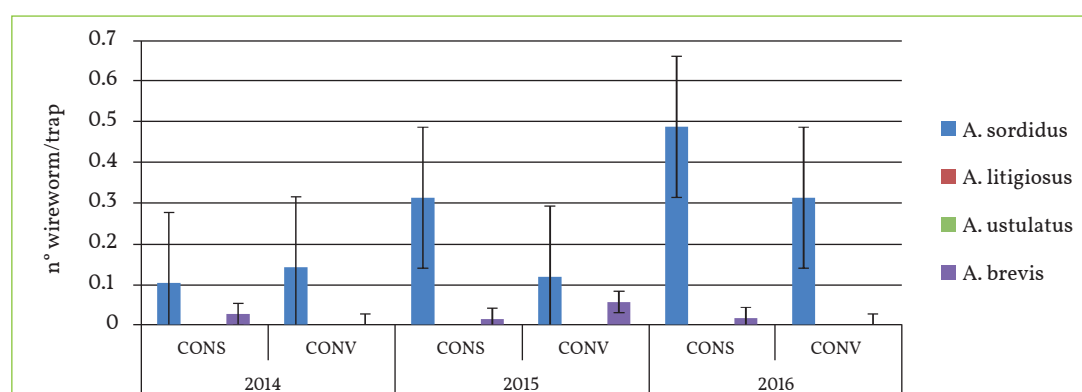
** adults in the period of greatest flight performance.

Table 9.2 - Monitoring of click beetle (*Agriotes* spp.) population level in fields intended for crop protection trials in 2016.

| Farm | Region/prov | click beetle larvae / trap | | | | | | <i>Agriotes brevis</i> adults/trap | | <i>Agriotes sordidus</i> adults/trap | |
|---------------|-------------|----------------------------|------|--------------------|--------------|------|--------------------|------------------------------------|-------|--------------------------------------|-------|
| | | Conventional | | | Conservation | | | Conv. | Cons. | Conv. | Cons. |
| | | Mean | Sd | Prevailing sp. | Mean | Sd | Prevailing sp. | | | | |
| ValleVecchia* | Veneto/VE | 0.08 | 0.29 | <i>A. sordidus</i> | 0.17 | 0.39 | <i>A. sordidus</i> | 9 | 0 | 322 | 96 |
| Sasse* | Veneto/RO | 1.08 | 1.43 | <i>A. sordidus</i> | 0.71 | 1.05 | <i>A. sordidus</i> | 16 | 72 | 351 | 451 |
| Diana* | Veneto/TV | 0.29 | 0.55 | <i>A. sordidus</i> | 0.06 | 0.20 | <i>A. sordidus</i> | 56 | 185 | 90 | 147 |

* Autumn monitoring.

Figure 9.2 - Monitoring of wireworm (*Agriotes* spp.) presence over the 2014-2016 period in the three pilot farms of Veneto.



| Agriotes adults | | A. sordidus | | A. litiginosus | | A. ustulatus | | A. brevis | |
|------------------|-----------|-------------|----------|----------------|----------|--------------|----------|-----------|----------|
| Year | Treatment | Mean | St. err. | Mean | St. err. | Mean | St. err. | Mean | St. err. |
| 2015 | CONV | 509.71 | 151.53 | 28.26 | 18.05 | 3.30 | 1.46 | 25.53 | 2.40 |
| | CONS | 582.94 | 151.53 | 26.78 | 18.05 | 7.51 | 1.46 | 20.94 | 2.40 |
| 2016 | CONV | 387.36 | 151.53 | 26.06 | 18.05 | 10.09 | 1.46 | 32.26 | 2.40 |
| | CONS | 376.78 | 151.53 | 31.83 | 18.05 | 1.66 | 1.46 | 37.69 | 2.40 |
| ANOVA | | F | P | F | P | F | P | F | P |
| Year | | 1.18 | 0.31 | 0.01 | 0.94 | 0.02 | 0.90 | 0.22 | 0.65 |
| Treatment | | 0.04 | 0.84 | 0.01 | 0.91 | 0.11 | 0.75 | 0.00 | 0.98 |
| Year x Treatment | | 0.08 | 0.79 | 0.04 | 0.85 | 0.084 | 0.42 | 0.04 | 0.84 |

Table 9.3 - Monitoring of click beetle (*Agriotes* spp.) adult presence over the 2015-2016 period in the three pilot farms of Veneto.

Long-term trends

In order to have even more reliable data on the influence of the introduction of Conservation agriculture on soil parasite populations, some plots were monitored from the very beginning of the implementation of the RDP of Veneto, and a similar protocol was used to assess the trends of click beetle population over time. This was run for eight consecutive years. The results clearly show that the introduction of Conservation agriculture, in particular in no-till soil, has not led to a significant increase in soil pests such as wireworms, and therefore has not created the need to increase pesticide treatments. It should be remembered that pesticides are associated with significant environmental impacts and serious risks for the pollinating insects, particularly in the case of neonicotinoids.

In summary, Conservation agriculture, contrary to theoretical expectations, has not led to an increase in the population levels and damage caused by soil pests. The levels of damage from click beetles and other soil pests resulted as being low and maize crops have not suffered from any reductions due to these factors.

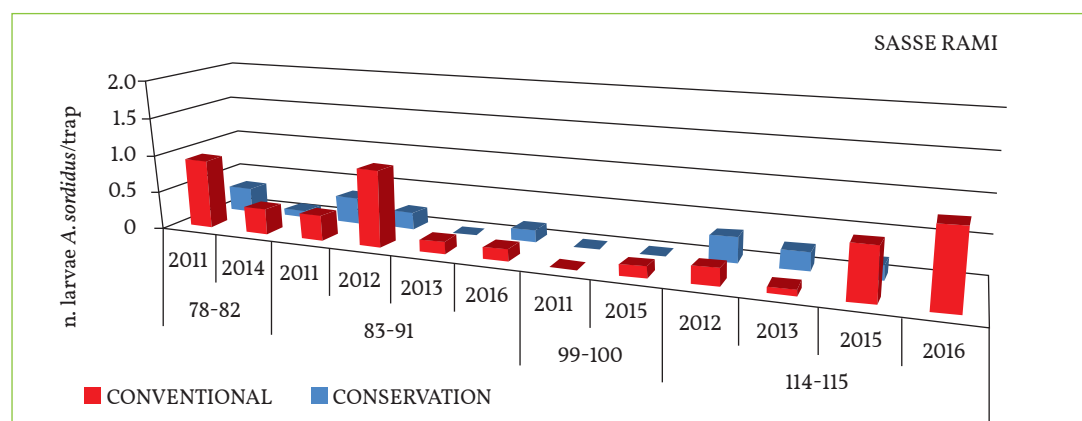


Figure 9.3 - The evolution trends of click beetle (*Agriotes sordidus*) larvae populations in plots of the pilot farm Sasse Rami, monitored between 2011 and 2016.

Birds

The introduction of Conservation agriculture has not significantly increased the risk of damage from birds in the monitored plots, even if the number of damaged maize plants has increased. The risk seems rationally manageable through mutual fund insurance coverage².

Final considerations

The risk of damage from any kind of plant pests (birds, insects, gastropods) turned out to be low in Conservation agriculture, even in the case of no-tillage; in most cases, therefore, there is no need for pesticide interventions for tanning the seed or application of micro-granular pesticides during sowing.

On-going monitoring of the phytophagous populations and reliable assessment of the risk of damage are possible. The YATLORf trap allows timely monitoring not only of click beetle adult populations, but also gastropod populations such as snails (*Helix* spp.). If the values from adult traps exceed the risk values (300 adults/trap per season for *A. brevis*, 1000 adults/trap per season for the other species), before sowing a crop that is susceptible to attacks, such as maize, it would be appropriate to estimate the soil larval density³.

² For information on the mutual funds see www.venetoagricoltura.org/2017/02/newsletter/bollettino-coltureerbacee-n-142017-del-16-febbraio/.

³ For more details on monitoring methods, population estimates and indications on possible treatments, please see the 'Bollettino Colture Erbacee' (regularly updated) available on www.venetoagricoltura.org/bollettino-colture-erbacee/.

SHEET 10

MYCOTOXINS IN MAIZE AND WHEAT GRAINS

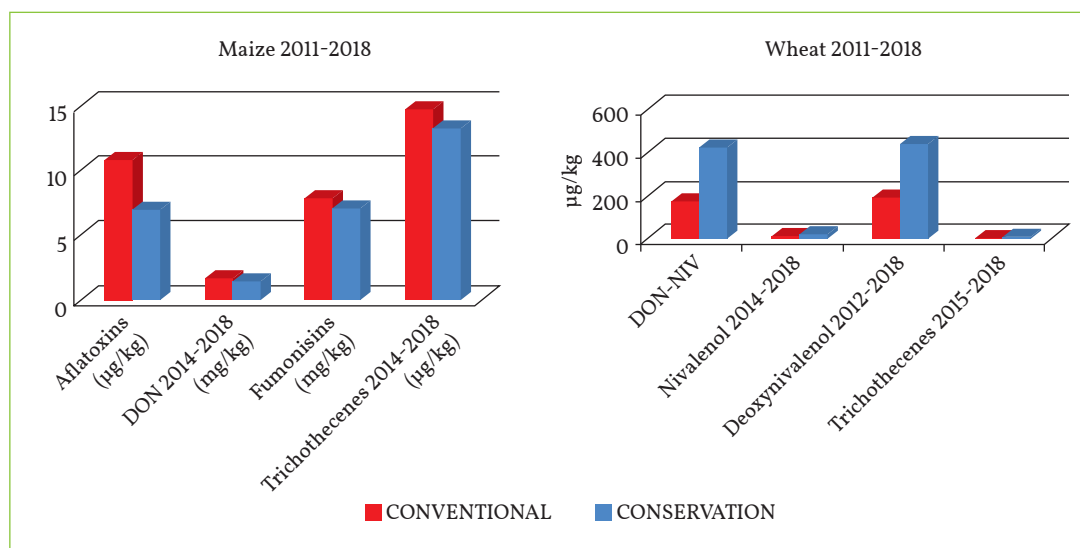
Fungal pathogens and toxins, their synthetic products, can severely damage the wholesomeness and commercial value of crops. Surface residues, on which toxin-producing fungal species can develop, can theoretically aggravate such problems, particularly in no-till Conservation agriculture. Mycotoxin values are mainly affected by meteorological conditions and stress factors in general (high humidity, temperature variations, water stress and attack by soil insects). Moreover, the succession of grasses, and especially monocultures, does not help to prevent mycotoxins (fumonisins, aflatoxins, trichothecenes, etc.): leaving crop residues on the ground, in particular, is a potential source of inoculum for fungal infections, especially for fusarium. However, crop rotation, one of the founding principles of Conservation agriculture, can help reduce the persistence of fungal inoculum, and the consequent formation of mycotoxins in the grains. Moreover, this same crop diversification, which involves greater biological activity in land farmed with Conservation agriculture, may constitute an important natural factor of adversity control.

Experimental results on the farms in Veneto

The field experiment analysed the extent of mycotoxin contamination. Analysis was performed on grain samples (using dynamic flow in the period from 2011 to 2018) following the method described in the report on IPM of the LIFE+ HELPSOIL Project.

No-till soil management did not lead to any significant differences in the levels of mycotoxins in maize; whilst for wheat, the samples from no-till plots, both for total DON and deoxynivalenol, showed significantly higher values compared to the conventional plots (Fig. 10.1).

Figure 10.1 - Effect of soil management on the mycotoxin content of maize and wheat grain. Comparison between pairs of no-till (CONSERVATION) and conventionally farmed (CONVENTIONAL) plots of land (average of the different sites from 2011 to 2018).



Maize

Total fumonisins (B1 and B2), Aflatoxins, Deoxynivalenol (DON) and its derivatives, Nivalenol (NIV) and Trichothecenes (T2/HT2) are reported in Tables 10.1, 10.2, 10.3 and 10.4.

No significant differences in fumonisin content (B1 + B2) were observed according to treatment and year, even if higher contamination was observed in 2013, 2014 and 2016, (Tab. 10.1, Fig. 10.2).

Table 10.1 - Fumonisin content in maize, from 2011 to 2018, on the different Veneto farms and comparison CONSERVATION-CONVENTIONAL.

| YEAR | Fumonisin (B1 + B2) (µg/kg) | St. err. | Test | FARM | Fumonisin (B1 + B2) (µg/kg) | St. err. | Test | TREATMENT | Fumonisin (B1 + B2) (µg/kg) | St. err. | Test |
|-------|-----------------------------------|----------|------|-----------------|-----------------------------------|----------|------|-----------|-----------------------------------|----------|------|
| 2011 | 1854.46 | 2804.96 | c | AGR. SANTILARIO | 4263.00 | 2745.33 | b | CONV | 7815.99 | 593.27 | a |
| 2012 | 6491.89 | 1435.12 | bc | DIANA | 5709.86 | 960.19 | b | CONS | 7090.96 | 745.52 | a |
| 2013 | 12458.56 | 1435.12 | a | PASTI | 13845.13 | 1585.02 | a | ANOVA | N | F | P |
| 2014 | 12887.46 | 1073.94 | a | SASSE | 9311.95 | 919.77 | ab | | 83 | 0.07 | 0.80 |
| 2015 | 6112.32 | 1110.55 | bc | VALLEVECCHIA | 5572.85 | 786.42 | b | ANOVA | N | F | P |
| 2016 | 9813.05 | 1101.29 | ab | ANOVA | N | F | P | | | | |
| 2017 | 1964.35 | 1274.79 | c | | 83 | 6.83 | 0.00 | | | | |
| 2018 | 2217.20 | 1435.12 | c | | | | | | | | |
| ANOVA | N | F | P | | | | | | | | |
| | 83 | 11.95 | 0.00 | | | | | | | | |

Legend: N = number of cases; F = Fisher's test; P = associated probability.

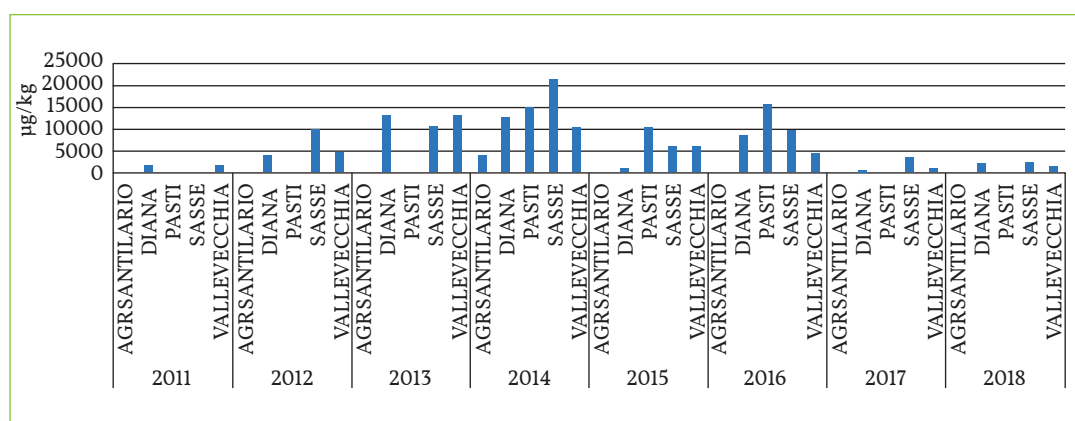


Figure 10.2 - Fumonisin content in maize for the different Veneto farms from 2011 to 2018.

Table 10.2 - Aflatoxin content in maize, from 2011 to 2018, on the different Veneto farms and comparison CONSERVATION-CONVENTIONAL.

| YEAR | Aflatoxins (µg/kg) | St. err. | Test | FARM | Aflatoxins (µg/kg) | St. err. | Test | TREATMENT | Aflatoxins (µg/kg) | St. err. | Test |
|-------|-----------------------|----------|------|-----------------|-----------------------|----------|------|-----------|-----------------------|----------|------|
| 2011 | 0.19 | 21.99 | a | AGR. SANTILARIO | 2.88 | 31.01 | a | CONV | 10.80 | 6.58 | a |
| 2012 | 37.18 | 16.21 | a | DIANA | 1.63 | 9.20 | a | CONS | 6.97 | 8.19 | a |
| 2013 | 1.82 | 16.21 | a | PASTI | 0 | 17.9 | a | ANOVA | N | F | P |
| 2014 | 0.68 | 12.13 | a | SASSE | 28.83 | 10.98 | a | | 84 | 0.08 | 0.78 |
| 2015 | 3.92 | 13.27 | a | VALLEVECCHIA | 0.28 | 8.88 | a | ANOVA | N | F | P |
| 2016 | 1.37 | 12.44 | a | ANOVA | N | F | P | | | | |
| 2017 | 35.24 | 14.40 | a | | 84 | 1.22 | 0.31 | | | | |
| 2018 | 0.67 | 16.21 | a | | | | | | | | |
| ANOVA | N | F | P | | | | | | | | |
| | 84 | 1.09 | 0.38 | | | | | | | | |

Legend: N = number of cases; F = Fisher's test; P = associated probability.

Analysis of aflatoxins in maize grain (Table 10.2), did not show differences between treatments and years. Higher presence of aflatoxins has apparently been detected at Sasse Rami, particularly in 2012 and 2017 (Fig. 10.2).

Figure 10.3 - Aflatoxin content in maize for the different Veneto farms from 2011 to 2018.

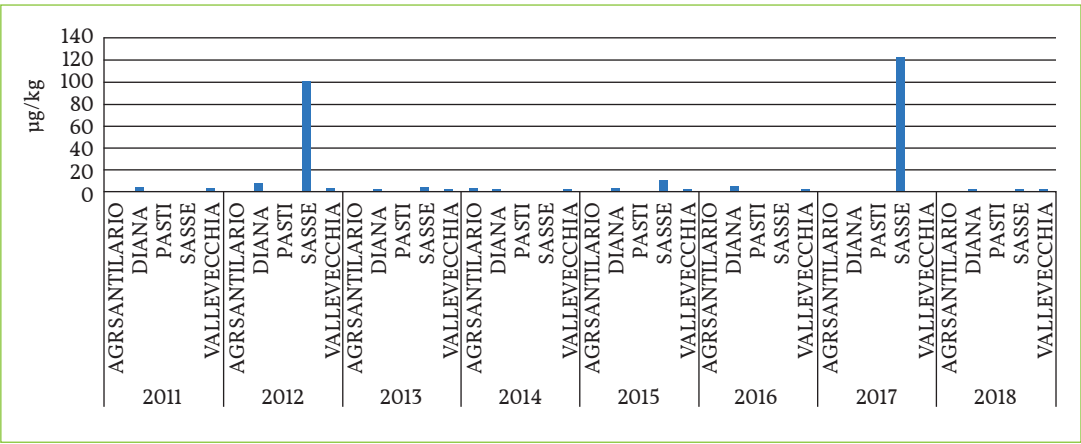


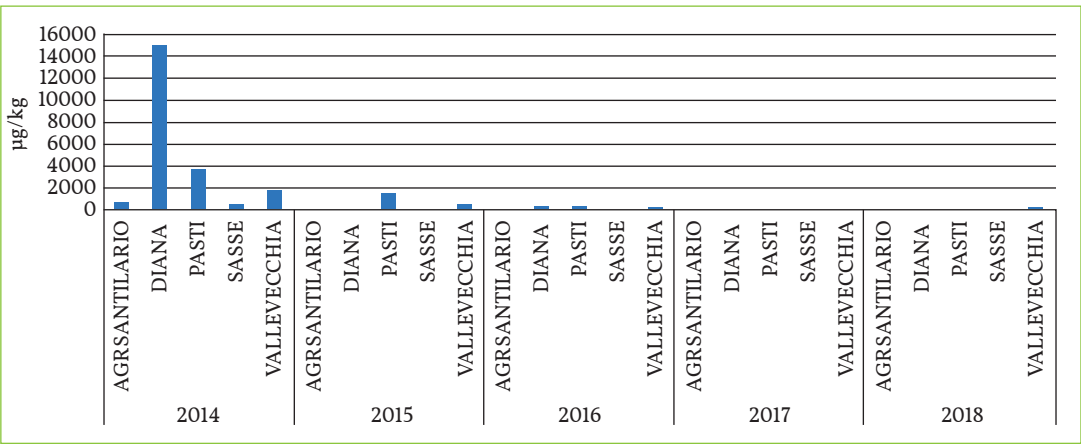
Table 10.3 - DON (Deoxynivalenol) and its derivatives (3- and 15-acetil-Deoxynivalenol) and NIV (Nivalenol) content on the maize grain, from 2011 to 2018, on the different Veneto farms and comparison CONSERVATION-CONVENTIONAL.

| YEAR | DON ¹ -NIV ² (µg/kg) | St. err. | Test | FARM | DON ¹ -NIV ² (µg/kg) | St. err. | Test | TREATMENT | DON ¹ -NIV ² (µg/kg) | St. err. | Test |
|-------|---|----------|------|-----------------|---|----------|------|-----------|---|----------|------|
| 2014 | 4360.63 | 337.48 | a | AGR. SANTILARIO | 718.84 | 862.56 | b | CONV | 1669.14 | 264.82 | a |
| 2015 | 658.09 | 473.56 | b | DIANA | 5138.60 | 395.67 | a | CONS | 1433.43 | 289.18 | a |
| 2016 | 174.77 | 415.29 | b | PASTI | 1803.33 | 498.00 | b | ANOVA | N | F | P |
| 2017 | 23.13 | 609.92 | b | SASSE | 137.98 | 365.95 | b | | 44 | 0.03 | 0.86 |
| 2018 | 106.98 | 451.52 | b | VALLEVECCHIA | 646.51 | 365.78 | b | | | | |
| ANOVA | N | F | P | ANOVA | N | F | P | | | | |
| | 44 | 30.68 | 0.00 | | 44 | 29.37 | 0.00 | | | | |

Legend: DON¹ = Deoxynivalenol and its derivatives; NIV² = Nivalenol; N = number of cases; F = Fisher's test; P = associated probability.

For DON-NIV (Table 10.3), the average values were also similar between Conservation and Conventional agriculture, with mean values in any case higher than the threshold required for direct consumption (DON <1750 µg/kg). Differences were noted between farms; two farms in particular recorded values on average exceeding the limits for human consumption (DON <1250 µg/kg), but still below that for animal husbandry (DON <8000 µg/kg). For the other farms, the grain showed an acceptable quality, with the exception of Diana in 2014 (Fig. 10.4).

Figure 10.4 - DON (Deoxynivalenol) and its derivatives (3- and 15-acetil-Deoxynivalenol) and NIV (Nivalenol) content in the maize grain of the different Veneto farms from 2014 to 2018.



Finally, as regards the analysis of the trichothecene (T2/HT2) content, all samples (conservation/conventional) showed values far below the legal limits, with no marked difference between the conventional and conservation farming methods (Table 10.4).

On average, 2014 showed significantly higher values than all other years of the study. The other years showed values that were almost always below the legal limits, or even zero, as in the years from 2016 to 2018.

Table 10.4 - Trichothecene content (T2/HT2) in maize, from 2014 to 2018, on the different Veneto farms and comparison CONSERVATION-CONVENTIONAL

| YEAR | Trichothecene (T2/HT2) (µg/kg) | St. err. | Test | FARM | Trichothecene (T2/HT2) (µg/kg) | St. err. | Test | TREATMENT | Trichothecene (T2/HT2) (µg/kg) | St. err. | Test |
|-------|--------------------------------|----------|------|-----------------|--------------------------------|----------|------|-----------|--------------------------------|----------|------|
| 2014 | 44.72 | 2.46 | a | AGR. SANTILARIO | 40.83 | 6.27 | a | CONV | 14.76 | 1.93 | a |
| 2015 | 0.34 | 3.45 | b | DIANA | 13.94 | 2.88 | a | CONS | 13.22 | 2.10 | a |
| 2016 | 0 | 3.02 | b | PASTI | 13.55 | 3.62 | a | ANOVA | N | F | P |
| 2017 | 0 | 4.44 | b | SASSE | 10.99 | 2.66 | a | | 44 | 0.02 | 0.90 |
| 2018 | 0 | 3.29 | b | VALLEVECCHIA | 11.40 | 2.66 | a | | | | |
| ANOVA | N | F | P | ANOVA | N | F | P | | | | |
| | 44 | 51.98 | 0.00 | | 44 | 0.36 | 0.83 | | | | |

Legend: N = number of cases; F = Fisher's test; P = associated probability.



Figure 10.5 - Trichothecene content (T2/HT2) in maize for the different Veneto farms from 2014 to 2018.

Wheat

The data for DON, NIV and T2/HT2 relating to the test fields cultivated with wheat are recorded in Tables 10.5 and 10.6.

The statistical analysis reveals a considerable difference between cropping years, with values above the limit required for human consumption (DON: <1250 µg/kg) in 2013; on average, the conservation treatment had higher contents than the conventional one (with P=0.06); furthermore, the values that exceeded the threshold were approximately 10% of total, almost all in 2013 and equally distributed among CONV and CONS.

Table 10.5 - DON-NIV (Deoxynivalenol + Nivalenol) content in wheat grain, from 2011 to 2018, on the different Veneto farms and comparison CONSERVATION-CONVENTIONAL.

| YEAR | DON-NIV (µg/kg) | St. err. | Test | FARM | DON-NIV (µg/kg) | St. err. | Test | TREATMENT | DON-NIV (µg/kg) | St. err. | Test |
|-------|-----------------|----------|------|-----------------|-----------------|----------|------|-----------|-----------------|----------|------|
| 2011 | 316.52 | 382.31 | b | AGR. SANTILARIO | 274.54 | 457.54 | a | CONV | 278.54 | 154.57 | a |
| 2012 | 503.49 | 298.65 | b | DIANA | 224.59 | 170.15 | a | CONS | 580.42 | 169.91 | a |
| 2013 | 1877.88 | 242.36 | a | SASSE | 395.48 | 165.83 | a | ANOVA | N | F | P |
| 2014 | 248.01 | 242.36 | b | VALLEVECCHIA | 823.32 | 117.53 | a | | 62 | 3.677 | 0.06 |
| 2015 | 435.80 | 279.21 | b | ANOVA | N | F | P | | | | |
| 2016 | 567.94 | 161.14 | b | | 62 | 3.451 | 0.02 | | | | |
| 2017 | 19.49 | 298.65 | b | | | | | | | | |
| 2018 | 99.77 | 218.18 | b | | | | | | | | |
| ANOVA | N | F | P | | | | | | | | |
| | 62 | 7.934 | 0.00 | | | | | | | | |

Legend: N = number of cases; F = Fisher's test; P = associated probability.

Table 10.6 - Trichothecene content (T2/HT2) of wheat grain, in 2015 and 2016, on the different Veneto farms, and comparison CONSERVATION-CONVENTIONAL.

| YEAR | Trichothecene (T2/HT2) (µg/kg) | St. err. | Test | FARM | Trichothecene (T2/HT2) (µg/kg) | St. err. | Test | TREATMENT | Trichothecene (T2/HT2) (µg/kg) | St. err. | Test |
|-------|--------------------------------|----------|------|-----------------|--------------------------------|----------|------|-----------|--------------------------------|----------|------|
| 2015 | 12.00 | 2.49 | a | AGR. SANTILARIO | 0 | 4.07 | b | CONV | 5.31 | 1.79 | a |
| 2016 | 4.94 | 1.61 | b | DIANA | 9.27 | 2.25 | ab | CONS | 9.28 | 2.03 | a |
| ANOVA | N | F | P | SASSE | 19.75 | 2.88 | a | ANOVA | N | F | P |
| | 20 | 13.92 | 0.05 | VALLEVECCHIA | 2.73 | 2.25 | b | | 20 | 2.857 | 0.12 |
| | | | | ANOVA | N | F | P | | | | |
| | | | | | 20 | 12.65 | 0.01 | | | | |

Legend: N = number of cases; F = Fisher's test; P = associated probability.

Differences between DON-NIV and Trichothecene were affected by farm factor in the case of Trichothecene and by year for both mycotoxins (Fig. 10.5 and Fig. 10.6). However, no significant differences were detected between conservation and conventional treatment.

Figure 10.6 - DON-NIV (Deoxynivalenol + Nivalenol) content in wheat grain for the different Veneto farms from 2011 to 2018.

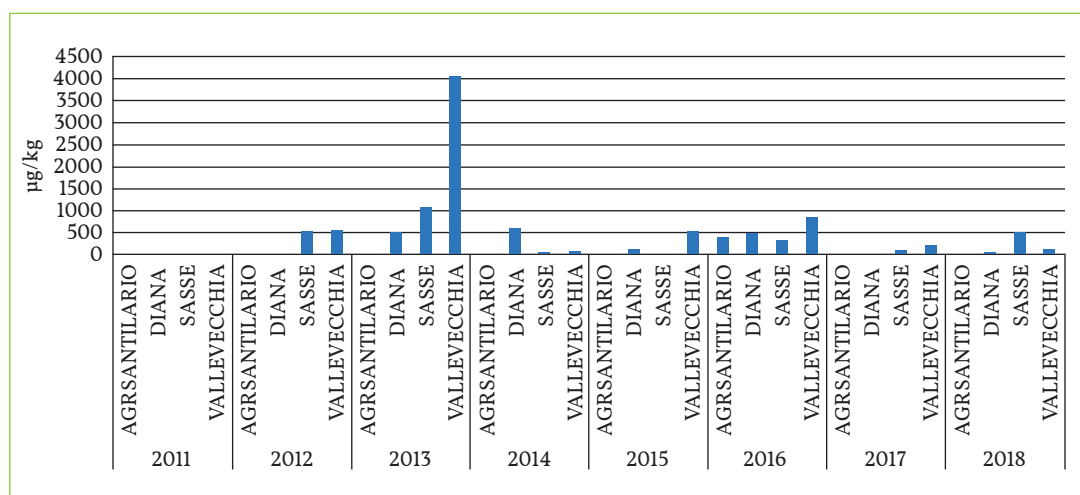
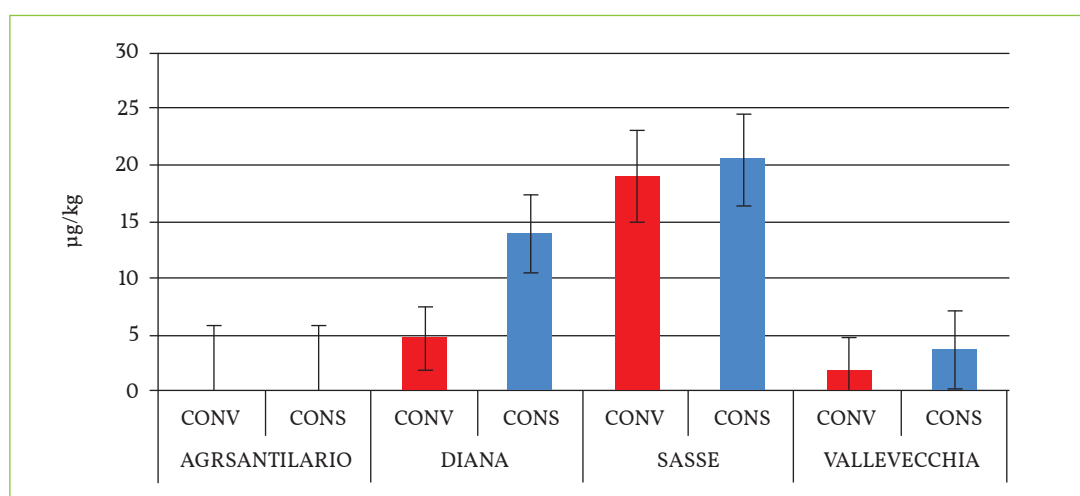


Figure 10.7 - Trichothecene content (T2/HT2) in wheat grain for the different Veneto farms in 2015 and 2016.



Final Considerations

In summary, long term experimentation showed that the levels of mycotoxins, for both maize and wheat, are mainly determined by the meteorological and soil conditions of the farm or production area. There was no increase in the average mycotoxins content in maize or wheat grains, determined by the adoption of Conservation agriculture.

The data available suggest that the recommendations to continue to monitor the presence of mycotoxins and apply strategies to limit their development, including the use of fungal antagonists such as *Trichoderma*, are potentially a valid solution for mycotoxin control in both Conventional and Conservation agriculture.

BIBLIOGRAPHY

Brera C., De Santis B, 2009 - Micotossine: il campione giusto permette analisi precise. *L'Informatore Agrario*, 32: 15-18.

<http://www.lifehelpsoil.eu/download/>



SHEET 11

EVOLUTION OF FLORA AND WEED MANAGEMENT

Conservation agriculture results in major environmental and economic benefits but requires the adaptation of cultivation techniques. In particular, weed management is more complicated because there is no mechanical control through soil tillage and the weed seeds are no longer buried, instead they accumulate in the top soil where there is a greater probability of germination. This results in an increase of dependence on the use of herbicides, even for the devitalisation of cover crops, thus increasing the risk of weed populations developing resistance to herbicides, as has already been observed in many parts of the world. The dissemination of weeds that are resistant to herbicides or that are increasingly difficult to control is the main constraint in the long-term sustainability of Conservation agriculture. It is therefore essential to adopt integrated weed management, based on rational chemical weeding strategies, in addition to the careful management of cover crops, crop residues, and the choice of appropriate crop rotations. Once the equilibrium of the system has been reached, this approach will ensure optimum weed control, reducing dissemination and the seed bank in the soil together with the reduced use of herbicides.

Experimental results on the Veneto Agricoltura pilot farms

Flora examination of the weed species and infestation level was performed according to the Braun-Blanquet method, modified by Barralis. In 2014, monitoring on the farms produced data sheets indicating the weed flora composition, with an index value estimate of the average density.

Table 11.1 - Braun-Blanquet Method (mod. Barralis, 1976).

| Braun Blanquet index- mod. Barralis | |
|-------------------------------------|-----------------------------|
| + | < 1 plant/m ² |
| 1 | 0-1 plants/m ² |
| 2 | 1-2 plants/m ² |
| 3 | 3-20 plants/m ² |
| 4 | 21-50 plants/m ² |
| 5 | >50 plants/m ² |

In 2015-2016, the monitoring of weeds continued following the same methodology. From the survey card updated for each farm check, indications were drawn from two numerical parameters:

- percentage cover (% cover), estimated overall at every inspection;
- density index (weeds), obtained by averaging the data grouped into classes and according to the Barralis Method and relative scale.

The two values and the indication of the number of different species identified (n = number of species) were then used as descriptors to better compare the test fields with their respective treatments also on the basis of the crops in rotation (wheat, maize and soybean).

Considering the effect of weeds on three crops in 2015 and 2016, aggregate data taken from the average survey results on all of the Veneto Agricoltura farms is given below: Diana (Treviso), Sasse Rami (Rovigo), ValleVecchia (Venice), for the three crops: wheat (Figure 11.1, 11.2, 11.3), maize (Figure 11.4, 11.5, 11.6, 11.7, 11.8), soybean (Figure 11.9, 11.10, 11.11).

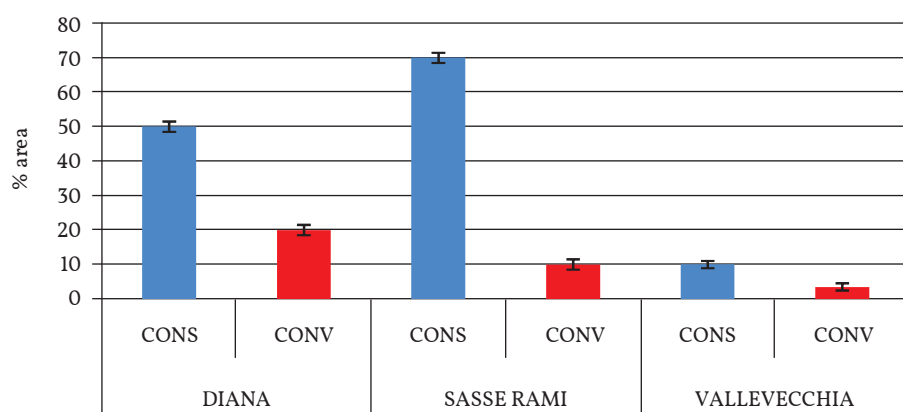


Figure 11.1 - Average estimated area (%) covered by weeds in wheat in 2015-2016 on the Veneto Agricoltura farms.

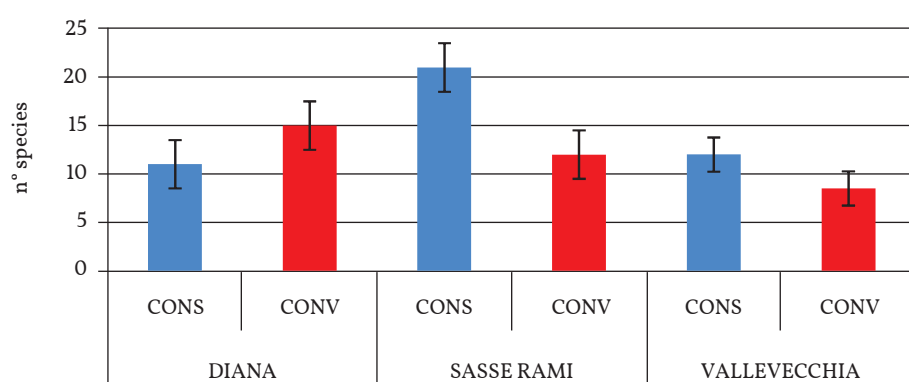


Figure 11.2 - Number of weed species in wheat in 2015-2016 on the Veneto Agricoltura farms.

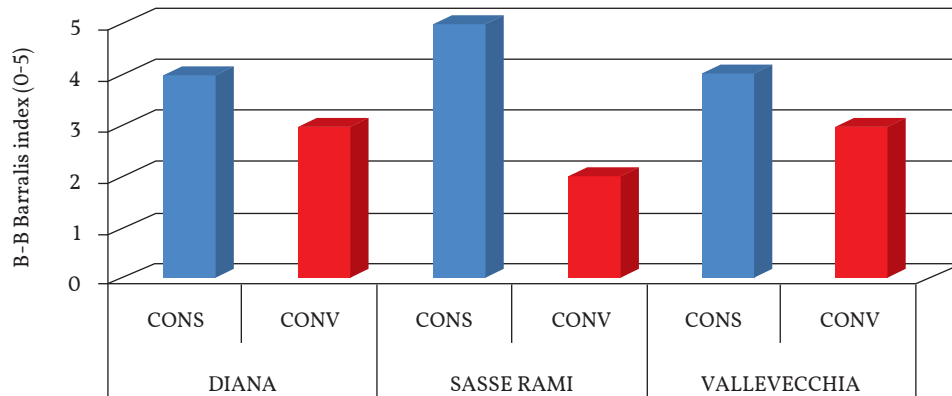


Figure 11.3 - Weed density index (Braun-Blanquet mod. Barralis) in wheat in 2015-2016 on the Veneto Agricoltura farms.

For wheat, the average data for both the number of species found and the percentage area covered by weeds is not statistically different for the two forms of management, even if the data are basically higher in Conservation agriculture for both parameters. The weed density index (B-B Barralis) is significantly higher for conservation management as compared to conventional management (5 = density >50 pp/m² and 3 = density between 3 and 20 pp/m² respectively).

Figure 11.4 - Estimated area (%) covered by weeds in maize in 2015-2016 on Veneto Agricoltura farms.

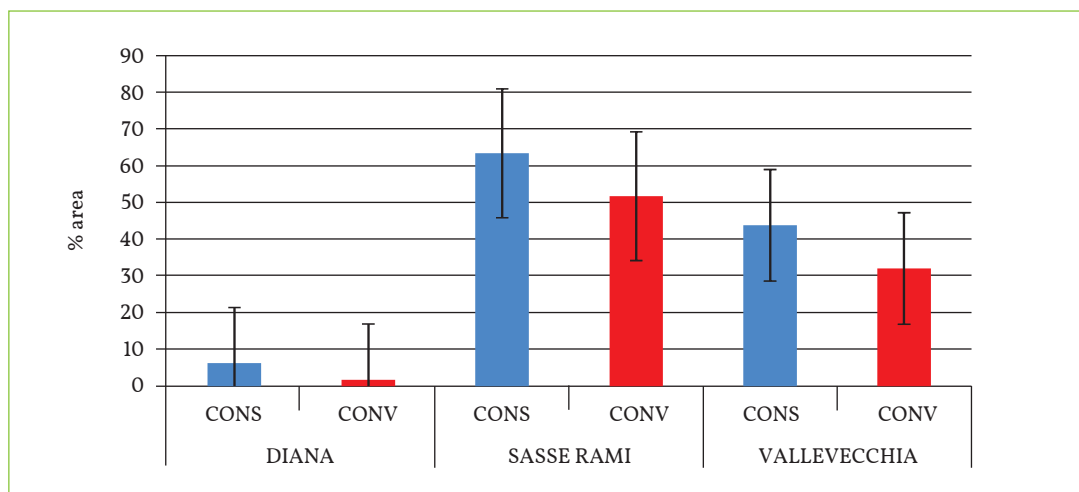


Figure 11.5 - Average number of weed species in maize in 2015-2016 on Veneto Agricoltura farms.

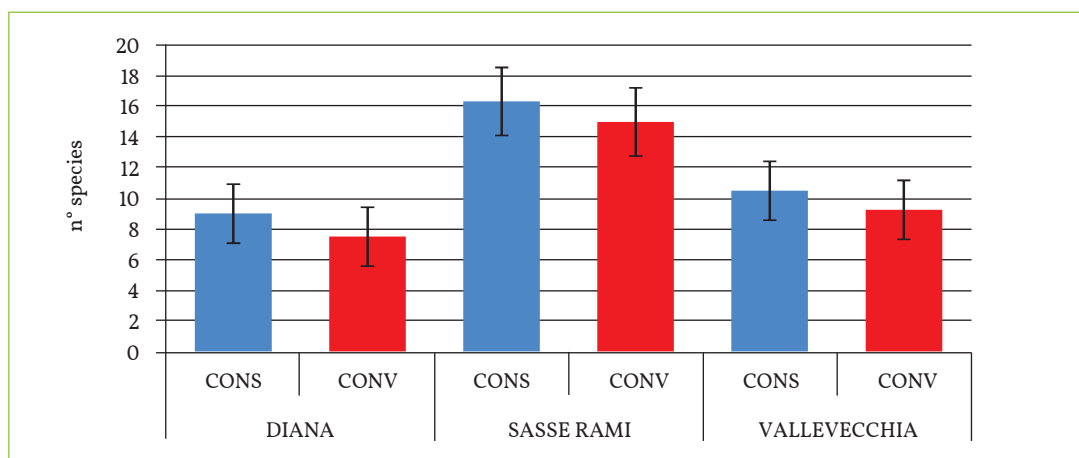
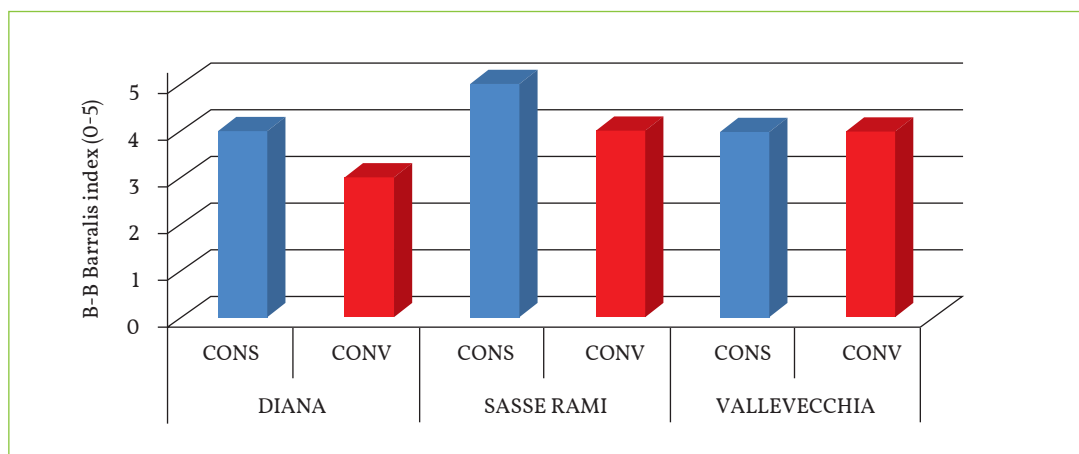


Figure 11.6 - Weed density index (Braun-Blanquet mod. Barralis) in maize in 2015-2016 on Veneto Agricoltura farms.



For the cultivation of maize, the number of species, density index and percentage area covered by weeds tend to be higher in Conservation management as compared to conventional farming, albeit without statistically significant differences (Figures 11.4, 11.6, 11.7). However, all the parameters developed were significantly different among the three studied farms, with ValleVecchia in the middle between Sasse Rami (higher incidence) and Diana (lower). Figure 11.7.

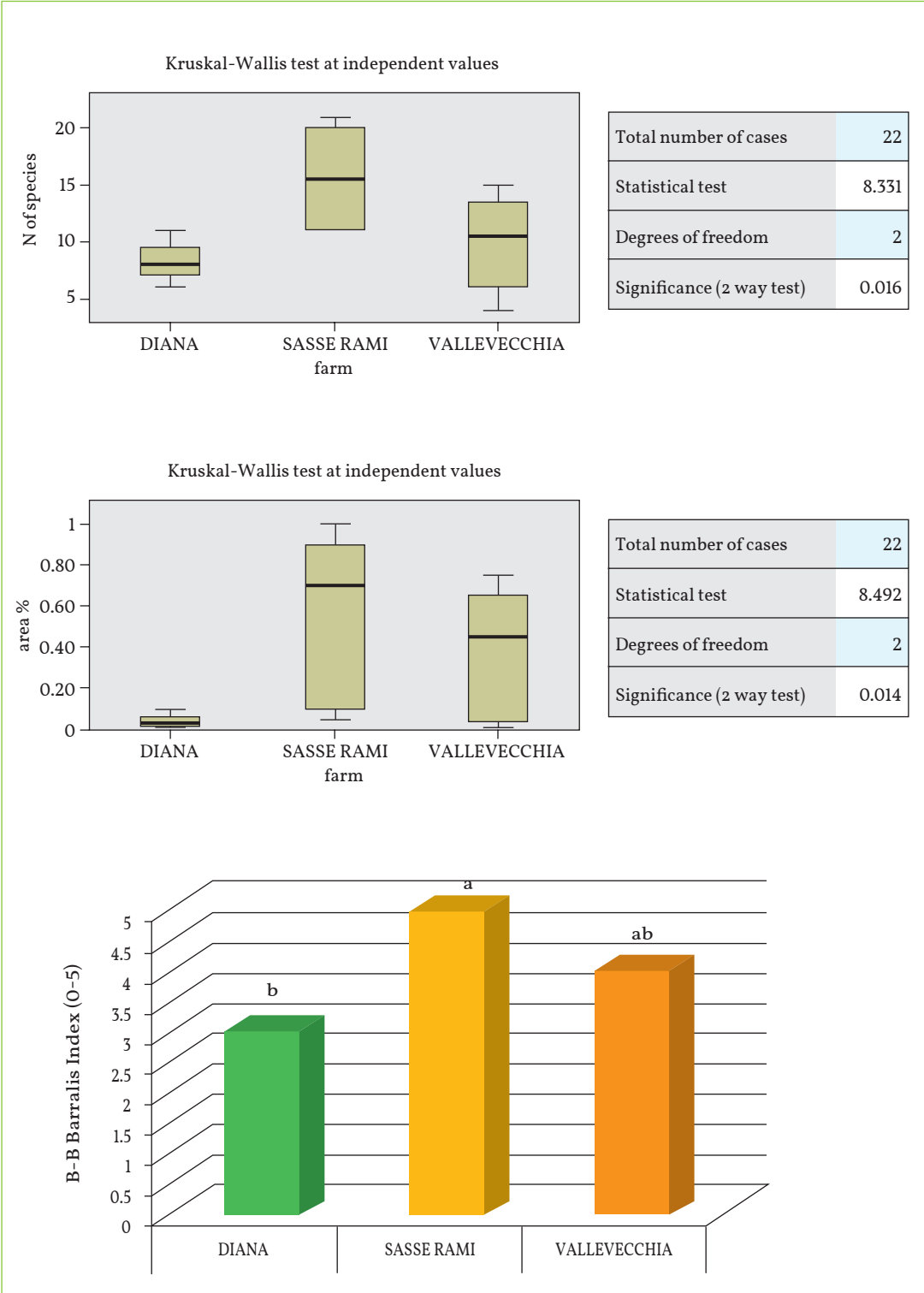


Figure 11.7 - Comparison between the three Veneto Agricoltura farms in terms of evaluation parameters for the presence of weeds in maize.

With regard to soybean, the number of species was similar for both forms of management (Fig. 11.9) while the cover percentage (Fig. 11.8) was notably higher in conservation management with a statistically significant difference between 44.8% of Conservation agriculture and 13.1% of Conventional farming.

Figure 11.8 - Average estimated area (%) covered by weeds in soybean in 2015-2016 on Veneto Agricoltura farms.

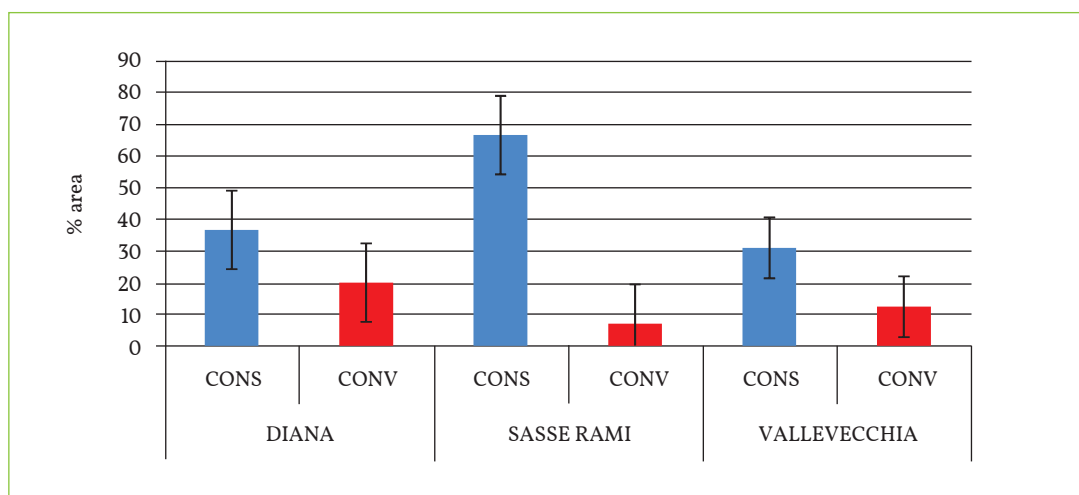


Figure 11.9 - Average number of weed species in soybean in 2015-2016 on Veneto Agricoltura farms.

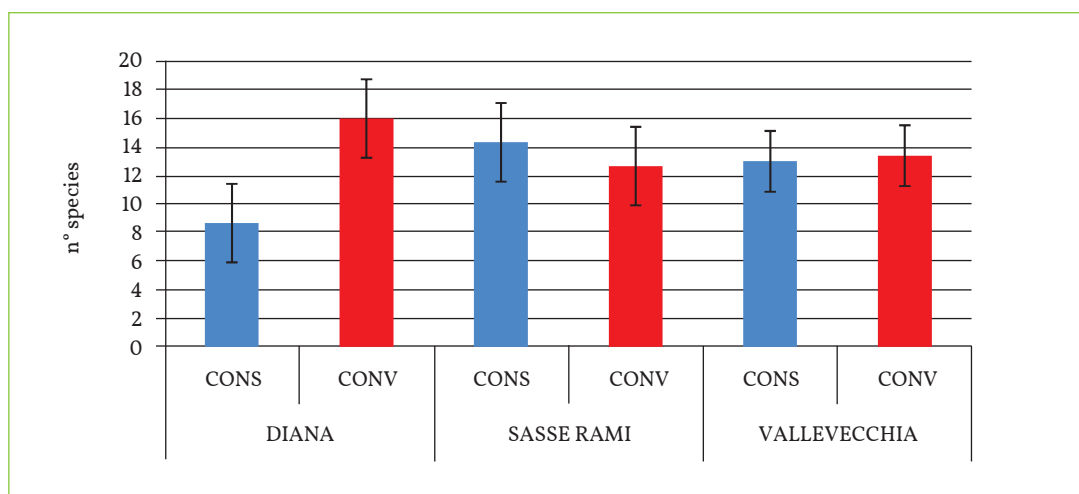
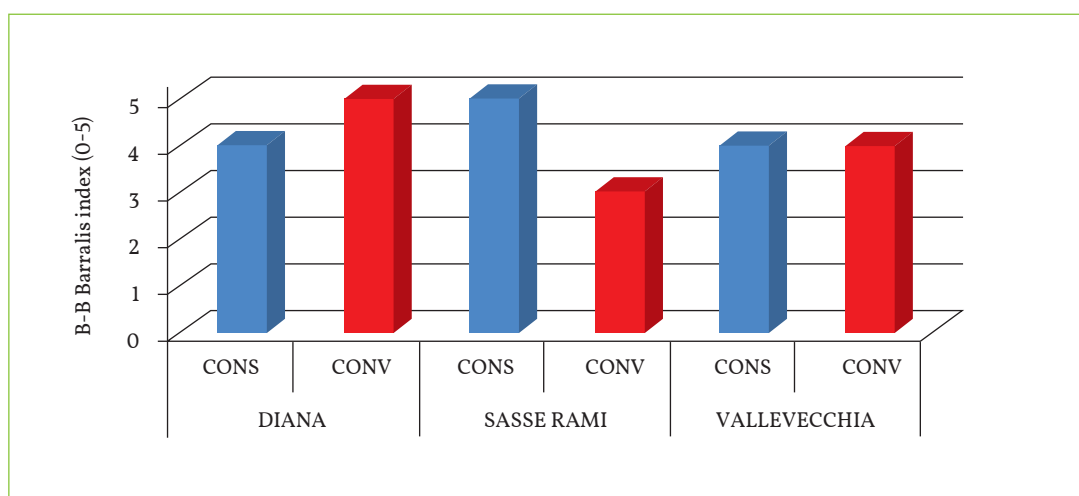


Figure 11.10 - Weed density index (Braun Blanquet mod. Barralis) in soybean in 2015-2016 on Veneto Agricoltura farms.



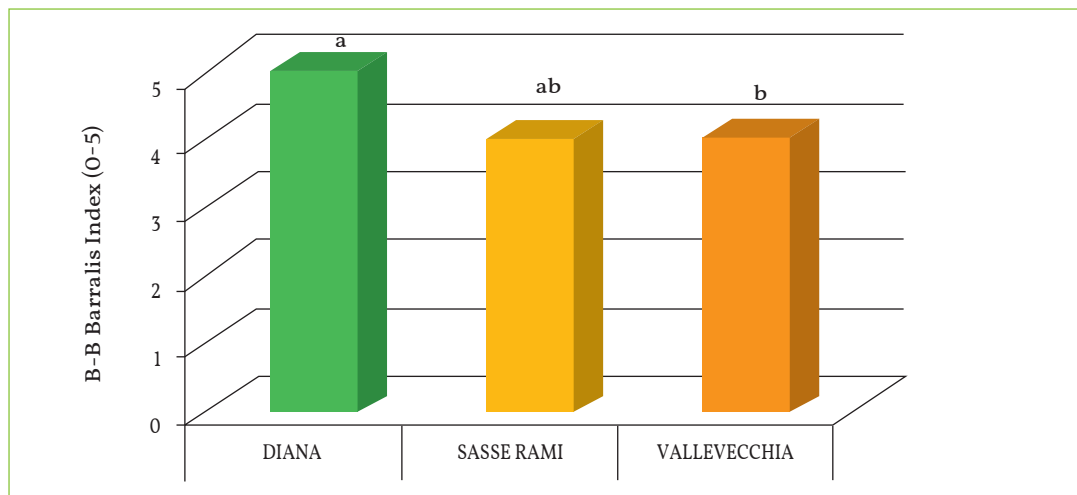


Figure 11.11 - Comparison of weed density (Braun Balnquet mod. Barralis) in soybean on the three Veneto Agricoltura farms in 2015-2016.

With regards to the Barralis density index, there was no difference between the two management techniques, while among the three farms, there were significant differences in recorded values (Fig. 11.11), with higher weed density on Diana than on Sasse Rami and ValleVecchia.

Final Considerations

In conclusion, the surveys conducted over two years (2015-2016) recorded a high variability in weed communities among the different farms and plots of land, even under the same management.

In the case of soybean and wheat, some parameters like percentage cover in the former and weed density in the latter, were higher in conservation farming as compared to Conventional agriculture.

The number of weed species, however, did not show a clear trend, which was probably due to the spatial and temporal variability inherent to the weed communities, due in part to the different soil and climatic conditions on each farm, which often made the differences between farms more marked than those between managements.

Among the problems encountered in Conservation management there is typically the risk of dissemination of perennial weeds, which tends to increase with no-till methods. This difference was most evident in wheat and soybean. In general, we have observed that, in order to tackle and limit weed dissemination, it is necessary to intervene in a timely and effective manner, and pay particular attention to the most problematic situations.

BIBLIOGRAPHY

- Beckie HJ, Hall LM, Meers S, Laslo JJ, Stevenson FC (2004). Management practices influencing herbicide resistance in wild oat. *Weed Technology* 18, 853-859
- Beckie HJ, Leeson JY, Thomas G, Hall LM, Brenzil CA (2008). Risk Assessment of weed resistance in the Canadian Prairies. *Weed Technology* 22, 741-746
- Chauhan BS, Singh RG, Mahajan G (2012). Ecology and management of weeds under Conservation agriculture: a review. *Crop Protection* 38, 57-65
- Nichols V, Verhulst N, Cox R, Govaerts B (2015). Weed dynamics and Conservation agriculture principles: a review. *Field Crop Research* 183, 56-68
- Norsworthy JK, Ward SM, Shaw DR et al (2012). Reducing the risk of herbicide resistance: best management practices and recommendations. *Weed Science* 12, 31-62
- Stanton RA, Pratley JE, Hudson D, Dill GM (2008). A risk calculator for glyphosate resistance in *Lolium rigidum* (Gaud.). *Pest Management Science* 64, 402-408

SHEET 12

SOIL BIODIVERSITY: EARTHWORMS

Earthworms are known for their positive influence on the development of organic matter and soil structure. They also play a central role in the ecological function of agricultural ecosystems. Earthworm burrows allow the rapid circulation of water, ensure aerated conditions with high water content and provide a preferential route for the development of roots at depth.

The earthworm density in the soil and their biomass depend on the amount of nourishment available, such as organic matter and microorganisms, which in turn depend on the quantity and quality of crop residues from the use of cover crops and the cultivation practices adopted. Actinobacteria, for example, increase over 6-7 times during the passage of soil through the earthworm's intestinal tract and, together with other microorganisms, they play an extremely important role in the decomposition of organic matter and in the synthesis of humus. Other organisms, such as mycorrhizal fungi, also play an important role in the availability of nutrients, such as phosphorus, which would otherwise be fixed in the soil. Moreover, the microorganisms produce growth hormones and compounds that stimulate rapid growth, improving the structure, aeration, water infiltration and retention capacity of the soil, in addition to creating a substrate with a lower impact of pathogens and plant diseases.

.....
Photo 12.1 - Adult earthworm (with the clitellum visible) identified on one of the Veneto Agricoltura farms using the pitchfork method.



Earthworm density can be up to three times higher in no-till soils as compared to soils managed using conventional methods. The effects of Conservation agriculture on soil structure in the medium term (months/years), due to the high activity of macroinvertebrates such as earthworms, may create a network of predominantly vertical macropores, which promotes the drainage capacity of the soil following heavy rainfall.

For all these reasons, earthworms are recommended as suitable for creating a summary quality index, thanks to these three characteristics:

- they are not highly mobile and are tied exclusively to the soil;
- they are easily identifiable using the pitchfork method and/or with the use of aqueous irritants;
- they are very sensitive to soil management, both through ploughing and the use of pesticides, chemical fertilizers and manure, rotations, mulching and compaction.

Experimental results on the Veneto farms

The study identified the species and numbers of earthworms, as well as dividing them into edaphic classes that could be used later to calculate the summary index QBS-e.

With regard to the estimated earthworm presence, the results of two years of sampling using the pitchfork method in the autumn of 2012 and 2014 unequivocally show that there is significantly higher density of earthworms in Conservation management as compared to Conventional farming, considering the total number of earthworms in a 25 cm square sod (30 cm deep) for both adults and juveniles (Fig. 12.1).

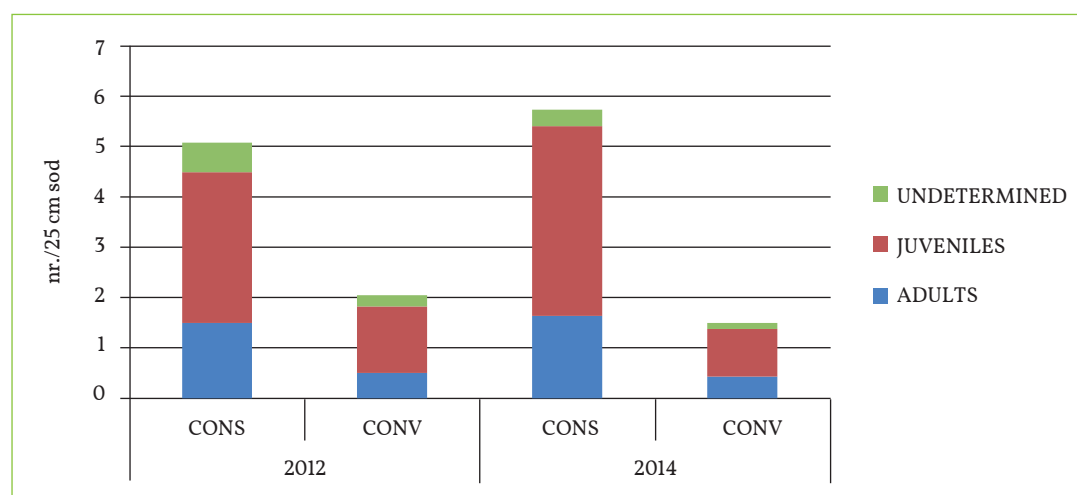


Figure 12.1 - Earthworm density (no./25 cm sod) for the different management methods in the two years of monitoring (2012-2014) for the different earthworm forms and stages (average of the three farms).

The locations also differ greatly, with a larger number of earthworms found at the Diana farm as compared to the others, perhaps thanks in part to the greater number of ecological infrastructures found there, such as hedges and grassy strips (Fig. 12.2).

The two most frequently found species of earthworm on all farms were *Allolobophora caliginosa* and *Allolobophora chlorotica* (Fig. 12.3); in particular *A. chlorotica* showed a significantly higher density in the CONS soil as compared to the CONV plots land (Fig. 12.4 top), and with differences among the different farms (more significant at Diana and Sasse Rami); *A. caliginosa* was also found to have higher density in no-till soils indiscriminately at all three farms (Fig. 12.4 bottom).

Figure 12.2 - Earthworm density (no./25 cm sod) for the different management methods on the three farms (average for the two years 2012-2014).

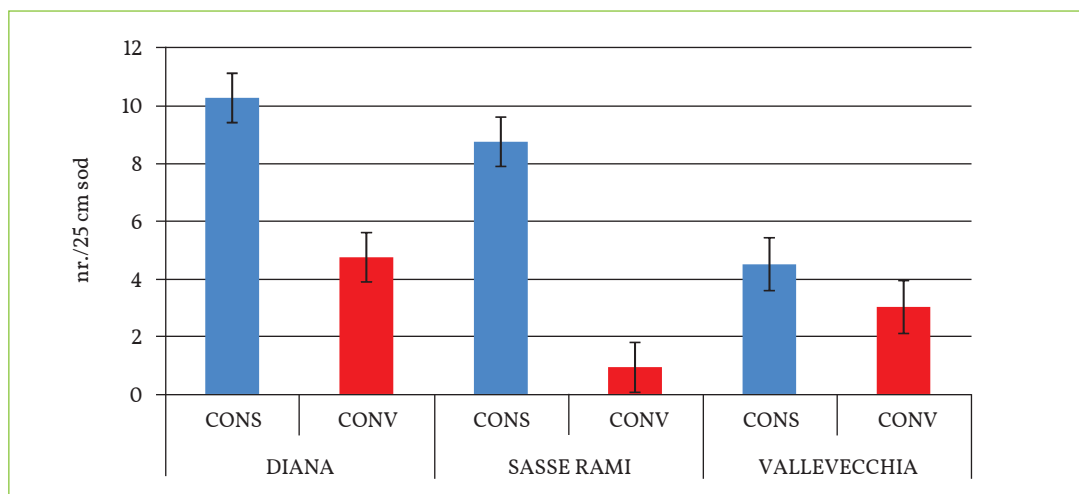
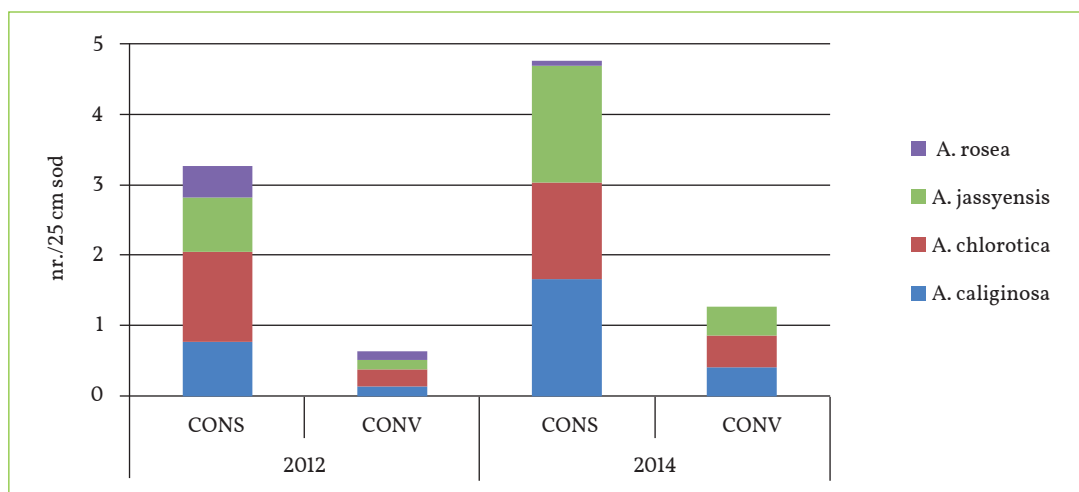


Photo 12.2 - Soil sod sampled using the pitchfork method for the counting and identification of the earthworm species (adult earthworm visible).



Figure 12.3 - Density of the more common adult earthworm species (no./25 cm sod) for the different management methods in the two years of monitoring (average for the three farms).



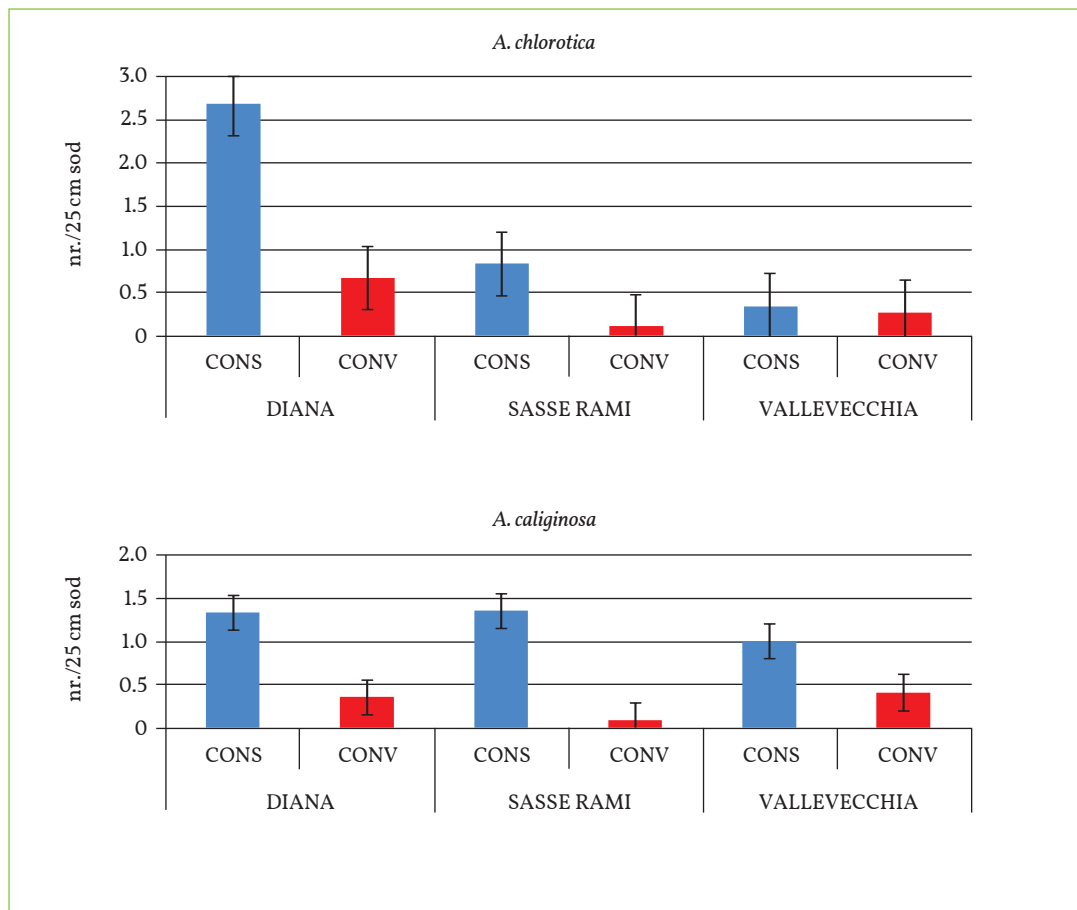


Figure 12.4 - Density of the two most common adult earthworm species (no./25 cm sod) (*A. chlorotica* - top and *A. caliginosa* - bottom) for the different management methods on three farms (average for the two years).

Finally, for the farms of the LIFE+ Helpsoil project in Veneto (5 in all, including the 3 Veneto Agricoltura pilot farms monitored in the previous survey with the Monitamb 214i project) there was confirmation of the much higher density in CONS as compared to CONV agriculture (Fig. 12.5), a trend already recorded at global level where Conservation management has been compared with Conventional agriculture using classic methods, such as ploughing.

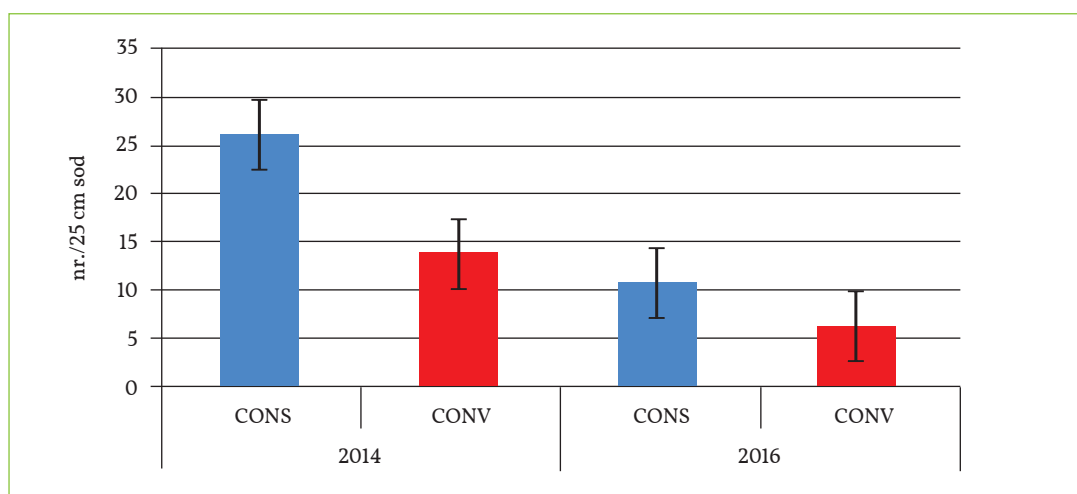


Figure 12.5 - Total earthworm density (no./25 cm sod) for the different management methods in the two years of monitoring of the Helpsoil Project (average for the five farms).

Acknowledgements

The study, based on the taxonomic classification of species belonging to the Lumbricidae family, was undertaken by Dr Vladimir Toniello, thanks also to the experience gained as part of the working group of Professor Maurizio G. Paoletti of the Department of Biology of the University of Padua, who designed the software for the identification of earthworm species.

BIBLIOGRAPHY

- MANUALE DI AUTOVALUTAZIONE DEL SUOLO Life+ Environment Policy and Governance
LIFE CarbOnFarm progetto: LIFE12 ENV/IT/000719 www.carbonfarm.eu
- Paoletti M.G., Sommaggio D., Fusaro S. 2013. Proposta di Indice di Qualità Biologica del Suolo (QBS-e) basato sui Lombrichi e applicato agli Agroecosistemi. *Biologia Ambientale*, 27 (2): 25-43.
- Paoletti M.G. and Gradenigo C. 1997. Lombri Cd-rom: un programma innovativo per classificare e utilizzare i lombrichi come bioindicatori. *Biologi Italiani*, 27 (5): 10.
- VISUAL SOIL ASSESSMENT VSA – Field Guide ISBN 978-92-5-105937-1 © FAO 2008. Annual crops 12-13. <http://www.fao.org/docrep/pdf/010/i0007e/i0007E00.pdf>

SHEET 13

SOIL BIODIVERSITY: MESOFAUNA

Soil fauna is one of the most important components that ensures the proper functioning of the soil, by acting in a complex manner on its physical, chemical and biological characteristics. The fauna is made up of mostly small organisms, capable of moving among the micro and macropores within the soil..

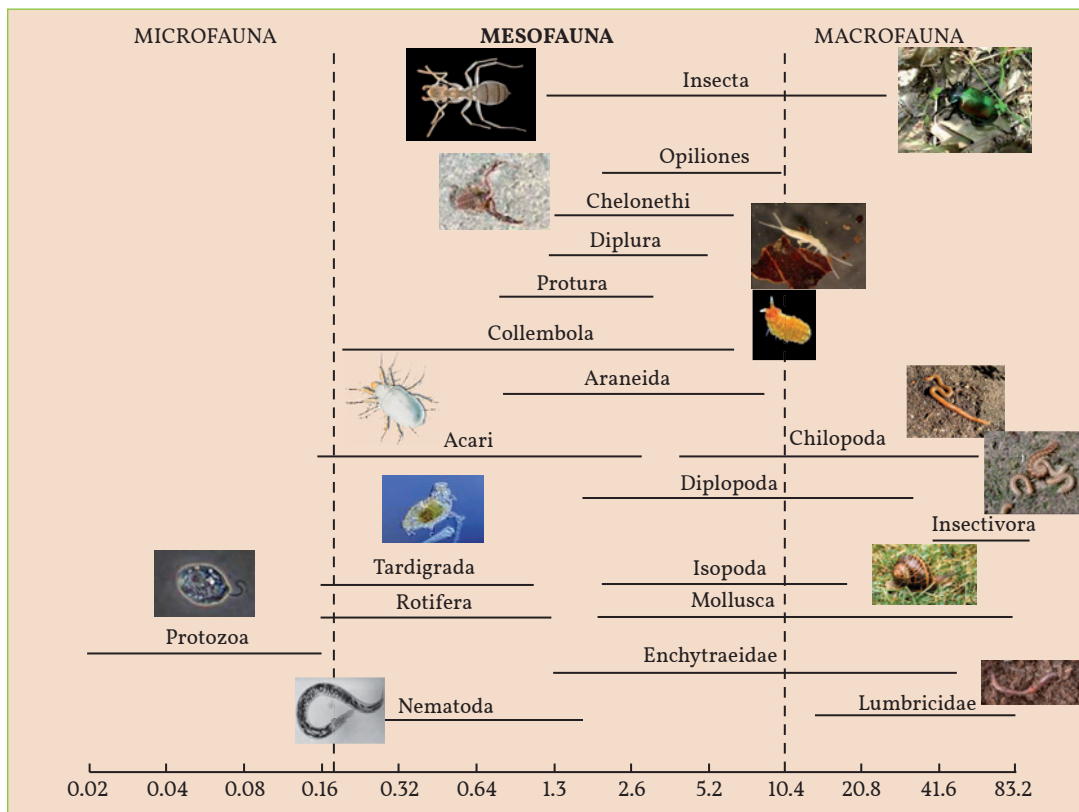


Figure 13.1 - Distribution of microfauna, mesofauna and macrofauna in soils.

The chain of debris in the soil that becomes the basis for hypogeal trophic networks has a fundamental role, given that many organisms feed on the plant and animal debris that is deposited on the ground.

The soil fauna has a mainly mechanical role, but also affects the soil through the secretion of skin mucus that acts as a cement for the mineral particles in the soil, promoting stability, structure and making it less vulnerable to erosion. Moreover, mucous secretions, droppings and the animal's body itself bring part of the soil's nutrients, in particular potassium, phosphorus and nitrogen, reducing the C/N ratio of litter and facilitating its decomposition. Lastly, digging organisms create spaces within the soil with resulting increases in porosity; the increase in pores between the clumps of soil in turn increases aerobic bacterial activity and the consequent speed of the breakdown of organic matter.

The mechanical action of moving soil particles by the organisms also has positive effects on water retention, percolation and development of the rhizosphere. In addition, the action of invertebrates that use the microflora as a source of food is crucial to both regulation of the biomass and its activity and the diffusion of microorganisms.

Springtails, for example, hexapods often found in the soil in very high densities, by feeding on fungal hyphae and spores, disperse them via their faeces, even up to a distance of a few metres.

Photo 13.1 - Arthropods
extracted from a
sample of soil and
photographed under a
stereomicroscope.



Photo 13.2 - Typical
arthropods found in soils
(Dipluro, Pauropode and
Diplopode, respectively)
photographed under a
stereomicroscope.



Photo 13.3 - Adult
individuals of the
Folsomia candida
(Collembola)
photographed under a
stereomicroscope.



It is important to emphasize that the majority of biodiversity in agricultural systems is found in the soil. Interactions within the food chain among soil-dwelling organisms have profound effects on the quality of the crops, the incidence of diseases and health of the organisms themselves.

Soil fauna is made up of organisms that are particularly sensitive to natural or anthropogenic changes to the chemical-physical balances that characterize this environment; such organisms can thus be considered good indicators. Over the course of evolution, the confinement of groups of mesofauna within the soil has led to the impossibility for them to survive the deterioration of soil factors, or in any case intervals and cycles of variations that are too far beyond their tolerance limits. Even simple trampling can cause a dramatic lowering of the biological diversity of the soil mesofauna.

QBS-ar Index and Biological Forms

The *Soil Biological Quality Index QBS-ar*, was created with the intention of evaluating the level of adaptation of the mesofauna (microarthropods) to the soil. This index is based on the notion that the presence of a large number of groups of microarthropods that are well adapted to the soil, and therefore vulnerable to soil disturbances, corresponds to good biological quality. Operationally, the microarthropods are divided according to their “Biological Forms” (FB), with the intention of evaluating the degree of adaptation of hypogeal life and to overcome the difficulties of taxonomic classification.

The *QBS-ar* is therefore a synthetic index of biological quality of the soil and allows us to evaluate the effects of different agronomic practices.

In the years of experimentation of Conservation agriculture, the *Soil Biological Quality Index QBS-ar* was thus calculated and, in order to gain a more complete and exhaustive overview on the environments investigated, in the final year, the organisms found in the samples were counted for each group (number of FB).

Calculation of the QBS-ar Index and Biological Forms

Dividing the organisms into “*Biological Forms*” (FB) means assessing the soil adaptation of each organism, through the analysis of elements that show the better or poorer adaptation to this extreme environment, such as loss of pigmentation, reduction in the length of the tail or the reduction or loss of visual system, etc. This division allows us to give each taxonomic group a numerical value called the “*Ecomorphological Index*” (EMI): the EMI, between 1 and 20, increases with the increase in number of morphological elements of soil adaptation. For certain systematic groups, all, or almost all, of the species have adapted to soil life; in this case, a single EMI value is allocated to the whole group. For other groups where different levels of adaptation can be identified, a range of values indicated in the EMI tables is used. Through this procedure, we can also obtain a table of the presence/absence of the different groups of microarthropods. If more than one biological form is identified in a group, the calculation of the *QBS-ar* considers the highest EMI value that represents the maximum degree of adaptation to the soil shown by the group for the station under examination. The calculation of the *QBS-ar* is obtained by adding up the individual EMI values, while the total number of Biological Forms recorded for the different groups is an additional index.

Experimental results on the Veneto farms

From the results obtained in the first four years of experimentation (2011-2014), the different treatments showed values fully comparable to those generally observed in cultivated fields, both in terms of groups of microarthropods and *QBS-ar* values.

However, analyzing the average trend on Veneto Agricoltura farms during the four years of the project MONITAMB 214i, both the *QBS-ar* and FB values of conservation management (CONS) were always higher than or equal to the respective conventional method (CONV); moreover, the majority of the entomological groups responded positively to the lack of soil disturbance and the use of permanent cover, with the exception of Collembola and Diptera, which appear to benefit more from conventional practices.

Furthermore, considering the trend at the five Veneto farms in the Helpsoil project, the average QBS-ar values at the start and end of the project (2014-2016) were statistically different in favour of conservation management (CONS) as compared to conventional farming (CONV), while there was no significant trend recorded comparing the two years of sampling. Ultimately, these data seem to highlight that conservation management techniques have a lower impact on soil communities than conventional ones, even if six years of survey are in any case a short time frame with regard to the dynamics of agricultural soil fertility evolution.

Figure 13.2 - Average trend on the three farms of Veneto Agricoltura of the Soil Biological Quality Index (QBS-ar, top) and the number of Biological Forms (FB, bottom) in the years 2011 to 2014; comparison between management methods: CONS = Conservation; CONV = Conventional.

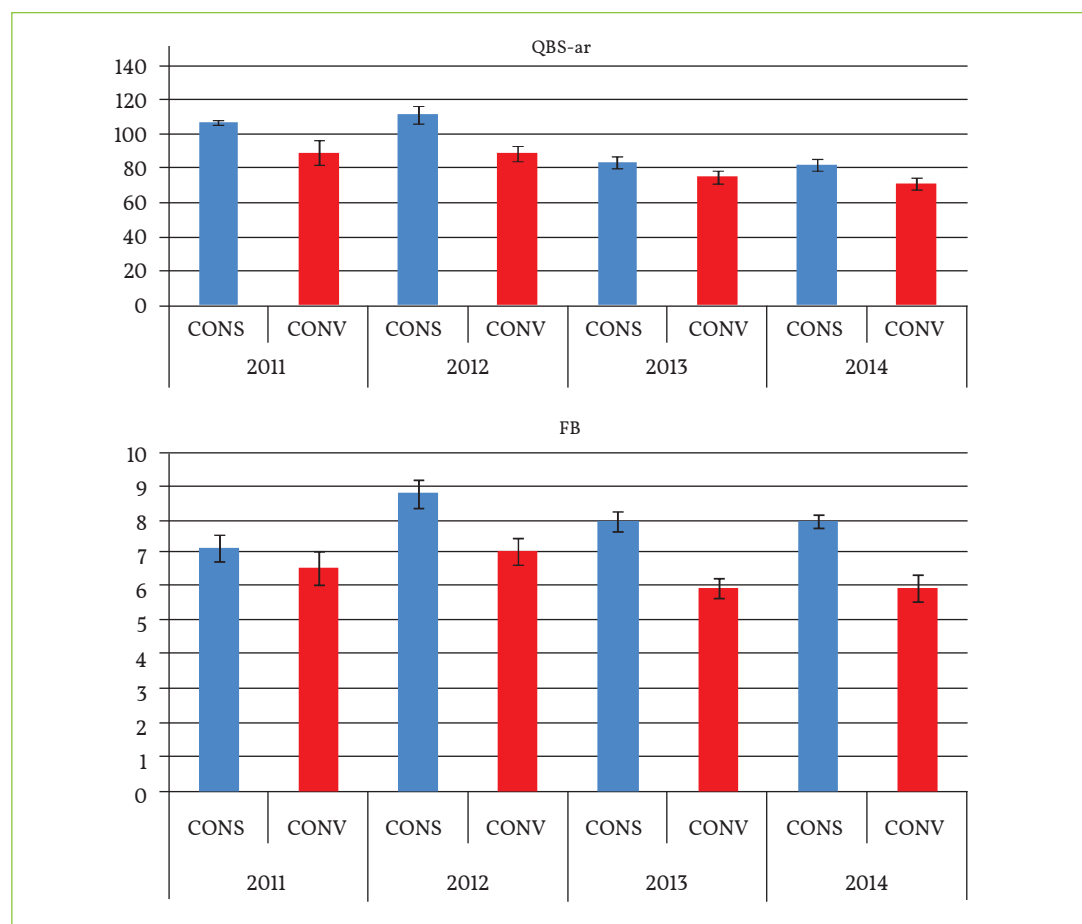
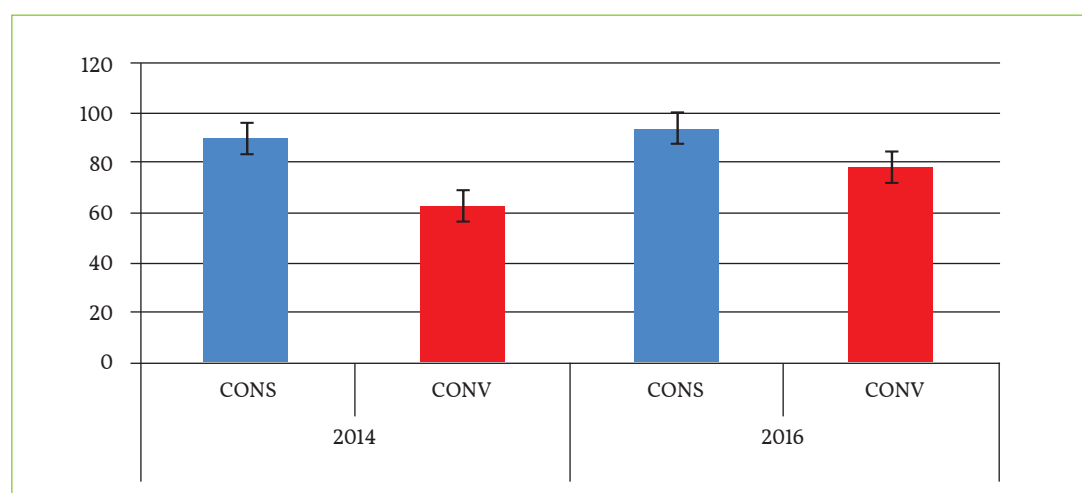


Figure 13.3 - Average trend on the five Veneto farms participants in the HELPSOIL project, Soil Biological Quality Index (QBS-ar) in the years 2014 and 2016; comparison between management methods: CONS = Conservation; CONV = Conventional.



BIBLIOGRAPHY

- Brussaard L., de Ruiter P.C., Brown G.G., 2007. Soil biodiversity for agricultural sustainability. *Agriculture, Ecosystems and Environment*, 121. 233-244.
- Parisi V., 2001. La qualità biologica del suolo. Un metodo basato sui microartropodi. *Acta Naturalia de «L'Ateneo Parmense»*, 37 (3/4). 105-114.
- Parisi V., Menta C., Gardi C., Jacomini C., Mozzanica E. 2005. Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. *Agriculture, Ecosystems & Environment* 105, p. 323-333.
- Menta C., 2008. Guida alla conoscenza della biologia e dell'ecologia del suolo – Funzionalità, degrado, indicatori. Bologna: Alberto Perdisa Editore, p. 1-265, ISBN: 978-88-8372-454-1.
- Menta C., Conti F.D., Pinto S., Bodini A., 2018. Soil Biological Quality index (QBS-ar): 15 years of application at global scale. *Ecol. Indic.* 85, 773-780. DOI: 10.1016/j.ecolind.2017.11.030
- Menta C, Bonati B, Staffilani F, Conti FD, 2017. Agriculture management and soil fauna monitoring: The case of Emilia-Romagna Region (Italy). *Agri Res & Tech: Open Access J.* 4(5): 555649. DOI: 10.19080/ARTOAJ.2017.04.555649002
- Menta C., Leoni A., Conti F., 2011. Il ruolo della fauna edafica nel mantenimento della funzionalità del suolo. In: *La percezione del suolo – atti del workshop*, ISBN: 978-88-95315-11-9, Palermo.



SHEET 14

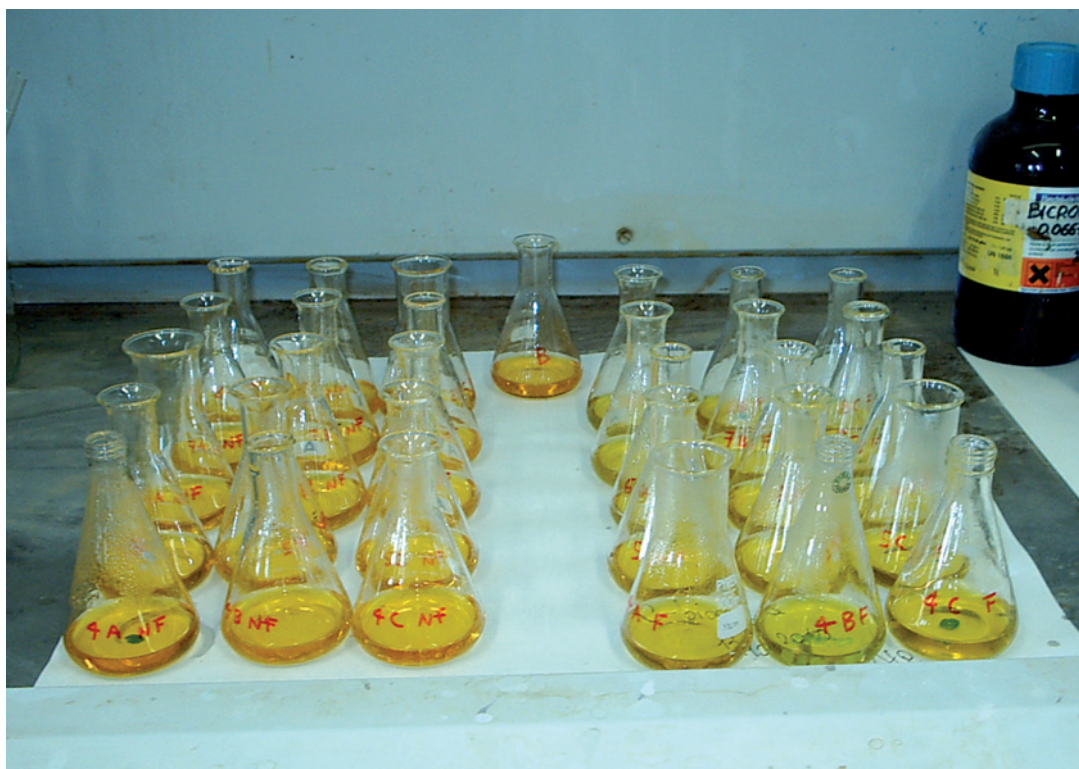
SOIL BIODIVERSITY: MICROBIOTA AND ENZYMES

This sheet outlines the results of three soil quality indicators determined by conservation management: carbon and nitrogen in microbial biomass and enzymatic activity, highlighting the experimental data acquired in the measurements recorded in 2012, 2013 and 2014 at three farms and within the field of Conservation and Conventional agriculture.

Carbon in the Microbial Biomass

Carbon contained in the microbial biomass is one of the soil components most commonly used in the literature to estimate soil quality. Despite the fact that the percentage of microbial biomass in organic matter is usually lower than 5%, it has many important functions in soil ecosystems.

.....
Photo 14.1 - Fumigation methods have been used to quantify soil microbial biomass - according to Sparling and West (1988).



Conservation agriculture can increase soil microbial biomass. This effect is related to the increase of organic matter in the soil, which provides carbon for the development of microorganisms. This is a phenomenon that is highlighted in the long term and is strongly influenced by seasonal trends and climate.

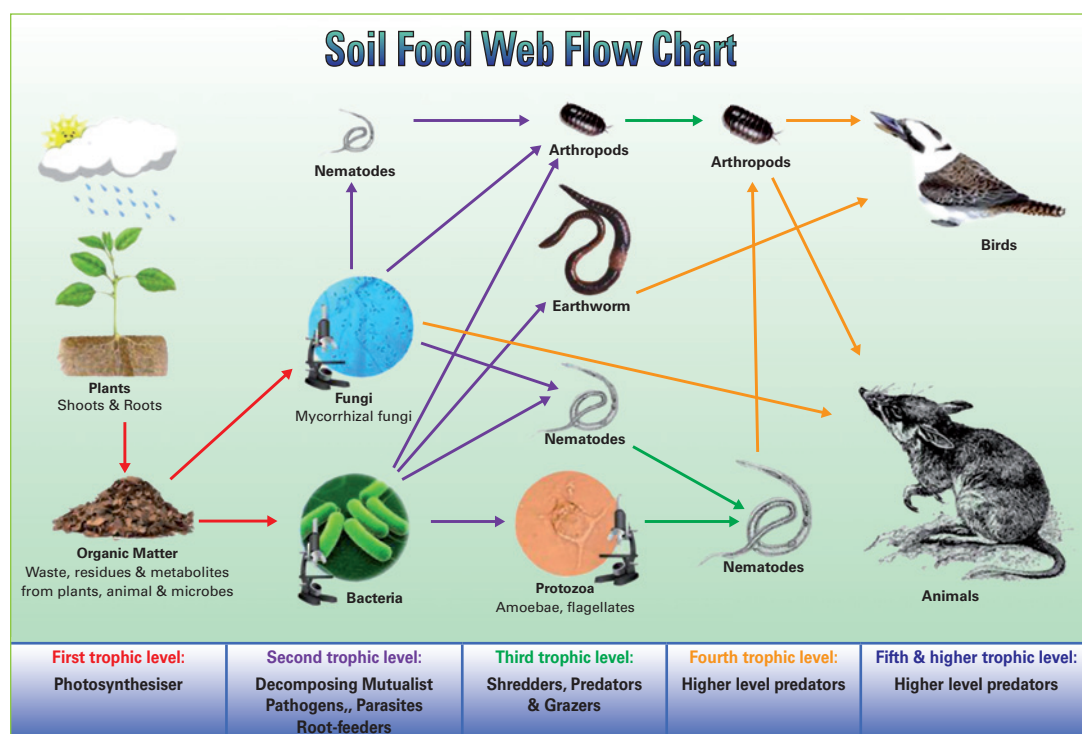
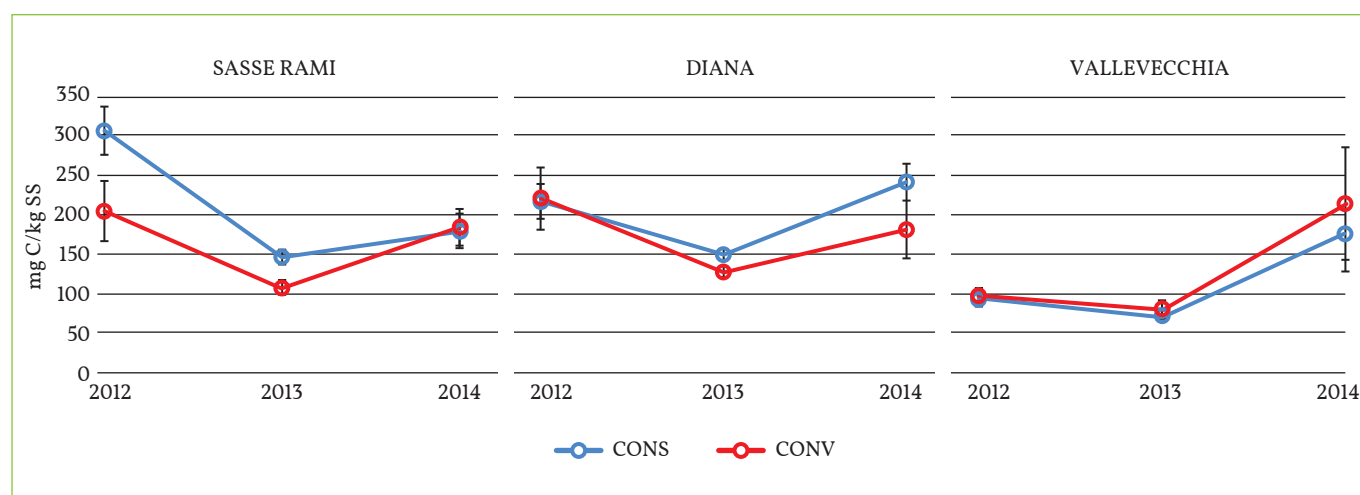


Figure 14.1 - Soil Food trophic chain <http://patrickwhitefield.co.uk/soil-fertility-factors/1-web-2/>

Experimental results in the Veneto Agricoltura pilot farms

Considered as a whole, the data detected at the three farms over the three years do not show significant effects of the different managements, while there appears to be overall a perceptible decline in the biomass carbon content in 2013 (Fig. 14.2).

Figure 14.2 - Mean \pm standard error of soil microbial carbon content (mg C/kg dry soil).



Sasse Rami farm is the only one that has a significant higher content of microbial carbon in conservation management, in the comparison between CONS and CONV at the different farms. This confirms how the different physical and chemical conditions of the soil found at the three farms affect responses to the changes in agronomic management. This could be the result of the different locations of the farms that influence the phenomena of accumulation and degradation of biomass depending on microclimate conditions and different pedological properties, in particular the soil structure. It may also be the effect of the different soil conditions at the three farms prior to the test.

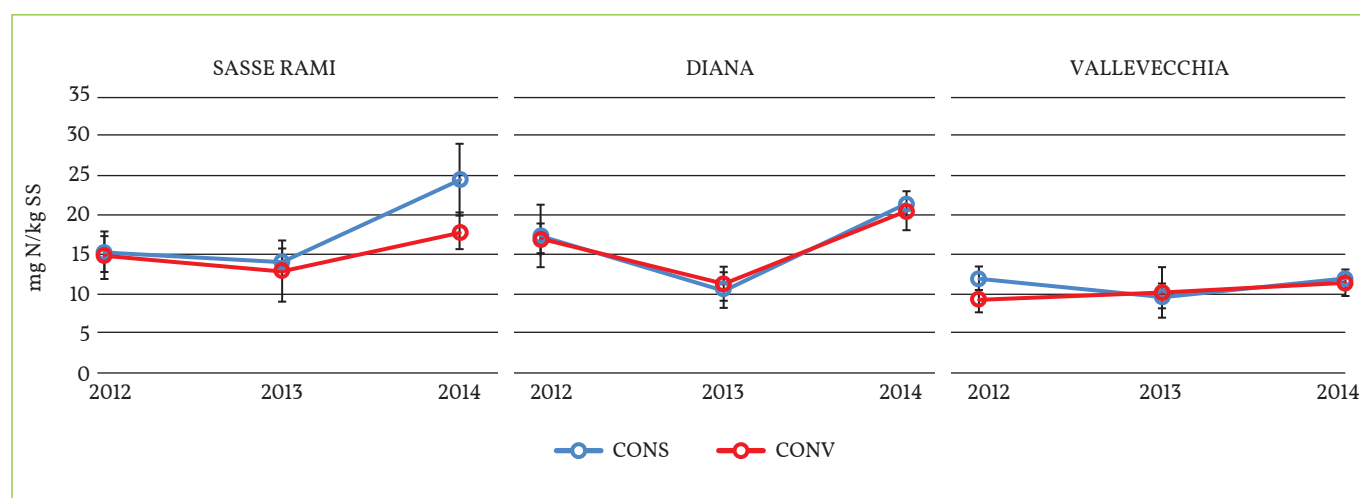
Nitrogen in the microbial biomass

The turnover time of nitrogen immobilised in microbial biomass is about ten times faster than the nitrogen from plant tissues. The determination of microbial nitrogen is therefore important for the quantification of nitrogen dynamics in the agro-ecosystems as it controls the availability and loss of inorganic nitrogen in the soil.

Experimental results in the Veneto Agricoltura pilot farms

The soils analyzed in the Veneto Agricoltura farms do not show statistically significant differences of microbial nitrogen content in the soils subjected to different agronomic management, while there appears to be a perceptible decline in nitrogen biomass in 2013 in both management methods (Fig. 14.3).

Figure 14.3 - Mean \pm standard error of microbial nitrogen content in soils (mg N/kg dry soil).



The soil at Sasse Rami showed a nitrogen increase in the biomass in the last year of the study, in samples from conservation management; the results from Diana followed a pattern similar to that of the carbon biomass, with a decline in 2013 compared to the other two years; however, ValleVecchia farm had comparably lower values than the other farms.

The nitrogen content of the biomass also responded differently to agronomic management in the three farms taken into consideration.

Enzymatic activities

The activity of edaphic enzymes can be considered as a sensitive and pre-emptive indicator when establishing the soil degradation level in natural habitats and agro-ecosystems, and is adequate to measure the impact of pollution on soil quality.

This detection system requires placing the soil in contact with a substrate that has been subject to the attack of the studied enzyme, which frees a reagent that can be detected by spectrophotometry.

The activity of soil enzymes generally increases in Conservation agriculture, under conditions of organic matter accumulation and greater microbial biomass. This index is also strongly influenced by climatic conditions, especially in the Mediterranean area, with periods of low rainfall that reduce the edaphic moisture.

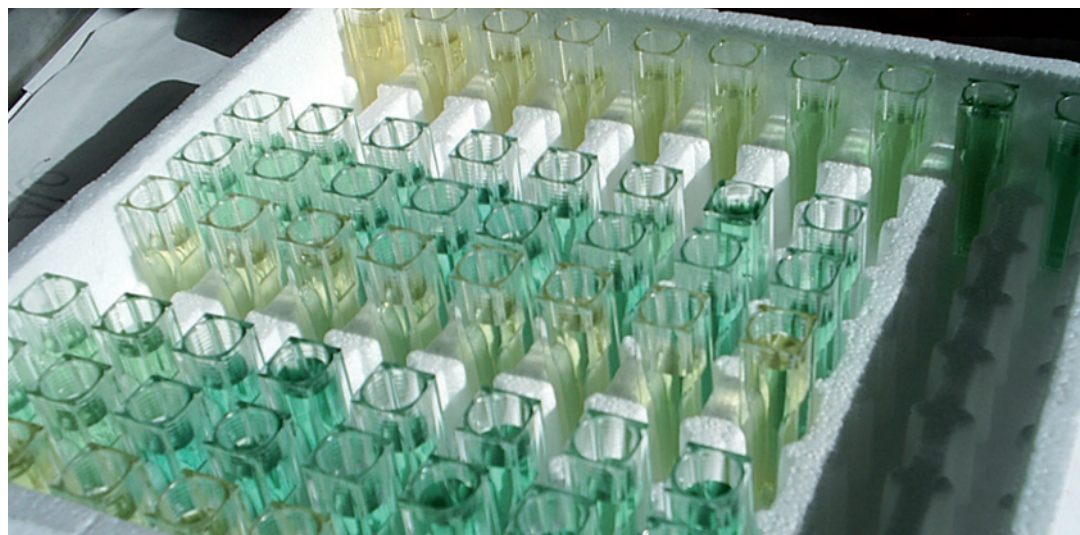


Photo 14.2 - Detection of the content of Fluorescein Diacetate Hydrolysis (FDA, Adam and Duncan method, 2001), and β -glucosidase (Eivazi and Tabatabai method, 1988).

Experimental results in Veneto Agricoltura pilot farms

As the farm constitutes a discriminating parameter for enzymatic activity, data was analyzed separately in the three locations (Fig. 14.4).

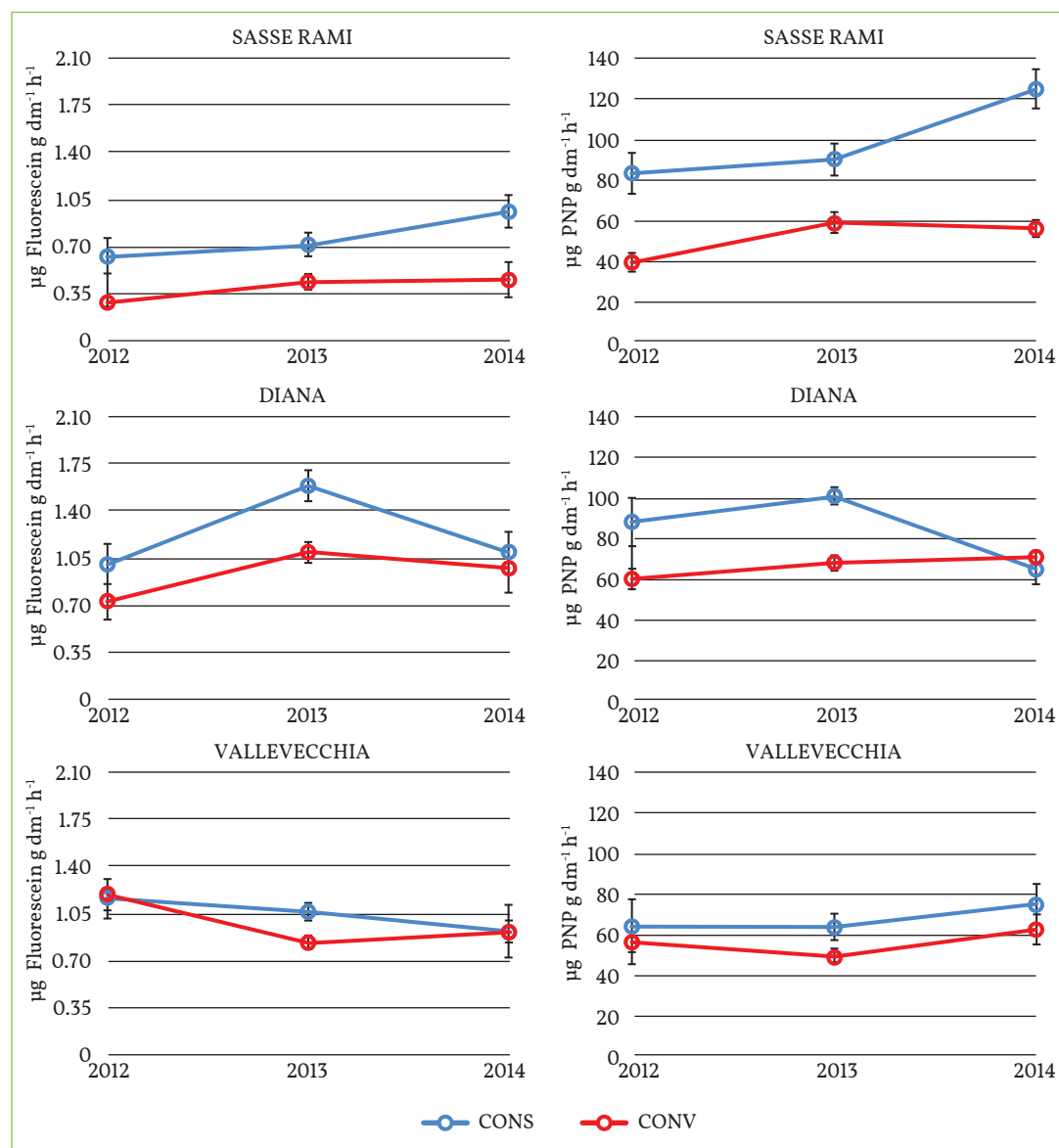


Figure 14. 4 - Mean \pm standard error of the PNP content ($\mu\text{g g dm}^{-1} \text{h}^{-1}$) for β -Glucosidase (right); Fluorescein content ($\mu\text{g g dm}^{-1} \text{h}^{-1}$) for FDA (left).

The Sasse Rami farm showed significant differences for both enzyme activities in three years, with higher values on average for the conservation method compared to the conventional one, and a gradual increase over the three years (Fig. 14.4). Management changes also lead to significant differences for both activities in the Diana farm, with higher conservation values on average, compared to the conventional method. Finally, the conservation management did not significantly change the average enzymatic activity in the ValleVecchia farm, even if the values were slightly higher in conservation management, for both activities, similarly to the other two sites.

Final Considerations

The farms concerned are characterized by different edaphic properties that affect the response of the parameters of the enzymatic activities to the two managements, confirming the fact that the soil responds differently to management practices depending on its intrinsic characteristics and the surrounding environment. In our case study, the soil of the Sasse Rami farm is in a pedoclimatic condition that allows short-term response in terms of biological fertility, even after just one year of being adopted, and subsequently confirmed in the following years. The soil of the ValleVecchia farm is taking much longer to respond. In the early years of management change to Conservation agriculture, a decrease in edaphic fertility is often reported. At the Diana and ValleVecchia farms, the soil subject to the conservation method showed higher values compared to the conventional method, indicating an improvement of the biological conditions of the soil already by the end of the second year of application of the measure (2013). Finally, the data of enzymatic activities is often related to the values of organic carbon in the soil. In this study, the trend found in the organic carbon content, with higher average values in conservation management, seems to correspond to the results of enzymatic activities.

BIBLIOGRAPHY

- Andrews S.S., Karlen D.L., and Cambardella C.A., 2004. The soil management assessment framework: A quantitative soil quality evaluation method. *Soil Sci Soc Am J* 68(6):1945-1962.
- COMAGRI, 2007-2009. Sustainable agriculture and soil conservation.
- Gil-Sotres F., Trasar-Cepeda C., Leirós M.C., and Seoane S., 2005. Different approaches to evaluating soil quality using biochemical properties. *Soil Biology and Biochemistry* 37(5):877-887.
- Jimenez M.D., de la Horra A.M., Pruzzo L., and Palma R.M., 2002. Soil quality: a new index based on microbiological and biochemical parameters. *Biol Fert Soils* 35(4): 302-306.
- Moore J.M., Klose S., and Tabatabai M.A., 2000. Soil microbial biomass carbon and nitrogen as affected by cropping systems. *Biol Fert Soils* 31(3-4):200-210.
- Nannipieri P., Kandeler E., and Ruggiero P., 2002. Enzyme activities and microbiological and biochemical processes in soil. In: Burns R.G., and Dick R.P., editors. *Enzymes in the Environment* Marcel Dekker. New York. p 1-34.
- Smith J.L., and Paul E.A., 1990. The significance of soil microbial biomass estimations. In: Bolag J.M., and Stotzky G. S., editors. *Soil Biochemistry*. Marcel Dekker: New York. p 357-396.
- Trasar-Cepeda C., LLeiro's M., Seoane S., and Gil-Sotres F., 2000. Limitation of soil enzymes as indicators of soil pollution. *Soil Biology and Biochemistry* 32:1867-1875.



PART TWO

**LAND MANAGEMENT
IN CONSERVATION
AGRICULTURE**

SHEET 15

SOWING AND HARVESTING MACHINERY

In Conservation agriculture, especially when no-till is applied, the whole cultivation technique (starting from the choice of crop, management of crop residues and harvesting method) must be carefully considered, providing solutions that reduce soil compaction. The machines that enter the field must be adapted and used in moments suitable for reducing this phenomenon.

Sowing on no-till (sod-seeding)

Sod-seeding machines are substantially different from the conventional seeders because, in addition to creating an optimal environment for seed germination, they allow:

- the ground to be broken only in the area used for seed furrows;
- the rest of the ground not to be disturbed, or even trodden on;
- the residues of the previous crop to be cut effectively leaving the great mass of residues undisturbed on the surface.

For this, compared to conventional seeders, no-tillage seeders are much heavier and bulkier, and require powerful tractors that share the same large working capacity.

This type of equipment is fitted with:

- specific components that prepare the rows and manage crop residues (deviation, cutting, incorporation);
- furrow openers;
- furrow closers;
- compaction components.

Specific components that work on the preparation of the row and the management of crop residues

The crop residues are partially displaced by star-shaped disks, set at different angles according to the type of feed; they are followed by other kinds of disks (smooth, toothed, and corrugated) that cut the remaining residues, exerting a weight of 100-200 kg, whilst inducing minimal work along the seed row, and adapting to the type of soil.

Furrow openers

They are responsible for creating the groove in the soil and depositing the seeds at the correct depth. There are three types of furrowers: blade, disk and subsurface. The most often used, are the disk furrowers because they can adapt to any need or situation according to the soil condition. However, the machines that use this type of furrower are very heavy and more suitable for heavy and difficult soils. Instead, the blade furrower, which is simpler and more cost-effective may be recommended for soil that is well levelled and/or very stony. The subsurface furrower, an evolution of the blade furrower, also performs a horizontal cut, placing the seed not in contact with the crop residues.

Compaction Components

These components play a vital role in the covering of the seed and its adherence with the soil. This is for rapid hydration, a prerequisite for achieving homogeneous germination and regular emergence of the seedlings of all crops. The crop needing a perfectly covered furrow is maize, as otherwise it will be easily eaten by fauna. Generally, the components that cover and compact the soil can be individual or combined into a single device, whose load on the ground is adjusted by a spring.



Photo 15.1 - Mechanical seed drill for sod-seeding,

Harvesting machines

After seeding, in order to complete and maintain the good structure of the soil under no-till conditions, the harvesting is done with modern combine harvesters, suitably prepared to reduce soil compaction and crop residue distribution.

Especially when harvesting grains, the combine harvester must ensure the proper distribution of straw and husks during the discharge operation. This avoids to create a thick layer of biomass, which, would become a real obstacle during sod-seeding. Therefore, fitting straw and chaff spreaders at the rear of the combine harvesters is recommended.

Modern combine harvesters with low pressure tyres or rubber tracks are fundamental when the soil is not tilled, and are always recommended because they can positively affect all the other cultivation techniques, including conventional ones.

Indeed, a wide tyre has very low inflation pressures which increases the surface area in contact with the ground, with a pressure on the latter of 0.8 bar, practically more than halved compared to that produced by a standard tyre, at 1.7 bar.

A rubberized track further increases the surface area in contact with the ground, with a pressure of 0.5 bar, comparable to the same force as a person walking on the ground.

In light of these considerations, these types of tyres may also be used when the bearing capacity of the soil is rather low.

In addition to adjusting the combine harvesters, the reduction of soil compaction can be pursued with techniques aimed at limiting vehicle traffic on the ground by adopting appropriate methods, such as: the adoption of controlled traffic or traffic lanes in the case of fertilization and pesticide applications, choice of the optimum moment and promptness of intervention, and organization of the transport yards. In addition, other agronomic practices are recommended because they tend to prevent the phenomenon: introduction of cover crops, proper management of crop residues, organic fertilization, introduction of suitable renewal crops in the rotation. In this sense, an important contribution is made by the adoption of precision farming techniques as demonstrated by the LIFE+ Project Agricare (www.lifeagricare.eu).

.....
Photo 15.2 - Example of a
tractor with a rubberized
track.



SHEET 16

FERTILIZER AND LIQUID MANURE DISTRIBUTION TECHNIQUES

Finding solutions for rational distribution of livestock effluents and other types of wastes (e.g. digestates) is fundamental in the context of Conservation agriculture as they are an alternative agronomic resource to chemical fertilizers. It is thus necessary to have suitable equipment to ensure:

- correct supply of nutrients in the soil;
- reduction of nitrogen losses, even with the increase of the crop distribution period;
- reducing disturbances to the soil when covering and compacting it;
- absence or reduction of odours;
- low cost;
- respect of regulatory constraints.

Here we describe the equipment tested at the pilot and demonstration Diana farm, which was considered suitable for the distribution of farm waste in the pre-sowing and cropping periods, to evaluate the methods for burying organic matter in Conservation agriculture (no-till).



Photo 16.1 - Towed Liquid Manure Spreader (tank) - VENDRAME M60 Type.

Towed Liquid Manure Spreader (tank) - VENDRAME M60 type

Vendrame M60's tank falls within the broader category of towed liquid manure spreaders which have common construction characteristics of a tank and a series of equipment to regulate the pressure and dose of the manure to be distributed in the field.

The manner in which the manure is put under pressure can be:

- the introduction of air into the tank (manure spreader with pressure tanks);
- direct action on the liquid by means of volumetric pumps or centrifuges to pressurize the liquid (manure) and direct it towards the distribution system located in the rear of the machine (manure spreader with regulated tank at atmospheric pressure).

Today, these are without doubt the most popular machines in many small and medium-sized farms due to their relatively simple construction and affordability. They must meet weight and maneuverability requirements, and are therefore characterized by small mass and dimensions, allowing for a higher working width.

To demonstrate the features that have just been outlined, we can refer to some of the construction aspects and functional features of the VENDRAME M60 tank, which is being tested at the Diana farm. This is a single axle towed implement mounted on a steel frame attached to the tractor with a drawbar, featuring a hydraulic braking system and leaf spring suspensions.

This machine, and similar models from other manufacturers, enables burying of the manure even at a very shallow depth (approx. 5 cm), on bare soil and on fields with wide crop rows, which is an efficient solution to allow the fertilizer distribution in the ideal period for the crops. In fact, the adjustable track (from 1880-2250 mm), the equipment with narrow tyres (270/95-44), and reasonable maximum load (8000 kg), are the keys to success in avoiding useless bulk on the plots, and make it very easy to change direction at the end of the field. The shape of the injector tool makes it suitable for hoeing with crops in place (e.g. maize, sorghum, etc.) and for processing stubble after the harvest of the previous crop.

The lateral support wheels for adjustment of the work depth, the elastic or rigid blade furrowing components (fixed on an articulated parallelogram), the versatility of the distribution apparatus that allows rapid displacement, exchange and replacement of its components, are all valid solutions for the burial of organic matter on land in which it is important to disturb the soil as little as possible.

Self-propelled sprayer - CHALLENGER TERRAGATOR 2244NMS type

Other solutions for manure distribution may be the self-propelled liquid manure spreader “Challenger Terragator 2244NMS”, used in a demonstration trial at the Diana farm and briefly described below.

It is part of the large size ‘self-propelled machinery’, consisting of towing tractors with considerably powerful engines (243 kW) and four isodiametric wheels with power shift transmission and electronic controls. The chassis can support a 15 cubic metre tank, with solutions between 5 and 21 cubic metres.

The wide tyres (1050 mm) are equipped with a continuous control of the inflation/deflation pressure and a misalignment of the rear axle compared to the front one, so that the front wheel ruts are not covered by the back ones, reducing the trampling on soil with low load-bearing capacity. These enable this machine to limit the effects of soil compaction to 0.5-0.7 bar.

This machine is equipped with the most modern electronic systems:

- an on-board satellite navigation system for georeferencing all operating data;
- assisted or semi-automatic driving system to eliminate the occurrence of overlaps or strips of land that do not get treated;
- a system that controls the dosage (manual or automatic) through the use of prescription maps, which provide a variable distribution of the organic matter (precision farming).

.....
Photo 16.2 - Self-propelled sprayer
- CHALLENGER
TERRAGATOR 2244NMS
type.



This machine, despite its large size, has great versatility, thanks to the connections with the distribution equipment of livestock effluents in the field. In-band distribution systems and localized interleaving systems in lawns and straw cereals are the systems that allow extraordinary work capacities to be reached.

The self-propelling machines appropriate for comprehensive use (as they can be used by several farms, even if they are far from the storage point) are a valid solution for the distribution with shallow manure burial.

The distribution on covered soil by the classic large inter-row crops (such as maize, sorghum, beet, etc.) may be more difficult due to their size and the size of the tyres, which should be replaced by narrower tyres specifically for this kind of operation, but it is also possible to intervene in the spring on crops seeded in narrow rows with the appropriate equipment.

Underground Piping System

An underground piping system on land plots could be an alternative to the aforementioned manure distribution systems.

An example may be that of the Aquafert Company, which provides a drip system for the distribution of manure on land covered by a crop, by injecting it into the soil. The manure is previously stored in a mobile tank, installed near the pumping system.

The system's instruments and equipment are the following:

- Pumping system;
- Filtering system for fertigation;
- Control systems (flow-rates, pressure and automation sectors);
- Non-return valves, air relief valves and volumetric meters;
- Both main and secondary pipelines, or head pipes composed of flat pipes that can be installed with specific fittings;
- Drip lines.

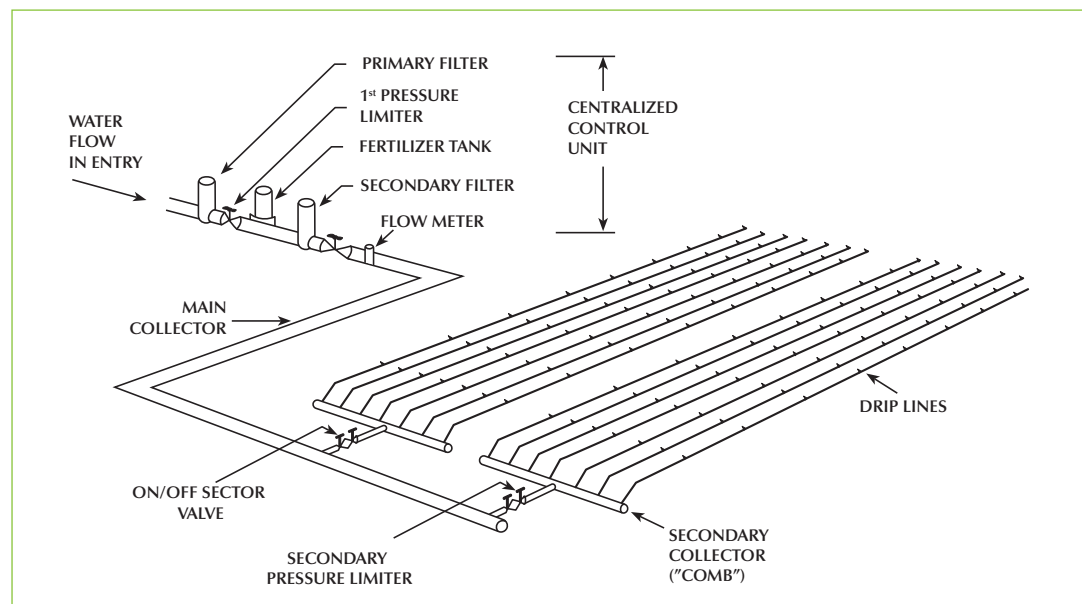


Figure 16.1 - General scheme of the drip irrigation system.

The amount of water and fertilizer is managed by an electronic control unit that can be programmed on site or via modem, with remote control. The secondary pipes are flattened and are laid every year and collected at the end of the campaign. The pipes that compose the irrigation rows are slightly buried using specific equipment, in order to optimize the irrigation and fertigation.

SHEET 17

DECOMPACTORS

Compaction of soils not subject to tillage, with low levels of organic matter and not particularly sandy, is the first factor that reduces the yield potential of harvests, which indirectly causes an increase in weeds due to the smaller size of the plants, and therefore reduced competitiveness. If the long process of increasing organic matter does not lead to a significant improvement in the soil structure, recourse to decompactors is of fundamental importance during the transition period of Conservation agriculture.

What is a decompactor?

A decompactor is a tool that restores a good apparent density ("softness") to the soil without reversing the soil layers and without production of clods, thus avoiding the negative effects of ploughing.

Decompactors are considered a type of subsoiler, but their construction characteristics are substantially different, especially in terms of their tines, which look more like a knife than a chisel (i.e. smaller thickness compared to the width); this allows them to have a real "curative effect" on the soil, restoring the volume and aerating it at depth, breaking the possible hardpan produced by previous interventions and avoiding, with respect to the subsoiler, the mixing with the most superficial layers, the formation of surface clods and thus keeping the soil sufficiently settled.

Their versatility allows them to be used in different techniques: in so-called 'two-layer tillage' and in reduced tillage, for arranging direct sowing and without additional steps for refining the seedbed.

Several types of decompactors with different characteristics (Table 17.1, Photo 17.1) were tested at Veneto Agricoltura's demonstration pilot farm in ValleVecchia in Caorle (VE) in order to provide some indications for their rational and successful use.

The tests were performed after winter wheat with a FENDT model 820 tractor with the nominal power of 157 kW and were conducted on the occasion of the Demo Day on 12th July 2013.

Table 17.1 - Technical data of the three solutions tested for the evaluation of the decompactors.

| TECHNICAL DATA OF DECOMPACTORS | | | |
|--------------------------------|--|---|-----------------------|
| Type of tine | Straight with inclined tip and foot with slanting fins | Straight with upside down "T" and parallel fins | Laterally curved tine |
| Frame/arrangement of tines | In a V | In line | In line |
| Rear roller | Cambridge | Cage | Full |
| Tillage width (m) | 3 | 3 | 3 |
| OPERATING DATA RECORDED | | | |
| Speed (km/h) | 4 | 4 | 4 |
| Depth (cm) | 40 | 40 | 40 |
| Effective capacity (ha/h) | 1.2 | 1.2 | 1.2 |
| Required tensile force (N) | 59729 | 54333 | 51889 |
| Required towing power (kW) | 65.04 | 59.16 | 56.50 |
| Hourly consumption (l/h) | 19.0 | 18.2 | 14.4 |
| Unit consumption (l/ha) | 15.8 | 15.2 | 12.0 |

A preliminary analysis of the field revealed that there was a compacted layer at a depth of 25-30 cm, for which the tillage depth of all the tools was adjusted to 40 cm, at least 10 cm below the compacted layer. The speed was set to 4 km/h on the basis of the test conditions, in such a way that excessive surface clods or carryover of soil on the surface were not created.

Photo 17.1 - Detail of the tines of the three decompactors tested (from left to right): straight tine, arranged on the frame in a "V" with an inclined tip and foot with slanting fins; straight upside down "T" with fins parallel to the horizontal plane; laterally curved tine (Micheal type).



The penetrometer readings taken with an interval of 10 cm, along a width of 3 m and depth of 50 cm, enabled us to evidence how the soil was tilled at depth.

Before tillage, the soil showed different degrees of compaction, with a soft surface layer up to about 10 cm, and an apparent compacted layer at depths varying between 15 and 30 cm, and values over 5 Mega Pascals (MPa); deeper down in the soil, the compaction decreased, with values from 2 to 4 MPa (Figure 17.1). After tillage, a net improvement of the situation was obtained for all tools, but to a different extent. In particular, the decompactors with curved tines rigorously tilled the soil due to the reduced distance between the tools; those with straight tilling tines, if used in optimum soil humidity conditions, allowed a surface profile more suitable for subsequent sowing to be obtained, hardly disturbing the soil.

The positive and significant results achieved in the tests have led Veneto Agricoltura and many other companies in Veneto to use decompactors within the scope of Conservation agriculture techniques.

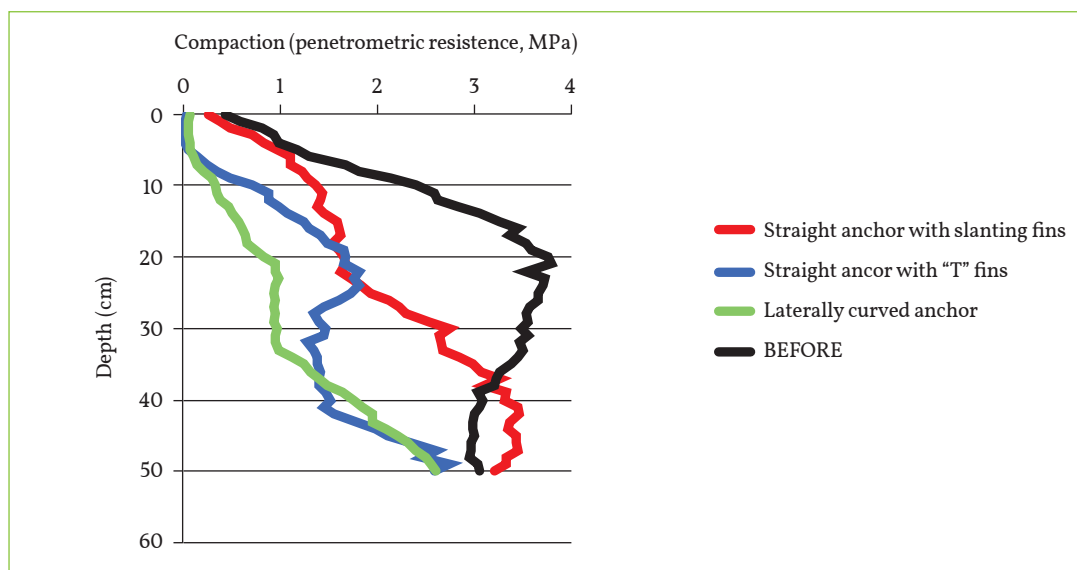


Figure 17.1 - Level of compaction of the soil in a section from 0 to 50 cm, before and after the decompaction.

SHEET 18

COVER CROPS

The simultaneous and continuous application of the three principles on which Conservation agriculture is based (crop rotation, non-inversion of the layers in soil tillage, continuous soil coverage) has the ultimate purpose of restoring the biological balance needed for the development of vital fertile agricultural ecosystems, capable of generating productive and environmental benefits.

There are many benefits from the introduction of cover crops:

- soil protection against erosion and compaction;
- recycling nutrients whilst reducing their loss and therefore lessening the environmental impact of agriculture;
- weed and parasite control when the cover crops are sufficiently competitive and well managed, in such a way as to prevent the spread of perennial weeds and dissemination of annual weeds;
- and last but certainly not least, increasing the soil organic matter.

It has also been proven that the crop residues from various sources will preserve and even improve the structure of the soil by increasing its biodiversity.

.....
Photo 18.1 - Green manure ground by stalk chopper (left) and burial of the chopped green manure with a shallow digger, after a few days of drying out on the field (right).



Choice of species in summer and autumn-winter

Cover crops are not usually meant to be harvested, but left in the field (shredded or chemically treated, left on the surface or buried) and must be chosen in such a way as to:

- be adequate for the local climate: in June-July sorghum, millet, foxtail millet, cowpea and *Crotalaria juncea* can be sown after wheat; in the autumn the most suitable grasses are barley, oats, rye associated with legumes such as vetch or different species of clover, or, if sown in September, some cruciferous species with biocide or nematicide activity for the control of soil fungi;
- have a rapid growth in order to be competitive compared to weeds;
- have short cycles to be placed between two primary crops (e.g. buckwheat, Photo 18.2);
- do not share the same parasites as the primary crops, this is why it is good to alternate botanical families within the rotation system, usually chosen among three families: legumes, crucifers and grasses.

.....

Photo 18.2 - Green manure from summer cover crops: hybrid sorghum (*Sorghum bicolor* ssp. *sudanense*, left); Sudangrass and buckwheat (*Polygonum fagopyrum*) sown in strips, right.



One must pay particular attention to the use of certain perennial species or those that resurface easily (e.g. the ryegrass *Lolium* spp.) considering the problems that these characteristics could involve, such as becoming weeds or developing resistance to weeding.

.....

Photo 18.3 - Green manure from winter cover crops: Oat+vetch+forage pea (left), barley+common vetch (right).



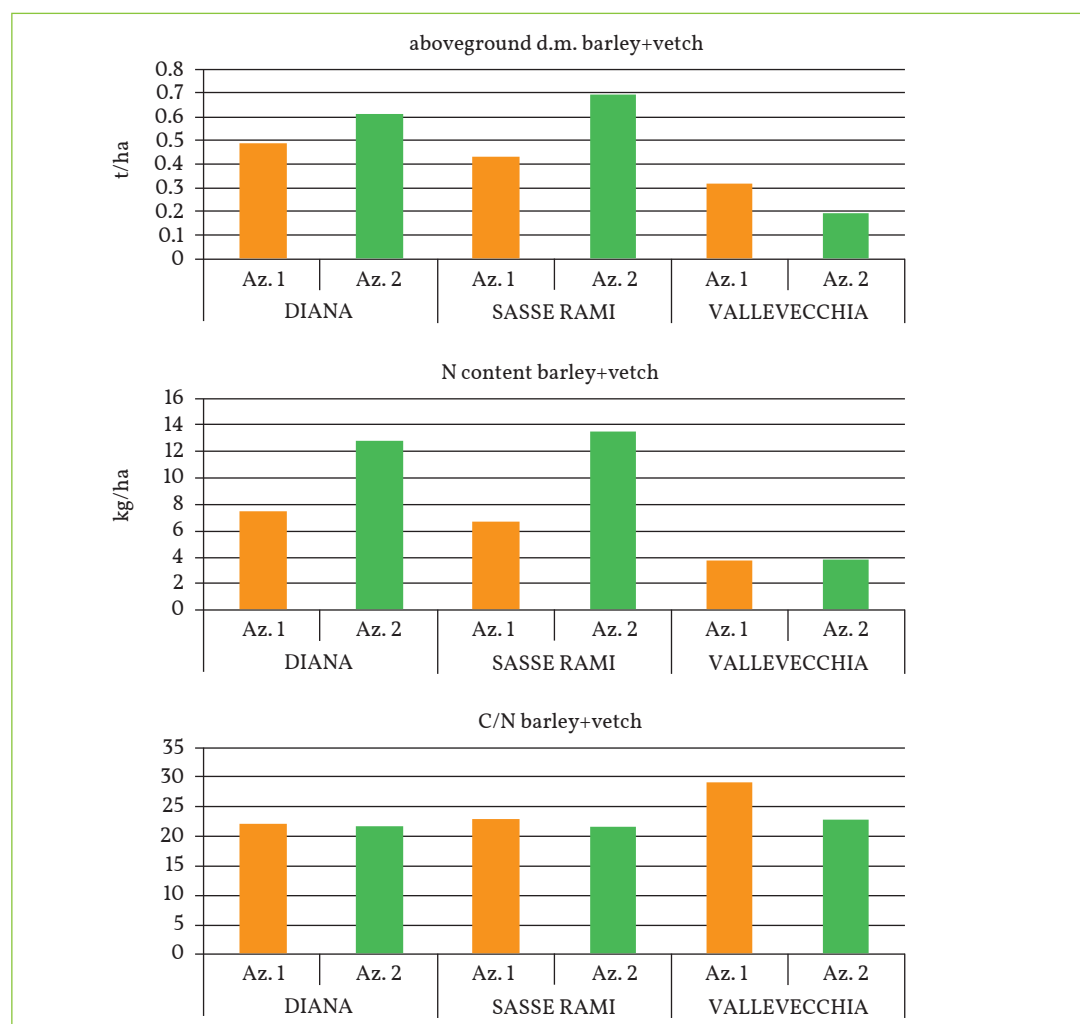
Experimental results of the cover crops used in the long-term tests at the Veneto Agricoltura farms

The long-term test for Conservation agriculture monitoring, included a wheat-rapeseed-maize-soybean rotation in the protocol. The green manure crops were chosen according to which would be the most useful for summer cover (sorghum after wheat and rapeseed) and autumn-winter (barley and vetch, barley or wheat alone) after the harvests of maize and soybean.

The biomass produced by the autumn-winter cover crop were not significantly different for the farm factor or the two different actions provided for by the PSR 2007-2013 of the Veneto Region, concerning the contributions of dry matter and organic carbon: “Measure 214 the Action 1 - Adoption of Conservation agriculture techniques” and “Measure 214 the Action 2 - Continuous soil coverage”. However, we noticed that for both parameters (DM and CO), a tendency to differentiate between farms, with highest values being obtained at the Diana and Sasse Rami farms (Fig. 18.1). In absolute terms, however, the quantities of organic matter obtained from cover crops

remained well below the potential of the same species when they are allowed to complete their development cycle until full bloom: previous experiments had supplied 7-9 t/ha of dry matter of pure barley or combined with common vetch or *Vicia villosa*.

Figure 18.1 - Production of dry matter (t/ha) and provision of Nitrogen (kg/ha) and C/N ratio of the aboveground part of barley and vetch plants of autumn-winter green manure in plots for Action 1 (Az. 1) and Action 2 (Az. 2). Years 2012-2015.



Aboveground biomass dry matter, nitrogen and C/N of summer cover crops under Action 1 (Az. 1) and Action 2 (Az. 2), started mainly since 2012 with sorghum, are reported in Fig. 18.2. As for the autumn-winter covers, there were no statistically significant differences with sorghum (spring-summer cover), in the different actions of the measure, nor for the three farms. In terms of absolute value, the quantities of organic matter and consequent carbon and elements released (like nitrogen) were far higher than the autumn-winter covers and could be even greater if the timing of the rotation allowed the shredding and subsequent soil incorporation at the sorghum full bloom stage. Previous experiments in our surroundings, with sorghum shredding at this stage, have produced between 6 and 10 t/ha of dry matter, depending on the variety of sorghum (Sudangrass, hybrid or sweet). Among all the summer cover crops tested on the pilot farms of Veneto Agricoltura over the years, sorghum resulted the most suitable as a summer cover crop both because of its ability to produce biomass even in summers with low rainfall, and because it competes more with weeds than foxtail millet and millet at the same level of water availability. As regards the ratio C/N there were no statistical differences for both sorghum and barley-vetch mixture, either among pilot farms or among treatments (Action 1, Action 2), with higher average values for sorghum (34.9) than for barley-vetch mixture (23.4).

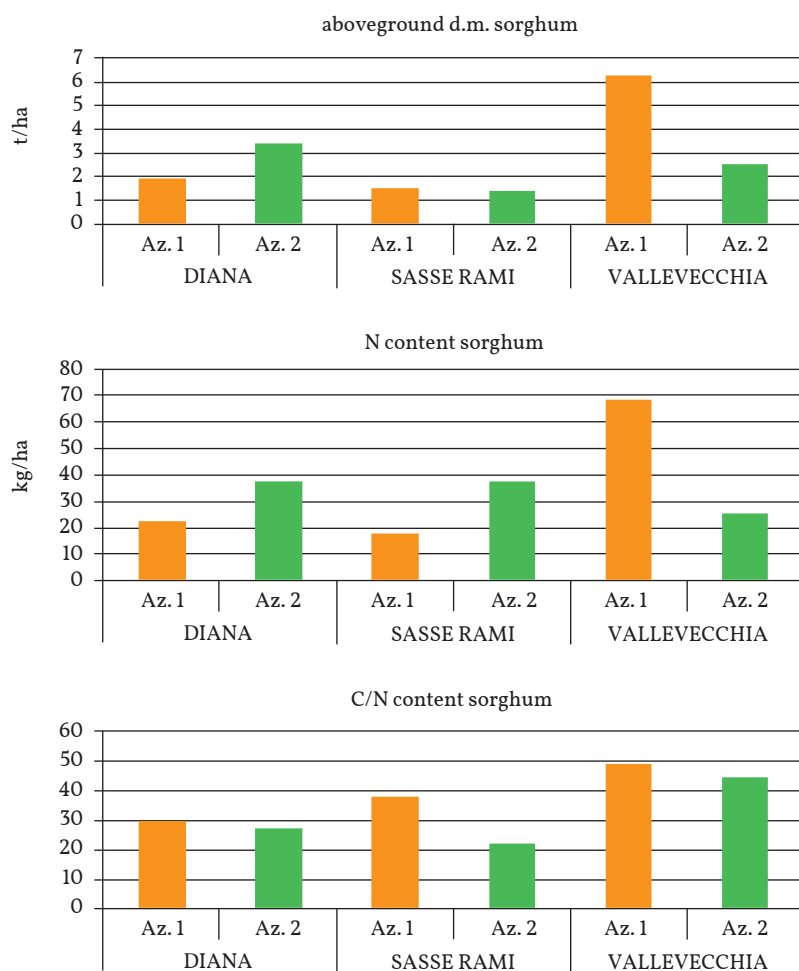


Figure 18.2 - Production of dry matter (t/ha) and provision of Nitrogen (kg/ha) and C/N ratio of the aerial part of sorghum plants from summer cover crops in plots for Action 1 (Az. 1) and Action 2 (Az. 2). Years 2012-2014.

Final Considerations

The carbon inputs in the soil are obviously proportional to the cover crop cropping period; therefore the farm organization must allow for immediate sowing of cover crops, as well as rapid harvesting of the primary crops; this haste, together with the use of a drill seeder that exploits the residual moisture of the soil surface layer, is crucial in order to start the summer cover crop in time. Furthermore, particular attention must be paid to not bury the above-ground residues of cover and primary crops too deeply (20-30 cm, where possible) to avoid the risk of counterbalancing carbon inputs with excessive mineralization by tillage.

BIBLIOGRAPHY

- Chiarini F., Conte L., 2006. Tutti i numeri dei sovesci estivi. Bioagricoltura Ed. AIAB, 100, 36-40.
- Conte L., Costantini E., 2008. La gestione del suolo in agricoltura biologica – Veneto Agricoltura.
- Chiarini F., Conte L., 2008. Winter cover crops in the Veneto region: two years of trials to evaluate the most effective species in this season. Book of abstracts del 13th IFOAM Scientific Conference, p. 321.
- Chiarini F., Conte L. 2010. Avvicendamenti, consociazioni e fertilità del suolo in Agricoltura biologica. Veneto Agricoltura.



PART THREE

CONSERVATION AGRICULTURE PROFITABILITY

SHEET 19

ECONOMIC BALANCE: COSTS AND REVENUES

The agronomic experiments conducted at the three Veneto Agricoltura pilot farms enabled the recording of a set of data that could also be used to perform an economic evaluation of the two types of cultivation, Conservation agriculture and Conventional agriculture, as described in Sheet 1. The cultivation costs were analyzed (excluding any costs of drying the products, transport, etc.) on the basis of the cropping operations performed and production factors used. Cover crop operations were also excluded from the economic calculations: as with other agronomic factors, the land improvements expected from the use of cover crops and from conservation farming practices in general, occur very slowly and, therefore, in this economic analysis, we preferred to consider them in a separate calculation, in order not to arbitrarily attribute their costs to a single year and/or crop.

The comparison tables (19.1, 19.2, and 19.3) were thus elaborated, from which we can draw the following conclusions:

- aside from certain years with anomalous values (indicated in the tables with an asterisk), Conservation agriculture generally has lower total costs than Conventional agriculture: during the project period, the difference was, on average, -12.2% for wheat, -24.5% for maize and -27.7% for soybean;
- due to the lower yields, the production value achievable in Conservation agriculture is generally lower than that with Conventional agriculture: for the same price value, the relative difference is in fact attributable to the lower yield, with lower average relative incidences differing among crops. Wheat, with an average yield differential of around 19.2%, seems to be subjected to yield reduction less than soybean (31.2%) and maize, whose recorded yields were on average 46.5% lower. These values differ slightly from those recorded on production results in Sheet 1, insofar as the economic calculations refer to the first seven years, instead of eight (up to 2017);
- given the lower production costs, the differences in terms of gross margin (obtained by the difference between the production value and total costs and recalling that it involves the cultivation costs only) tend to fall and in certain cases, for example for wheat, give positive values in favour of conservation techniques. It should be noted that, aside from certain years in which the yields on no-till cultivation were particularly low, this technique produces generally a positive economic result, even if it is lower than that achieved with conventional techniques;
- finally, we calculated for the different years the yield that should have been achieved using Conservation agriculture in order to achieve a balance in terms of gross margin compared to Conventional agriculture. In relative terms (far-right column in the tables), on average, the yield from no-till cropping system should have been at most around 9% less than the conventional one with regard to wheat (excluding one anomalous year). For soybean, the yield should be at most 15% lower (except for one anomalous year, due to re-seeding, for which the yield should be even higher than that for Conventional agriculture). Lastly, the yield of maize from no-till system should be at most an average of 18% lower, to be able to achieve an economic balance compared to the conventional system. In substance, if the yields obtained using the conservation technique were not too lower (between 9 and 18% depending on the crop) than those obtained from Conventional agriculture, this would allow a very similar economic result to be achieved, due to the lower cultivation costs.

Table 19.1 - Comparison of economic values for the cultivation of **wheat** using conservation and conventional methods.

| WHEAT | Total cost (euro/ha) | | Diff. CONS-CONV (euro/ha) | Production value (euro/ha) | | Diff. % PV CONS-CONV | Diff. GM CONS-CONV (euro/ha) | CONS yield balance GM CONV (t/ha) | Diff. % CONS yield balance / CONV |
|----------------------|----------------------|----------|---------------------------------|-------------------------------|----------|-------------------------|------------------------------------|---|---|
| AGRICULTURAL YEAR | CONS | CONV | | CONS | CONV | | | | |
| 2010/2011 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2011/2012 | 575,14 | 678,67 | -103,54 | 1.788,56 | 1.925,64 | -7,12 | -33,54 | 7,44 | -5,38 |
| 2012/2013 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2013/2014 | 677,56 | 845,63 | -168,08 | 803,94 | 846,54 | -5,03 | 125,48 | 3,40 | -19,85 |
| 2014/2015 | 712,76 | 766,23 | -53,46 | 748,38 | 1.145,89 | -34,69 | -344,05 | 5,85 | -4,67 |
| 2015/2016 | 939,98 | 1.022,19 | -82,21 | 905,55 | 1.039,13 | -12,86 | -51,37 | 5,78 | -7,91 |
| 2016/2017 | 594,50 | 671,32 | -76,81 | 832,15 | 1.309,98 | -36,48 | -401,02 | 6,79 | -5,86 |
| Averages | 699,99 | 796,81 | -96,82 | 1.015,71 | 1.253,43 | -19,23 | | 5,85 | -8,73 |

Table 19.2 - Comparison of economic value for **maize** cultivation with conservation and conventional methods.

| MAIZE | Total cost (euro/ha) | | Diff. CONS-CONV (euro/ha) | Production value (euro/ha) | | Diff. % PV CONS-CONV | Diff. GM CONS-CONV (euro/ha) | CONS yield balance GM CONV (t/ha) | Diff. % CONS yield balance / CONV |
|----------------------|----------------------|----------|---------------------------------|-------------------------------|----------|-------------------------|------------------------------------|---|---|
| AGRICULTURAL YEAR | CONS | CONV | | CONS | CONV | | | | |
| 2010/2011 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2011/2012 | 665,51 | 991,23 | -325,72 | 512,91 | 1.062,41 | -51,72 | -223,78 | 3,29 | -30,66 |
| 2012/2013 | 628,02 | 924,09 | -296,08 | 629,26 | 1.572,44 | -59,98 | -647,11 | 6,07 | -18,83 |
| 2013/2014 | 1.007,49 | 1.250,39 | -242,91 | 1.208,85 | 1.760,69 | -31,34 | -308,93 | 8,56 | -13,80 |
| 2014/2015 | 786,05 | 1.029,01 | -242,96 | 614,49 | 1.148,25 | -46,48 | -290,80 | 5,87 | -21,16 |
| 2015/2016 | 743,58 | 922,61 | -179,02 | 989,68 | 1.622,46 | -39,00 | -453,76 | 8,49 | -11,03 |
| 2016/2017 | 566,35 | 709,06 | -142,71 | 621,84 | 1.253,01 | -50,37 | -489,84 | 6,46 | -11,39 |
| Averages | 732,83 | 971,07 | -238,23 | 762,84 | 1.403,21 | -46,48 | | 6,46 | -17,81 |

Table 19.3 - Comparison of economic value for **soybean** cultivation with conservation and conventional methods.

| SOYBEAN | Total cost (euro/ha) | | Diff. CONS-CONV (euro/ha) | Production value (euro/ha) | | Diff. % PV CONS-CONV | Diff. GM CONS-CONV (euro/ha) | CONS yield balance GM CONV (t/ha) | Diff. % CONS yield balance / CONV |
|----------------------|----------------------|--------|---------------------------------|-------------------------------|----------|-------------------------|------------------------------------|---|---|
| AGRICULTURAL YEAR | CONS | CONV | | CONS | CONV | | | | |
| 2010/2011 | 389,15 | 561,48 | -172,33 | 829,88 | 1.069,68 | -22,42 | -67,47 | 2,38 | -16,11 |
| 2011/2012 | 762,82 | 965,89 | -203,06 | -- | -- | -- | -- | -- | -- |
| 2012/2013 | 726,39 | 700,12 | 26,27 | 447,96 | 745,04 | -39,87 | -323,34 | 1,64 | 3,53 |
| 2013/2014 | 521,49 | 756,34 | -234,84 | 1.319,34 | 1.960,55 | -32,71 | -406,37 | 4,21 | -11,98 |
| 2014/2015 | 651,20 | 820,66 | -169,46 | 1.169,45 | 1.426,97 | -18,05 | -88,07 | 3,56 | -11,88 |
| 2015/2016 | 481,70 | 664,29 | -182,59 | 799,04 | 1.362,73 | -41,36 | -381,09 | 3,36 | -13,40 |
| 2016/2017 | 475,54 | 683,59 | -208,05 | 597,22 | 1.021,41 | -41,53 | -216,14 | 2,08 | -20,37 |
| Averages | 503,82 | 697,27 | -195,06 | 942,99 | 1.368,27 | -31,21 | | 3,12 | -14,75 |

The effect of cover crops on the economic balance

One of the principles of Conservation agriculture is permanent soil cover, which can be achieved by planting cover crops (Sheet 18) left in the fields or intercrops intended for sale (e.g. soybean, fodder sorghum, etc.).

It is clear that these options affect the economic results differently and, in any case, do not take into account the environmental benefits of Conservation agriculture.

Indeed, from a technical point of view, a good intercrop that produces significant amounts of biomass and thus root systems, which are an important contribution to soil organic matter, can significantly help to improve the soil structure as compared to a cover crop that hasn't been fertilized and sometimes for that reason poorly developed.

It is obvious that, from an economic point of view and in the long term, the costs of introducing cover crops into a farm's cultivation practices must be taken into consideration: hypothetically, if we only consider cover crops that do not generate income and allocate the relative costs for each year, the economic result in terms of gross margin for conservation techniques is further reduced by about 150 €/ha (the average cost of cover crops) as compared to Conventional agriculture. This difference can be completely offset by a supplementary income if we introduce income-generating intercrops, i.e. second harvest crops.

Furthermore, it should be recalled that the application of Conservation agriculture was supported in the Veneto region with specific measures of the RDP¹. During this trial period, payment of the Conservation Measure (No Till) remained well above 400 €/ha per year in both programme periods. If we include these payments into our economic calculation, considering the current differences in margin between the two techniques (see the relevant column in the tables), the differential in terms of gross margin achievable becomes positive in most cases in favour of the no-till system as compared to conventional cultivation, except for some particular years during which the yield on no-till soil was very low.

¹ RDP 2014-2020:

(Measure 10.1.1 -

Agronomic techniques
with low environmental
impact Multiannual call
for applications 2015
<http://bit.ly/2RSmZRn>)

RDP 2007-2013:

Measure 214/i Agri-
compatible management
of agricultural areas:
Action 1 "Adoption of
Conservation agriculture
techniques" and Action 2
"Permanent soil cover".

MY EXPERIENCE IN CONSERVATION AGRICULTURE

Anna Trettenero Farm

Management under lease of around 100 hectares of arable land divided into three separate areas, in the provinces of Vicenza and Venice

First year of direct seeding: 1995

The technique adopted: direct seeding with rotations and cover crops.

Crops: Grain maize for animal feed and food use, grain sorghum, soybean also for seed production, wheat, barley and triticale also for seed production, grasslands, vetch, buckwheat.

Crop rotations is a rule but rarely with repeated patterns.

Planter: Baumer Euro Combi, with working width of 3 metres.

Soil type: silty loam/silty sand. Rock fragments in the province of Vicenza.

Organic matter content: 1.8%

I first became interested in sod seeding during a Congress of the French Association of Maize Producers in Pau in the Pyrenees. It was 2002, and our cousins across the Alps had organized a field event where visitors could meet producers from different parts of the world and compare their production techniques. Federico Zerboni, an Argentine farmer from Buenos Aires, won the prize for most efficient producer. Three thousand hectares, three tractors, three men. Federico farmed using sod seeding and his story sparked my interest, partly because for some time I had been trying to find solutions to the poor competitiveness of our farms. It seemed to me that the budgets of agricultural businesses could withstand the weight of important costs only because they were counterbalanced by good production and the safety net of EU grants, but I was convinced that, for the future, we could no longer rely on stable markets, nor on the continuity of the CAP, as conceived up to that moment. In actual fact, market volatility and CAP changes were then added to the economic crisis, each year more pressing, with related solvency and financial liquidity problems, as well as climate variability. But this is the story we are still experiencing.

During that time, I had a trade union role among the young people of the Farmers' Association Confagricoltura and, together with some of my colleagues, I believed we needed to pursue longer term objectives, to find new strategies, some of which could be business strategies, others involving regional, national, or EU policies.

Many years have passed since that day in Pau, but the memory is fixed in my mind, because it marked a change in pace. On that occasion, I started to think that learning to produce using direct seeding, on our soils, under our conditions, could have been one of the possible challenges for the future. After a few years, in-depth study trips, especially to Argentina where the direct seeding technique was well established, and thanks to contacts with the NIAT (Instituto Nacional de Tecnologia Agropecuaria) and Aapresid (Argentine Association for Direct Seeding) together with fellow farmers, I purchased a sod seeder directly from Argentina and with great enthusiasm, I started my adventure.

If I look back, I do wonder how I managed to overcome all the difficulties that I faced, as can be expected for anyone who takes his first steps on rough and unknown terrain. Even now, I am still convinced that it was only with the help of so many passionate individuals, with far more experience than me, together with the determination to achieve the goal, that I was able to overcome the disappointments.

Experience has taught me that Conservation agriculture, understood as direct seeding, combined with rotations and cover crops, is a technique that has to be refined over time, calibrated to suit different climates and soils and, above all, that there is no "one size fits all". Today, I know that mistakes can be really expensive, and that you need humility to share them and transform them into opportunities for growth.

If I have to describe the right attitude for those who want to get closer to Conservation agriculture, I must think of sharing experiences in the field, rather than in the classroom. As with every innovation, especially in agriculture, which is traditionally conservative, Conservation agriculture is based on the willingness to change, especially your mental attitude. I have had to face various problems during the first few years, and I will list some here, but without going into too much detail.

.....
Photo 20.1 - Example of
soybean after a cover crop
(previous maize).



From a mechanical point of view, I think that the shortage of sod seeders, suited to our land and present on the Italian market is a limiting factor. In particular, it is essential to be able to sow precisely, each on his own land, with seeding units that close the furrows perfectly, even in difficult conditions, such as with heavy, wet soil, even with a lot of crop residues. I have always found it very difficult to find spare parts in a short time lapse and support has always been brilliantly guaranteed, but only from friends and colleagues with more expertise than I have. The planter is important but what is crucial is sowing with care, patience, and precision, adjusting the planter and researching all the parts of the seeding unit that make laying the seed precise and regular in the different ground conditions and in the presence of crop residues. The precision planting associated with direct seeding may be of help, just as it is already a consolidated reality and success in America.

From an agronomic point of view, I soon had to learn about all types of slugs, both epigeal and hypogeal, voracious eaters of soybean, but also destructive on rapeseed sprouts and cereals. I understood how important it is to work quickly in fighting weeds and to vary my choice of active ingredients.

I learned a lot from Dwayne Beck, Professor at South Dakota State University and director of the Dakota Lakes Research Farm in Pierre, South Dakota. The history of this Research Farm is interesting (www.dakotalakes.com) because it stems from the desire of a group of farmers to give their working lives and their land, where wheat is produced as a monoculture and cattle are bred, with particularly harsh climatic conditions. The Research Farm is owned by the farmers, who sit on the Board of Directors, and is managed by the South Dakota State University. The primary objective is to identify, research and demonstrate the efficacy of methods that strengthen and stabilize the agricultural economy. The vision is clear but it is a practice consolidated by dozens of years of daily work in the countryside, not theory: *“Working with nature to ensure that the soil is protected, fertile and that it produces harvests to feed the world for many generations to come. The agronomic practices adopted are under continuous improvement, generating results in maintaining and ‘encouraging’ living soil, clean water, healthy food and diversified fauna.”* The rotations and cover crops, in addition to the direct seeding technique, make the Dakota Lakes a centre of excellence. The recommendation of Dwayne Beck is very clear cut: *“Bearing in mind the market and the business organization, try not to be predictable, vary crop rotations and the interval between crops. The main reason why agriculture is facing problems such as weed and insect biotypes resistance is that the cultivation programmes create conditions that favour specific individuals with regard to the population, and maintain these conditions in place for a sufficiently long time or frequently enough and/or with sufficient predictability to allow a biotype to become a predominant population.”*

I am well aware that producing different crops means you have to find new customers, strengthen relations and dialogue with different stakeholders along the production chain. It is not an easy task, just as cover crops are not easy, finding the correctly calibrated species for each farm, finding someone who will sell you the mixtures at an affordable price, helping the operators to understand that sowing a cover crop is not an operation that you can do hastily and without care, but that it must receive the same care as sowing the primary crop. Only a well-established cover will produce interesting effects, among other things for soil nutrition, weed control and for the establishment of the following crop.



.....
Photo 20.2 - Earthworms on cover crops.

Over time, I have seen an increase in bearing capacity, the soil structure has improved, the water drains more quickly and I am less afraid of environmental variability from year to year. I am learning to manage weeds even through the use of cover crops and this reduces the need for fertilizers. The slugs are partially under control using the same products that are used in organic farming, but even with crop rotations, particular attention is given to the time of seeding and preserving natural antagonists through the choice and reduction of insecticides. The search for new market outlets for crops is ongoing and in some cases I have found wide-spread opportunities in the Po river area, such as maize genetics for specific productions (Planta), seed producers (Zanandrea Sementi) and a specialized mill to which I sell maize for a gluten free production chain.

I became interested in sod seeding for economic considerations and production efficiency, but, by studying and getting to know other producers, I was immediately able to appreciate the environmental returns, with the objective of safeguarding the environment while producing for the market and improving the land over the years with economic satisfaction. It is a continuously evolving challenge, within the reach of anyone who is ready for change.

.....
Photo 20.3 - Example of
Maize after a cover crop
(previous crops wheat-
soybean of 2nd harvest).



ISBN 978-88-6337-209-0



9 788863 372090