Environmental effectiveness of GAEC cross-compliance standard 2.1 'Maintaining the level of soil organic matter through management of stubble and crop residues' and economic evaluation of the competitiveness gap for farmers

Domenico Ventrella,[1] Nino Virzì,[2] Francesco Intrigliolo,[2] Massimo Palumbo,[2] Michele Cambrea,[2] Alfio Platania,[2] Fabiola Sciacca,[2] Stefania Licciardello,[2] Antonio Troccoli,[3] Mario Russo,[3] Rosa Francaviglia,[4] Ulderico Neri,[4] Margherita Falcucci,[4] Giampiero Simonetti,[4] Olimpia Masetti,[4] Gianluca Renzi,[4] Marisanna Speroni,[5] Lamberto Borrelli,[5] Giovanni Cabassi,[5] Luigi Degano,[5] Roberto Fuccella,[5] Francesco Savi,[5] Paolo Tagliabue,[5] Marco Fedrizzi,[6] Roberto Fanigliulo,[6] Mauro Pagano,[6] Giulio Sperandio,[6] Mirko Guerrieri,[6] Daniele Puri,[6] Francesco Montemurro,[1] Vittorio A. Vonella,[1] Luisa Giglio,[1] Francesco Fornaro,[1] Mirko Castellini,[1] Rita Leogrande,[1] Carolina Vitti,[1] Marcello Mastrangelo,[1] Angelo Fiore,[1] Mariangela Diacono,[1] Lorenzo Furlan,[7] Francesca Chiarini,[7] Michele Colauzzi,[7] Francesco Fracasso,[7] Erica Sartori,[7] Antonio Barbieri,[7] Francesco Fagotto,[7] Paolo Bazzoffi[8]

[1]CREA-SCA, Council for Agricultural Research and Economics, Research Unit for Cropping Systems in Dry Environments, Bari
[2]CREA-ACM, Council for Agricultural Research and Economics, Research Centre for the Citrus crops and the Mediterranean, Acireale (CT)
[3]CREA-CER, Council for Agricultural Research and Economics, Research Centre for Cereal Crops, Foggia
[4]CREA-RPS, Council for Agricultural Research and Economics, Research Centre for the Soil-Plant System, Roma
[5]CREA-FLC, Council for Agricultural Research and Economics, Research Centre for Fodder Crop and Dairy Productions, Lodi
[6]CREA-ING, Council for Agricultural Research and Economics, Research Unit for Agricultural Engineering, Monterotondo (RM)
[7]Veneto Agricoltura, Regional Agency for the agricultural, forestry and agri-food sector, Legnaro (PD), Italy
[8]CREA-ABP, Council for Agricultural Research and Economics, Research Centre for Agrobiology and Pedology, Firenze, Italy

Corresponding author: Domenico Ventrella
E-mail: domenico.ventrella@crea.gov.it

Key words: Cross-compliance; rural development; Standard 2.1; stubble and crop residues management; competitiveness.

Work done under the Project MO.NA.CO. (National network for monitoring the environmental effectiveness of cross compliance and the differential of competitiveness charged against agricultural enterprises) funded by the Ministry of Agricultural, Food and Forestry Policies (MiPAAF) in the context of Action 1.2.2 'Interregional Workshops for development' of the Operational Programme called 'National Rural Network 2007-2013', Coord. Paolo Bazzoffi.

Contributions: Domenico Ventrella: leader of Standard 2.1, coordinator of CREA-SCA operative unit (UO), text writing, statistical analysis, design and set up of field experiment. Francesco Montemurro: coordinator CREA-SSC UO, design and set up of field experiment, data processing, text writing. Vittorio Alessandro Vonella: set up and management of field experiment, agronomic management, experimental surveys. Luisa Giglio: field measurements, data processing. Francesco Fornaro: field measurements, data processing, data geo-reference. Mirko Castellini: field measurements, data processing. Rita Leogrande: field measurements, data processing. Carolina Vitti: soil chemical analysis for CREA-SCA, data processing. Angelo Fiore: field measurements, data processing, text writing. Mariangela Diacono: field measurements, data processing, text writing. Marcello Mastrangelo: soil chemical analysis for CREA-SCA. Nino Virzì: leader of CREA-ACM UO, design and set up of field experiment, experimental surveys text writing. Francesco Intrigliolo: leader of CREA-ACM UO, design and set up of field experiment. Massimo Palumbo: data processing, text writing. Michele Cambrea: set up of field experiment, agronomic management, field measurements. Alfio Platania: set of field experiment. Fabiola Sciacca: data processing. Stefania Licciardello: field measurements, quantitative analysis. Antonio Troccoli: leader of CREA-CER UO, design and set up of field experiment, experimental surveys text writing, data processing. Mario Russo: field measurements, data processing, text writing. Rosa Francaviglia: leader of CREA-RPS UO, text writing, data processing. Ulderico Neri: set up of field experiment, field measurements, text writing, data processing. Margherita Falcucci: chemical analysis of soil and crop. Giampiero Simonetti: set up of field experiment, field measurements. Olimpia Masetti: laboratory determination of biological and biochemical soil parameters;. Marisanna Speroni: leader of CREA-FLC UO, design and set up of field experiment. Lamberto Borrelli: design and set up of field experiment, data processing, text writing. Giovanni Cabassi: design and set up of field experiment, data processing, text writing. Luigi Degano: design and set up of field experiment, data processing, text writing; Roberto Fuccella: field measurements, data processing. Francesco Savi: field measurements, data processing. Paolo Tagliabue (Fondazione Morando Bolognini - S. Angelo Lodigiano): set up of field experiment, agronomic management. Marco Fedrizzi (leader of CREA-ING UO), Roberto Fanigliulo, Mauro Pagano, Giulio Sperandio, Mirko Guerrieri, Daniele Puri: Field surveys, data processing for economic evaluation of the competitiveness gap. Lorenzo Furlan: leader of Veneto Agricoltura (Veneto Agricoltura); Francesca Chiarini: set of field experiment, data processing; Michele Colauzzi (freelance employee): experimental schedule, text writing, data processing; Antonio Barbieri. set up of field experiment. agronomic management; Francesco Fagotto: field measurements, reports; Francesco Fracasso: set up of field experiment, field measurements; Erica Sartori: field measurements, reports.

Italian Journal of Agronomy 2015; 10(s1):697
doi:10.4081/ija.2015.697

Abstract

Within the Project MO.NA.CO. the Environmental effectiveness of GAEC cross-compliance standard 2.2 'Maintaining the level of soil organic matter through management of stubble and crop residues' and economic evaluation of the competitiveness gap for farmers were evaluated. The monitoring was performed in eight experimental farms of the Council for agricultural research and economics (CREA), distributed throughout Italy and with different soil and climatic conditions. Yield parameters and several components of soil organic matter were evaluated in two contrasting treatments applied to one-year rotation of winter durum wheat and maize: i) incorporation into the soil of crop residues (Factual treatment) and ii) burning or removal of crop residues (Counterfactual treatment).

The application of the standard 'crop residue management' has showed contrasting results with differences (for yield and soil) between the two treatments resulted almost always non significant.

The analysis of economic competitiveness gap showed that the CR incorporation is more expensive than CR burning or removal, but the economic disadvantage can be considered rather small and thus easily compensated by Community aids. Therefore, the soil incorporation of crop residues can be considered a 'good agricultural practice' that does not penalize farmers in terms of production and cost and at the same time contributes to the maintenance of fertility and soil biodiversity. On the contrary, the burning and removal of residues result in a low or no-addition of organic matter into the soil. Moreover, burning can contribute to decrease the biodiversity and to increase the risk of air pollution, fires and road accidents.

Introduction

The management of crop residues (CR) in different cropping systems is a topic widely discussed in the agronomic literature (Bonciarelli *et al.*, 1972, 1974; Morel *et al.*, 1981; Maiorana *et al.*, 1992, 1993, 1996, 1997, 2001, 2003; Ferri *et al.*, 1993; Nicholson *et al.*, 1997; Lal, 1997, 2009; Convertini *et al.*, 1998; Fischer *et al.*, 2002; Franzluebbers, 2002; Lemke *et al.*, 2010). The effect of CR incorporation on soil physical-chemical properties is considered positive, but rarely there is agreement on the amount of change of the organic carbon content due to this agronomic practice. This is because the efficiency of CR incorporation depends on several factors related to physical-chemical properties of the soil, weather condition, characteristics of CR, methods of incorporation and agronomic practices adopted to improve the CR decomposition that is a microbiological process that consists in a progressive transformation of organic material ending with the release of carbon and nutrients into the ecosystem at both local and global scale. In particular, the characteristics linked to the soil are mainly important in areas under adverse climatic conditions while those depending by CR quality have greater effect under more advantageous environmental conditions for CR decomposition.

In general, smaller residues decompose before than bigger ones, as well as residues of young plants decompose before than those of older plants because with the age of the plant there is an increase in the amount of cellulose and lignin that, with the polyphenols, have inhibitory effects on the action of enzymes that regulate the decomposition. The burning of stubble and straw is common in areas where cereals are traditionally cultivated. The adoption of this method is based on a series of motivations. It is not always easy to harvest stubble and straw because of irregularity or steepness of the land. Nowadays there is less need for using straw in stables following a reduction in livestock farming and heads of cattle. The burning is a cheap way to

Table 1. Monitoring farms of MO.NA.CO. Project.

Farm (Research Unit)	Monitoring sites latitude (Lat) longitude (Lon)	Climate Rainfall (R) Temperature (T)	Soil type	Soil texture (%)	pH	Total organic carbon (g kg^{-1})
RAM (CREA-ACM)	Acireale Lat 37.54172° Lon 14.58462°	R=450 mm T=17.0°C	Vertisol	Sand= 14.3 Clay=47.5	8.5	5.2
MTP (CREA-SCA)	Metaponto Lat 40.38296° Lon 16.80883°	R=500 mm T=16°C	Typic Epiaquerts	Sand=19 Clay =42	7.8	10
FOG-CER (CREA-CER)	Foggia Lat 41.46337° Lon 15.49671°	R=526 T=15.8°C	Chromic Calcixerert	Sand=19.5 Clay =49.4	8.3	15.3
FOG-SCA (CREA-SCA)	Foggia Lat 41.4496° Lon 15.50266°	R=526 T=15.8°C	Chromic Haploxerert	Sand=19.5 Clay =49.4	8.3	14.1
MON (CREA-RPS)	Monterotondo Lat 42.09786° Lon 12.63737°	R=800 mm T=15.2°C	Entic Lithic Haploxeroll	Sand=33 Clay =21	6.9	14.6
LOD (CREA-FLC)	Lodi Lat 45.30304° Lon 9.514188°	R=800 mm T=12.5°C	Typic Haplustalf	Sand=67 Clay =12	6.2	10.5
ANG (CREA-FLC)	Sant'Angelo Lodigiani Lat 45.23105° Lon 9.423971°	R=800 mm T=12.5°C	Typic Haplustalf	Sand=68 Clay =14	5.6	13.5
CAO (Reg. Veneto)	Caorle Lat 45.64036° Lon 12.95414°	R=970 mm T=13.7°C	Calcari-Gleyc Fluvisols	Sand=18.1 Clay =30.5	7.8	11.4

clear soil of residues, avoiding machinery utilization and reducing the tillage depth. For some pathogens the straw burning can have the effect to eradicate the inoculums present in the residue of the previous crop. Finally the straw burning can have a positive effect in reducing the number of germinable weed seeds. With the choice of burning, rather than CR incorporation, the advantages and possible long term improvements of soil fertility and physical properties were underestimated. These effects were contrasted, however, by the consideration of further higher costs necessary for the CR incorporation into the soil and by likely yield reduction expected in the early years since the adoption of CR incorporation (Convertini *et al.,* 1998).

A number of studies demonstrated that burning residue over a period of twenty years did not result in any significant reduction in grain yield or soil organic matter; subsequently, a reduction in microbial activity was noted with an increase in the loss of soil organic carbon (Rasmussen *et al.*, 1991). Straw and stubble burning does not, therefore, determine a rapid loss of soil carbon but significantly affects important physical properties, since soil colour, aggregate stability and the rate of water infiltration differ depending on whether straw is burnt or incorporated (Rasmussen *et al.*, 1980). After ten years of continuous straw burning, in a long term experiment of Foggia (Southern Italy) district, Castellini *et al.* (2014) have not found significant differences in soil quality compared to CR incorporation.The residues that remain after burning on the soil decompose very slowly because the black-burned carbon is less biologically active and has a long turnover. For this reason, the CR burning is proposed as a technique for soil carbon sequestration. However, it is necessary to refer the risks of CR burning that are the main reasons why this practice, in different Italian regions, is forbidden or regulated in a more or less stringent way. Burning may determine risks of major damage to the natural heritage and agricultural products, as well as road safety problems in addition to the air pollution. Moreover, negative consequences are expected for the dissipation of the organic carbon and the alteration of the ecosystem equilibrium that could undermine the soil microbial activity.

The straw removal, subtracting to the soil a significant amount of C, can rightly be considered even more harmful than burning in order to conserve soil fertility. Although also this practice may nevertheless be justified by the need to diversify agricultural activity and stabilize income levels. In fact, the surplus of residues (especially of low quality) can be utilized for various purposes: livestock, building material, energy production, compost, *etc*. However, when the straw is used in stables or composting processes a more or less substantial part of that may return to the soil even in more efficient forms compared to the straw,

Figure 1. Geographical position of monitoring farms for the Standard 2.1.

Table 2. Means and standard deviations of the main productive parameters of durum wheat and soft wheat (MON 2014): grain yield, harvest index (HI) and grain protein content.

Farm (Research Unit)	Year	Treatment	Yield (t ha^{-1}) Mean	SD	HI (-) Mean	SD	Protein content (%) Mean	SD
RAM (ACM)	2013	F	2.60	0.24	0.38	0.05	11.57	0.38
		CF	3.26	0.44	0.43	0.05	12.83	0.24
			ns	ns		**		
MTP (SSC)	2013	F	4.48	0.81	0.36	0.00	10.27	0.42
		CF	4.78	0.52	0.33	0.02	14.94	0.60
			ns	ns		***		
FOG-CER (CER)	2012	F	2.59	0.34	0.37	0.02	16.10	0.00
		CF	2.51	0.08	0.42	0.03	13.53	0.06
			ns	ns		***		
	2013	F	4.82	0.25	0.39	0.02	13.73	0.85
		CF	4.65	0.39	0.42	0.01	12.70	0.10
			ns	ns		ns		
	2014	F	2.80	0.48	0.33	0.04	12.63	0.21
		CF	3.00	0.47	0.36	0.04	12.63	0.42
			ns	ns		ns		
FOG-SCA (SCA)	2013	F	5.74	1.65	0.26	0.07	15.80	0.72
		CF	4.55	0.53	0.25	0.01	15.70	0.72
			ns	ns		ns		
MON (RPS)	2013	F	2.90	0.03	0.31	0.03	11.93	0.58
		CF	2.56	0.09	0.29	0.09	9.69	0.97
			ns	ns		*		
	2014	F	2.26	0.07	0.31	0.07	10.68	0.51
		CF	1.50	0.06	0.20	0.06	10.56	0.68
			ns	ns		ns		

F, factual; CF, counterfactual; *P<0.05; **P<0.01; ***P<0.001; ns, not significant.

such as, for example, manure, compost, anaerobic digestate, *etc*.

A large supply of straw, with or without nitrogen, does not guarantee the maintenance of soil nitrogen and carbon levels; on the other hand, even with large organic supply, some soils, cultivated in the same way and under the same environmental conditions, maintain or even increase their levels of nitrogen and carbon. Morel *et al.* (1981) underlined the importance of considering the role of roots in influencing the level of soil organic matter. Lemke *et al.* (2010) carried out different research studies in 22 locations to evaluate the effect of incorporation over varying periods of time, which, however, were at minimum of 11 years. Results showed that even an appropriate use of residue did not always result in an increase in soil organic matter; indeed, in some cases, small losses were detected, regardless of the adopted technique of cultivation. This demonstrates that it is not possible to derive conclusions valid for all soil types, climates and different type and utilization of CR.

The activity described in this work, is a continuation and deepening of the previous project EFFICOND (Environmental eFFectIveness of CrOss-compliaNce stanDards) carried out by CREA started in 2009. Ventrella *et al.* (2011) reported the results of EFFICOND related to Objective 2 Standard 2.1. The Standard 'Management of stubble and crop residues' concerns measures for the maintenance of soil organic matter. Therefore, the CR burning is forbidden otherwise provided by regional laws. In compliance with the standard, the CR burying can be performed by shredding and ploughing. The cost of ploughing is not considered in the calculation of the economic competitiveness gap, because it represents a cost of cultivation to be allocated to the next crop cycle. In case of failing to comply with the standard, the farmer, after the harvest, does not perform the shredding and the burying of straw and will burn CR after ploughing on harrowing perimeter of the soil to prevent the spread of fire. Alternatively, the farmer may perform total or partial removal by raking and baling of stubble.

The research has been carried out in the framework of the project MO.NA.CO. that has established on a national scale a network of experimental farms, with the specific task of monitoring the effects and effectiveness of the Standards of cross compliance to the environmental problem for which each standard was conceived (see. Annex III REGULATION (EC) No 73/2009) and meet the specification of the Italian Ministry of Agriculture to 'monitor and evaluate' the effects on the environment mandated by the National Policy.

The main goal of this research was to evaluate the effectiveness of objective 2 Standard 2.1 concerning the measures for the maintenance of soil organic matter trough the incorporation into the soil of crop residues compared to their burning or removal.

Materials and methods

Monitoring design

In order to evaluate the effectiveness of 'management of stubble and crop residues' for the maintenance of organic matter in Italian soils, in 2011 a project was started for monitoring at field scale in several monitoring sites, experimental farms of Research Centres of CREA and Regione Veneto, characterized by different soil and climatic conditions and distributed in the entire Italian territory.

The monitoring of the Standard 2.1 was carried out in eight farms (Figure 1 and Table 1):

RAM: monitoring farm 'Libertinia' - Ramacca (Catania), Research Centre for the Citrus crops and the Mediterranean (CREA-ACM), Acireale (Catania).

MTP: monitoring farm 'Campo 7' – Metaponto (Matera), Unit for the Study of Cropping Systems (CREA-SSC), now Research Unit for Cropping Systems in Dry Environments (CREA-SCA), Bari.

FOG-CER: monitoring farm 'Manfredini' – Foggia, Research Centre for Cereal Crops (CREA-CER), Foggia.

FOG-SCA: monitoring farm 'Pod. 124' – Foggia, Research Unit for Cropping Systems in Dry Environments, CREA-SCA (SCA), Bari.

MON: monitoring farm 'Tor Mancina' – Monterotondo (Roma), Research Centre for the Soil-Plant System (CREA-RPS), Roma

ANG: monitoring farm of 'Fondazione Morando Bolognini' – S. Angelo Lodigiano (Lodi), Research Centre for Fodder Crop and Dairy Productions (CREA-FLC), Lodi.

LOD: monitoring farm of 'Viale Piacenza' – Lodi, Research Centre for Fodder Crop and Dairy Productions (CREA-FLC), Lodi.

CAO: monitoring farm 'Vallevecchia' – Caorle (Venezia), Veneto Agricoltura (VA), Legnaro (Padova).

In each experimental farm two fields, with prescribed dimensions, omogeneous for pedologic and principal soil characteristics, crop rotation, were set up:

factual (F): where the standard of crop residue (straw and stubble) incorporation was carried out;

Table 3. Mean and standard deviation of grain yield and harvest index (HI) of maize.

Farm (Research Unit)	Year	Treatment	Yield (t ha^{-1}) Mean	Yield (t ha^{-1}) SD	HI (-) Mean	HI (-) SD
ANG (FLC)	2013	F	9.85	1.25	0.48	0.02
		CF	9.04	0.14	0.50	0.02
			ns	ns		
LOD (FLC)	2011	F	10.23	0.09	0.44	0.03
		CF	9.07	0.90	0.44	0.03
			ns	ns		
	2012	F	10.13	0.30	0.47	0.01
		CF	8.55	0.67	0.45	0.04
			*	ns		
	2013	F	7.84	0.96	0.48	0.04
		CF	6.98	2.09	0.43	0.07
			ns	ns		
CAO (VA)	2013	F	7.03	0.33		
		CF	4.77	0.60		
			**			

F, factual; CF, counterfactual. *P<0.05; **P<0.01; ***P<0.001; ns, not significant.

counterfactual (CF): where burning or removal of crop residues (straw and stubble) were carried out.

In order to compare the results also in different environments, we have identified the following minimum common factors:

Shape and size: area not less than 0.5 ha, regular in shape, plots characterized by similar conditions of soil, exposure and slope;

Crops: winter durum wheat (*Triticum durum*, Desf.) or winter soft wheat (*Triticum aestivum, L.)* in continuous crop rotation;

Soil management: tillage and all agronomic practices (fertilization, weeding, pesticide treatments, irrigation, *etc*.) were the conventional and ordinary ones applied in each monitoring area.

At the start of the monitoring period, initial conditions of soils in each farm and plot were assessed.

Sampling and determinations

In each plot three soil samples to a depth of 40 cm were collected and sent to laboratory analysis for the determination of the nitrogen and Total Organic Carbon (TOC) content, respiration, microbial biomass. The index of biological fertility was calculated. Samplings were carried out at the beginning of the monitoring and the end of each crop cycle or after harvesting.

In order to evaluate the effect of crop residue management on productivity performance, we measured, in three sampling areas of about 10 m^2, the emergence of the plants, the number of weeds and the yield. To assess the quality of yield we calculate the weight of 1000 seeds, the test weight, harvest index and the protein content.

Data analysis

Statistical analyses were performed with the software SAS (2009). The comparison between data was done using the procedure TTEST by which the response variables of plant and soil were analysed comparing the two treatments F and CF For this purpose, the Student *t*-test was applied after carrying out the test for assessing the homogeneity of variance. The statistical distribution was analysed through the blox-

Table 4. Parameters of soil chemical fertility.

(Research Unit)	Year	Treatment	Total organic carbon (g/kg) Mean	SD	Total nitrogen (g/kg) Mean	SD	C/N Mean	SD
RAM (ACM)	2012	F	4.16	0.84	0.52	0.08	7.96	0.60
		CF	5.01	0.88	0.62	0.08	8.10	0.43
			ns	ns		ns		
	2013	F	6.05	1.44	0.69	0.12	8.69	0.87
		CF	5.81	1.23	0.66	0.08	8.75	0.89
			ns	ns		ns		
MTP (SSC)	2012	F	9.28	1.05				
		CF	8.65	0.26				
			ns					
FOG-LTE (SCA)	2012	F	16.15	0.57				
		CF	18.58	0.28	1.64	0.28	11.54	1.65
			**					
	2013	F	12.77	0.25	1.45	0.13	8.82	0.63
		CF	13.91	0.25	1.50	0.08	9.29	0.64
			**	ns		ns		
FOG_LTE (SCA)	2009	F	14.22	0.20	1.21	0.04	11.77	0.22
		CF	14.10	0.59	1.18	0.09	11.97	0.71
			ns	ns		ns		
FOG-SCA (SCA)	2013	F	15.03	0.25	1.37	0.16	11.07	1.46
		CF	14.89	0.48	1.37	0.24	11.05	1.86
			ns	ns		ns		
MON (RPS)	2013	F	12.10	0.69	1.08	0.03	11.18	0.83
		CF	7.87	1.53	1.00	0.17	7.84	0.20
			*	ns		**		
	2014	F	10.86	3.11	0.98	0.29	11.13	0.81
		CF	11.57	2.87	0.96	0.12	11.93	1.52
			ns	ns		ns		
ANG (FLC)	2013	F	13.97	3.18	1.48	0.38	9.49	0.29
		CF	13.06	1.06	1.37	0.11	9.51	0.02
			ns	ns		ns		
LOD (FLC)	2009	F	10.30	1.54	1.05	0.24	9.98	0.92
		CF	9.53	1.61	0.99	0.13	9.61	0.95
			ns	ns		ns		
	2013	F	11.92	1.46	1.21	0.05	9.91	1.51
		CF	10.26	1.64	1.14	0.18	9.03	0.29
			ns	ns		ns		
CAO (VA)	2013	F	9.27	2.60	0.93	0.21	9.86	0.55
		CF	9.22	1.20	0.96	0.15	9.61	0.45
			ns	ns		ns		

F, factual; CF, counterfactual. *P<0.05; **P<0.01; ***P<0.001; ns, not significant.

plots with the indication of 25th and 75th percentiles, mean, median and outliers.

Chemical analysis

In the chemical laboratory of CREA-SCA (Bari), the total carbon (TOC) was determined by Springer-Klee method (1954) the total nitrogen applying the Kjeldahl method. CREA-RPS carried out the soil analysis for combustion by LECO Carbon Analyzer RC612.

CREA-RPS determined also the following soil parameters: microbial Carbonium (Cmic; Vance *et al.*, 1987); basal respiration (Cbas; Isermeyer, 1952), hourly emission of CO_2 in the absence of organic substrate at the end of incubation; cumulative respiration (Ccum; Isermeyer, 1952), total emission of CO_2 in the absence of organic substrate; metabolic quotient (qCO_2), activity of soil microorganisms; quotient of Mineralization (qM, percentage of C breathed). In order to calculate the Biological Fertility index (IBF; Benedetti *et al.,* 2006; Benedetti and Mocali, 2008) for each of the six above parameters five intervals were fixed with relative score. The IBF is the algebraic sum of the scores providing of a scale biological fertility. The extraction, fractionation and the determination of the extractable organic carbon (TEC) and the separation and purification of the humic and fulvic acids (HA + FA), were performed according to Ciavatta *et al.* (1990).

Economic evaluation of the competitiveness gap

The Research Unit of Agricultural Engineering (CREA-ING) carried out this part of monitoring activity.

In order to assess the competitiveness gap, data from the monitoring of farming operations were used. At the time the study of work was conducted adopting the recommendation of the Associazione Italiana di Genio Rurale (A.I.G.R.) IIIa R1 (Manfredi, 1971) that is based on the methodology of Commission Internationale de l'Organisation Scientifique du Travail en Agriculture (C.I.O.S.T.A.). The surveys carried out in the field have been related to the effective work time (TE) and to the turning accessory time (TAV), whose sum is the net work time (TN). The calculation of hourly cost of the machines and equipment, was carried out using an analytical methodology (Biondi, 1981) and technical standards to which this refers (ASAE, 2003a, 2003b), to determine the cost per hectare of the agricultural operations. The data relating to the remuneration of farm labour, used in the above method, are the average of the values fixed by Confederazione Italiana Agricoltori in the national collective agreement in force for the qualification of super specialized worker, level A, Area 1, reported to the monitored provinces.

For each type of cultural operation the average value of the cost and the values obtained by subtracting and adding the average standard deviation were calculated and are indicated as lower limit and upper

Table 5. Parameters of microbiological analysis.

Farm (Research Unit)	Year	Treatment	Cmic (mg/kg)		Cbas (mg/kg)		Ccum (mg/kg)	
			Mean	SD	Mean	SD	Mean	SD
FOG-CER	2012	F	159.47	31.43	6.25	0.41	208.02	11.99
		CF	195.07	49.47	7.25	1.67	242.30	12.56
			ns	ns		*		
FOG-SCA	2012	F	272.67	50.89	7.03	0.76	309.61	37.75
		CF	259.13	18.77	6.97	1.69	293.37	21.56
			ns	ns		ns		
	2013	F			5.80	2.09	316.93	25.32
		CF			6.20	2.21	295.03	10.43
					ns		ns	
MON	2012	F	323.80	83.60	3.77	1.42	181.97	107.76
		CF	226.43	35.89	5.33	1.06	170.60	36.38
			ns	ns		ns		
	2013	F	282.13	37.23	10.13	5.76	207.50	23.25
		CF	202.43	20.35	3.70	0.26	144.07	15.90
			*		ns		*	

Cmic, Microbial carbonium; Cbas, basal respiration; Ccum, cumulative respiration; F, factual; CF, counterfactual. *P<0.05.

Table 6. Parameters of microbiological analysis and index of biological fertility.

Farm (Research Unit)	Year	Treatment	qCO_2 (mg/kg)		qM (%)		IBF	
			Mean	SD	Mean	SD	Mean	Class
FOG-CER	2012	F	0.17	0.05	1.28	0.09	16	Medium
		CF	0.16	0.02	1.27	0.08	17	Medium
			ns	ns				
SCA-124	2012	F	0.11	0.03	1.76	0.21	20	Good
		CF	0.12	0.03	1.73	0.09	19	Good
			ns	ns				
MON	2012	F	0.05	0.01	1.11	0.49	18	Medium
		CF	0.10	0.04	1.36	0.58	17	Medium
			ns	ns				
	2013	F	0.15	0.08	1.71	0.12	17	Medium
		CF	0.08	0.01	1.88	0.40	15	Medium
			ns	ns				

qCO_2, metabolic quotient; qM, quotient of mineralization; IBF, biological fertility index; F, factual; CF, counterfactual. *P<0.05; **P<0.01; ***P<0.001; ns, not significant.

limit, respectively. The data of common wheat technical input costs were obtained by Centro Ricerche Produzioni Vegetali (CRPV, 2014). The average sales price of common wheat grain in the last 12 months was obtained by Istituto di Servizi per il MErcato agricolo Alimentare (ISMEA, 2014) and is equal to 209.77 € t^{-1}. The production datum was recorded by monitoring and is equal to 5.52 t ha^{-1}. The gross operative margin of the cultivations was calculated by difference between total revenue and total costs directly related to the production. The calculation of the competitiveness gap (€ ha^{-1}), has been determined by the difference between the cumulative gross operative margin in compliance with the standard and failing to comply with the standard.

Results and Discussion

Effect of Standard 2.1 on productive parameters

Tables 2 and 3 show the productive data related to the monitoring activity for winter wheat and maize, respectively. Taking into account only the years when the treatments were actually applied, the average yield of five locations was 3.8 t ha^{-1} with a protein content of 13.2% and a HI of 0.35 (Table 2).

The 'year' effect can be detected only for FOG-CER where the treatments have been differentiated since the first year of monitoring activity. As expected, the 'year' had a considerable influence in differentiating the results for both the yield and the protein content. In particular, in the second year the yields increased by an average of 86%, while the protein content had reduced by approximately 10%. The HI was almost unchanged around 0.4 with the rainfall of the second year that has promoted the translocation during the reproductive phase. In contrast the productive results of the third year were lower than in the second year but better when compared to the first one. Compared to the general average, the yields achieved at FOG-CER in the second year are therefore particularly high along with those of FOG-SCA and MTP (5.1 and 4.6 t ha^{-1}, respectively). The yields of MON and RAM were lower than average but still next to 3 t ha^{-1}. Regarding the protein content, average values slightly above 12% were recorded at RAM and MTP, while highest values were achieved at FOG-SCA (15.7%) and FOG-CER (14.8% in the first year). The HI was not very differentiated between locations varying from a minimum of 0.34 (MTP) to 0.4 at RAM and FOG-CER (second year).

The comparison F *vs* CF shows that any statistically significant differences on the wheat yield were detected. On the contrary, the statistical analysis showed a significant effect of CR management on the protein content with the F treatment resulting in higher content at FOG-CER in 2012 (+19%) and MON (+23%). The comparison was however reversed at RAM (-10%) and MTP (-31%), while the effect was statistically zero at FOG-SCA and FOG-CER in 2013. Compared to CREA-CER, CREA-SCA and CREA-SSC, the yield obtained at MON was lower with average values of 2.7 t ha^{-1} and 11% of yield and protein content, respectively. The soil fertility of RAM was not particularly high and the unfavourable meteorological trend of 2012/13 had not allowed to obtain high yields of winter wheat (less than 3 t ha^{-1}). For maize cultivation the CF treatment consisted in the removal of CR and not in their burning. Table 3 shows the results obtained in experiments of ANG, LOD and CAO. The yields of corn of ANG and LOD were rather high with values greater than 9 t ha^{-1}, with the exception of the third year (LOD) when the average yield dropped to 7.4 t ha^{-1}. The monitoring of CAO recorded an average production rather low with about 6 t ha^{-1}.

Table 7. Perimeter tilled per hectare and labour costs for surveillance during burning.

Percentage of tilled soil (%)	Area perimeter of tilled soil (m^2 ha^{-1})	Cost of soil tillage (€ ha^{-1} $year^{-1}$)			Labour costs for surveillance during burning (€ ha^{-1} $year^{-1}$)		
		Lower limit	Average	Upper limit	Lower limit	Average	Upper limit
1	100	0.74	0.85	0.95	13.18	24.05	34.92
3	300	2.23	2.54	2.84	12.92	23.56	34.21
5	500	3.72	4.23	4.74	12.65	23.08	33.51
7	700	5.21	5.92	6.63	12.38	22.59	32.80
9	900	6.69	7.61	8.53	12.12	22.11	32.10
11	1100	8.18	9.30	10.42	11.85	21.62	31.39
13	1300	9.67	10.99	12.32	11.59	21.14	30.69
15	1500	11.16	12.68	14.21	11.32	20.65	29.98

Table 8. Annual values of the competitiveness gap in the case of crop residues incorporation *vs* burning.

Percentage of tilled soil (%)	Area perimeter of tilled soi (m^2 ha^{-1})	Lower limit (€ ha^{-1} $year^{-1}$)	Average (€ ha^{-1} $year^{-1}$)	Upper limit (€ ha^{-1} $year^{-1}$)
1	100	-31.91	-42.16	-52.41
3	300	-30.69	-40.95	-51.22
5	500	-29.46	-39.75	-50.03
7	700	-28.24	-38.54	-48.84
9	900	-27.02	-37.34	-47.65
11	1100	-25.80	-36.13	-46.46
13	1300	-24.58	-34.92	-45.27
15	1500	-23.36	-33.72	-44.08

The yield of corn was always higher for F treatment with variable increments between 9% (ANG in 2013) and 18 % (LOD in 2013). The same result was detected at CAO with a positive result for F (+45%). No significant effects were detected for HI.

Effect of Standard 2.1 on soil fertility

The soil indicator for the Standard 2.1 is the content of soil organic matter as determined by chemical analysis of the soil for the determination of total organic carbon (TOC). In this section we report the results of monitoring in respect of all the indicators of fertility measured in the two years of activity. For each location, we took into account the sampling of soil carried out only after the differentiation of treatments F and CF.

The effect of the Standard was considered in terms of percentage change ($\Delta_{y\_S2.1}$) as effectiveness of factual treatment (F) compared to the counterfactual one (CF), using the following equation:

$$\Delta_{Y\_S2.1} = 100\frac{(Y_F - Y_{CF})}{Y_{CF}} \quad (1)$$

where Y is the considered parameter between TOC, total nitrogen content (N) and ratio carbon-nitrogen (CN).

The soils of Southern Italy considered in this monitoring are all mainly clay, deep and with characteristics typical of vertisols with deep and wide cracks that occur during the summer, especially in non-irrigated fields. Among these, the soil of MTP is characterized by a particularly high silt content which makes its workability difficult to manage. According to USDA textural classes, the TOC of these soils (Table 1) can be considered as good for FOG (14-15 g kg^{-1}), while is lower at MTP (about 10 g kg^{-1}) and very low at RAM (5 g kg^{-1}). The soil of MON, with a loam texture, has a good amount of TOC (about 14 g kg^{-1}). With a higher sand fraction, even the soils of ANG and LOD (11 g kg^{-1}) fall into the category of a good supply of TOC. The value of 11 g kg^{-1} character-

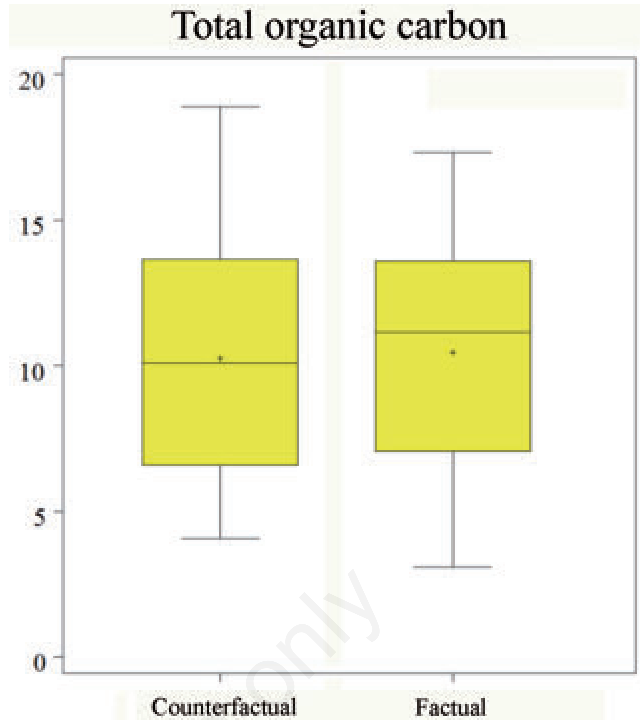

Figure 2. Box-plot of total organic carbon. Symbol and central line represent mean and median of the distribution. The lower and higher side of the rectangle correspond to the first and third quartile whose difference is the 'Range interquartile' (IQR). The extreme segments represent the maximum and minimum value above and below of the threshold value defined by IQR above and below the third and first quartile. The outliers are indicated by the symbols above and below the extreme segments.

Table 9. Competitiveness gap in the case of removal of crop residues by raking and baling.

Balance items	Lower limit (€ ha^{-1} year^{-1})		Average (€ ha^{-1} year^{-1})		Upper limit (€ ha^{-1} year^{-1})	
	F	CF	F	CF	F	CF
Ploughing	139.51	139.51	210.17	210.17	280.82	280.82
Harrowing	28.04	28.04	50.08	50.08	72.12	72.12
Fertilization	3.50	3.50	6.86	6.86	10.21	10.21
Sowing	24.93	24.93	39.01	39.01	53.08	53.08
Soil rolling	16.02	16.02	19.32	19.32	22.62	22.62
Weed control	4.87	4.87	6.78	6.78	8.68	8.68
Combine harvesting	93.98	93.98	126.64	126.64	159.29	159.29
Raking		37.10		42.18		47.26
Baling		54.15		60.71		67.27
Shredding	45.83		67.05		88.27	
Total cost of mechanized operations	356.69	402.11	525.89	561.73	695.09	721.34
Technical input cost	529.00	529.00	529.00	529.00	529.00	529.00
Total revenue	1157.46	1248.71	1157.46	1260.35	1157.46	1271.99
Gross operative margin	271.77	317.60	102.57	169.62	-66.63	21.64
Competitiveness gap	-45.83	-67.05	-88.27			

F, factual; CF, counterfactual.

izes also the soil of CAO which, however, due to a heavier texture, is in the lower class of TOC. Table 4 shows the monitoring results for TOC, N and CN. Two long-term field experiments localized in FOG-SCA and LOD were considered in this analysis to take into account long-term effects due to F and CF. A wide variability was found between different soils, but also between different years above all in the case of RAM, FOG and LOD.

The comparison F *vs* CF showed statistically significant differences of TOC only for FOG-CER and MON. In the first case, the difference, unfavourable for F, was higher at the end of the first year of cultivation (-13%) and lower in the second one (-8%). At MON we detected a favourable difference for F to much high (+50%) at the end of 2013, but this percentage change was not confirmed in the next year when no significant differences were found as reported for the other monitoring sites. In fact, for all the soils, including those of long term experiment, the management did not influence the soil content of TOC. The box-plots of Figures 2, 3 and 4 show the most important parameters of statistical distributions of TOC, N e C/N, distributions that are not affected by the treatments considered in this comparison. The percentage variation as described by the indicator $\Delta_{y\_S2.1}$ and reported by soil and year are shown in Figure 5, 6 and 7. With the only exception of MON for 2013, the indicator, varied in a fairly narrow range between -15 and + 15%, for the three soil variables. Figures 8 and 9 are related to different components of organic carbon determined for FOG-SCA and MON. In the first case, the differences between F and CF are small and involve in a homogeneous way all the fractions of carbon. In the case of MON, the difference, already highlighted at TOC for F treatment, mainly concerned the more recalcitrant fraction, the umina estimated as the difference between TOC and TEC, rather than the other two fractions represented by TEC and HA + HF. The soil biological parameters were measured for the farms of FOG e MON. Such parameters showed a larger variability due to location and year factor rather than to the treatments. Indeed, also in Table 5 and 6 the average differences based on F/CF comparison were no statistically significant. Compared to CF, the F treatment showed higher microbial carbonium (Cmic) and cumulative respiration (Ccum), but the differences were statistically sgnificanto at $P<0.05$ only for MON in 2013. However, in any case, the basal respiration (Cbas) was affected by the treatments (Table 5).

Also the parameters of metabolic quotient (qCO_2) and mineralization (qM), reported in Table 6, showed rather small and not statistically significant differences. The synthetic index, with values ranging from 15 to 20, shows as the soils of FOG-CER e MON can be considered with a good level of fertility, while the soil of FOG-SCA is included in the upper class although with a value of IBF closed to the lower limit (Table 6).

Effect of Standard 2.1 on economic competitiveness gap

The perimeter soil tillage can affect, in a hectare of crop, an area that can vary in function of the machines and equipment used and their width, as well as the particular shape of the plot. Several scenarios have been hypothesized in which the percentage of soil used for the perimeter tillage varied (Table 7). The perimeter tillage represents a cost that has been computed with the others in the definition of the economic competitiveness gap. The realization of the perimeter soil tillage is of very low cost, due to the speed of execution, to the reduced area involved, with reference to the calculation assumptions.

Considering the average values of manual and mechanized operations, the competitiveness gap takes values ranging from -42.16 to -33.72 € ha^{-1} $year^{-1}$ as a function of the surface of tilled soil (Table 8). Taking into account the computation performed with lower and upper

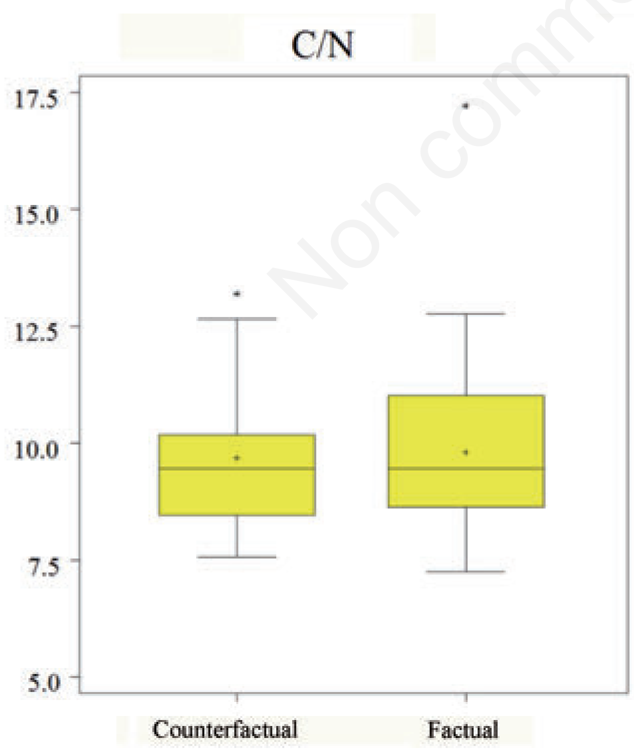

Figure 3. Box plot of carbon/nitrogen ratio. See Figure 2 for the explanation of box-plot.

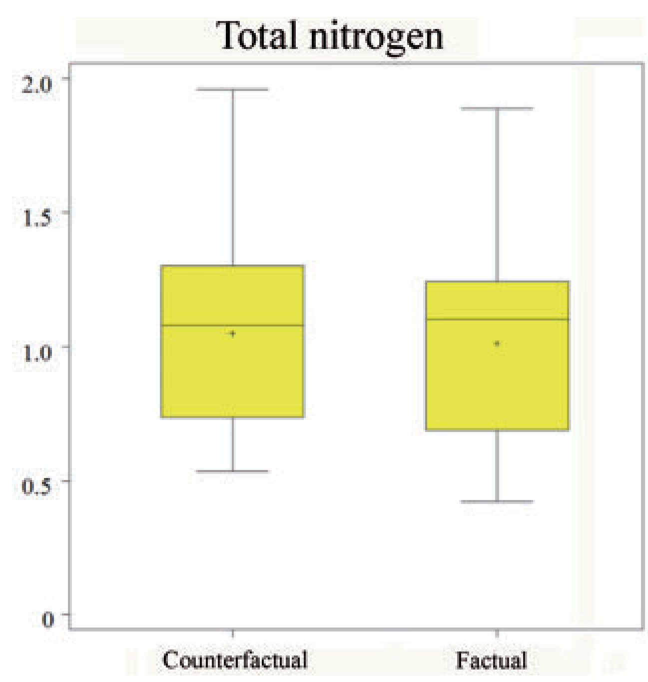

Figure 4. Box plot of total nitrogen. See Figure 2 for the explanation of box-plot.

limits, the competitiveness gap takes values that range from -52.41 to -23.36 ha^{-1} year^{-1}. In case of failing to comply with the Standard (CF), it is observed that by increasing the area of tilled soil, the costs increase and therefore the economic competitiveness gap is reduced compared to compliance with the Standard (F). When the total or partial removal of crop residues is carried out by raking and baling, the competitiveness gap assumes an average value of -67.05 € ha^{-1} year^{-1} (Table 9). Generally, the straw is removed where local conditions permit the sale at a price that compensates the costs of straw harvest. Sometimes this harvest is performed by a farmer contractor that has previously made the threshing and retaining as compensation of their work crop residues harvest. Therefore, in the calculations performed, the cost for the harvest of the straw was offset by revenue from the sale of straw. With reference to calculations performed with the lower and upper limits, the competitiveness gap takes values that range from -45.83 to -88.27 € ha^{-1} year^{-1}.

In compliance with the standard, avoiding burning straws, the farmer incurs in an economic loss that ranges from -33.72 to -42.16 € ha^{-1} year^{-1}. In compliance with the standard, avoiding the partial or total removal of straw, the farmer suffers a greater economic loss amounting to -67.05 € ha^{-1} year^{-1}.

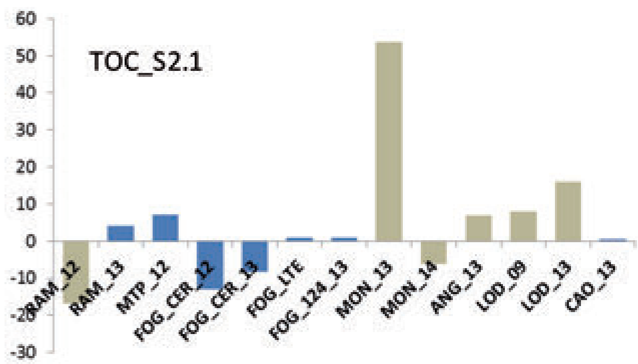

Figure 5. Change in TOC (%) according to equation (1). The blue histograms are related to crop residue burning. The other histograms refer to the removal of crop residues.

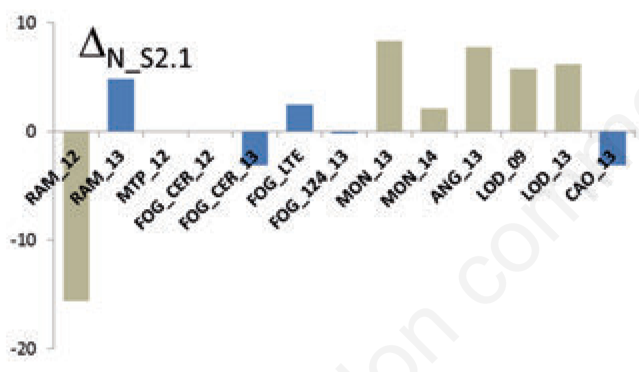

Figure 6. Change in total N (%) according to equation (1). See Figure 5 for explanation of different colours.

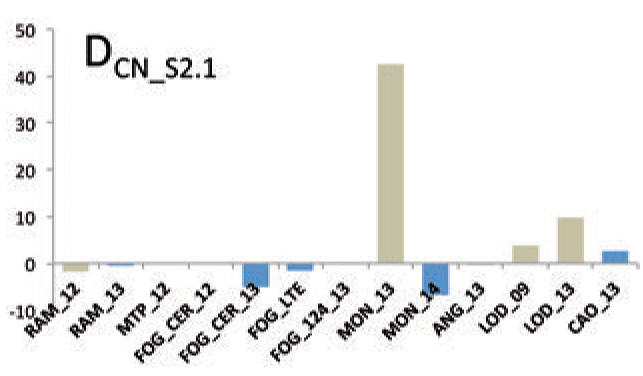

Figure 7. Change in C/N ratio (%) according to equation (1). See Figure 5 for explanation of different colours.

Conclusions

Temporal variations of parameters related to soil fertility, with particular reference to organic carbon, nitrogen and their main components, follow long-term dynamics and agronomic practices can have a different impact in determining the magnitude of these changes.

In this monitoring of the Standard 2.1, the factual treatment consisted in incorporation of crop residues of wheat or corn and it has been compared to the 'counterfactual' treatment consisting of their removal or burning. The comparison involved productive parameters, parameters related to soil fertility and economic budget of farmer activity. As regards the wheat and maize yields, the TOC content and soil parame-

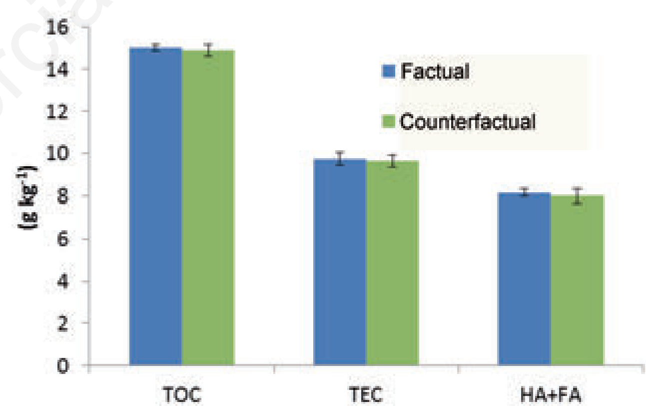

Figure 8. Components of TOC for FOG-SCA, 2013.

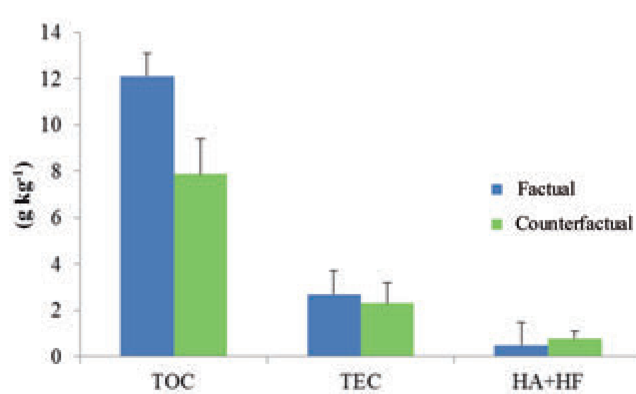

Figure 9. Components of TOC for MON, 2013.

ters, significant differences between the two treatments were rarely detected. The percentage changes of TOC, N and CN, between F and CF, with values of +/- 10%, have not exceeded the threshold of significance with only one exception and such results were in agreement with those of two long-term experiments. In Lodi (Northern Italy) in the two years reported in this paper, the increase due to CR incorporation was not significant but around 10% compared to CR removal. As described by Ventrella *et al.* (2012), in Southern Italy (Foggia), after 32 years of continuous treatment the CR incorporation caused an increase of TOC lower than 1% compared to CR burning, while TEC and the humic and fulvic acids increased by +2 and +10%, with the latter resulted significant.

Definitely, the effectiveness of the Standard 2.1 is rather limited both for crop yield and for soil fertility. However, considering the temporal dynamics of the processes affected by the crop residue management and affecting soil fertility, the results of this monitoring confirm those already appeared in the field experiment of EFFICOND: the agronomic practice of crop residues incorporation should be considered as a 'good agricultural practice' that can help to maintain soil fertility rather than to determine its improvement. Moreover, the effectiveness of this practice, above all in typical Mediterranean environments, can be significantly increased with suitable agronomic practices, such as fertilization and irrigation aimed at increasing the availability of nitrogen and water during the microbial processes of crop residue decomposition. When a farmer complies with the Standard 2.1, in agreement with the hypothesis of this monitoring, the economic competitiveness gap always assumes negative values. In fact, incorporating into the soil CR, the farmers have to bear additional costs compared to their burning or removal. In other words, with the incorporation there is always an economic loss that ranges from a minimum of -33.72 € to a maximum of -67.05 € ha^{-1} $year^{-1}$. The economic advantage of CR burning could then justify the adoption of this practice compared to incorporation.

However, given the small amount of this economic disadvantage and the aids provided by specific policies of national or local authorities for those who complies with this standard, farmers adopting the CR incorporation can suffer economic losses but not significant and therefore they can give a contribution to maintain the soil fertility, conserve biodiversity and contribute to road safety by preventing the fire spread.

References

ASAE, 2003a. Standard EP496.2. American Society of Agricultural Engineers Publ., St. Joseph, MI, USA, pp. 367-372.

ASAE, 2003b. Standard D497.4. American Society of Agricultural Engineers Publ., St. Joseph, MI, USA, pp. 373-380.

Benedetti A, Dell'Abate MT, Mocali S, Pompili L, 2006. Indicatori microbiologici e biochimici della qualità del suolo. In: ATLAS – Atlante di Indicatori della Qualità del Suolo. Ministero delle Politiche Agricole. Alimentari e Forestali. Osservatorio Nazionale Pedologico. Edizioni Delta Grafica, Città di Castello (PG), Italy.

Benedetti A, Mocali S, 2008. Analisi a livello di suolo. In: Indicatori di biodiversità per la Sostenibilità in Agricoltura. Linee guida, strumenti e metodi per la valutazione della qualità degli agroecosistemi. ISPRA, Report 47/2008.

Biondi P, 1981. Meccanica agraria. Le macchine agricole. UTET, Torino, Italy, pp. 547-561.

Bonciarelli F, Ciriciofolo E, 1972. Decomposizione in campo di residui organici di diversa specie. Riv. Agron. 6:148-151.

Bonciarelli F, Bianchi AA, Ciriciofolo E, 1974. Risultati di prove di interramento di residui coltutali in Riv. Agron. 8:358-362.

Castellini M, Niedda M, Pirastru M, Ventrella D, 2014. Temporal changes of soil physical quality under two residue management systems. Soil Use Manage. 30:423-434.

Ciavatta C, Govi M, Vittori Antisari L, Sequi P, 1990. Characterization of humified compounds by extraction and fractionation on solid polyvynilpyrrolidone. J. Chromatogr. 509:141-146.

Convertini G, Ferri D, Maiorana M, Giglio L, La Cava P, 1998. Influenza dell'interramento dei residui colturali sulla sostanza organica e su alcune proprietà biologiche del terreno in una prova a lungo termine in ambiente mediterraneo. Boll. Soc. Ital. Scienza Suolo 47:169-181.

CRPV, 2014. Centro Ricerche Produzioni Vegetali. Available from: http://www.crpv.it

FAO, 2014. World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps. FAO Publ., Rome, Italy.

Ferri D, Convertini G, 1993. Regimi transitori di fertilità del suolo indotti da diversi precedenti colturali ed interventi agronomici in un caratteristico ambiente meridionale. Agricoltura Ricerca 151/152:155-174.

Fischer RA, Santiveri F, Vidal IR, 2002. Crop rotation. tillage and crop residue management for wheat and maize in the sub-humid tropical highland. I. Wheat and legume performance. Field Crop Res. 79:107-122.

Franzluebbers AJ, 2002. Soil organic matter stratification ratio as an indicator of soil quality. Soil Till. Res. 66:95-106.

ISMEA, 2014. Istituto di Servizi per il Mercato agricolo Alimentare. Available from: http://www.ismea.it

Kjeldahl J, 1883. A new method for the estimation of nitrogen in organic compounds. Z. Anal. Chem. 22:366.

Kottek M, Grieser J, Beck C, Rudolf B, Rubel F, 2006. World Map of the Köppen-Geiger climate classification updated. Meteorol. Z. 15:259-263.

Lal R, 1997. Residue management. conservation tillage and soil restoration for mitigating greenhouse effect by CO2 -enrichment. Soil Till. Res. 43:81-107.

Lal R, 2009. Soil quality impacts of residue removal for bioethanol production. Soil Till. Res. 102:233-241.

Lemke RL, VandenBygaart AJ, Campbell CA, Lafond GP, Grant B, 2010. Crop residue removal and fertilizer N: Effects on soil organic carbon in a long-term crop rotation experiment on a Udic Boroll. Agr. Ecosyst. Environ. 105:42-51.

Maiorana M, Castrignanò A, Fornaro F, 2001. Crop residue management effects on soil mechanical impedance. J. Agr. Eng. Res. 79:231-237.

Maiorana M, Colucci R, Ventrella D, 1996. Crop residue and soil tillage management effects on soil strength. Book of abstracts 4th European Society For Agronomy Congress. Veldhoven-Wageningen (The Netherlands). pag. 576-577.

Maiorana M, Convertini G, Di Bari V, Rizzo V, 1992. Yield and quality of durum wheat (Triticum durum Desf.) under continuous cropping after nine years of straw incorporation. Eur. J. Agron. 1:11-19.

Maiorana M, Convertini G, Ferri D, Montemurro F, 2003. Effects of soil tillage depth and crop residues incorporation on yields and quality of winter wheat (Triticum durum Desf.) in continuous cropping. In: Proc. 4th Int. Conf. of ORBIT Ass., Perth, Australia, pp. 295-303.

Maiorana M, Di Bari V, Ventrella D, Convertini G, Ferri D, Colucci R, 1997. Interramento e bruciatura dei residui colturali di frumento duro in monosuccessione: effetti di diverse modalità di lavorazione del terreno e di somministrazione dell'azoto. Agricoltura Ricerca 168:49-56.

Maiorana M, Rizzo V, Di Bari V, Convertini G, 1993. Interramento dei residui vegetali di frumento duro in monosuccessione con dosi crescenti di azoto e fosforo. I. Effetti sulle componenti quantitative e qualitative della produzione. Agricoltura Ricerca 151/152:69-76.

Manfredi E, 1971. Raccomandazione A.I.G.R. IIIa sezione denominazione, simbolo e unità di misura delle grandezza fondamentali relative all'impiego delle macchine in agricoltura, con particolare riguardo alle colture erbacee. Riv. Ing. Agr. 2:258-260.

Morel R, Chabouis C, Bourgeois S, 1981. Evolution des taux d'azote et de carbone organiques dans un sol nu après 15 ans d'enfouissement de paille sous différentes conditions. Agronomie 1:7-17.

Nicholson FA, Chambers BJ, Mills AR, Strachan PJ, 1997. Effects of repeated straw incorporation on crop fertilizer nitrogen requirements. soil mineral nitrogen and nitrate leaching losses. Soil Use Manage. 13:136-142.

Rasmussen PE, Allmaras RR, Rohde CE, Roager NC, 1980. Crop residue influences on soil carbon and nitrogen in a wheat-fallow system. Soil Sci. Soc. Am. J. 44:596-600.

Rasmussen PE, Collins HP, 1991. Long-term impacts of tillage. fertilizer. and crop residue on soil organic matter in temperate semiarid regions. Adv. Agron. 45:93-134.

Riffaldi R, Saviozzi A, Levi-Minzi R, 1996. Carbon mineralization kinetics as influenced by soil properties. Biol. Fert. Soils 22:293-298.

SAS, 2009. SAS/STAT Software, ver. 9.1.3. SAS Inst. Inc., Cary, NC, USA.

Sequi P, De Nobili M, Leita L, Cercignani G, 1986. A new index of humification. Agrochimica 30:175-179.

Soil Survey Staff, 2014. Keys to soil taxonomy, 12th ed. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington DC, USA.

Springer U, Klee J, 1954. Prufung der Leistungsfa higkeit von einigen wichtigen Verfahren zur Bestimmung des Kohlenstoffs mittels Chromschwefelsaure sowie Vorschlag einer neuen Schnellmethode. J. Plant Nutr. Soil Sci. 64:1-26.

Troccoli A, Colecchia SA, Cattivelli L, Gallo A, 2007. Caratterizzazione agro-climatica del capoluogo dauno - Analisi della serie storica delle temperature e delle precipitazioni rilevate a Foggia dal 1955 al 2006. Digital Print Ed., Orta Nova (FG), Italy.

Vance ED, Brookes PC, Jenkinson DS, 1987. An extraction method for measuring soil microbial biomass C. Soil Biol. Biochem. 19:703-707.

Ventrella D, Fiore A, Vonella AV, Fornaro F, 2011. Effectiveness of the GAEC cross-compliance standard management of stubble and crop residues in the maintenance of adequate contents of soil organic carbon. Ital. J. Agron. 6(s1):e7.